Electric car

From Wikipedia, the free encyclopedia

Electric cars charging on street in Rome in 2016.

An **electric car** is an automobile that is propelled by one or more electric motors, using electrical energy stored in rechargeable batteries or another energy storage device. Electric motors give electric cars instant torque, creating strong and smooth acceleration. They are also around three times as efficient as cars with an internal combustion engine. The first practical electric cars were produced in the 1880s.[1][2] Electric cars were popular in the late 19th century and early 20th century, until advances in internal combustion engines, electric starters in particular, and mass production of cheaper gasoline vehicles led to a decline in the use of electric drive vehicles. The energy crises of the 1970s and 1980s brought a short-lived interest in electric cars; although those cars did not reach the mass marketing stage, as became the case in the 21st century.

Since 2008, a renaissance in electric vehicle manufacturing has occurred due to advances in batteries and energy management, concerns about increasing oil prices, and the need to reduce greenhouse gas emissions.[3][4] Several national and local governments have established tax credits, subsidies, and other incentives to promote the introduction and now adoption in the mass market of new electric vehicles depending on battery size and their all-electric range. Electric cars are significantly quieter than conventional internal combustion engine automobiles. They do not emit tailpipe pollutants,[5] giving a large reduction of local air pollution, and, can give a significant reduction in total greenhouse gas and other emissions (dependent on the method used for electricity generation[3][4]). They also provide for independence from foreign oil, which in several countries is cause for concern about vulnerability to oil price volatility and supply disruption.[3][6][7] Recharging can take a long time and in many places there is a patchy recharging infrastructure. For long distance driving, many cars support fast charging that can give around 80% charge in half an hour using public rapid chargers.[8][9][10] While battery cost is decreasing fairly rapidly, it is still relatively high, and because of this, most electric cars have a more limited range and a somewhat higher purchase cost than conventional vehicles. Drivers can also sometimes suffer from range anxiety- the fear that the batteries will be depleted before reaching their destination.[3][4]

As of December 2015, there were over 30 models of highway legal all-electric passenger cars and utility vans available for retail sales, mainly in the United States, China, Japan, and Western European countries. By the end of 2015, almost 60% of the global stock of light-duty plug-in electric vehicles were pure electric cars and vans.[11] Cumulative global sales of highway-capable light-duty pure electric vehicles passed the one million unit milestone in September 2016.[12] The world's all-time top selling highway-capable electric car is the Nissan Leaf, released in December 2010, with almost 240,000 units sold worldwide through September 2016.[13] The Tesla Model S, released in June 2012, ranks second with global sales of over 150,000 units through November 2016.[14]

Contents

Terminology

Electric cars are a variety of electric vehicle (EV). The term "electric vehicle" refers to any vehicle that uses electric motors for propulsion, while "electric car" generally refers to highway-capable automobiles powered by electricity. Low-speed electric vehicles, classified as neighborhood electric vehicles (NEVs) in the United States,[15] and as electric motorised quadricycles in Europe,[16] are plug-in electric-powered microcars or city cars with limitations in terms of weight, power and maximum speed that are allowed to travel on public roads and city streets up to a certain posted speed limit, which varies by country. While an electric car's power source is not explicitly an on-board battery, electric cars with motors powered by other energy sources are generally referred to by a different name: an electric car carrying solar panels to power it is a solar car, and an electric car powered by a gasoline generator is a form of hybrid car. Thus, an electric car that derives its power from an on-board battery pack is a form of battery electric vehicle (BEV). Most often, the term "electric car" is used to refer to battery electric vehicles.

History

Thomas Parker built the first practical production electric car in London in 1884, using his own specially designed high-capacity rechargeable batteries.[2][18][19] The *Flocken Elektrowagen* of 1888 by German inventor Andreas Flocken is regarded as the first real electric car of the world.[20] Electric cars were among the preferred methods for automobile propulsion in the late 19th century and early 20th century, providing a level of comfort and ease of operation that could not be achieved by the gasoline cars of the time.[21] The electric vehicle stock peaked at approximately 30,000 vehicles at the turn of the 20th century.[22] Advances in internal combustion engines in the first decade of the 20th century lessened the relative advantages of the electric car. The greater range of gasoline cars, and their much quicker refueling times, made them more popular and encouraged a rapid expansion of


Early electric car, built by Thomas Parker, photo from 1895[17]

petroleum infrastructure, making gasoline easy to find, but what proved decisive was the introduction in 1912 of the electric starter motor which replaced other, often laborious, methods of starting the ICE engine, such as hand-cranking.

Flocken Elektrowagen, 1888 (reconstruction, 2011)

In the early 1990s, the California Air Resources Board (CARB) began a push for more fuel-efficient, lower-emissions vehicles, with the ultimate goal being a move to zero-emissions vehicles such as electric vehicles.[3][23] In response, automakers developed electric models, including the Chrysler TEVan, Ford Ranger EV pickup truck, GM EV1, and S10 EV pickup, Honda EV Plus hatchback, Nissan Altra EV miniwagon, and Toyota RAV4 EV. These cars were eventually withdrawn from the U.S. market.[24]

The General Motors EV1, one of the cars introduced due to the California Air Resources Board mandate, had a range of 160 mi (260 km) with NiMH batteries in 1999.

California electric automaker Tesla Motors began development in 2004 on the Tesla Roadster, which was first delivered to customers in 2008. The Roadster was the first highway legal serial production all-electric car to use lithium-ion battery cells, and the first production all-electric car to travel more than 320 km (200 miles) per charge.[25] Models released to the market between 2010 and December 2016 include the Mitsubishi i-MiEV, Nissan Leaf, Ford Focus Electric, Tesla Model S, BMW ActiveE, Coda, Renault Fluence Z.E., Honda Fit EV, Toyota RAV4 EV, Renault Zoe, Roewe E50, Mahindra e2o, Chevrolet Spark EV, Fiat 500e, Volkswagen e-Up!, BMW i3, BMW Brilliance Zinoro 1E, Kia Soul EV, Volkswagen e-Golf, Mercedes-Benz B-Class Electric Drive, Venucia e30, BAIC E150 EV, Denza EV, Zotye Zhidou E20, BYD e5, Tesla Model X, Detroit Electric SP.01, BYD Qin EV300, Hyundai Ioniq Electric and Chevrolet Bolt EV.

Cumulative global sales of the Nissan Leaf, the world's all-time top selling highway legal plug-in electric car, passed the 200,000 unit milestone in December 2015, five years after its introduction.[26][27] The same month, the Renault-Nissan Alliance, the top selling all-electric vehicle manufacturer, passed the milestone of 300,000 electric vehicles sold worldwide.[27] The Tesla Model 3 was unveiled on March 31, 2016 and more than 325,000 reservations were made during the first week since bookings opened, each customer paying a refundable US$1,000 deposit to reserve the car.[28] Cumulative global sales of all-electric cars and vans passed the 1 million unit milestone in September 2016.[12] Global Tesla Model S sales achieved the 150,000 unit milestone in November 2016.[14] Norway achieved the milestone of 100,000 all-electric vehicles registered in December 2016.[29]

Economics

Price

An important goal for electric vehicles is overcoming the disparity between their costs of development, production, and operation, with respect to those of equivalent internal combustion engine vehicles (ICEVs). As of 2013, electric cars are significantly more expensive than conventional internal combustion engine vehicles and hybrid electric vehicles due to the cost of their lithium-ion battery pack.[30] Although cheaper alternatives exist, lithium-ion batteries are perferred over other types of batteries because of their high energy per unit mass relative to other electrical energy storage systems.[31] However, battery prices are coming down about 8% per annum with mass production, and are expected to drop further.[32][33]

Not only is the high purchase price hindering mass transition from gasoline cars to electric cars, but also the continued subsidization of fossil fuels, such as huge tax breaks and financial help in finding and developing oil fields for oil companies, higher allowed pollution for coal-fired power stations owned by oil refineries, as well as unpriced harm resulting from tailpipe emissions. According to a survey taken by Nielsen for the Financial Times in 2010, around three quarters of American and British car buyers have or would consider buying an electric car, but they are unwilling to pay more for an electric car. The survey showed that 65% of Americans and 76% of Britons are not willing to pay more for an electric car than the price of a conventional car.[34]

The electric car company Tesla Motors uses laptop -size cells for the battery packs of its electric cars, which were 3 to 4 times cheaper than dedicated electric car battery packs of other auto makers. Prior to 2012, dedicated battery packs cost about $700–$800 per kilowatt hour, while battery packs using small laptop cells had a cost of about $200 per kilowatt hour. This could drive down the cost of electric cars that use Tesla's battery technology such as the Toyota RAV4 EV, Smart ED and Tesla Model X which announced for 2014.[35][36][37] As of June 2012, and based on the three battery size options offered for the Tesla Model S, The New York Times estimated the cost of automotive battery packs between US$400 to US$500 per kilowatt-hour.[38]

A 2013 study, by the American Council for an Energy-Efficient Economy reported that battery costs came down from US$1,300 per kilowatt hour in 2007 to US$500 per kilowatt hour in 2012. The U.S. Department of Energy has set cost targets for its sponsored battery research of US$300 per kilowatt hour in 2015 and US$125 per kilowatt hour by 2022. Cost reductions of batteries and higher production volumes will allow plug-in electric vehicles to be more competitive with conventional internal combustion engine vehicles.[39] However, in 2014 manufacturers were already offering battery packs with a cost of about $300/kWh.[40]

According to a study published in February 2016 by Bloomberg New Energy Finance (BNEF), battery prices fell 65% since 2010, and 35% just in 2015, reaching US$350 per kWh. The study concludes that battery costs are on a trajectory to make electric vehicles without government subsidies as affordable as internal combustion engine cars in most countries by 2022. BNEF projects that by 2040, long-range electric cars will cost less than US$22,000 expressed in 2016 dollars. BNEF expects electric car battery costs to be well below US$120 per kWh by 2030, and to fall further thereafter as new chemistries become available.[41][42]

Several governments have established policies and economic incentives to overcome existing barriers, promote the sales of electric cars, and fund further development of electric vehicles, batteries and components. Several national and local governments have established tax credits, subsidies, and other incentives to reduce the net purchase price of electric cars and other plug-ins.[43][44][45][46]

Maintenance

Electric cars have expensive batteries that must be replaced if they become defective; however, the lifetime of said batteries can be very long (many years). Otherwise, electric cars incur very low maintenance costs, particularly in the case of current lithium-based designs. The documentary film *Who Killed the Electric Car?*[47] shows a comparison between the parts that require replacement in gasoline-powered cars and EV1s, with the garages stating that they bring the electric cars in every 5,000 mi (8,000 km), rotate the tires, fill the windshield washer fluid and send them back out again. Other advantages of electric cars are that they do not need to be driven to petrol stations and there are often fewer fluids which need to be changed. Electric cars also do not have cooling problems like other vehicles.[48][49]

The Tesla Roadster, launched in 2008, has a range of 244 mi (393 km) and ended production in 2011.

Running costs

The cost of charging the battery depends on the price paid per kWh of electricity – which varies with location. As of November 2012, a Nissan Leaf driving 500 miles (800 km) per week is estimated to cost US$600 per year in charging costs in Illinois, U.S.,[50] as compared to US$2,300 per year in fuel costs for an average new car using regular gasoline.[51][52]

The EV1 energy use at 60 mph (97 km/h) was about 16.8 kW·h/100 mi (10.4 kW·h/100 km; 205 mpg-e).[53] The 2011/12 Nissan Leaf uses 21.25 kW·h/100 km (34.20 kW·h/100 mi; 100.6 mpg-e) according to the US Environmental Protection Agency.[54] These differences reflect the different design and utility targets for the vehicles, and the varying testing standards. The energy use greatly depends on the driving conditions and driving style. Nissan estimates that the Leaf's 5-year operating cost will be US$1,800 versus US$6,000 for a gasoline car in the US.[55] According to Nissan, the operating cost of the Leaf in the UK is 1.75 pence per mile (1.09 p/km) when charging at an off-peak electricity rate, while a conventional petrol-powered car costs more than 10 pence per mile (6.21 p/km). These estimates are based on a national average of British Petrol Economy 7 rates as of January 2012, and assumed 7 hours of charging overnight at the night rate and one hour in the daytime charged at the Tier-2 daytime rate.[56]

The following table compares out-of-pocket fuel costs estimated by the U.S. Environmental Protection Agency according to its official ratings for fuel economy (miles per gallon gasoline equivalent in the case of plug-in electric vehicles) for series production all-electric passenger vehicles rated by the EPA as of November 2016,[57][58] versus EPA rated most fuel efficient plug-in hybrid with long distance range (Chevrolet Volt – second generation), gasoline-electric hybrid car (Toyota Prius Eco - fourth generation),[59][60][61] and EPA's average new 2016 vehicle, which has a fuel economy of 25 mpg_{-US} (9.4 L/100 km; 30 mpg_{-imp}).[57][59]

Comparison of fuel efficiency and costs for all the electric cars rated by the EPA for the U.S. market as of November 2016 against EPA rated most fuel efficient plug-in hybrid, hybrid electric vehicle and 2016 average gasoline-powered car in the U.S.
(Fuel economy and operating costs as displayed in the Monroney label)[57][58][62]

Vehicle	Model year	EPA rated Combined fuel economy	EPA rated City fuel economy	EPA rated Highway fuel economy	Cost to drive 25 miles (40 km)	Annual fuel cost	Notes
Hyundai Ioniq Electric [58][63]	2017	136 mpg-e (25 kW·h/100 mi 15.7 kW·h/100 km)	150 mpg-e (22 kW·h/100 mi 14 kW·h/100 km)	122 mpg-e (28 kW·h/100 mi 17.5 kW·h/100 km)	$0.81	$500	(1) (4)
BMW i3 (60 A·h)[64][65]	2014/15/16	124 mpg-e (27 kW·h/100 mi 17.2 kW·h/100 km)	137 mpg-e (25 kW·h/100 mi 15.6 kW·h/100 km)	111 mpg-e (30 kW·h/100 mi 19.3 kW·h/100 km)	$0.88	$550	(1) (3) (4) (5)
Scion iQ EV [66]	2013	121 mpg-e (28 kW·h/100 mi 17.7 kW·h/100 km)	138 mpg-e (24 kW·h/100 mi 15.5 kW·h/100 km)	105 mpg-e (32 kW·h/100 mi 20.4 kW·h/100 km)	$0.91	$550	(1)
Chevrolet Bolt EV[67]	2017	119 mpg-e (28 kW-hrs/100 mi 17.7 kW·h/100 km)	128 mpg-e (16.7 kW·h/100 km)	110 mpg-e (19 kW·h/100 km)	$0.91	$550	
Chevrolet Spark EV[68]	2014/15/16	119 mpg-e (28 kW·h/100 mi 18.0 kW·h/100 km)	128 mpg-e (26 kW·h/100 mi 16.7 kW·h/100 km)	109 mpg-e (31 kW·h/100 mi 19.6 kW·h/100 km)	$0.91	$550	(1)
BMW i3 (94 A·h)[64]	2017	118 mpg-e (29 kW·h/100 mi 18.1 kW·h/100 km)	129 mpg-e (16.6 kW·h/100 km)	106 mpg-e (20.2 kW·h/100 km)	$0.94	$550	(1)
Honda Fit EV[69]	2013/14	118 mpg-e (29 kW·h/100 mi 18.1 kW·h/100 km)	132 mpg-e (26 kW·h/100 mi 16.2 kW·h/100 km)	105 mpg-e (32 kW·h/100 mi 20.4 kW·h/100 km)	$0.94	$550	(1)
Fiat 500e[70]	2013/14/15	116 mpg-e (29 kW·h/100 mi 18.4 kW·h/100 km)	122 mpg-e (28 kW·h/100 mi 17.5 kW·h/100 km)	108 mpg-e (31 kW·h/100 mi 19.8 kW·h/100 km)	$0.95	$550	(1)
Volkswagen e-Golf[71]	2015/16	116 mpg-e (29 kW·h/100 mi 18.4 kW·h/100 km)	126 mpg-e (27 kW·h/100 mi; 17.0 kW·h/100 km)	105 mpg-e (33 kW·h/100 mi; 20.4 kW·h/100 km)	$0.95	$550	(1)
Nissan Leaf (24 kW-hr) [72]	2013/14/15/16	114 mpg-e (30 kW·h/100 mi; 18.7 kW·h/100 km)	126 mpg-e (27 kW·h/100 mi; 17.0 kW·h/100 km)	101 mpg-e (33 kW·h/100 mi; 21 kW·h/100 km)	$0.96	$600	(1) (6)
Mitsubishi i [73]	2012/13/14/16	112 mpg-e (30 kW·h/100 mi; 19.1 kW·h/100 km)	126 mpg-e (27 kW·h/100 mi; 17.0 kW·h/100 km)	99 mpg-e (34 kW·h/100 mi; 22 kW·h/100 km)	$0.98	$600	(1)
Nissan Leaf (30 kW-hr) [72]	2016	112 mpg-e (30 kW·h/100 mi; 19.1 kW·h/100 km)	124 mpg-e (28 kW·h/100 mi; 17.2 kW·h/100 km)	101 mpg-e (34 kW·h/100 mi; 21 kW·h/100 km)	$0.97	$600	(1)
Fiat 500e[74]	2016	112 mpg-e (30 kW·h/100 mi; 19.1 kW·h/100 km)	121 mpg-e (28 kW·h/100 mi; 17.7 kW·h/100 km)	103 mpg-e (33 kW·h/100 mi; 21 kW·h/100 km)	$0.97	$600	(1)
Smart electric drive[75]	2013/14/15/16	107 mpg-e (32 kW·h/100 mi; 20.0 kW·h/100 km)	122 mpg-e (28 kW·h/100 mi; 17.5 kW·h/100 km)	93 mpg-e (36 kW·h/100 mi; 23 kW·h/100 km)	$1.02	$600	(1) (7)
Kia Soul EV [76]	2015/16	105 mpg-e (32 kW·h/100 mi; 20.4 kW·h/100 km)	120 mpg-e (29 kW·h/100 mi; 18 kW·h/100 km)	92 mpg-e (37 kW·h/100 mi; 23 kW·h/100 km)	$1.04	$600	(1)

Vehicle	Model year	EPA rated Combined fuel economy	EPA rated City fuel economy	EPA rated Highway fuel economy	Cost to drive 25 miles (40 km)	Annual fuel cost	Notes
Comparison of fuel efficiency and costs for all the electric cars rated by the EPA for the U.S. market as of November 2016 against EPA rated most fuel efficient plug-in hybrid, hybrid electric vehicle and 2016 average gasoline-powered car in the U.S. (Fuel economy and operating costs as displayed in the Monroney label)[57][58][62]							
Ford Focus Electric[77]	2012/13/14/15/16	105 mpg-e (32 kW·h/100 mi; 20.4 kW·h/100 km)	110 mpg-e (31 kW·h/100 mi; 19 kW·h/100 km)	99 mpg-e (34 kW·h/100 mi; 22 kW·h/100 km)	$1.04	$600	(1)
Tesla Model S AWD - 70D[57][78]	2015/16	101 mpg-e (33 kW·h/100 mi; 21 kW·h/100 km)	101 mpg-e (33 kW·h/100 mi; 21 kW·h/100 km)	102 mpg-e (33 kW·h/100 mi; 21 kW·h/100 km)	$1.07	$650	(1)
Tesla Model S AWD - 85D[57][79]	2015/16	100 mpg-e (34 kW·h/100 mi; 21 kW·h/100 km)	95 mpg-e (35 kW·h/100 mi; 22 kW·h/100 km)	106 mpg-e (32 kW·h/100 mi; 20.2 kWh/100 km)	$1.10	$650	(1) (8)
Tesla Model S AWD - 90D[57][78]	2015/16	100 mpg-e (34 kW·h/100 mi; 21 kW·h/100 km)	95 mpg-e (35 kW·h/100 mi; 22 kW·h/100 km)	106 mpg-e (32 kW·h/100 mi; 20.2 kW·h/100 km)	$1.10	$650	(1)
Tesla Model S (60 kW·h)[57][78]	2014/15/16	95 mpg-e (35 kW·h/100 mi; 22 kW·h/100 km)	94 mpg-e (36 kW·h/100 mi; 23 kW·h/100 km)	97 mpg-e (35 kW·h/100 mi; 22 kW·h/100 km)	$1.14	$700	(1)
Tesla Model S AWD - P85D[57][79]	2015/16	93 mpg-e (36 kW·h/100 mi; 23 kW·h/100 km)	89 mpg-e (38 kW·h/100 mi; 24 kW·h/100 km)	98 mpg-e (35 kW·h/100 mi; 22 kW·h/100 km)	$1.17	$700	(1) (8)
Tesla Model S AWD - P90D[57][78]	2015/16	93 mpg-e (36 kW·h/100 mi; 23 kW·h/100 km)	89 mpg-e (38 kW·h/100 mi; 24 kW·h/100 km)	98 mpg-e (35 kW·h/100 mi; 22 kW·h/100 km)	$1.17	$700	(1)
Tesla Model X AWD – 90D[80]	2016	92 mpg-e (34 kW·h/100 mi; 23 kW·h/100 km)	90 mpg-e (37 kW·h/100 mi; 24 kW·h/100 km)	94 mpg-e (32 kW·h/100 mi; 23 kW·h/100 km)	$1.20	$700	(1)
Tesla Model X AWD – P90D[80]	2016	89 mpg-e (38 kW·h/100 mi; 24 kW·h/100 km)	89 mpg-e (38 kW·h/100 mi; 24 kW·h/100 km)	90 mpg-e (38 kW·h/100 mi; 24 kW·h/100 km)	$1.23	$750	(1)
Tesla Model S (85 kW·h)[81]	2012/13/14/15	89 mpg-e (38 kW·h/100 mi; 24 kW·h/100 km)	88 mpg-e (38 kW·h/100 mi; 24 kW·h/100 km)	90 mpg-e (37 kW·h/100 mi; 24 kW·h/100 km)	$1.23	$750	(1)
Mercedes-Benz B-Class Electric Drive[82]	2014/15/16	84 mpg-e (40 kW·h/100 mi; 25 kW·h/100 km)	85 mpg-e (40 kW·h/100 mi; 25 kW·h/100 km)	83 mpg-e (41 kW·h/100 mi; 26 kW·h/100 km)	$1.30	$800	(1)
Toyota RAV4 EV[83]	2012/13/14	76 mpg-e (44 kW·h/100 mi; 28 kW·h/100 km)	78 mpg-e (43 kW·h/100 mi; 27 kW·h/100 km)	74 mpg-e (46 kW·h/100 mi; 29 kW·h/100 km)	$1.43	$850	(1)
BYD e6[57][84]	2012/13/14/15/16	63 mpg-e (54 kW·h/100 mi; 34 kW·h/100 km)	61 mpg-e (55 kW·h/100 mi; 35 kW·h/100 km)	65 mpg-e (52 kW·h/100 mi; 33 kW·h/100 km)	$1.76	$1,050	(1)
Second gen Chevrolet Volt[57][85][86] Plug-in	2016	106 mpg-e (31 kW·h/100 mi; 20.2 kW·h/100 km) 42 mpg	113 mpg-e (30 kW·h/100 mi; 18.9 kW·h/100 km) 43 mpg	99 mpg-e (35 kW·h/100 mi; 22 kW·h/100 km) 42 mpg	$1.01/ $1.23	$650	(1) (2) (9)

Comparison of fuel efficiency and costs for all the electric cars rated by the EPA for the U.S. market as of November 2016 against EPA rated most fuel efficient plug-in hybrid, hybrid electric vehicle and 2016 average gasoline-powered car in the U.S. **(Fuel economy and operating costs as displayed in the Monroney label)**[57][58][62]							
Vehicle	**Model year**	**EPA rated Combined fuel economy**	**EPA rated City fuel economy**	**EPA rated Highway fuel economy**	**Cost to drive 25 miles (40 km)**	**Annual fuel cost**	**Notes**
hybrid (PHEV) Electricity only/ gasoline only							
2016 Toyota Prius Eco (4th gen)[60] Hybrid electric vehicle (HEV) Gasoline-electric hybrid	2016	56 mpg	58 mpg	53 mpg	$0.92	$550	(2) (10)
Ford Fusion AWD A-S6 2.0L[57][87] Gasoline-powered (Average new vehicle)	2016	25 mpg	22 mpg	31 mpg	$2.06	$1,250	(2) (11)

Notes: All estimated fuel costs based on 15,000 miles (24,000 km) annual driving, 45% highway and 55% city

(1) Values rounded to the nearest $50. Electricity cost of $0.13/kW·h (as of 18 November 2016). Conversion 1 gallon of gasoline=33.7 kW·h.
(2) Regular gasoline price of US$2.06 per gallon (as of 3 December 2015).
(3) The 2014 i3 REx is classified by EPA as a series plug-in hybrid, while for CARB is a range-extended battery-electric vehicle (BEVx). The i3 REx is the most fuel efficient EPA-certified current year vehicle with a gasoline engine with a combined gasoline/electricity rating of 88 mpg-e, but its total range is limited to 150 mi (240 km).[59][88]
(4) The 2014/16 BMW i3 (60 A·h) ranked as the most fuel efficient EPA-certified vehicle of all fuel types considered in all years until MY 2016. It was surpassed by the 2017 Hyundai Ioniq Electric in November 2016.[88]
(5) The i3 REx has a combined fuel economy in all-electric mode of 117 mpg-e (29 kW·h/100 mi; 18 kW·h/100 km).[89]
(6) The 2016 model year Leaf correspond to the variant with the 24 kW·h battery pack.
(7) Ratings correspond to both convertible and coupe models.
(8) Model with 85 kW·h battery pack
(9) Most fuel efficient plug-in hybrid capable of long distance travel. The 2016 Volt has a rating of 77 mpg-e for combined gasoline/electricity operation.[59]
(10) Most fuel efficient hybrid electric car.[57][59] (11) Other 2016 MY cars achieving 25 mpg_{-US} (9.4 L/100 km; 30 mpg_{-imp}) combined city/hwy include the Honda Accord A-S6 3.5L, Toyota Camry A-S6 3.5L and Toyota RAV4 A-S6 2.5L.[57][87]

Mileage costs

Most of the mileage-related cost of an electric vehicle can be attributed to electricity costs of charging the battery pack, and its potential replacement with age, because an electric vehicle has only around five moving parts in its motor, compared to a gasoline car that has hundreds of parts in its internal combustion engine.[90] To calculate the cost per kilometer of an electric vehicle it is therefore necessary to assign a monetary value to the wear incurred on the battery. With use, the capacity of a battery decreases. However, even an 'end of life' battery which has insufficient capacity has market value as it can be re-purposed, recycled or used as a spare. The Tesla Roadster's very large battery pack is expected to last seven years with typical driving and costs US$12,000 when pre-purchased today.[91][92] Driving 40 miles (64 km) per day for seven years or 102,200 miles (164,500 km) leads to a battery consumption cost of US$0.1174 per 1 mile (1.6 km) or US$4.70 per 40 miles (64 km).

Plug in America did a survey on the service life of the installed battery in the Tesla Roadster. It found that after 100,000 miles = 160,000 km, the battery still had a remaining capacity of 80 to 85 percent. This was regardless of in which climate zone the car is moved.[93][94] The Tesla Roadster was built and sold between 2008 and 2012. For its 85-kWh batteries in the Tesla Model S Tesla are 8-year warranty with unlimited mileage.[95] The now-defunct company Better Place provided another cost comparison when it anticipated meeting contractual obligations to deliver batteries, as well as clean electricity to recharge the batteries, at a total cost of US$0.08 per 1 mile (1.6 km) in 2010, US$0.04 per mile by 2015 and US$0.02 per mile by 2020.[96] 40 miles (64 km) of driving would initially cost US$3.20 and fall over time to US$0.80.

Total cost of ownership

A 2010 report, by J.D. Power and Associates states that it is not entirely clear to consumers the total cost of ownership of battery electric vehicles over the life of the vehicle, and "*there is still much confusion about how long one would have to own such a vehicle to realize cost savings on fuel, compared with a vehicle powered by a conventional internal combustion engine (ICE). The resale value of HEVs and BEVs, as well as the cost of replacing depleted battery packs, are other financial considerations that weigh heavily on consumers' minds*."[97]

A study published in 2011, by the Belfer Center, Harvard University, found that the gasoline costs savings of plug-in electric cars over their lifetimes do not offset their higher purchase prices. The study compared the lifetime net present value at 2010 purchase and operating costs for the US market with no government subsidies.[98][99] The study estimated that a PHEV-40 is US$5,377 more expensive than a conventional internal combustion engine, while a battery electric vehicle is US$4,819 more expensive. But assuming that battery costs will decrease and gasoline prices increase over the next 10 to 20 years, the study found that BEVs will be significantly cheaper than conventional cars (US$1,155 to US$7,181 cheaper). PHEVs, will be more expensive than BEVs in almost all comparison scenarios, and more expensive than conventional cars unless battery costs are very low and gasoline prices high. Savings differ because BEVs are simpler to build and do not use liquid fuel, while PHEVs have more complicated power trains and still have gasoline-powered engines.[98]

BYD calculates on its website (2015) that a BYD e6 (taxi) achieved with a maturity of 5 years alone in energy costs, so power consumption instead of petrol consumption, a saving of about $74,000.[100]

Dealership reluctance to sell

With the exception of Tesla Motors, almost all new cars in the United States are sold through dealerships, so they play a crucial role in the sales of electric vehicles, and negative attitudes can hinder early adoption of plug-in electric vehicles.[101][102] Dealers decide which cars they want to stock, and a salesperson can have a big impact on how someone feels about a prospective purchase. Sales people have ample knowledge of internal combustion cars while they do not have time to learn about a technology that represents a fraction of overall sales.[101] As with any new technology, and in the particular case of advanced technology vehicles, retailers are central to ensuring that buyers, especially those switching to a new technology, have the information and support they need to gain the full benefits of adopting this new technology.[102]

There are several reasons for the reluctance of some dealers to sell plug-in electric vehicles. PEVs do not offer car dealers the same profits as gasoline-powered car. Plug-in electric vehicles take more time to sell because of the explaining required, which hurts overall sales and sales people commissions. Electric vehicles also may require less maintenance, resulting in loss of service revenue, and thus undermining the biggest source of dealer profits, their service departments. According to the National Automobile Dealers Association (NADA), dealers on average make three times as much profit from service as they do from new car sales. However, a NADA spokesman said there was not sufficient data to prove that electric cars would require less maintenance.[101] According to The New York Times, BMW and Nissan are among the companies whose dealers tend to be more enthusiastic and informed, but only about 10% of dealers are knowledgeable on the new technology.[101]

A study conducted at the Institute of Transportation Studies (ITS), at the University of California, Davis (UC Davis) published in 2014 found that many car dealers are less than enthusiastic about plug-in vehicles. ITS conducted 43 interviews with six automakers and 20 new car dealers selling plug-in vehicles in California's major metro markets. The study also analyzed national and state-level J.D. Power 2013 Sales Satisfaction Index (SSI) study data on customer satisfaction with new car dealerships and Tesla retail stores. The researchers found that buyers of plug-in electric vehicles were significantly less satisfied and rated the dealer purchase experience much lower than buyers of non-premium conventional cars, while Tesla Motors earned industry-high scores. According to the findings, plug-in buyers expect more from dealers than conventional buyers, including product knowledge and support that extends beyond traditional offerings.[102][103]

Car dealerships play a crucial role in the sales of plug-in electric vehicles. Shown a Tesla Motors retail store in Washington, D.C.

In 2014 Consumer Reports published results from a survey conducted with 19 secret shoppers that went to 85 dealerships in four states, making anonymous visits between December 2013 and March 2014. The secret shoppers asked a number of specific questions about cars to test the salespeople's knowledge about electric cars. The consumer magazine decided to conduct the survey after several consumers who wanted to buy a plug-in car reported to the organization that some dealerships were steering them toward gasoline-powered models. The survey found that not all sales people seemed enthusiastic about making PEV sales; a few outright discouraged it, and one dealer was reluctant to even show a plug-in model despite having one in stock. And many sales people seemed not to have a good understanding of electric-car tax breaks and other incentives or of charging needs and costs. Consumer Reports also found that when it came to answering basic questions, sales people at Chevrolet, Ford, and Nissan dealerships tended to be better informed than those at Honda and Toyota. The survey found that most of the Toyota dealerships visited recommended against buying a Prius Plug-in and suggested buying a standard Prius hybrid instead. Overall, the secret shoppers reported that only 13 dealers "discouraged sale of EV," with seven of them being in New York. However, at 35 of the 85 dealerships visited, the secret shoppers said sales people recommended buying a gasoline-powered car instead.[104]

The ITS-Davis study also found that a small but influential minority of dealers have introduced new approaches to better meet the needs of plug-in customers. Examples include marketing carpool lane stickers, enrolling buyers in charging networks, and preparing incentive paperwork for customers. Some dealers assign seasoned sales people as plug-in experts, many of whom drive plug-ins themselves to learn and be familiar with the technology and relate the car's benefits to potential buyers. The study concluded also that carmakers could do much more to support dealers selling PEVs.[102]

Environmental aspects

Electricity generation for electric cars

Electric cars usually also show significantly reduced greenhouse gas emissions, depending on the method used for electricity generation to charge the batteries.[3][4] For example, some battery electric vehicles do not produce CO_2 emissions at all, but only if their energy is obtained from sources such as solar, wind, nuclear, or hydropower.[105]

A solar energy charging station in North America

Even when the power is generated using fossil fuels, electric vehicles usually, compared to gasoline vehicles, show significant reductions in overall well-wheel global carbon emissions due to the highly carbon-intensive production in mining, pumping, refining, transportation and the efficiencies obtained with gasoline.[106] Researchers in Germany have claimed that while there is some technical superiority of electric propulsion compared with conventional technology that in many countries the effect of electrification of vehicles' fleet emissions will predominantly be due to regulation rather than technology.[107] Indeed, electricity production is submitted to emission quotas, while vehicles' fuel propulsion is not, thus electrification shifts demand from a non-capped sector to a capped sector. This means that the emissions of electrical grids can be expected to improve over time as more wind and solar generation is deployed.

Many countries are introducing CO_2 average emissions targets across all cars sold by a manufacturer, with financial penalties on manufacturers that fail to meet these targets. This has created an incentive for manufacturers, especially those selling many heavy or high-performance cars, to introduce electric cars as a means of reducing average fleet CO_2 emissions.[108]

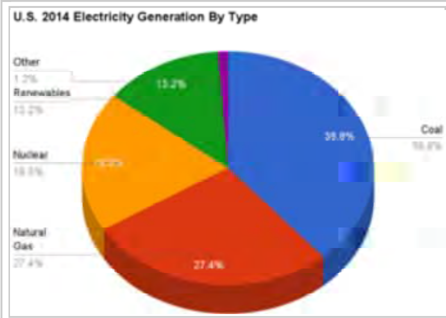
Air pollution and carbon emissions

Electric cars have several benefits over conventional internal combustion engine automobiles, including a significant reduction of local air pollution, especially in cities, as they do not emit harmful tailpipe pollutants such as particulates (soot), volatile organic compounds, hydrocarbons, carbon monoxide, ozone, lead, and various oxides of nitrogen.[109][110][111] The clean air benefit may only be local because, depending on the source of the electricity used to recharge the batteries, air pollutant emissions may be shifted to the location of the generation plants.[3] This is referred to as the long tailpipe of electric vehicles. The amount of carbon dioxide emitted depends on the emission intensity of the power sources used to charge the vehicle, the efficiency of the said vehicle and the energy wasted in the charging process. For mains electricity the emission intensity varies significantly per country and within a particular country, and on the demand, the availability of renewable sources and the efficiency of the fossil fuel-based generation used at a given time.[112][113][114]

Charging a vehicle using renewable energy (e.g., wind power or solar panels) yields very low carbon footprint-only that to produce and install the generation system (see Energy Returned On Energy Invested.) Even on a fossil-fueled grid, it's quite feasible for a household with a solar panel to produce enough energy to account for their electric car usage, thus (on average) cancelling out the emissions of charging the vehicle, whether or not the panel directly charges it.[115] Even when using exclusively grid electricity, introducing EVs comes with a major environmental benefits in most (EU) countries, except those relying on old coal fired power plants.[113] So for example the part of electricity, which is produced with renewable energy is (2014) in Norway 99 percent and in Germany 30 percent.

United States

The following table compares tailpipe and upstream CO_2 emissions estimated by the U.S. Environmental Protection Agency for all series production model year 2014 all-electric passenger vehicles available in the U.S. market. Since all-electric cars do not produce tailpipe emissions, for comparison purposes the two most fuel efficient plug-in hybrids and the typical gasoline-powered car are included in the table. Total emissions include the emissions associated with the production and distribution of electricity used to charge the vehicle, and for plug-in hybrid electric vehicles, it also includes emissions associated with tailpipe emissions produced from the internal combustion engine. These figures were published by the EPA in October in its 2014 report "*Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends*."[117]



U.S. 2014 electricity generation by type[116]

To account for the upstream CO_2 emissions associated with the production and distribution of electricity, and since electricity production in the United States varies significantly from region to region, the EPA considered three scenarios/ranges with the low end scenario corresponding to the California powerplant emissions factor, the middle of the range represented by the national average powerplant emissions factor, and the upper end of the range corresponding to the powerplant emissions factor for the Rocky Mountains. The EPA estimates that the electricity GHG emission factors for various regions of the country vary from 346 g CO_2/kWh in California to 986 g CO_2/kWh in the Rockies, with a national average of 648 g CO_2/kWh.[117] In the case of plug-in hybrids, and since their all-electric range depends on the size of the battery pack, the analysis introduced a utility factor as a projection of the share of miles that will be driven using electricity by an average driver.[117]

Comparison of tailpipe and upstream CO_2 emissions(1) estimated by EPA for the MY 2014 all-electric vehicles available in the U.S. market[117]						
Vehicle	**Overall fuel economy (mpg-e)**	**Utility factor(2) (share EV miles)**	**Tailpipe CO_2 (g/mi)**	**Tailpipe + total upstream CO_2**		
				Low (g/mi)	**Avg (g/mi)**	**High (g/mi)**
BMW i3	124	1	0	93	175	266
Chevrolet Spark EV	119	1	0	97	181	276
Honda Fit EV	118	1	0	99	185	281
Fiat 500e	116	1	0	101	189	288
Nissan Leaf	114	1	0	104	194	296
Mitsubishi i	112	1	0	104	195	296
Smart electric drive	107	1	0	109	204	311
Ford Focus Electric	105	1	0	111	208	316
Tesla Model S (60 kWh)	95	1	0	122	229	348
Tesla Model S (85 kWh)	89	1	0	131	246	374
BMW i3 REx(3)	88	0.83	40	134	207	288
Mercedes-Benz B-Class ED	84	1	0	138	259	394
Toyota RAV4 EV	76	1	0	153	287	436
BYD e6	63	1	0	187	350	532
Chevrolet Volt plug-in hybrid	62	0.66	81	180	249	326
Average 2014 gasoline-powered car	**24.2**	**0**	**367**	**400**	**400**	**400**
Notes: (1) Based on 45% highway and 55% city driving. (2) The utility factor represents, on average, the percentage of miles that will be driven using electricity (in electric only and blended modes) by an average driver. (3) The EPA classifies the i3 REx as a series plug-in hybrid.[51][117]						

The Union of Concerned Scientists (UCS) published in 2012, a report with an assessment of average greenhouse gas emissions resulting from charging plug-in car batteries considering the full life-cycle (well-to-wheel analysis) and the fuel used to generate electric power by region in the U.S. The study used the Nissan Leaf all-electric car to establish the analysis's baseline. The UCS study expressed the results in terms of miles per gallon instead of the conventional unit of grams of carbon dioxide emissions per year. The study found that in areas where electricity is generated from natural gas, nuclear, or renewable resources such as hydroelectric, the potential of plug-in electric cars to reduce greenhouse emissions is significant. On the other hand, in regions where a high proportion of power is generated from coal, hybrid electric cars produce less CO_2 emissions than plug-in electric cars, and the best fuel efficient gasoline-powered subcompact car produces slightly less emissions than a plug-in car. In the worst-case scenario, the study estimated that for a region where all energy is generated from coal, a plug-in electric car would emit greenhouse gas emissions equivalent to a gasoline car rated at a combined city/highway fuel economy of 30 mpg$_{\text{-US}}$ (7.8 L/100 km; 36 mpg$_{\text{-imp}}$). In contrast, in a region that is completely reliant on natural gas, the plug-in would be equivalent to a gasoline-powered car rated at 50 mpg$_{\text{-US}}$ (4.7 L/100 km; 60 mpg$_{\text{-imp}}$) combined.[118][119]

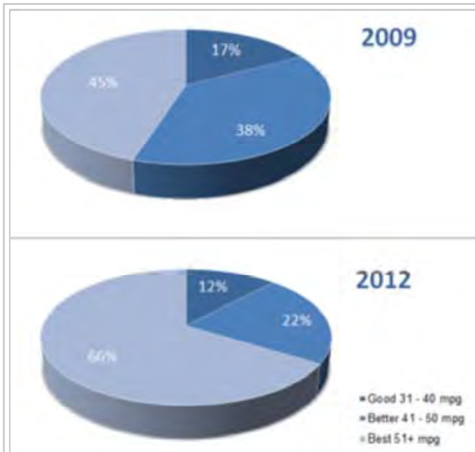
The study found that for 45% of the U.S. population, a plug-in electric car will generate lower CO_2 emissions than a gasoline-powered car capable of a combined fuel economy of 50 mpg$_{\text{-US}}$ (4.7 L/100 km; 60 mpg$_{\text{-imp}}$), such as the Toyota Prius. Cities in this group included Portland, Oregon, San Francisco, Los Angeles, New York City, and Salt Lake City, and the cleanest cities achieved well-to-wheel emissions equivalent to a fuel economy of 79 mpg$_{\text{-US}}$ (3.0 L/100 km; 95 mpg$_{\text{-imp}}$). The study also found that for 37% of the population, the electric car emissions will fall in the range of a gasoline-powered car rated at a combined fuel economy between 41 to 50 mpg$_{\text{-US}}$ (5.7 to 4.7 L/100 km; 49 to 60 mpg$_{\text{-imp}}$), such as the Honda Civic Hybrid and the Lexus CT200h. Cities in this group include Phoenix, Arizona, Houston, Miami, Columbus, Ohio and Atlanta, Georgia. An 18% of the population lives in areas where the power supply is more dependent on burning carbon, and emissions will be equivalent to a car rated at a combined fuel economy between 31 to 40 mpg$_{\text{-US}}$ (7.6 to 5.9 L/100 km; 37 to 48 mpg$_{\text{-imp}}$), such as the Chevrolet Cruze and Ford Focus. This group includes Denver, Minneapolis, Saint Louis, Missouri, Detroit, and Oklahoma City.[119][120][121] The study found that there are no regions in the

U.S. where plug-in electric cars will have higher greenhouse gas emissions than the average new compact gasoline engine automobile, and the area with the dirtiest power supply produces CO_2 emissions equivalent to a gasoline-powered car rated 33 mpg-US (7.1 L/100 km; 40 mpg-imp).[118]

In September 2014, the UCS published an updated analysis of its 2012 report. The 2014 analysis found that 60% of Americans, up from 45% in 2009, live in regions where an all-electric car produce fewer CO_2 equivalent emissions per mile than the most efficient hybrid. The UCS study found two reasons for the improvement. First, electric utilities have adopted cleaner sources of electricity to their mix between the two analysis. Second, electric vehicles have become more efficient, as the average 2013 all-electric vehicle used 0.33 kWh per mile (0.21 kWh/km), representing a 5% improvement over 2011 models. Also, some new models are cleaner than the average, such as the BMW i3, which is rated at 0.27 kWh by the EPA. In states with a cleaner mix generation, the gains were larger. The average all-electric car in California went up to 95 mpg-US (2.5 L/100 km) equivalent from 78 mpg-US (3.0 L/100 km) in the 2012 study. States with dirtier generation that rely heavily on coal still lag, such as Colorado, where the average BEV only achieves the same emissions as a 34 mpg-US (6.9 L/100 km; 41 mpg-imp) gasoline-powered car. The author of the 2014 analysis noted that the benefits are not distributed evenly across the U.S. because electric car adoptions is concentrated in the states with cleaner power.[122][123]

One criticism to the UCS analysis and several other that have analyze the benefits of PEVs is that these analysis were made using average emissions rates across regions instead of marginal generation at different times of the day. The former approach does not take into account the generation mix within interconnected electricity markets and shifting load profiles throughout the day.[124][125] An analysis by three economist affiliated with the National Bureau of Economic Research (NBER), published in November 2014, developed a methodology to estimate marginal emissions of electricity demand that vary by location and time of day across the United States. The marginal analysis, applied to plug-in electric vehicles, found that the emissions of charging PEVs vary by region and hours of the day. In some regions, such as the Western U.S. and Texas, CO_2 emissions per mile from driving PEVs are less than those from driving a hybrid car. However, in other regions, such as the Upper Midwest, charging during the recommended hours of midnight to 4 a.m. implies that PEVs generate more emissions per mile than the average car currently on the road.

The results show a tension between electricity load management and environmental goals as the hours when electricity is the least expensive to produce tend to be the hours with the greatest emissions. This occurs because coal-fired units, which have higher emission rates, are most commonly used to meet base-level and off-peak electricity demand; while natural gas units, which have relatively low emissions rates, are often brought online to meet peak demand.[125] In November 2015, the Union of Concerned Scientists published a new report comparing two battery electric vehicles (BEVs) with similar gasoline vehicles by examining their global warming emissions over their full life-cycle, craddle-to-grave analysis. The two BEVs modeled, midsize and full-size, are based on the two most popular BEV models sold in the United States in 2015, the Nissan LEAF and the Tesla Model S. The study found that all-electric cars representative of those sold today, on average produce less than half the global warming emissions of comparable gasoline-powered vehicles, despite taken into account the higher emissions associated with BEV manufacturing. Considering the regions where the two most popular electric cars are being sold, excess manufacturing emissions are offset within 6 to 16 months of average driving. The study also concluded that driving an average EV results in lower global warming emissions than driving a gasoline car that gets 50 mpg-US (4.7 L/100 km) in regions covering two-thirds of the U.S. population, up from 45% in 2009. Based on where EVs are being sold in the United States in 2015, the average EV produces global warming emissions equal to a gasoline vehicle with a 68 mpg-US (3.5 L/100 km) fuel economy rating. The authors identified two main reason for the fact that EV-related emissions have become even lower in many parts of the country since the first study was conducted in 2012. Electricity generation has been getting cleaner, as coal-fired generation has declined while lower-carbon alternatives have increased. In addition, electric cars are becoming more efficient. For example, the Nissan Leaf and the Chevrolet Volt, have undergone improvements to increase their efficiencies compared to the original models launched in 2010, and other even more efficient BEV models, such as the most lightweight and efficient BMW i3, have entered the market.[126][127]



Change from 2009 to 2012 of the percentage of Americans that live in regions where powering an electric vehicle on the regional electricity grid produces lower global warming emissions than a gasoline car expressed in terms of combined cith/highway fuel economy rating. Source: Union of Concerned Scientists.[126]

United Kingdom

A study made in the UK in 2008, concluded that electric vehicles had the potential to cut down carbon dioxide and greenhouse gas emissions by at least 40%, even taking into account the emissions due to current electricity generation in the UK and emissions relating to the production and disposal of electric vehicles.[128] The savings are questionable relative to hybrid or diesel cars (according to official British government testing, the most efficient European market cars are well below 115 grams of CO_2 per kilometer driven, although a study in Scotland gave 149.5 gCO_2/km as the average for new cars in the UK[129]), but since UK consumers can select their energy suppliers, it also will depend on how 'green' their chosen supplier is in providing energy into the grid. In contrast to other countries, in the UK a stable part of the electricity is produced by nuclear, coal and gas plants. Therefore, there are only minor differences in the environmental impact over the year.[113]

Germany

In a worst-case scenario where incremental electricity demand would be met exclusively with coal, a 2009 study conducted by the World Wide Fund for Nature and IZES found that a mid-size EV would emit roughly 200 g(CO_2)/km (11 oz(CO_2)/mi), compared with an average of 170 g(CO_2)/km (9.7 oz(CO_2)/mi) for a gasoline-powered compact car.[130] This study concluded that introducing 1 million EV cars to Germany would, in the best-case scenario, only reduce CO_2 emissions by 0.1%, if nothing is done to upgrade the electricity infrastructure or manage demand.[130] A more reasonable estimate, relaxing the coal assumption, was provided by Massiani and Weinmann taking into account that the source of energy used for electricity generation would be determined based on the temporal pattern of the additional electricity demand (in other words an increase in electricity consumption at peak hour will activate the marginal technology, while an off peak increase would typically activate other technologies). Their conclusion is that natural gas will provide most of the energy used to reload EV, while renewable energy will not represent more than a few percent of the energy used.[131]

Volkswagen conducted a life-cycle assessment of its electric vehicles certified by an independent inspection agency. The study found that CO_2 emissions during the use phase of its all-electric VW e-Golf are 99% lower than those of the Golf 1.2 TSI when powers comes from exclusively hydroelectricity generated in Germany, Austria and Switzerland. Accounting for the electric car entire life-cycle, the e-Golf reduces emissions by 61%. When the actual EU-27 electricity mix is considered, the e-Golf emissions are still 26% lower than those of the conventional Golf 1.2 TSI.[132] In 2014 in Germany, 28 percent of whole electricity was renewable energy produced in Germany.

France and Belgium

In France and Belgium, which have many nuclear power plants, CO_2 emissions from electric car use would be about 12 g/km (19.3 g/mi).[133] Because of the stable nuclear production, the timing of charging electric cars has almost no impact on their environmental footprint.[113]

Emissions during production

Several reports have found that hybrid electric vehicles, plug-in hybrids and all-electric cars generate more carbon emissions during their production than current conventional vehicles, but still have a lower overall carbon footprint over the full life cycle. The initial higher carbon footprint is due mainly to battery production.[113] As an example, the Ricardo study estimated that 43 percent of production emissions for a mid-size electric car are generated from the battery production.[134]

Environmental impact of manufacturing

Electric cars are not completely environmentally friendly, and have impacts arising from manufacturing the vehicle.[135][136] Since battery packs are heavy, manufacturers work to lighten the rest of the vehicle. As a result, electric car components contain many lightweight materials that require a lot of energy to produce and process, such as aluminium and carbon-fiber-reinforced polymers. Electric motors and batteries also add to the energy of electric-car manufacture.[137] Additionally, the magnets in the motors of many electric vehicles contain rare earth metals. In a study released in 2012, a group of MIT researchers calculated that global mining of two rare Earth metals, neodymium and dysprosium, would need to increase 700% and 2600%, respectively, over the next 25 years to keep pace with various green-tech plans.[138] Substitute strategies do exist, but deploying them introduces trade-offs in efficiency and cost.[137] The same MIT study noted that the materials used in batteries are also harmful to the environment.[139] Compounds such as lithium, copper, and nickel are mined from the Earth and processed in a manner that demands energy and can release toxic components. In regions with poor legislature, mineral exploitation can even further extend risks. The local population may be exposed to toxic substances through air and groundwater contamination.[137]

A paper published in the Journal of Industrial Ecology named *"Comparative environmental life cycle assessment of conventional and electric vehicles"* begins by stating that it is important to address concerns of problem-shifting.[140] The study highlighted in particular the toxicity of the electric car's manufacturing process compared to conventional petrol/diesel cars. It concludes that the global warming potential of the process used to make electric cars is twice that of conventional cars. The study also finds that electric cars do not make sense if the electricity they consume is produced predominately by coal-fired power plants.[141] However, the study was later corrected by the authors due to them overstating the environmental damage of electric vehicles in the first paper; many of the components of electric vehicles had been incorrectly modelled, and the European power grids were cleaner in many respects than their paper had assumed.[142]

In February 2014, the Automotive Science Group (ASG) published the result of a study conducted to assess the life-cycle of over 1,300 automobiles across nine categories sold in North America. The study found that among advanced automotive technologies, the Nissan Leaf holds the smallest life-cycle environmental footprint of any model year 2014 automobile available in the North American market with minimum four-person occupancy. The study concluded that the increased environmental impacts of manufacturing the battery electric technology is more than offset with increased environmental performance during operational life. For the assessment, the study used the average electricity mix of the U.S. grid in 2014.[143][144]

Performance

Acceleration and drivetrain design

Electric motors can provide high power-to-weight ratios, and batteries can be designed to supply the large currents to support these motors. Electric motors have very flat torque curves down to zero speed. For simplicity and reliability, many electric cars use fixed-ratio gearboxes and have no clutch.

Rimac Concept One, electric supercar, since 2013. 0 to 100 km/h (62 mph) in 2.8 seconds, 1088 hp

Although some electric vehicles have very small motors, 15 kW (20 hp) or less and therefore have modest acceleration, many electric cars have large motors and brisk acceleration. In addition, the relatively constant torque of an electric motor, even at very low speeds tends to increase the acceleration performance of an electric vehicle relative to that of the same rated motor power internal combustion engine.

Electric vehicles can also use a direct motor-to-wheel configuration which increases the amount of available power. Having multiple motors connected directly to the wheels allows for each of the wheels to be used for both propulsion and as braking systems, thereby increasing traction.[145][146][147] When not fitted with an axle, differential, or transmission, electric vehicles have less drivetrain rotational inertia.

For example, the Venturi Fetish delivers supercar acceleration despite a relatively modest 220 kW (295 hp), and top speed of around 160 km/h (100 mph). Some DC-motor-equipped drag racer EVs have simple two-speed manual transmissions to improve top speed.[148] The Tesla Roadster 2.5 Sport can accelerate from 0 to 97 km/h (0 to 60 mph) in 3.7 seconds with a motor rated at 215 kW (288 hp).[149] The Tesla Model S P90D currently holds the world record for the quickest production electric car to do 402 m (¼ mi), which it did in 10.9 seconds.[150] And the Wrightspeed X1 prototype created by Wrightspeed Inc was in 2009 the worlds fastest street legal electric car to accelerate from 0 to 97 km/h (0 to 60 mph), which it does in 2.9 seconds.[151][152] The electric supercar Rimac Concept One can go from 0–100 km/h (0–62 mph) in 2.8 seconds using 811 kW (1,088 hp). The electric supercar Toroidion 1MW Concept can accelerate from 0 to 400 km/h (249 mph) in 11 seconds with 1 MW of power equating to 1341 horsepower.

Energy efficiency

Internal combustion engines are relatively inefficient at converting on-board fuel energy to propulsion as most of the energy is wasted as heat. On the other hand, electric motors are more efficient in converting stored energy into driving a vehicle, and electric drive vehicles do not consume energy while at rest or coasting, and some of the energy lost when braking is captured and reused through regenerative braking, which captures as much as one fifth of the energy normally lost during braking.[3][153] Also energy can get back from shock absorbers of the car.[154] Typically, conventional gasoline engines effectively use only 15% of the fuel energy content to move the vehicle or to power accessories, and diesel engines can reach on-board efficiencies of 20%, while electric drive vehicles have on-board efficiency of around 80%.[153]

Production and conversion electric cars typically use 10 to 23 kW·h/100 km (0.17 to 0.37 kW·h/mi).[53][155] Approximately 20% of this power consumption is due to inefficiencies in charging the batteries. Tesla Motors indicates that the vehicle efficiency (including charging inefficiencies) of their lithium-ion battery powered vehicle is 12.7 kW·h/100 km (0.21 kW·h/mi) and the well-to-wheels efficiency (assuming the electricity is generated from natural gas) is 24.4 kW·h/100 km (0.39 kW·h/mi).[156]

Cabin heating and cooling

Electric vehicles generate very little waste heat and resistance electric heat may have to be used to heat the interior of the vehicle if heat generated from battery charging/discharging cannot be used to heat the interior.

While heating can be simply provided with an electric resistance heater, higher efficiency and integral cooling can be obtained with a reversible heat pump (this is currently implemented in the hybrid Toyota Prius). Positive Temperature Coefficient (PTC) junction cooling[157] is also attractive for its simplicity — this kind of system is used for example in the Tesla Roadster.

To avoid draining the battery and thus reducing the range, some models allow the cabin to heated while the car is plugged in. For example, the Nissan Leaf, the Mitsubishi i-MiEV and the Tesla Model S can be pre-heated while the vehicle is plugged in.[158][159][160]

Some electric cars, for example the Citroën Berlingo Electrique, use an auxiliary heating system (for example gasoline-fueled units manufactured by Webasto or Eberspächer) but sacrifice "green" and "Zero emissions" credentials. Cabin cooling can be augmented with solar power, most simply and effectively by inducting outside air to avoid extreme heat buildup when the vehicle is closed and parked in the sunlight (such cooling mechanisms are available for conventional vehicles, in some cases as aftermarket kits). Two models of the 2010 Toyota Prius include this feature as an option.[161]

Safety

The safety issues of BEVs are largely dealt with by the international standard ISO 6469. This document is divided in three parts dealing with specific issues:

- On-board electrical energy storage, i.e. the battery
- Functional safety means and protection against failures
- Protection of persons against electrical hazards.

Risk of fire

Frontal crash test of a Volvo C30 DRIVe Electric to assess the safety of the battery pack

Lithium-ion batteries may suffer thermal runaway and cell rupture if overheated or overcharged, and in extreme cases this can lead to combustion.[162] Several plug-in electric vehicle fire incidents have taken place since the introduction of mass-production plug-in electric vehicles in 2008. Most of them have been thermal runaway incidents related to their lithium-ion battery packs, and have involved the Zotye M300 EV, Chevrolet Volt, Fisker Karma, BYD e6, Dodge Ram 1500 Plug-in Hybrid, Toyota Prius Plug-in Hybrid, Mitsubishi i-MiEV and Outlander P-HEV. As of November 2013, four post-crash fires associated with the batteries of all-electric cars—involving one BYD e6 and three Tesla Model S cars—have been reported.

The first modern crash-related fire was reported in China in May 2012, after a high-speed car crashed into a BYD e6 taxi in Shenzhen.[163] The second reported incident occurred in the United States on October 1, 2013, when a Tesla Model S caught fire over ten minutes after the electric car hit metal debris on a highway in Kent, Washington state, and the debris punctured one of 16 modules within the battery pack.[164][165] A second reported fire occurred on October 18, 2013 in Merida, Mexico. In this case the vehicle was being driven at high speed through a roundabout and crashed through a wall and into a tree. The fire broke out many minutes after the driver exited the vehicle. On November 6, 2013, a Tesla Model S being driven on Interstate 24 near Murfreesboro, Tennessee caught fire after it struck a tow hitch on the roadway, causing damage beneath the vehicle.[166]

In the United States, General Motors ran in several cities a training program for firefighters and first responders to demonstrate the sequence of tasks required to safely disable the Chevrolet Volt's powertrain and its 12 volt electrical system, which controls its high-voltage components, and then proceed to extricate injured occupants. The Volt's high-voltage system is designed to shut down automatically in the event of an airbag deployment, and to detect a loss of communication from an airbag control module.[167][168] GM also made available an Emergency Response Guide for the 2011 Volt for use by emergency responders. The guide also describes methods of disabling the high voltage system and identifies cut zone information.[169] Nissan also published a guide for first responders that details procedures for handling a damaged 2011 Leaf at the scene of an accident, including a manual high-voltage system shutdown, rather than the automatic process built-in the car's safety systems.[170][171]

Vehicle safety

Great effort is taken to keep the mass of an electric vehicle as low as possible to improve its range and endurance. However, the weight and bulk of the batteries themselves usually makes an EV heavier than a comparable gasoline vehicle, reducing range and leading to longer braking distances. However, in a collision, the occupants of a heavy vehicle will, on average, suffer fewer and less serious injuries than the occupants of a lighter vehicle; therefore, the additional weight brings safety benefits[172] despite having a negative effect on the car's performance.[173] They also use up interior space if packaged ineffectively. If stored under the passenger cell, not only is this not the case, they also lower the vehicles's center of gravity, increasing driving stability, thereby lowering the risk of an accident through loss of control. An accident in a 2,000 lb (900 kg) vehicle will on average cause about 50% more injuries to its occupants than a 3,000 lb (1,400 kg) vehicle.[174] In a single car accident, and for the other car in a two car accident, the increased mass causes an increase in accelerations and hence an increase in the severity of the accident.

Some electric cars use low rolling resistance tires, which typically offer less grip than normal tires.[175][176][177] Many electric cars have a small, light and fragile body, though, and therefore offer inadequate safety protection. The Insurance Institute for Highway Safety in America had condemned the use of low speed vehicles and "mini trucks," referred to as neighborhood electric vehicles (NEVs) when powered by electric motors, on public roads.[178] Mindful of this, several companies (Tesla Motors, BMW) have succeeded in keeping the body light, while making it very strong.

Hazard to pedestrians

At low speeds, electric cars produced less roadway noise as compared to vehicles propelled by internal combustion engines. Blind people or the visually impaired consider the noise of combustion engines a helpful aid while crossing streets, hence electric cars and hybrids could pose an unexpected hazard.[179][180] Tests have shown that this is a valid concern, as vehicles operating in electric mode can be particularly hard to hear below 20 mph (30 km/h) for all types of road users and not only the visually impaired. At higher speeds, the sound created by tire friction and the air displaced by the vehicle start to make sufficient audible noise.[180]

The Government of Japan, the U.S. Congress, and the European Parliament passed legislation to regulate the minimum level of sound for hybrids and plug-in electric vehicles when operating in electric mode, so that blind people and other pedestrians and cyclists can hear them coming and detect from which direction they are approaching.[180][181][182][183] The Nissan Leaf was the first electric car to use Nissan's Vehicle Sound for Pedestrians system, which includes one sound for forward motion and another for reverse.[184][185] As of January 2014, most of the hybrids and plug-in electric and hybrids available in the United States, Japan and Europe make warning noises using a speaker system. The Tesla Model S is one of the few electric cars without warning sounds, because Tesla Motors will await until regulations are enacted.[186] Volkswagen and BMW also decided to add artificial sounds to their electric drive cars only when required by regulation.[187]

Several anti-noise and electric car advocates have opposed the introduction of artificial sounds as warning for pedestrians, as they argue that the proposed system will only increase noise pollution.. Added to this, such an introduction is based on vehicle type and not actual noise level, a concern regarding ICE vehicles which themselves are becoming quieter.

Electrical interference

On-board electrical systems generate enough interference that some manufacturers have removed AM radios from their vehicles due to poor reception.[188]

Controls

Presently most EV manufacturers do their best to emulate the driving experience as closely as possible to that of a car with a conventional automatic transmission that motorists are familiar with. Most models therefore have a PRNDL selector traditionally found in cars with automatic transmission despite the underlying mechanical differences. Push buttons are the easiest to implement as all modes are implemented through software on the vehicle's controller.

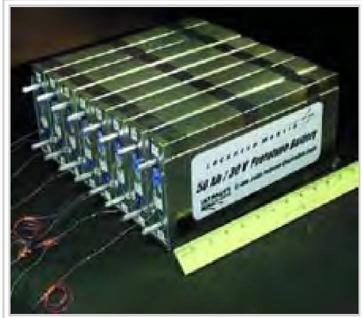
Even though the motor may be permanently connected to the wheels through a fixed-ratio gear and no parking pawl may be present the modes "P" and "N" will still be provided on the selector. In this case the motor is disabled in "N" and an electrically actuated hand brake provides the "P" mode.

In some cars the motor will spin slowly to provide a small amount of creep in "D", similar to a traditional automatic.[189]

When the foot is lifted from the accelerator of an ICE, engine braking causes the car to slow. An EV would coast under these conditions, but applying mild regenerative braking instead provides a more familiar response and recharges the battery somewhat. Selecting the L mode will increase this effect for sustained downhill driving, analogous to selecting a lower gear. These features also reduce the use of the conventional brakes, significantly reducing wear and tear and maintenance costs as well as improving vehicle range.

Batteries

While most current highway-speed electric vehicle designs focus on lithium-ion and other lithium-based variants a variety of alternative batteries can also be used. Lithium-based batteries are often chosen for their high power and energy density but have a limited shelf life and cycle lifetime which can significantly increase the running costs of the vehicle. Variants such as Lithium iron phosphate and Lithium-titanate attempt to solve the durability issues with traditional lithium-ion batteries.



Prototypes of 75 watt-hour/kilogram lithium-ion polymer battery. Newer lithium-ion cells can provide up to 130 W·h/kg and last through thousands of charging cycles.

Other battery types include lead acid batteries which are still the most used form of power for most of the electric vehicles used today. The initial construction costs are significantly lower than for other battery types, but the power to weight ratio is poorer than other designs,[190] Nickel metal hydride (NiMH) which are somewhat heavier and less efficient than lithium ion, but also cheaper. Several other battery chemistries are in development such as zinc-air battery which could be much lighter, and liquid batteries that might be rapidly refilled, rather than recharged, are also under development.

Range

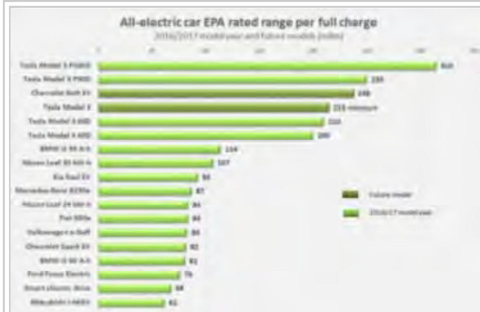
The range of an electric car depends on the number and type of batteries used. The weight and type of vehicle, and the performance demands of the driver, also have an impact just as they do on the range of traditional vehicles. Range may also significantly be reduced in cold weather. The list of electric cars currently available has a column with range information for electric cars sold worldwide.

External image

List of ranges for electric cars in Norway as of 2014 (http://www.tu.no/samferdsel/2015/04/10/stor-oversikt-her-er-rekkevidden-til-alle-elbilene-du-kan-kjope-i-norge)

Summary of Nissan Leaf results using EPA L4 test cycle operating the 2011 Leaf under different real-world scenarios[191][192]								
Driving condition	**Speed**		**Temperature**		**Total drive duration**	**Range**		**Air conditioner**
	mph	**km/h**	**°F**	**°C**		**mi**	**km**	
Cruising (ideal condition)	38	61	68	20	3 hr 38 min	138	222	Off
City traffic	24	39	77	25	4 hr 23 min	105	169	Off
Highway	55	89	95	35	1 hr 16 min	70	110	In use
Winter, stop-and-go traffic	15	24	14	−10	4 hr 08 min	62	100	Heater on
Heavy stop-and-go traffic	6	10	86	30	7 hr 50 min	47	76	In use
EPA five-cycle tests[54]	n.a.					73	117	Varying

- The Tesla Roadster (build 2008-2012) can travel 245 mi (394 km) per charge;[196]
- Tesla Model S with 85 kWh battery has a range of 265 mi (426 km). Tesla Model S is build since 2012. Price for the car is around US$80,000.
- Tesla Model S with 90 kWh battery and dual motors has a range of 294 mi (473 km). This Tesla Model S has been build since 2014. Price for the car is around US$82,000.
- Tesla Model X with 90 kWh battery and dual motors has a range of 257 mi (414 km). Tesla Model X has been build since 2015. Price for the car is around US$88,000.
- The supercar Rimac Concept One with 82 kWh battery has a range of 311 mi (501 km). The car has been build since 2013.
- The pure electric car BYD e6 with 60 kWh battery has a range of 186 mi (299 km).[197]
- The bestseller Nissan Leaf model year 2016 with 30kWh battery has a range of 107 mi (172 km).
- Urban cars like the Renault Twizy and Volkswagen XL1 have a 5 - 6 kWh battery and a range of 50 – 100 km.



Comparison of EPA-rated range for model year 2016 and 2017 electric cars available in the U.S. market, and two upcoming models, Chevrolet Bolt EV and Tesla Model 3. Tesla Motors vehicles included correspond to the variants with the longest and shortest range for each model (Model S and Model X).[193][194][195]

Electric cars are virtually universally fitted with an expected range display. This may take into account many factors, including battery charge, the recent average power use, the ambient temperature, driving style, air conditioning system, route topography etc. to come up with an estimated driving range. However, since factors can vary over the route, the estimate can vary from the actual achieved range. People can thus be concerned that they would run out of energy from their battery before reaching their destination, a worry known as range anxiety. The display allows the driver able to make informed choices about driving speed and whether to, perhaps briefly, stop at a charging point en route to ensure that they have enough charge that they arrive at their destination successfully. Some roadside assistance organizations offer charge trucks to reload empty electric cars.[198]

A study in 2016 stated that 87% of US vehicle-days can be met by current affordable electric cars.[199][200]

Charging

Most cars with internal combustion engines can be considered to have indefinite range, as they can be refueled very quickly. Electric cars typically have less maximum range on one charge than fossil fueled cars can travel on a full tank, and they can take considerable time to recharge. However, they can be charged at home overnight, which fossil fueled cars cannot. 71% of all car drivers in America drive less than 40 miles (64 km) per day, and require only a relatively quick topping up.[201]

Home charging

As examples of on-board chargers, the Nissan Leaf at launch had a 3.3 kW charger,[202] and the Tesla Roadster can accept up to 16.8 kW (240 V at 70 A) from the *High Power Wall Connector*.[203] These charging rates are slow compared with the effective power delivery rate of an average petrol pump, about 5,000 kW.

Fast charging

Panoramic view of Tesla supercharger rapid charging station in Tejon Ranch, California

However, most vehicles also support much faster charging, where a suitable power supply is available. Therefore, for long distance travel, in the US and elsewhere, there has been the installation of Fast Charging stations with high-speed charging capability from three-phase industrial outlets so that consumers could recharge the battery of their electric vehicle to 80 percent in about 30 minutes (for example Nissan Leaf, Tesla Model S, Renault Zoe, BMW i3 etc.).[8][9][10] Although charging at these stations is still relatively time consuming compared to refueling, in practice it often meshes well with a normal driving pattern, where driving is usually done for a few hours before stopping and resting and drinking or eating; this gives the car a chance to be charged.[204]

As of December 2013, Estonia is the first and only country that had deployed an EV charging network with nationwide coverage, with fast chargers available along highways at a minimum distance of between 40 to 60 km (25 to 37 mi), and a higher density in urban areas.[205][206][207] DC Fast Chargers are going to be installed at 45 BP and ARCO locations and will be made available to the public as early as March 2011.[208] The EV Project will deploy charge infrastructure in 16 cities and major metropolitan areas in six states.[209][210] Nissan has announced that 200 of its dealers in Japan will install fast chargers for the December 2010 launch of its Leaf EV, with the goal of having fast chargers everywhere in Japan within a 25-mile radius.[211]

Charging time

BYD e6 taxi. Recharging in 15 Minutes to 80 percent

The Tesla Model S and Tesla Model X can be fast charged from a proprietary DC rapid-charging station that provides up to 135 kW of power, giving 85 kWh vehicles an additional 180 mi (290 km) of range in about 30 minutes.

Most electric cars can be recharged to 80 percent in about 30 minutes (for example Nissan Leaf, Tesla Model S, Renault Zoe, BMW i3 etc.) In most cases it happens with DC.

According to the manufacturer BYD the lithium iron phosphate battery of the electric car e6 is charged at a fast charging station within 15 minutes to 80%, after 40 minutes at 100%.[197]

Battery swapping

The battery swap process on a Zotye M300 EV.

Another way to extend the limited range of electric vehicles is by battery swapping. An EV can go to a battery switch station and swap a depleted battery with a fully charged one in a few minutes. In 2011, Better Place deployed the first modern commercial application of the battery switching model, but due to financial difficulties, the company filed for bankruptcy in May 2013.[212][213][214][215]

Tesla Motors designed its Model S to allow fast battery swapping.[216] In June 2013, Tesla announced their goal to deploy a battery swapping station in each of its supercharging stations. At a demonstration event Tesla showed that a battery swap operation with the Model S takes just over 90 seconds, about half the time it takes to refill a gasoline-powered car.[217][218] The first stations are planned to be deployed along Interstate 5 in California where, according to Tesla, a large number of Model S sedans make the San Francisco-Los Angeles trip regularly. These will be followed by the Washington, DC to Boston corridor. Each swapping station will cost US$500,000 and will have about 50 batteries available without requiring reservations. The service would be offered for the price of about 15 US gallons (57 l; 12 imp gal) of gasoline at the current local rate, around US$60 to US$80 at June 2013 prices.[217]

Range extension

A similar idea is that of the range-extension trailer which is attached only when going on long trips. The trailers can either be owned or rented only when necessary.[219]

BMW i is offering a built-in gasoline-powered range extender engine as an option for its BMW i3 all-electric car.[220] The range-extender option will cost an additional US$3,850 in the United States,[221] an additional €4,710 (~ US$6,300) in France,[222] and €4,490 (~ US$6,000) in the Netherlands.[223]

The BMW i3 has an optional gasoline-powered range extender engine

Lifespan

Battery life should be considered when calculating the extended cost of ownership, as all batteries eventually wear out and must be replaced. The rate at which they expire depends on the type of battery and how they are used — many types of batteries are damaged by depleting them beyond a certain level. Lithium-ion batteries degrade faster when stored at higher temperatures, when they are rapidly charged, and when they are fully charged. Many users set their cars to charge to 80% for their daily charging; which is usually enough for daily mileage, only charging them to 100% for longer journeys.

Although there are times when batteries do fail the electric vehicles' batteries are designed to last for the expected life of the vehicle. The failure rate of some electric vehicles batteries already on the road is as low as 0.003%. There are also high mileage warranties on electric vehicle batteries. Several manufactures offer up to eight year and one hundred thousand mile warranties on the batteries alone.[224]

A full replacement battery is relatively costly. With technological advances there are now recycle options available ("Maintenance and Safety of Electric Vehicles"), and a battery that is no longer capable of delivering sufficient range nevertheless has significant trade-in value.

Nissan stated in 2015 that thus far only 0.01 percent of batteries had to be replaced because of failures or problems and then only because of externally inflicted damage. There are few vehicles that have already covered more than 200,000 km (124,274 mi) anyway. These have no problems with the battery.[225]

Future

Lithium availability

Many electric cars use a lithium-ion battery and an electric motor which uses rare earth elements. The demand for lithium, heavy metals, and other specific elements (such as neodymium, boron and cobalt) required for the batteries and powertrain is expected to grow significantly due to the future sales increase of plug-in electric vehicles in the mid and long term.[228][229] Some of the largest world reserves of lithium and other rare metals are located in countries with strong resource nationalism, unstable governments or hostility to U.S. interests, raising concerns about the risk of replacing dependence on foreign oil with a new dependence on hostile countries to supply strategic materials.[226][228][229][230] It is estimated that there are sufficient lithium reserves to power 4 billion electric cars.[231][232]

The Salar de Uyuni in Bolivia is one of the largest known lithium reserves in the world.[226][227]

Other methods of energy storage

Experimental supercapacitors and flywheel energy storage devices offer comparable storage capacity, faster charging, and lower volatility. They have the potential to overtake batteries as the preferred rechargeable storage for EVs.[233][234] The FIA included their use in its sporting regulations of energy systems for Formula One race vehicles in 2007 (for supercapacitors) and 2009 (for flywheel energy storage devices).

Solar cars

Solar cars are electric vehicles powered completely or significantly by direct solar energy, usually, through photovoltaic (PV) cells contained in solar panels that convert the sun's energy directly into electric energy.

Electrified Road

In March 2016 Toyohashi University of Technology and Taisei Corp of Japan unveiled the first electrical car in the world that would be able to run without a battery. The electric car receives its charge from an electrified road. The test was made on electrified road in Toyohashi, in the Aichi Prefecture.[235]

Infrastructure

Charging station

Charging station at Rio de Janeiro, Brazil. This station is run by Petrobras and uses solar energy.

Batteries in BEVs must be periodically recharged (see also Replacing, above). Unlike vehicles powered directly by fossil fuels, BEVs are most commonly and conveniently charged from the power grid overnight at home, without the inconvenience of having to go to a filling station. Charging can also be done using a street, garage or shop charging station. The electricity on the grid is in turn generated from a variety of sources; such as coal, hydroelectricity, nuclear and others. Power sources such as photovoltaic solar cell panels, micro hydro or wind may also be used and are promoted because of concerns regarding global warming.

More electrical power to the car reduces charging time. Power is limited by the capacity of the grid connection, and, for level 1 and 2 charging, by the power rating of the car's on-board charger. A normal household outlet is between 1.5 kW (in the US, Canada, Japan, and other countries with 110 volt supply) to 3 kW (in countries with 230 V supply). The main connection to a house may sustain 10, 15 or even 20 kW in addition to "normal" domestic loads—although, it would be unwise to use all the apparent capability—and special wiring can be installed to use this.

As part of its commitment to environmental sustainability, the Dutch government initiated a plan to establish over 200 recharging stations for electric vehicles across the country by 2015. The rollout was undertaken by Switzerland-based power and automation company ABB and Dutch startup Fastned, and aims to provide at least one station every 50 kilometres (31 miles) for the Netherlands' 16 million residents.[236]

There are several types of charging machines. The Japanese-developed CHAdeMO standard is favored by Nissan, Mitsubishi, and Toyota, while the Society of Automotive Engineers' (SAE) International J1772 Combo standard is backed by GM, Ford, Volkswagen, and BMW. Both are direct-current quick-charging systems designed to charge the battery of an electric vehicle to 80 percent in approximately 20 minutes, but the two systems are incompatible. Unless the two companies cooperate, experts have warned that the momentum of the electric vehicle market will be restricted.[237][238] Richard Martin, editorial director for clean technology marketing and consultant firm Navigant Research, stated:

> Fast charging, however and whenever it gets built out, is going to be key for the development of a mainstream market for plug-in electric vehicles. The broader conflict between the CHAdeMO and SAE Combo connectors, we see that as a hindrance to the market over the next several years that needs to be worked out.[238]

Research continues on ways of reducing the charging times for electric cars. The BMW i3 for example, can charge 0-80% of the battery in under 30 minutes in rapid charging mode.[239] The superchargers developed by Tesla Motors provided up to 130 kW of charging, allowing a 50% charge in 20 minutes. Considering the size of the battery, that translated to approx. 212 km of range.

US charging standards

Around 1998 the California Air Resources Board classified levels of charging power that have been codified in title 13 of the California Code of Regulations, the U.S. 1999 National Electrical Code section 625 and SAE International standards. Four standards were developed, termed AC Level 1, AC Level 2, AC Level 3 charging, and Combo Charging System (CCS).

Level	Original definition[240]	ChargePoint's definition[241]	Connectors
AC Level 1	AC energy to the vehicle's on-board charger; from the most common U.S. grounded household receptacle, commonly referred to as a 120 volt outlet.	120 V AC; 16 A (= 1.92 kW)	SAE J1772 (16.8 kW), NEMA 5-15
AC Level 2	AC energy to the vehicle's on-board charger; 208–240 V, single phase. The maximum current specified is 32 A (continuous) with a branch circuit breaker rated at 40 A. Maximum continuous input power is specified as 7.68 kW (= 240 V × 32 A*).	208-240 V AC; 12 A - 80 A (= 2.5–19.2 kW)	SAE J1772 (16.8 kW), IEC 62196 (44 kW), Magne Charge (Obsolete), Avcon, IEC 60309 16 A (3.8 kW) IEC 62198-2 Type 2 same as VDE-AR-E 2623-2-2, colloquially known as the "Mennekes connector" (43.5 kW) IEC 62198-2 Type 3 colloquially known as "Scame"
AC Level 3	AC energy to the vehicle's on-board charger; 208–240 V, single phase. The maximum power of 96 kW (continuous).	208-240 V AC; 11.6 to 96 kW	SAE J1772 standard pending
Combo Charging System (CCS)	DC energy from an off-board charger; with additional pins to accommodate fast DC charging at 200–450 V DC and up to 90 kW. This will also use Power Line Carrier technology to communicate between the vehicle, off-board charger, and smart grid.	200–450 Volts DC and up to 90 kW	SAE J1772 Combo Coupler

* or potentially 208 V × 37 A, out of the strict specification but within circuit breaker and connector/cable power limits. Alternatively, this voltage would impose a lower power rating of 6.7 kW at 32 A.

More recently the term "Level 3" has also been used by the SAE J1772 Standard Committee for a possible future higher-power AC fast charging standard.[242] To distinguish from Level 3 DC fast charging, this would-be standard is written as "Level 3 AC". SAE has not yet approved standards for either AC or DC Level 3 charging.[243]

As of June 2012, some electric cars provide charging options that do not fit within the older California "Level 1, 2, and 3 charging" standard, with its top charging rate of 40 A. For example, the Tesla Roadster may be charged at a rate up to 70 A (16.8 kW) with a wall-mounted charger.[203]

For comparison, in Europe the IEC 61851-1 charging modes are used to classify charging equipment. The provisions of IEC 62196 charging modes for conductive charging of electric vehicles include Mode 1 (max. 16 A / max. 250 V AC. or 480 V three-phase), Mode 2 (max. 32 A / max. 250 V AC or 480 V three-phase), Mode 3 (max. 63 A (70 A U.S.) / max. 690 V AC or three-phase) and Mode 4 (max. 400 A / max. 600 V DC).[244]

Connectors

Most electric cars have used conductive coupling to supply electricity for recharging after the California Air Resources Board settled on the SAE J1772-2001 standard[245] as the charging interface for electric vehicles in California in June 2001.[246] In Europe, the ACEA has decided to use the Type 2 connector from the range of IEC_62196 plug types for conductive charging of electric vehicles in the European Union as the Type 1 connector (SAE J1772-2009) does not provide for three-phase charging.[247]

Another approach is inductive charging using a non-conducting "paddle" inserted into a slot in the car. Delco Electronics developed the Magne Charge inductive charging system around 1998 for the General Motors EV1 and it was also used for the Chevrolet S-10 EV and Toyota RAV4 EV vehicles.

Vehicle-to-grid: uploading and grid buffering

A Smart grid allows BEVs to provide power to the grid, specifically:

- During peak load periods, when the cost of electricity can be very high. These vehicles can then be recharged during off-peak hours at cheaper rates while helping to absorb excess night time generation. Here the batteries in the vehicles serve as a distributed storage system to buffer power.
- During blackouts, as an emergency backup supply.

Hobbyists and conversions

Eliica prototype

The full electric Formula Student car of the Eindhoven University of Technology

Hobbyists often build their own EVs by converting existing production cars to run solely on electricity. There is a cottage industry supporting the conversion and construction of BEVs by hobbyists.[248] Universities such as the University of California, Irvine even build their own custom electric or hybrid-electric cars from scratch.

Short-range battery electric vehicles can offer the hobbyist comfort, utility, and quickness, sacrificing only range. Short-range EVs may be built using high-performance lead–acid batteries, using about half the mass needed for a 100 to 130 km (60 to 80 mi) range. The result is a vehicle with about a 50 km (30 mi) range, which, when designed with appropriate weight distribution (40/60 front to rear), does not require power steering, offers exceptional acceleration in the lower end of its operating range, and is freeway capable and legal. But their EVs are expensive due to the higher cost for these higher-performance batteries. By including a manual transmission, short-range EVs can obtain both better performance and greater efficiency than the single-speed EVs developed by major manufacturers. Unlike the converted golf carts used for neighborhood electric vehicles, short-range EVs may be operated on typical suburban throughways (where 60–80 km/h / 35-50 mph speed limits are typical) and can keep up with traffic typical on such roads and the short "slow-lane" on-and-off segments of freeways common in suburban areas.

Faced with chronic fuel shortage on the Gaza Strip, Palestinian electrical engineer Waseem Othman al-Khozendar invented in 2008 a way to convert his car to run on 32 electric batteries. According to al-Khozendar, the batteries can be charged with US$2 worth of electricity to drive from 180 to 240 km (110 to 150 mi). After a 7-hour charge, the car should also be able to run up to a speed of 100 km/h (60 mph).[249][250]

In 2008, several Chinese manufacturers began marketing lithium iron phosphate ($LiFePO_4$) batteries directly to hobbyists and vehicle conversion shops. These batteries offered much better power-to-weight ratios allowing vehicle conversions to typically achieve 75 to 150 mi (120 to 240 km) per charge. Prices gradually declined to approximately US$350 per kW·h by mid-2009. As the $LiFePO_4$ cells feature life ratings of 3,000 cycles, compared to typical lead acid battery ratings of 300 cycles, the life expectancy of $LiFePO_4$ cells is around 10 years. $LiFePO_4$ cells require more expensive battery management and charging systems than lead acid batteries.

Racing

Electric drag racing is a sport where electric vehicles start from standstill and attempt the highest possible speed over a short given distance.[251] They sometimes race and usually beat gasoline sports cars.[252] Organizations such as NEDRA keep track of records worldwide using certified equipment.

Formula E racing car

At the Formula Student competition at the Silverstone Circuit in July 2013, the electric powered car of the ETH Zurich won against all cars with internal combustion engines. It is believed to be the first time that an electric vehicle has beaten cars powered by combustion engines in any accredited motorsport competition.[253]

Formula E, officially the **FIA Formula E Championship**, is a class of auto racing, sanctioned by the Fédération Internationale de l'Automobile (FIA), and is the highest class of competition for one-make, single-seater, electrically powered racing cars.[254] The series was conceived in 2012, and the inaugural championship started in Beijing on 13 September 2014.[255]

In 2015, an electric car won all places of the Pikes Peak International Hill Climb. Also in that year the second place on all classes was won by an electric car. Already in 2014, electric cars had won second and third place.[256][257][258]

Politics

Electric vehicles provide for less dependence on foreign oil, which for the United States and other developed or emerging countries is cause for concern about vulnerability to oil price volatility and supply disruption.[3][6][7] Also for many developing countries, and particularly for the poorest in Africa, high oil prices have an adverse impact on their balance of payments, hindering their economic growth.[259][260]

Currently available electric cars

Neighborhood electric vehicles


The GEM is among the world's top selling NEVs, with more than 50,000 units sold by 2015.[261]

Until the 2010s, most electric vehicles were low-speed, low-range neighborhood electric vehicles (NEVs) or electric quadricycles, with an estimated stock of 479,000 NEVs on the world roads in 2011.[262] As of July 2006, there were between 60,000 and 76,000 low-speed battery-powered vehicles in use in the United States.[263] The two largest NEV markets in 2011 were the United States, with 14,737 units sold, and France, with 2,231 units.[264] As of October 2015, the GEM neighborhood electric vehicle was the market leader in North America, with global sales of more than 50,000 units since 1998.[261] As of June 2016, global sales of the Renault Twizy heavy quadricycle, a popular model in Europe, totaled 17,873 units.[265]

Sales of this low-speed small electric cars experienced considerable growth in China between 2012 and 2015 due to their affordability and flexibility because they can be driven without a driver license. Most of these small electric cars are popular in small cities, but hey are expanding to larger cities.[11] A total of 200,000 low-speed small electric cars were sold in the country in 2013, most of which were powered by lead-acid batteries. These electric vehicles are not considered by the government as new energy vehicles due to safety and environmental concerns, and consequently, do not enjoy the same purchase benefits as highway legal plug-in electric cars.[266] In 2015, sales of low-speed small electric passenger vehicles totaled more than 600,000 units in China,[11] and more than 700,000 units during the first ten months of 2016.[267]

Highway capable


The Nissan Leaf is the world's all-time top selling highway legal plug-in electric car. Global sales passed the 200,000 unit milestone in December 2015, five years after its inception. [26][27]

As of December 2015, there were over 30 models of highway-capable all-electric passenger cars and utility vans available in the market for retail sales. The global stock of light-duty all-electric vehicles totaled 739,810 units, out of a global stock of 1.257 million light-duty plug-in electric vehicles on the road at the end of 2015.[11] The global ratio between all-electrics (BEVs) and plug-in hybrids (PHEVs) has consistently been 60:40 between 2014 and the first half of 2016, mainly due to the large all-electric market in China. In the U.S. and Europe, the ratio is approaching a 50:50 split.[268] Cumulative global sales of all-electric cars and vans passed the 1 million unit milestone in September 2016.[12]

The Renault-Nissan Alliance is the leading all-electric vehicle manufacturer with global sales of more than 350,000 units between December 2010 and August 2016.[269] Nissan global electric vehicle sales passed 275,000 units in December 2016.[270] Renault global electric vehicle sales passed the 100,000 unit milestone in September 2016.[271] In December 2014, Nissan announced that Leaf owners have accumulated together 1 billion kilometers (620 million miles) driven. This amount of electric miles translates into saving 180 million kilograms of CO_2 emissions by driving an electric car in comparison to travelling with a gasoline-powered car.[272] In December 2016, Nissan reported that Leaf owners worldwide achieved the milestone of 3 billion kilometers (1.9 billion miles) driven collectively through November 2016.[270]

Ranking second is Tesla Motors with almost 164,000 electric cars sold between 2008 and September 2016.[273] Its Model S was the world's best selling plug-in electric car in 2015,[274] and continued to lead global plug-in sales during the first nine months of 2016.[275] In September 2016, combined sales of Tesla Motors models totaled over 13,000 units worldwide, setting the best monthly plug-in sales volume on record ever, by any automaker of plug-in cars.[275] In early October 2016, Tesla reported that combined miles driven by its three models have accumulated 3 billion electric miles (4.8 billion km) traveled. The first billion mark was recorded in June 2015 and the second billion in April 2016.[276]

BMW is the third best selling all-electric vehicle manufacturer with more than 60,000 i3s sold by early November 2016, including the REx variant.[277] Next is Mitsubishi Motors with global sales of about 50,000 all-electric vehicles between July 2009 and June 2015, including the rebadged variants Peugeot iOn and Citroën C-Zero sold in Europe; and over 7,000 Mitsubishi Minicab MiEV all-electric utility vans and trucks sold in Japan through December 2015.[278][279][280]

The world's all-time top selling highway legal electric car is the Nissan Leaf, released in December 2010, with global sales of almost 240,000 units through September 2016.[13] The Tesla Model S ranked second with global deliveries of more than 150,000 cars as of November 2016.[14] The Renault Kangoo Z.E. utility van is the leader of the light-duty all-electric segment with global sales of 23,219 units through June 2016.[265] The following table list the best-selling highway-capable all-electric cars with cumulative global sales of around or more than 20,000 units since their inception through June 2016:

Top selling highway-capable electric cars and light utility vehicles produced between 2008 and June 2016(1)

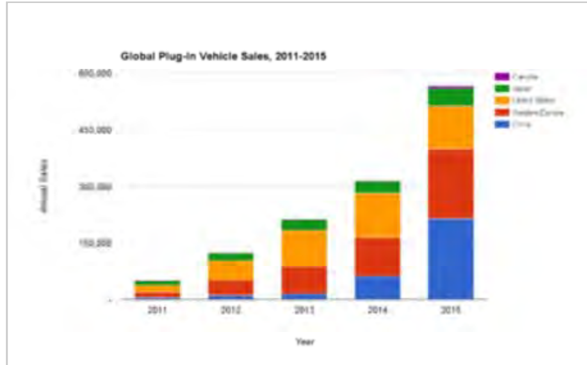
Model	Market launch	Global sales	Sales through
Nissan Leaf[281]	Dec 2010	+ 228,000	Jun 2016
Tesla Model S[282]	Jun 2012	129,393	Jun 2016
Renault Zoe[282]	Dec 2012	51,193	Jun 2016
BMW i3[282]	Nov 2013	~ 49,500(2)	Jun 2016
Mitsubishi i-MiEV family[282]	Jul 2009	~ 37,600	Jun 2016
BAIC EV series[283][284][285][286]	2012	33,809(3)	Jun 2016
Volkswagen e-Golf[287][288][289][290][291]	May 2014	24,498(4)	Jun 2016
BYD e6[283][284][292][293][294]	Oct 2011	23,483(3)	Jun 2016
JAC J3/iEV family[283][284][285][286][295][296]	2010	23,241(3)	Jun 2016
Renault Kangoo Z.E.[265]	Oct 2011	23,219	Jun 2016

Notes:
(1) Vehicles are considered highway-capable if able to achieve at least a top speed of 100 km/h (62 mph). Several models, such as the Chery QQ3 EV/eQ EV, Kandi EV and the Zotye Zhidou E20, are highway legal in China but do not meet this requirement.
(2) BMW i3 sales includes the REx variant.
(3) Sales in main China only. (4) Sales in Europe and the U.S. only.

Electric cars by country

By mid-September 2015, over one million highway legal plug-in electric passenger cars and light utility vehicles (PEVs) have been sold worldwide.[297][298] The stock of plug-in electric cars represented 0.1% of the one billion cars on the world's roads by the end of 2015.[41][299] Sales of plug-in electric vehicles achieved the one million milestone almost twice as fast as hybrid electric vehicles (HEV). While it took four years and 10 months for the PEV segment to reach one-million sales, it took more than around nine years and a few months for HEVs to reach its first million sales.[297][298] When global sales are broken down by type of powertrain, all-electric cars have oversold plug-in hybrids, with pure electrics capturing 58.9% of the global stock of 1.257 million light-duty plug-ins on the world's roads by the end of 2015.[11]

The global stock of plug-in electric vehicles between 2005 and 2009 consisted exclusively of all-electric cars, totaling about 1,700 units in 2005, and almost 6,000 in 2009. The plug-in stock rose to about 12,500 units in 2010, of which, only about 350 vehicles were plug-in hybrids.[11][301] By comparison, during the Golden Age of the electric car at the beginning of the 20th century, the EV stock peaked at approximately 30,000 vehicles.[22] After the introduction of the Nissan Leaf and the Chevrolet Volt in late December 2010, the first mass-production plug-in cars by major carmakers, plug-in car sales grew to about 50,000 units in 2011, and climbed to over 315,000 units in 2014, up 48% from 2013.[300] The all-electric segment followed a similar growth trend, with over 39,000 units sold in 2011, jumped to 58,000 in 2012, and totaled more than 112,000 units in 2013. Global sales totaled over 190,000 light-duty all-electric vehicles in 2014.[11]



Annual sales of light-duty plug-in electric vehicles in the world's top markets between 2011 and 2015.[300]

In five years, global sales of highway legal light-duty plug-in electric vehicles have increased more than ten-fold, totaling more than 550,00 units in 2015, of which, almost 329,000 were all-electric vehicles (59.8%).[11] Plug-in sales in 2015 increased about 80% from 2014, driven mainly by China and Europe.[300] Both markets passed in 2015 the U.S. as the largest plug-in electric car markets in terms of total annual sales, with China ranking as the world's best-selling plug-in electric passenger car country market in 2015.[302][303] As of December 2015, the global stock of highway-capable plug-in electric passenger cars and light utility vehicles totaled 1.257 million vehicles, consisting of 739,810 all-electric vehicles (58.9%) and 517,100 plug-in hybrids (41.1%).[11]

As of December 2015, China is the largest country market within the light-duty all-electric segment, with a stock of 225,720 vehicles on the roads, representing 30.5% of the global stock. The United States ranks second with 210,330 vehicles, representing 28.4% of the global stock. Japan ranks third with 70,930 units, followed by Norway with 60,650 units, and France with 45,170.[11] When all segments of the plug-in electric vehicle market are accounted for, China is the world's leader with 444,447 new energy vehicle sold between January 2011 and December 2015. These figures include heavy-duty commercial vehicles such buses and sanitation trucks.[266][304][305][306][307] As of December 2015, the global stock of plug-in electric buses is estimated to be about 173,000 units, almost entirely deployed in China, the world's largest electric bus market. Of these, almost 150,000 are all-electric buses.[11] China was the world's best-selling plug-in electric passenger car country market in 2015, ahead of the U.S., the top selling country in 2014.[302][308]

Norway has the largest plug-in market penetration in the world, with over 3 plug-in electric cars for every 100 passenger cars on the roads.[309][310]

As of December 2015, over 425,000 plug-in electric passenger cars and vans have been registered in Europe, making the continent the world's largest plug-in regional market.[311][312][313] Out of the plug-in stock registered in 2015, passenger cars accounted for 186,170 units (96.5%).[314][315] As of December 2015, sales in the European light-duty plug-in electric segment, which includes utility vans, are led by the Netherlands with 88,991 units registered, followed by Norway with 74,883 new units, France with 74,294 units registered, and the UK with 53,524 units.[302][316] Almost 25% of the European stock is on the roads in the Nordic countries, with over 100,000 registered plug-in electric cars as of December 2015. Combined registrations in the four countries in 2015 were up 91% from 2014.[316][317]

As of December 2015, France ranked as the largest European market for light-duty all-electric commercial vehicles or utility vans, accounting for nearly half of all vans sold in the European Union.[318] The French market share of all-electric utility vans reached a market share of 1.22% of new vans registered in 2014, and 1.30% in 2015.[319]

U.S. plug-in car sales are led by California, the largest American car market, which passed the 200,000 unit milestone in March 2016, out of about 425,000 plug-in cars sold nationwide through February 2016, representing 47% of all plug-in cars sold in the U.S. since 2008.[320][321] Plug-in electric cars represented about 0.5% of the passenger fleet on the Californian roads by September 2015.[322] Until December 2014 and with a plug-in market share of 3.2%, California had more plug-in electric vehicles than any other country.[323][324][325]

Norway, with a population of about 5.2 million, is the country with the highest plug-in electric car ownership per capita in the world.[326][327] As of July 2016, Norway had a concentration of 21.5 registered plug-in cars per 1,000 people, 14.2 times higher than the U.S.[328][329] In March 2014, Norway became the first country where over 1 in every 100 passenger cars on the roads is a plug-in electric,[330] and the segment's market penetration reached 2% in March 2015,[331] and passed 3% in December 2015.[309][310] Norway also has the world's largest plug-in electric segment market share of total new car sales, growing from 5.6% in 2013, to 13.8% in 2014, and reaching 22.4% in 2015.[302][332][333] In 2015 nine countries or autonomous territories achieved plug-in electric car sales with a market share equal or higher than 1% of total new car sales,[302] up from six in 2014.[333][334][335] The nine countries are Norway (22.39%), the Netherlands (9.74%), Hong Kong (4.84%), Iceland (2.93%), Sweden (2.62%), Denmark (2.29%), Switzerland (1.98%), France (1.2%), and the UK (1.1%).[302][336][337] In 2015 the European plug-in passenger car market share passed the one percent mark (1.41%) for the first time.[312]

The following table presents the top 10 countries, and selected regional markets or autonomous territories according to their PEV market share of total new car sales between 2015 and 2013.

Top 10 countries by plug-in electric passenger car market share of total new car sales between 2015 and 2013								
Rank	**Country**	**Market share (%) 2015**[302][336]	**Rank**	**Country**	**Market share (%) 2014**[333]	**Rank**	**Country**	**Market share (%) 2013**[338]
1	Norway	22.39 %	1	Norway	13.84 %	1	Norway	6.10 %
2	Netherlands	9.74 %	2	Netherlands	3.87 %	2	Netherlands	5.55 %
3	Iceland[337]	2.93 %	3	Iceland[335]	2.71 %	3	Iceland	0.94 %
4	Sweden	2.62 %	4	Estonia[335]	1.57 %	4	Japan	0.91 %
5	Denmark	2.29 %	5	Sweden[334]	1.53 %	5	France(2)	0.83 %
6	Switzerland	1.98 %	6	Japan	1.06 %	6	Estonia	0.73 %
7	France	1.19 %	7	Denmark[339]	0.88 %	7	Sweden[334]	0.71 %
8	United Kingdom	1.07 %	8	Switzerland[340]	0.75 %	8	United States	0.60 %
9	Austria[341]	0.90 %	9	United States	0.72 %	9	Switzerland	0.44 %
10	China[342]	0.84 %	10	France(2)	0.70 %	10	Denmark	0.29 %
Selected regional markets Plug-in electric passenger car market share between 2015 and 2013								
	Hong Kong[343]	4.84 %		Hong Kong	-		Hong Kong[343]	0.39 %
	California[344]	3.1 %		California[344]	3.2 %		California[344]	2.5 %
	Europe(1)[312]	1.41 %		Europe(1)[345]	0.66 %		Europe(1)[346]	0.49 %
Notes: (1) European figures correspond to European Union member countries plus EFTA countries (Norway and Switzerland) 2) The French market share corresponds to combined sales all-electric passenger cars and utility vans only (plug-in hybrids not included).								

Government subsidy

Several countries have established grants and tax credits for the purchase of new electric cars depending on battery size. The U.S. offers a federal income tax credit up to US$7,500,[46] and several states have additional incentives.[347] The UK offers a Plug-in Car Grant up to a maximum of GB£4,500 (US$5,929).[348] The U.S. government also pledged US$2.4 billion in federal grants for the development of advanced technologies for electric cars and batteries.[349]

As of April 2011, 15 European Union member states provide economic incentives for the purchase of new electrically chargeable vehicles, which consist of tax reductions and exemptions, as well as of bonus payments for buyers of all-electric and plug-in hybrid vehicles, hybrid electric vehicles, and some alternative fuel vehicles.[350][351]

See also

- Compressed air car
- Electric boat
- Electric bus
- Electric car use by country
- Electric motorcycles and scooters
- Electric vehicle conversion
- Government incentives for plug-in electric vehicles
- Electric vehicle industry in India
- Hybrid electric vehicle (HEV)
- List of electric cars currently available
- List of modern production plug-in electric vehicles
- List of production battery electric vehicles
- Nikola Tesla electric car hoax
- Patent encumbrance of large automotive NiMH batteries
- Plug-in electric vehicle (PEV)
- Plug-in electric vehicles in the Netherlands
- Plug-in hybrid (PHEV)
- Renewable energy by country
- Solar Golf Cart
- The Greenpower Challenge - EV racing for young people
- The long tailpipe
- Electric vehicle
- Battery electric vehicle
- Plug-in electric vehicle
- Green vehicle

Wikimedia Commons has media related to ***Electrically powered automobiles***.

References

1. Roth, Hans (March 2011). *Das erste vierrädrige Elektroauto der Welt* [*The first four-wheeled electric car in the world*] (in German). pp. 2–3.
2. Guarnieri, M. (2012). "Looking back to electric cars". *Proc. HISTELCON 2012 - 3rd Region-8 IEEE HISTory of Electro - Technology CONference: The Origins of Electrotechnologies*: #6487583. doi:10.1109/HISTELCON.2012.6487583.
3. Sperling, Daniel; Gordon, Deborah (2009). *Two billion cars: driving toward sustainability*. Oxford University Press. pp. 22–26. ISBN 978-0-19-537664-7.
4. David B. Sandalow, ed. (2009). *Plug-In Electric Vehicles: What Role for Washington?* (1st. ed.). The Brookings Institution. pp. 1–6. ISBN 978-0-8157-0305-1.*See Introduction*
5. "Electro Automotive: FAQ on Electric Car Efficiency & Pollution". Electroauto.com. Retrieved 2010-04-18.
6. Mitchell, William J.; Borroni-Bird, Christopher; Burns, Lawrence D. (2010). *Reinventing the Automobile: Personal Urban Mobility for the 21st Century* (1st. ed.). The MIT Press. pp. 85–95. ISBN 978-0-262-01382-6. Retrieved 2013-07-21. *See Chapter 5: Clean Smart Energy Supply*.
7. R. James Woolsey and Chelsea Sexton (2009). David B. Sandalow, ed. *Chapter 1: Geopolitical Implications of Plug-in Vehicles* (1st ed.). The Brookings Institution. pp. 11–21. ISBN 978-0-8157-0305-1. in *"Plug-in Electric Vehicles: What Role for Washington?"* (http://www.brookings.edu/press/Books/2009/pluginelectricvehicles.aspx)
8. "DC Fast Charger" (PDF). Archived from the original (PDF) on 2010-10-27.
9. "13 Key Questions and Answers about Nissan Leaf Battery Pack and Ordering".
10. Speedy charging driving a global boom in electric cars (http://www.bbc.co.uk/news/science-environment-29034483)
11. International Energy Agency (IEA), Clean Energy Ministerial, and Electric Vehicles Initiative (EVI) (May 2016). "Global EV Outlook 2016: Beyond one million electric cars" (PDF). IEA Publications. Retrieved 2016-08-31. *See pp. 4–5, and 24–25 and Statistical annex, pp. 34–37*.
12. Shahan, Zachary (2016-11-22). "1 Million Pure EVs Worldwide: EV Revolution Begins!". Clean Technica. Retrieved 2016-11-23.
13. "Nissan reveals stylish new LEAF Black Edition" (Press release). Paris: Nissan GB. 2016-11-08. Retrieved 2016-11-10. "Since the Nissan LEAF first went on sale in 2010, almost 240,000 units have been sold globally, with 64,000 of these on Europe’s roads; making it the world’s best-selling electric vehicle."
14. Cobb, Jeff (2016-12-05). "Tesla Model S Is Second Plug-in Car To Cross 150,000 Sales Milestone". *HybridCars.com*. Retrieved 2016-12-05. *The Volt/Ampera family of vehicles is the world's all-time third best selling plug-in electric car after the Nissan Leaf (240,000), and the Tesla Model S (over 150,000), with 130,500 vehicles sold globally through November 2016.*
15. "US DEPARTMENT OF TRANSPORTATION National Highway Traffic Safety Administration 49 CFR Part 571 Federal Motor Vehicle Safety Standards". Retrieved 2009-08-06.
16. summary EU proposal for a Regulation on L-category vehicles (two- or three-wheel vehicles and quadricycles) (http://ec.europa.eu/enterprise/sectors/automotive/files/cit-sum-com-542_en.pdfCitizens')

17. "Elwell-Parker, Limited". Retrieved 2016-02-17.
18. "Electric Car History". Archived from the original on 2014-01-05. Retrieved 2012-12-17.
19. "World's first electric car built by Victorian inventor in 1884". *The Daily Telegraph*. London. 2009-04-24. Retrieved 2009-07-14.
20. Neue Presse Coburg: Elektroauto in Coburg erfunden (German) (https://www.np-coburg.de/lokal/coburg/coburg/Elektroauto-in-Coburg-erfunden;art83423,1491254)
21. "Electric automobile". Encyclopædia Britannica (online). Retrieved 2014-05-02.
22. Justin Gerdes (2012-05-11). "The Global Electric Vehicle Movement: Best Practices From 16 Cities". *Forbes*. Retrieved 2014-10-20.
23. Boschert, Sherry (2006). *Plug-in Hybrids: The Cars that will Recharge America*. New Society Publishers. pp. 15–28. ISBN 978-0-86571-571-4.
24. See *Who Killed the Electric Car?* (2006)
25. Shahan, Zachary (2015-04-26). "Electric Car Evolution". Clean Technica. Retrieved 2016-09-08. *2008: The Tesla Roadster becomes the first production electric vehicle to use lithium-ion battery cells as well as the first production electric vehicle to have a range of over 200 miles on a single charge.*
26. Jeff Cobb (2015-12-08). "Nissan Sells 200,000th Leaf Just Before Its Fifth Anniversary". *HybriCars.com*. Retrieved 2015-12-08.
27. "Renault-Nissan Alliance Sells 8.5 Million Vehicles In 2015" (Press release). Paris: Renault-Nissan Alliance. 2016-02-04. Retrieved 2016-02-05.
28. Hull, Dana (2016-04-07). "Tesla Says It Received More Than 325,000 Model 3 Reservations". *Bloomberg News*. Retrieved 2016-04-07.
29. Frydenlund, Ståle (2016-12-13). "Norway now has 100,000 electric cars". Norsk Elbilforening (Norwegian Electric Vehicle Association). Retrieved 2016-12-13.
30. National Research Council (2010). "Transitions to Alternative Transportation Technologies--Plug-in Hybrid Electric Vehicles". The National Academies Press. Retrieved 2010-03-03.
31. "Alternative Fuels Data Center: Batteries for Hybrid and Plug-In Electric Vehicles". *www.afdc.energy.gov*. Retrieved 2016-12-04.
32. Loveday, Eric (2011-07-06). "Mitsubishi i-MiEV lineup expands for 2012 with cheaper "M" and extended-range "G" — Autoblog Green". *autoblog.com*. Retrieved 2011-07-21.
33. Nature:Rapidly falling costs of battery packs for electric vehicles (http://www.nature.com/nclimate/journal/v5/n4/full/nclimate2564.html)
34. John Reed (2010-09-19). "Buyers loath to pay more for electric cars". *Financial Times*. Retrieved 2012-06-26.
35. "Toyota sees Tesla EV battery cost at ⅓". *Reuters*. 2011-01-11.
36. "Toyota Adopts Tesla Laptop Strategy for Electric Cars". 2010-12-08. Archived from the original on 2010-12-13.
37. "Tesla says Model S will be profitable thanks to cheaper batteries".
38. Paul Stenquist (2012-06-25). "Tesla Model S Offers a Lesson in Electric-Vehicle Economics". *The New York Times*. Retrieved 2012-06-25.
39. Siddiq Khan; Martin Kushler (June 2013). "Plug-in Electric Vehicles: Challenges and Opportunities" (PDF). American Council for an Energy-Efficient Economy. Retrieved 2013-07-09. *ACEEE Report Number T133*.
40. Technology Review: Inexpensive Electric Cars May Arrive Sooner Than You Think (http://www.technologyreview.com/news/536336/inexpensive-electric-cars-may-arrive-sooner-than-you-think/)
41. Randall, Tom (2016-02-25). "Here's How Electric Cars Will Cause the Next Oil Crisis". *Bloomberg News*. Retrieved 2016-02-26. *See embedded video (http://www.bloomberg.com/news/videos/2016-02-24/the-peak-oil-myth-and-the-rise-of-the-electric-car).*
42. Bloomberg New Energy Finance (2016-02-25). "Here's How Electric Cars Will Cause the Next Oil Crisis" (Press release). London and New York: PR Newswire. Retrieved 2016-02-26.
43. "Fact Sheet - Japanese Government Incentives for the Purchase of Environmentally Friendly Vehicles" (PDF). Japan Automobile Manufacturers Association. Retrieved 2010-12-24.
44. Motavalli, Jim (2010-06-02). "China to Start Pilot Program, Providing Subsidies for Electric Cars and Hybrids". The New York Times. Retrieved 2010-06-02.
45. "Growing Number of EU Countries Levying CO2 Taxes on Cars and Incentivizing Plug-ins". Green Car Congress. 2010-04-21. Retrieved 2010-04-23.
46. "Notice 2009-89: New Qualified Plug-in Electric Drive Motor Vehicle Credit". Internal Revenue Service. 2009-11-30. Retrieved 2010-04-01.
47. Erickson, Glenn (2009-01-10). "DVD Savant Review:Who Killed the Electric Car?". dvdtalk.com. Retrieved 2009-11-17. See main article Who killed the electric car
48. http://cleantechnica.com/2013/09/27/tesla-model-s-almost-maintenance-free/
49. http://www.earth911.com/eco-tech/electric-car-home-charging-guide/
50. "The Cost to Charge an Electric Car". Verde Sustainable Solutions, L3C. 7 November 2012.
51. United States Environmental Protection Agency and U.S. Department of Energy (2014-09-10). "Model Year 2014 Fuel Economy Guide - Electric vehicles" (PDF). *fueleconomy.gov*. Retrieved 2014-09-12. *pp. 33–36.*
52. U. S. Environmental Protection Agency and U.S. Department of Energy (2012-11-30). "Comparison Side-by-Side -2013 Chrysler 200, 2013 Ford Taurus FWD, 2013 Toyota Venza, and 2013 Hyundai Santa Fe Sport 2WD". Fueleconomy.gov. Retrieved 2012-12-09.
53. "Performance Statistics - 1999 General Motors EV1 w/NiMH" (PDF). United States Department of Energy, Office of Energy Efficiency and Renewable Energy. 1999. Retrieved 2009-04-25.
54. Nick Bunkley (2010-11-22). "Nissan Says Its Electric Leaf Gets Equivalent of 99 M.P.G.". *The New York Times*. Retrieved 2010-11-23.
55. Carpenter, Susan (2010-03-30). "Nissan Leaf's promise: An affordable electric". Articles.latimes.com. Retrieved 2010-04-18.
56. Nissan (2012-06-23). "Nissan launches LEAF "taxi" campaign in London". Green Car Congress. Retrieved 2012-06-25.
57. United States Environmental Protection Agency and U.S. Department of Energy (2015-12-18). "Model Year 2016 Fuel Economy Guide - Electric vehicles & Plug-in Hybrid Electric Vehicles" (PDF). *fueleconomy.gov*. Retrieved 2015-12-18. *See pp. 27–28 for all-electric vehicles and pp. 30–31 for plug-in hybrid electric vehicles. The average 2016 vehicle gets 25 mpg*
58. United States Environmental Protection Agency and U.S. Department of Energy (2016-11-16). "Model Year 2017 Fuel Economy Guide - Electric vehicles & Plug-in Hybrid Electric Vehicles" (PDF). *fueleconomy.gov*. Retrieved 2016-11-19. *pp. 32–36.*
59. U. S. Environmental Protection Agency and U.S. Department of Energy (2015-12-04). "Fueleconomy.gov's Top Fuel Sippers (EPA Ratings, All Years)". fueleconomy.gov. Retrieved 2015-12-06. *Excludes all-electric vehicles. Click on the tab "Top Fuel Sippers (EPA Ratings, All Years)" - The 2016 Volt has a combined fuel economy of 77 mpg-e. The BMW i3 REx has a combined fuel economy of 88 mpg-e, and ranks as the most efficient EPA-certified current year vehicle with a gasoline engine.*

60. U. S. Environmental Protection Agency and U.S. Department of Energy (2015-12-18). "Compare Side-by-Side - 2015 Toyota Prius, 2016 Toyota Prius and 2016 Toyota Prius Eco". Fueleconomy.gov. Retrieved 2015-12-18. *The average 2016 vehicle gets 25 mpg.*
61. U. S. Environmental Protection Agency and U.S. Department of Energy (2015-08-14). "2016 Best and Worst Fuel Economy Vehicles - (excluding electric vehicles)". Fueleconomy.gov. Retrieved 2015-08-17. *See the tab "Cars excl. EVs" – The Prius c is the most fuel efficient in the compact class and the conventional Prius is the most fuel efficient in the midsize class, and both rank ahead of the most fuel efficient in any other clars.*
62. United States Environmental Protection Agency and U.S. Department of Energy (2015-08-12). "Model Year 2015 Fuel Economy Guide - Electric vehicles & Plug-in Hybrid Electric Vehicles" (PDF). *fueleconomy.gov*. Retrieved 2015-08-17. *pp. 31–34*.
63. United States Environmental Protection Agency and U.S. Department of Energy (2016-11-18). "Compare Side-by-Side: 2017 Hyundai Ioniq Electric". *fueleconomy.gov*. Retrieved 2016-11-19.
64. United States Environmental Protection Agency and U.S. Department of Energy (2016-09-29). "Compare Side-by-Side: 2015 BMW i3 REX, 2016 BMW i3 REX, 2017 BMW i3 REX (94 Amp-hour battery), and 2017 BMW i3 BEV (94 Amp-hour battery)". *fueleconomy.gov*. Retrieved 2016-09-30.
65. United States Environmental Protection Agency and U.S. Department of Energy (2015-12-04). "Compare Side-by-Side: 2014 BMW i3 BEV". *fueleconomy.gov*. Retrieved 2015-12-06.
66. U. S. Environmental Protection Agency and U.S. Department of Energy (2015-12-04). "2013 Scion iQ EV". Fueleconomy.gov. Retrieved 2015-12-06.
67. Energy Efficiency & Renewable Energy, U.S. Department of Energy and U. S. Environmental Protection Agency and (2016-09-20). "Compare Side-by-Syde - 2017 Chevrolet Bolt". fueleconomy.gov. Retrieved 2016-09-20.
68. U. S. Environmental Protection Agency and U.S. Department of Energy (2015-12-04). "2014 Chvevrolet Spark EV". Fueleconomy.gov. Retrieved 2015-12-06.
69. U. S. Environmental Protection Agency and U.S. Department of Energy (2015-12-04). "2013 Honda Fit EV". Fueleconomy.gov. Retrieved 2015-12-06.
70. U. S. Environmental Protection Agency and U.S. Department of Energy (2015-12-04). "2013 Fiat 500e". Fueleconomy.gov. Retrieved 2015-12-06.
71. U.S. Environmental Protection Agency and U.S. Department of Energy (2015-12-04). "2015 Volkswagen e-Golf". Fueleconomy.gov. Retrieved 2015-12-06.
72. U.S. Environmental Protection Agency and U.S. Department of Energy (2015-12-04). "Compare side by side: 2013 Nissan Leaf/2014 Nissan Leaf/2015 Nissan Leaf/2016 Nissan Leaf (24 kW-hr battery pack)/2016 Nissan Leaf (30 kW-hr battery pack)". Fueleconomy.gov. Retrieved 2015-12-06.
73. U.S. Environmental Protection Agency and U.S. Department of Energy (2015-12-04). "2011–12 Electric Vehicles- 2012 Mitsubishi i-MiEV". Fueleconomy.gov. Retrieved 2015-12-06.
74. U. S. Environmental Protection Agency and U.S. Department of Energy (2015-12-04). "2016 Fiat 500e". Fueleconomy.gov. Retrieved 2015-12-06.
75. U. S. Environmental Protection Agency and U.S. Department of Energy (2015-12-04). "2013 smart fortwo electric drive coupe". Fueleconomy.gov. Retrieved 2015-12-06.
76. U. S. Environmental Protection Agency and U.S. Department of Energy (2015-12-04). "2015 Kia Soul Electric". Fueleconomy.gov. Retrieved 2015-12-06.
77. U. S. Environmental Protection Agency and U.S. Department of Energy (2015-12-04). "2012 Ford Focus BEV". Fueleconomy.gov. Retrieved 2015-12-06.
78. U. S. Environmental Protection Agency and U.S. Department of Energy (2015-12-04). "Compare Side-by-Side - 2015 Tesla Model S 60 kW-hr/AWD - 70D/AWD - 90D/AWD - P90D". Fueleconomy.gov. Retrieved 2015-12-06.
79. U. S. Environmental Protection Agency and U.S. Department of Energy (2015-12-04). "2015 Tesla Model S (85 kW-hr battery pack); 2014 Tesla Model S AWD (85 kW-hr battery pack); 2015 Tesla Model S AWD - 85D; and 2015 Tesla Model S AWD - P85D". Fueleconomy.gov. Retrieved 2015-12-06.
80. U. S. Environmental Protection Agency and U.S. Department of Energy (2015-12-04). "2016 Tesla Model X AWD - 90D and P90D". Retrieved 2015-12-06.
81. U. S. Environmental Protection Agency and U.S. Department of Energy (2015-12-04). "2012 Tesla Model S". Fueleconomy.gov. Retrieved 2015-12-06.
82. U.S. Environmental Protection Agency and U.S. Department of Energy (2015-12-04). "2014/2015/2016 Mercedes-Benz B-Class Electric Drive". Fueleconomy.gov. Retrieved 2015-12-06.
83. U.S. Environmental Protection Agency and U.S. Department of Energy (2015-12-04). "2012/2013/2014 Toyota RAV4 EV". Fueleconomy.gov. Retrieved 2015-12-06.
84. U.S. Environmental Protection Agency and U.S. Department of Energy (2015-12-04). "Compare Side-by-Side: 2012/13/14/15 BYD e6". Fueleconomy.gov. Retrieved 2015-12-06.
85. U.S. Environmental Protection Agency and U.S. Department of Energy (2015-12-04). "Compare Side-by-Side - 2016/2015 Chevrolet Volt". Fueleconomy.gov. Retrieved 2015-12-06.
86. Eric Loveday (2015-09-01). "Detailed Look At 2016 Chevrolet Volt EPA Ratings". InsideEVs.com. Retrieved 2015-09-02.
87. United States Environmental Protection Agency and U.S. Department of Energy (2015-12-04). "Compare Side-by-Side: 2016 Ford Fusion AWD, 2016 Honda Accord, 2016 Toyota Camry, and 2016 Toyota RAV4 AWD". *fueleconomy.gov*. Retrieved 2015-12-06.
88. U.S. Environmental Protection Agency and U.S. Department of Energy (2016-11-18). "Most Efficient EPA Certified Vehicles". fueleconomy.gov. Retrieved 2016-11-19. *Current Model Year excludes all-electric vehicles.*
89. United States Environmental Protection Agency and U.S. Department of Energy (2014-07-04). "Compare Side-by-Side: 2014 BMW i3 BEV & 2014 BMW i3 REx". *fueleconomy.gov*. Retrieved 2014-07-26.
90. *THINK marks Earth Day 2010 with the release of CEO Richard Canny's 'Top 10 myths about electric vehicles - busted!*, archived from the original on 2011-10-05, retrieved 2013-04-22
91. "Tesla Motors Club Forum - FAQ". Teslamotorsclub.com. 2007-06-23. Retrieved 2010-07-16.
92. Abuelsamid, Sam (2009-01-17). "Tesla offers laundry list of new options, $12k prepaid battery replacement". *autoblog.com*. Retrieved 2010-07-16.

93. Tesla Roadster – Batterie langlebiger als erwartet (http://www.greenmotorsblog.de/elektroautos/tesla-raodster-%E2%80%93-batterie-langlebiger-als-erwartet/13861/), greenmotorsblog.de, abgerufen am 31. März 2014
94. Plug In America Research Shows That Tesla Roadster Battery Performance Bests Tesla Motors' Own Projections (http://www.pluginamerica.org/press-release/plug-america-research-shows-tesla-roadster-battery-performance-bests-tesla-motors%E2%80%99-own), pluginamerica.org, abgerufen am 31. März 2014
95. „Batteriegarantie: 8 Jahre, unbegrenzte km" (http://www.teslamotors.com/de_DE/models/features#/battery), teslamotors.com, abgerufen am 5. April 2014.
96. Shai Agassi (February 2009). *Shai Agassi's bold plan for electric cars*. Long Beach and Palm Springs, California: TED conference. Event occurs at 4m10s. Retrieved 2009-10-05. "See we're bound by today's technology on batteries, which is about 120 miles if you want to stay within reasonable space and weight limitations. 120 miles is a good enough range for a lot of people. But you never want to get stuck. So what we added as a second element to our network is a battery swap system. You drive. You take your depleted battery out. A full battery comes on. And you drive on. You don't do it as a human being. You do it as a machine. It looks like a car wash. You come into your car wash. And a plate comes up, holds your battery, takes it out, puts it back in. Within two minutes you're back on the road. And you can go again. If you had charge spots everywhere, and you had battery swap stations everywhere, how often would you do it? And it ends up that you'd do swapping less times than you stop at a gas station. As a matter of fact, we add it to the contract. We said that if you stop to swap your battery more than 50 times a year we start paying you money because it's an inconvenience."
97. J.D. Power and Associates (2010-10-27). "Future Global Market Demand for Hybrid and Battery Electric Vehicles May Be Over-Hyped; Wild Card is China". Retrieved 2012-06-26.
98. Henry Lee; Grant Lovellette (July 2011). "Will Electric Cars Transform the U.S. Vehicle Market?". Belfer Center for Science and International Affairs, Kennedy School of Government. Retrieved 2011-08-07.
99. Henry Lee; Grant Lovellette (July 2011). "WillElectricCars Transform the U.S. Vehicle Market?" (PDF). Belfer Center for Science and International Affairs, Kennedy School of Government. Retrieved 2011-08-07. Discussion Paper #2011-08.
100. *byd-auto.net* (http://www.byd-auto.net/innovations/gcs/overview.php) Highlights of BYD e-taxi in Public Transportation: Energy saving& Low cost. Abgerufen am 17. Februar 2016.
101. Matt Ritchel (2015-11-24). "A Car Dealers Won't Sell: It's Electric". *The New York Times*. Retrieved 2015-11-28.
102. Eric Cahill; Dan Sperling (2014-11-03). "The Future Of Electric Vehicles Part 1: Car Dealers Hold The Key". Institute of Transportation Studies (ITS), at the University of California, Davis. Retrieved 2015-11-28.
103. Cahill, Eric; Davies-Shawhyde, Jamie; Turrentine, Thomas S. (October 2014). "New Car Dealers and Retail Innovation in California's Plug-In Electric Vehicle Market". Institute of Transportation Studies (ITS), at the University of California, Davis. Retrieved 2015-11-29. *Working Paper – UCD-ITS-WP-14-04. Click on the bar "Download PDF"*
104. Eric Evarts (2014-04-22). "Dealers not always plugged in about electric cars, Consumer Reports' study reveals". *Consumer Reports*. Retrieved 2015-11-29.
105. Doucette, Reed; McCulloch, Malcolm (2011). "Modeling the CO2 emissions from battery electric vehicles given the power generation mixes of different countries". *Energy Policy*. **39**: 803–811 – via Science Direct.
106. "Well-to-Wheels Greenhouse Gas Emissions and Petroleum Use for Mid-Size Light-Duty Vehicles" (PDF). Department Of Energy United States of America. 2010-10-25. Retrieved 2013-08-02.
107. Massiani, Jerome; Weinmann, Jens (2012). "Estimating electric car's emissions in Germany: an analysis through a pivotal marginal method and comparison with other methods". *ECONOMICS AND POLICY OF ENERGY AND THE ENVIRONMENT*. **2**: 131–155.
108. Andrew English (2014-04-29). "Why electric cars must catch on". *Daily Telegraph*. Retrieved 2014-05-01.
109. "Should Pollution Factor Into Electric Car Rollout Plans?". Earth2tech.com. 2010-03-17. Retrieved 2010-04-18.
110. "Electro Automotive: FAQ on Electric Car Efficiency & Pollution". Electroauto.com. Retrieved 2010-04-18.
111. Raut, Anil K. "Role of electric vehicles in reducing air pollution: a case of Katmandu, Nepal". The Clean Air Initiative. Retrieved 2011-01-04.
112. "CO2 Intensity". Eirgrid. Retrieved 2010-12-12.
113. Buekers, J; Van Holderbeke, M; Bierkens, J; Int Panis, L (2014). "Health and environmental benefits related to electric vehicle introduction in EU countries". *Transportation Research Part D Transport and Environment*. **33**: 26–38. doi:10.1016/j.trd.2014.09.002.
114. Clark, Duncan (2009-07-17). "Real-time "CO2 intensity" site makes the case for midnight dishwashing". London: Guardian. Retrieved 2010-12-12.
115. http://www.plugincars.com/combining-solar-panels-electric-car-130161.html
116. "Net Generation by Energy Source: Total (All Sectors), 2004–March 2014". US: Energy Information Administration. Retrieved 2014-05-26.
117. U. S. Environmental Protection Agency (October 2014). "Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 Through 2014" (PDF). EPA. Retrieved 2014-10-11. *See Table 7.2 – MY 2014 Alternative Fuel Vehicle Powertrain and Range; p. 98; Table 7.3 for overall fuel economy (mpg-e), p. 100; Table 7.4 for tailpipe* CO_2 *emissions, p. 102; and Table 7.5 for upstream* CO_2 *emission, p. 105.*
118. Don Anair; Amine Mahmassani (April 2012). "State of Charge: Electric Vehicles' Global Warming Emissions and Fuel-Cost Savings across the United States" (PDF). Union of Concerned Scientists. Retrieved 2012-08-08. *pp. 5, 11, 16–20*.
119. Paul Stenquist (2012-04-13). "How Green Are Electric Cars? Depends on Where You Plug In". *The New York Times*. Retrieved 2012-04-14.
120. Paul Stenquist (2012-04-13). "Carbon In, Carbon Out: Sorting Out the Power Grid". *The New York Times*. Retrieved 2012-04-14. See map
121. Paul Stenquist (2012-04-13). "When it Comes to Carbon Dioxide, Lower is Better and Zero is Perfect". *The New York Times*. Retrieved 2012-04-14.
122. Paul Stenquist (2014-09-19). "Coal Fades, So Electrics Get Cleaner". *The New York Times*. Retrieved 2014-10-12.
123. Don Anair (2014-09-16). "How do EVs Compare with Gas-Powered Vehicles? Better Every Year….". Union of Concerned Scientists (UCS). Retrieved 2014-10-12.
124. "The ZEV's invisible tailpipe - Are zero-emission vehicles cleaner than petrol cars? It all depends...". *The Economist*. 2014-11-24. Retrieved 2014-12-08.

125. Graff Zivina, Joshua S.; Kotchenb, Matthew J.; Mansur, Erin T. (November 2014). "Spatial and temporal heterogeneity of marginal emissions: Implications for electric cars and other electricity-shifting policies". *Journal of Economic Behavior and Organization*. **107** (Part A): 248–268. doi:10.1016/j.jebo.2014.03.010. Published on line 2014-03-24. See p. 251.
126. Nealer, Rachael; Reichmuth, David; Anair, Don (November 2015). "Cleaner Cars from Cradle to Grave: How Electric Cars Beat Gasoline Cars on Lifetime Global Warming Emissions" (PDF). Union of Concerned Scientists (UCS). Retrieved 2014-11-22.
127. Sebastian Blanco (2015-11-17). "UCS: Well-to-wheel, EVs cleaner than pretty much all gas cars". *Autoblog (website)*. Retrieved 2015-11-22.
128. "Investigation into the Scope for the Transport Sector to Switch to Electric Vehicles and Plug-in Hybrid Vehicles" (PDF). Department for Business Enterprise and Regulatory Reform: Department for Transport, UK. October 2008. Retrieved 2011-01-04.
129. "Electric vehicles given thumbs up". Physorg. 2010-05-19. Retrieved 2010-10-15.
130. Palm, Erik (2009-05-01). "Study: Electric cars not as green as you think". CNET Networks. Retrieved 2009-05-04.
131. Massiani, Jerome; Weinmann, Jens (2012). "Estimating electric car's emissions in Germany: an analysis through a pivotal marginal method and comparison with other methods". *ECONOMICS AND POLICY OF ENERGY AND THE ENVIRONMENT*. **2**: 131–155.
132. Mike Millikin (2014-03-13). "Volkswagen: e-mobility and sustainability; Part 1, the e-Golf and Golf GTE". Green Car Congress. Retrieved 2014-03-13.
133. "Renault to sell electric cars for the same price as diesels | Motoring News". Honest John. 2010-09-16. Retrieved 2011-01-03.
134. "Ricardo study finds electric and hybrid cars have a higher carbon footprint during production than conventional vehicles, but still offer a lower footprint over the full life cycle". Green Car Congress. 2011-06-08. Retrieved 2011-06-11.
135. Notter, Dominic A.; Gauch, Marcel; Widmer, Rolf; Wäger, Patrick; Stamp, Anna; Zah, Rainer; Althaus, Hans-Jörg (2010-09-01). "Contribution of Li-Ion Batteries to the Environmental Impact of Electric Vehicles". *Environmental Science & Technology*. **44** (17): 6550–6556. doi:10.1021/es903729a. ISSN 0013-936X.
136. Notter, Dominic A.; Kouravelou, Katerina; Karachalios, Theodoros; Daletou, Maria K.; Haberland, Nara Tudela. "Life cycle assessment of PEM FC applications: electric mobility and μ-CHP". *Energy Environ. Sci*. **8** (7): 1969–1985. doi:10.1039/c5ee01082a.
137. Zehner, Ozzie (2013-06-30). "Unclean at Any Speed". IEEE. Retrieved 2013-08-31.
138. Chandler, David (2012-04-09). "Clean energy could lead to scarce materials". MIT. Retrieved 2013-08-31.
139. "Are Electric Cars Green? The External Cost of Lithium Batteries". The Energy Collective. 2013-05-15. Retrieved 2013-08-31.
140. Hawkins, Troy R.; Singh, Bhawna; Majeau-Bettez, Guillaume; Strømman, Anders Hammer (February 2012). "Comparative Environmental Life Cycle Assessment of Conventional and Electric Vehicles". *Journal of Industrial Ecology*. **17** (1): 53–64. doi:10.1111/j.1530-9290.2012.00532.x.
141. Hickman, Leo (2012-10-05). "Are electric cars bad for the environment?". The Guardian. Retrieved 2013-08-31.
142. Hawkins, Troy R.; Singh, Bhawna; Majeau-Bettez, Guillaume; Strømman, Anders Hammer (2013-01-13). "Corrigendum to: Comparative environmental life cycle assessment of conventional and electric vehicles Journal of Industrial Ecology". *Journal of Industrial Ecology*. doi:10.1111/jiec.12011. Retrieved 2015-11-07.
143. Eric Loveday (2014-02-11). "Nissan LEAF Has Smallest Lifecycle Footprint of Any 2014 Model Year Automobile Sold in North America". Inside EVs. Retrieved 2014-02-22.
144. Automotive Science Group (ASG) (2014-02-04). "Life-cycle Assessment of 1,300 Models Reveals Best of 2014". ASG Press Room. Retrieved 2014-02-22.
145. Contact Wes Siler: Comment Email Facebook Twitter (2010-04-13). "Helsinki Metropolia University's RaceAbout". Jalopnik.com. Retrieved 2011-12-06.
146. Contact Mike Spinelli: Comment (2007-10-05). "Nissan Pivo 2". Jalopnik.com. Retrieved 2011-12-06.
147. "Charles Perry's Plug-In Hybrid Retrofit Kit". Gizmag.com. Retrieved 2011-12-06.
148. Hedlund, R. (November 2008). "The Roger Hedlund 100 MPH Club". National Electric Drag Racing Association. Retrieved 2009-04-25.
149. "Roadster Sport 2.5 Specifications". Tesla. Archived from the original on 2013-02-12. Retrieved 2013-02-01.
150. Kozak, Graham (2013-01-29). "Tesla Model S walks 2005 Dodge Viper at the drag strip". Autoweek. Retrieved 2013-02-01.
151. "X1". Wrightspeed. Archived from the original on 2013-01-09. Retrieved 2013-02-01.
152. Simanaitis, Dennis (2009-01-23). "Eclectic Electrics: Wrightspeed X1". *Road & Track*. Retrieved 2013-02-01.
153. Shah, Saurin D. (2009). "2". *Plug-In Electric Vehicles: What Role for Washington?* (1st ed.). The Brookings Institution. pp. 29, 37 and 43. ISBN 978-0-8157-0305-1.
154. "Audis neue Stoßdämpfer gewinnen Strom english: Audis new shock absorber win power". wiwo.de. Retrieved 2016-09-23.
155. "Advanced Vehicle Testing Activity". Full Size Electric Vehicles (Report). Idaho National Laboratory. 2006-05-30. Archived from the original on 2009-03-18. Retrieved 2009-04-25.
156. "Energy Efficiency of Tesla Electric Vehicles". Tesla Motors. Retrieved 2009-04-25.
157. US 5889260 (https://worldwide.espacenet.com/textdoc?DB=EPODOC&IDX=US5889260), Golan, Gad & Yuly Galperin, "Electrical PTC heating device", published 30 March 1999
158. NativeEnergy (2012-09-07). "3 Electric Car Myths That Will Leave You Out in the Cold". Recyclebank. Retrieved 2013-07-21.
159. Piotrowski, Ed (2013-01-03). "How i Survived the Cold Weather". The Daily Drive - Consumer Guide Automotive. Retrieved 2013-07-21.
160. "Effects of Winter on Tesla Battery Range and Regen". *teslarati.com*. 2014-11-24. Retrieved 2015-02-21.
161. "2010 Options and Packages". *Toyota Prius*. Toyota. Retrieved 2009-07-09.
162. Spotnitz, R.; Franklin, J. (2003). "Abuse behavior of high-power, lithium-ion cells". *Journal of Power Sources*. **113**: 81. doi:10.1016/S0378-7753(02)00488-3.
163. China Autoweb (2012-05-28). "Initial details on fiery crash involving BYD e6 that killed 3". Green Car Congress. Retrieved 2012-08-13.
164. Christopher Jensen (2013-10-02). "Tesla Says Car Fire Started in Battery". The New York Times. Retrieved 2013-10-05.
165. Steven Russolillo (2013-10-04). "Musk Explains Why Tesla Model S Caught on Fire". *The Wall Street Journal*. Retrieved 2013-10-05.
166. Jaclyn Trop (2013-11-07). "Another Fire Raises Questions for Tesla". *The New York Times*. Retrieved 2013-11-10.
167. General Motors (2011-01-19). "Detroit First Responders Get Electric Vehicle Safety Training". *General Motors News*. Retrieved 2011-11-12.
168. "General Motors Kicks Off National Electric Vehicle Training Tour For First Responders". Green Car Congress. 2010-08-27. Retrieved 2011-11-11.

169. General Motors (2011-03-31). "First Responder Vehicle Guides". U.S. Fire Administration. Archived from the original on 2011-10-19. Retrieved 2011-11-12.
170. AOL Autos (2011-12-16). "Chevy Volt Unplugged: When To Depower Your EV After a Crash". *Translogic*. Retrieved 2011-12-20.
171. Nissan (2010). "2011 LEAF First Responder's Guide" (PDF). Nissan North America. Retrieved 2011-12-20.
172. *Effectiveness and impact of ...* Books.google.com.au. August 2002. ISBN 978-0-309-07601-2. Retrieved 2009-10-17.
173. Ehsani, Mehrdad (2005). *Modern electric, hybrid electric ... - Google Books*. Books.google.com.au. ISBN 978-0-8493-3154-1. Retrieved 2009-10-17.
174. "Vehicle Weight, Fatality Risk and Crash Compatibility of Model Year 1991-99 Passenger Cars and Light Trucks" (PDF). National Highway Traffic Safety Administration. October 2003. Retrieved 2009-04-25.
175. "Low-rolling-resistance tires". *Consumer Reports*. November 2007. Archived from the original on 2009-04-19. Retrieved 2009-04-25. (subscription required for full access)
176. Crowe, Paul (2008-07-21). "Low Rolling Resistance Tires Save Gas". *HorsePower Sports*. Retrieved 2009-04-25.
177. "Planned EU Requirements for Tires Would Reduce Road Traffic Safety". Continental AG. 2007-11-12. Retrieved 2011-12-07.
178. Shunk, Chris (2010-05-21). "IIHS condemns use of mini trucks and low-speed vehicles on public roads". *autoblog.com*. Retrieved 2010-10-15.
179. Nuckols, Ben (2007-03-03). "Blind people: Hybrid cars pose hazard". USA Today. Retrieved 2009-05-08.
180. "Electric cars and noise: The sound of silence". Economist. 2009-05-07. Retrieved 2009-05-08.
181. David Shepardson (2011-01-04). "Obama signs law to require 'quiet' cars to get noisier". *The Detroit News*. Retrieved 2011-01-05.
182. "TMC to Sell Approaching Vehicle Audible System for 'Prius' ". Toyota Motor Company News Release. 2010-08-24. Retrieved 2010-08-25.
183. European Commission Press Release (2014-04-02). "Commission welcomes Parliament vote on decreasing vehicle noise". European Commission. Retrieved 2014-04-03.
184. Jim Motavalli (2010-06-17). "Blind Advocates 'Disappointed' in Nissan E.V. Sounds for Pedestrians". New York Times. Retrieved 2010-06-19. *The article includes a sample of the two sounds*.
185. Jim Motavalli (2010-06-01). "Electric Car Warning Sounds: Don't Expect Ring Tones". New York Times. Retrieved 2010-06-02.
186. Gabe Nelson (2013-03-01). "Louder EVs may turn off drivers, automakers say". *Automotive News*. Retrieved 2013-03-21.
187. Dorothee Tschampa (2013-12-30). "Daimler Electrics Get Fake Vroom to Thwart Silent Threat: Cars". *Bloomberg*. Retrieved 2014-01-01.
188. Neal, Meghan (5 February 2015). "Why Electric Cars Are Ditching AM Radio". *Vice News*. Retrieved 5 February 2016.
189. "Ford Focus BEV - Road test". Autocar.co.uk. Retrieved 2011-01-03.
190. Ian Clifford, CEO of ZENN Motors, in Discovery Channel's Green Wheels episode 1
191. Joann Muler (2010-06-11). "Electric Car Warning: Actual Mileage May Vary". *Forbes*. Retrieved 2010-10-21.
192. Eric Loveday (2010-06-14). "Nissan pegs Leaf range between 47 and 138 miles, individual results may vary". *autoblog.com*. Retrieved 2010-10-21.
193. Energy Efficiency & Renewable Energy, U.S. Department of Energy and U. S. Environmental Protection Agency and (2016-09-14). "Find a car - Years: 2016–2017 - Vehicle Type: Electric". fueleconomy.gov. Retrieved 2016-09-14.
194. Baker, David R. (2016-04-01). "Tesla Model 3 reservations top 232,000". *San Francisco Chronicle*. Retrieved 2016-09-14.
195. Fleming, Charles (2016-09-12). "Chevy Bolt EV range is 238 miles: Prime time for the electric car?". *Los Angeles Times*. Retrieved 2016-09-14.
196. "Roadster / features and specs".
197. "BYD Auto, Build Your Dreams!". BYD. Archived from the original on 2016-02-06. Retrieved 2016-02-18.
198. "AAA says that its emergency electric vehicle charging trucks served "thousands" of EVs without power". *Electrek*. Retrieved 6 September 2016.
199. Ferris, Robert (2016-08-17). "Electric cars good enough for 90 percent of trips". *CNBC*. Retrieved 2016-08-17.
200. Needell, Zachary A.; McNerney, James; Chang, Michael T.; Trancik, Jessika E. (2015-12-31). "Potential for widespread electrification of personal vehicle travel in the United States : Nature Energy". *Nature*. doi:10.1038/nenergy.2016.112.
201. UC Davis Mini-E consumer study -June 2011 (http://phev.ucdavis.edu/project/uc-davis-mini-e-consumer-study/)
202. Nick Chambers (2010-05-27). "Nissan LEAF Will Include Fast Charge Capability and Emergency Charging Cable at Launch". gas2.org. Retrieved 2010-06-13.
203. "Electric Vehicle Charging Solutions". Tesla Motors. Retrieved 2012-06-10.
204. Elon Musk: The mind behind Tesla, SpaceX, SolarCity ... (http://www.ted.com/talks/elon_musk_the_mind_behind_tesla_spacex_solarcity.html)
205. Adam Palin (2013-11-19). "Infrastructure: Shortage of electric points puts the brake on sales". *Financial Times*. Retrieved 2013-12-28.
206. KredEx (2013-02-20). "Estonia becomes the first in the world to open a nationwide electric vehicle fast-charging network". Estonian World. Retrieved 2013-12-28.
207. Adam Vaughan (2013-02-20). "Estonia launches national electric car charging network". *The Guardian*. Retrieved 2013-12-28.
208. "BP and ARCO to Install 45 Electric Car Fast Charging Stations as Part of EV Project".
209. "ECOtality scores $10m from ABB; will use funds for EV Project". *autoblog.com*.
210. "The EV Project".
211. "Nissan announces 49 kW quick charger for EVs".
212. "Better Place. The Renault Fluence ZE". Better Place. 2010-10-22. Archived from the original on 2010-09-12. Retrieved 2010-10-22.
213. David McCowen (2013-02-18). "The rise and fall of Better Place". Drive.com.au. Retrieved 2013-04-14.
214. John Voelcker (2013-05-26). "Better Place Electric-Car Service Files For Bankruptcy". Green Car Reports. Retrieved 2013-05-26.
215. Dan Primack (2012-04-12). "Exclusive: Better Place to file for bankruptcy". Fortune (magazine). Retrieved 2013-05-26.
216. Sebastian Blanco (2009-09-27). "REPORT: Tesla Model S was designed with battery swaps in mind". *autoblog.com*. Retrieved 2013-06-22.
217. Mark Rogowsky (2013-06-21). "Tesla 90-Second Battery Swap Tech Coming This Year". *Forbes*. Retrieved 2013-06-22.
218. "Tesla Motors demonstrates battery swap in the Model S". *Green Car Congress*. 2013-06-21. Retrieved 2013-06-22.
219. Gordon-Bloomfield, Nikki (2012-09-20). "Forget Better Place, Hook Your Electric Car To A Battery Trailer". Retrieved 2012-12-24.
220. Viknesh Vijayenthiran (2010-07-20). "First Major Outing For BMW Megacity Vehicle At 2012 London Olympic Games". Motor Authority. Retrieved 2010-07-23.

221. Benjamin Preston (2013-07-29). "BMW Unveils i3 Electric Car". *The New York Times*. Retrieved 2013-07-29.
222. Michaël Torregrossa (2013-07-30). "Voiture électrique - La BMW i3 officiellement révélée" [Electric car - the BMW i3 officially revealed] (in French). Association pour l'Avenir du Véhicule Electrique Méditerranéen (AVEM). Retrieved 2013-07-31.
223. Eric Loveday (2013-07-22). "Official: BMW i3 Range Extender Option Adds 4,490 Euros ($5,919 US) to Price Tag in Netherlands". InsideEVs.com. Retrieved 2013-07-29.
224. "Maintenance and Safety of Hybrid and Plug-In Electric Vehicles". U.S. Department of Energy – Energy Efficiency and Renewable Energy Alternative Fuels Data Center. 2013-09-24. Retrieved 2014-11-18.
225. „zeit.de: Batterie-Upgrade? Unwahrscheinlich!“ (http://www.zeit.de/mobilitaet/2015-04/elektroauto-batterie-akku-tesla-s/seite-2), abgerufen am 22. Februar 2016.
226. Simon Romero (2009-02-02). "In Bolivia, Untapped Bounty Meets Nationalism". New York Times. Retrieved 2010-02-28.
227. "Página sobre el Salar (Spanish)". Evaporiticosbolivia.org. Retrieved 2010-11-27.
228. Irving Mintzer (2009). David B. Sandalow, ed. *Chapter 6: Look Before You Leap: Exploring the Implications of Advanced Vehicles for Import Dependence and Passerger Safety* (PDF). The Brookings Institution. pp. 107–126. ISBN 978-0-8157-0305-1. in *"Plug-in Electric Vehicles: What Role for Washington?"* (http://www.brookings.edu/press/Books/2009/pluginelectricvehicles.aspx)
229. Clifford Krauss (2009-03-09). "The Lithium Chase". New York Times. Retrieved 2010-03-10.
230. Jerry Garret (2010-04-15). "A Case for and Against Electric Cars". New York Times. Retrieved 2010-04-17.
231. "Learn About Lithium – In 10 Bullet Points". ElectroVelocity. 2010-12-13. Retrieved 2011-01-03.
232. Smith, Michael (2009-12-07). "Lithium for 4.8 Billion Electric Cars Lets Bolivia Upset Market". Bloomberg. Retrieved 2011-01-03.
233. Hively, Will (August 1996), "Reinventing the wheel - A flywheel may be the key to a car that's both powerful and efficient", *Discover (magazine)*, retrieved 2009-04-24
234. Schindall, Joel (November 2007). "The Charge of the Ultra - Capacitors Nanotechnology takes energy storage beyond batteries". *IEEE Spectrum*. Retrieved 2010-08-12.
235. Taguchi, Norihisa (2016-03-20). "Japan Unveils First Electric Car Without a Battery". *Mikado Shimbun*. Japan. Retrieved 2016-03-23.
236. Toor, Amar (2013-07-10). "Every Dutch citizen will live within 31 miles of an electric vehicle charging station by 2015". *The Verge*. Vox Media, Inc. Retrieved 2013-07-11.
237. Upton, John (2013-07-26). "EV market threatened by spat over charger standards". *Grist.org*. Grist Magazine, Inc. Retrieved 2013-07-29.
238. Pyper, Juliet (2013-07-24). "Charger standards fight confuses electric vehicle buyers, puts car company investments at risk". *ClimateWire*. E&E Publishing, LL. Retrieved 2013-07-29.
239. "Charging time for the BMW i3". UK: BMW. Archived from the original on 2013-09-21. Retrieved 2013-09-12.
240. "Public hearing to consider proposed amendments to the california zero emission vehicle regulations regarding treatment of majority owned small or intermediate volume manufacturers and infrastructure standardization" (PDF). California Air Resources Board. 2001-06-26. Retrieved 2010-05-23.
241. "FAQ: Standards - ChargePoint Network". *ChargePoint Network*. Coulomb Technologies. Archived from the original on 2010-04-17. Retrieved 2010-05-23.
242. David Herron (2010-07-30). "Electric vehicle charging standards". visforvoltage.org. Retrieved 2010-08-19.
243. Gartner, John (2010-08-03). "Fast Vehicle Charging Goes by Many Names". PluginCars.com. Retrieved 2010-08-19.
244. "IEC61851 Part 1: Charging of electric vehicles up to 250 A AC and 400 A DC" (PDF) (1st ed.). IEC. 2003. p. 7. Archived from the original (PDF) on 2011-07-06.
245. "Rulemaking: 2001-06-26 Updated and Informative Digest ZEV Infrastructure and Standardization" (PDF). *title 13, California Code of Regulations*. California Air Resources Board. 2002-05-13. Retrieved 2010-05-23. "Standardization of Charging Systems"
246. "ARB Amends ZEV Rule: Standardizes Chargers & Addresses Automaker Mergers" (Press release). California Air Resources Board. 2001-06-28. Retrieved 2010-05-23. "the ARB approved the staff proposal to select the conductive charging system used by Ford, Honda and several other manufacturers"
247. "ACEA position and recommendations for the standardization of the charging of electrically chargeable vehicles" (PDF). ACEA Brussels. 2010-06-14.
248. Franz, Paul. "Turning Old Gas Guzzlers into Electric Vehicles". TIME. Retrieved 2011-06-17.
249. Dalloul, Motasem (2008-05-29). "Gaza Cars From Cooking Oil to Batteries". IslamOnline. Archived from the original on 2008-12-07. Retrieved 2009-04-27.
250. Stephanov, Rostik, ed. (2008-08-21). "Gaza Engineers Offer Alternative To Gaza Fuel Crisis". infolive.tv. Retrieved 2009-04-27.
251. "Concept Or Not, Peugeot EX1 Is One Fast EV". *0-60mag*. December 2010. Retrieved 2013-07-12.
252. "MythBuster: Why Electric Vehicles Beat Gas in 5 Extreme Tests". Popular Mechanics. 2008-05-18. Retrieved 2016-05-24.
253. "Electric vehicle storms to victory in Formula Student 2013". Institution of Mechanical Engineers. 2013-07-08. Retrieved 2013-07-12.
254. "FIA Formula E Championship". fia.com.
255. Telegraph Sport (13 September 2014). "Formula E opens with spectacular crash involving Nick Heidfeld and Nicolas Prost as Lucas di Grassi claims win". *Daily Telegraph*. Retrieved 2014-09-13.
256. Electric power lights up Pikes Peak (http://www.gizmag.com/electric-cars-pikes-peak-winner/38214/)
257. Electric car wins title at Pikes Peak race (http://www.9news.com/story/sports/2015/06/28/pikes-peak-hill-climb-rhys-millen-electric-car/29437641/)
258. Rhys Millen wins Pikes Peak under all-electric power (http://www.autoblog.com/2015/06/28/2015-pikes-peak-hill-climb-results/)
259. "High oil prices disastrous for developing countries". Mongabay. 2007-09-12. Retrieved 2010-07-20.
260. "Impact of High Oil Prices on African Economies" (PDF). African Development Bank. 2009-07-29. Retrieved 2010-07-20.
261. Stephen Edelstein (2015-11-03). "Polaris Updates GEM Low-Speed Electric Vehicles". *Green Car Reports*. Retrieved 2015-11-22.
262. Danny King (2011-06-20). "Neighborhood Electric Vehicle Sales To Climb". Edmunds.com Auto Observer. Retrieved 2012-02-05.
263. Saranow, Jennifer (27 July 2006), "The Electric Car Gets Some Muscle", *Pittsburgh Post-Gazette*, retrieved 2009-04-24
264. Dave Hurst; Clint Wheelock (2011). "Executive Summary: Neighborhood Electric Vehicles - Low Speed Electric Vehicles for Consumer and Fleet Markets" (PDF). Pike Research. Retrieved 2012-02-05.

265. Groupe Renault (July 2016). "Ventes Mensuelles" [Monthly Sales] (in French). Renault.com. Retrieved 2016-07-29. *Includes passenger and light utility variants. Click on "Ventes mensuelles (juin 2016)" to download the file "XLSX - 240 Ko" for CYTD sales through June 2016, and open the tab "Sales by Model". Click on "+ Voir plus" (See more) to download the files "Ventes mensuelles du groupe (décembre 2011) (xls, 183 Ko)" "Ventes mensuelles (décembre 2012) (xls, 289 Ko)" - Ventes mensuelles (décembre 2013) (xlsx, 227 Ko)" - "XLSX - 220 Ko Ventes mensuelles (décembre 2014)" - "Ventes mensuelles (décembre 2015)" to download the file "XLSX - 227 Ko" for 2011, 2012, 2013, 2014 and 2015 sales. Sales figures for 2013 were revised in the 2014 report*
266. Jiang Xueqing (2014-01-11). "New-energy vehicles 'turning the corner' ". China Daily. Retrieved 2014-01-12.
267. Perkowski, Jack (2016-12-19). "Will Trump Hurt Tesla's Prospects In China?". *Forbes*. Retrieved 2016-12-19.
268. "The Electric Vehicle World Sales Database: Stable 60:40 Ratio". EV-Volumes. Archived from the original on 2016-10-17. Retrieved 2016-10-17.
269. "Renault-Nissan Alliance hits milestone of 350,000 electric vehicles sold, maintains position as global EV leader" (Press release). Paris/Yokohama: Renault-Nissan Alliance. 2016-09-13. Retrieved 2016-09-13. *The Alliance has sold its 350,000th electric vehicle since December 2010, when the Nissan LEAF went on sale. The milestone was achieved in August 2016. The Alliance also set an industry record of 100,000 EVs sold in a single year.*
270. "New Nissan Electric Café opens in Paris as the brand celebrates three billion EV kilometres worldwide" (Press release). Paris: Nissan Newsroom Europe. 2016-12-16. Retrieved 2016-12-17.
271. "Renault hands over the key to its 100,000th electric vehicle" (Press release). Oslo: Groupe Renault. 2016-09-09. Retrieved 2016-09-11.
272. Richardson, Jake (2014-12-10). "1 Billion Kilometers Driven By Nissan LEAFs". Clean Technica. Retrieved 2016-10-15.
273. Cobb, Jeff (2016-11-07). "China's BYD Becomes World's Third-Largest Plug-in Car Maker". *HybridCars.com*. Retrieved 2016-11-10.
274. Cobb, Jeff (2016-01-12). "Tesla Model S Was World's Best-Selling Plug-in Car in 2015". *HybridCars.com*. Retrieved 2016-01-23.
275. Kane, Mark (2016-11-05). "World's Top 10 Selling EVs Led By The Tesla Model S After Strong September". *EV Sales Blog*. InsideEVs.com. Retrieved 2016-11-06.
276. Loveday, Eric (2016-10-07). "Global Tesla Fleet Surpasses 3 Billion Collective Miles Driven". *Electrek*. InsideEVs.com. Retrieved 2016-10-15.
277. "Three years since the market launch of BMW i. 100,000 electrified BMW on the road" (Press release). Munich: BMW Group Press Club Global. 2016-11-03. Retrieved 2016-11-03. *Three year after the market launch of the BMW i3, the BMW Group has delivered more than 100,000 purely electric-powered cars and plug-in hybrids to customers worldwide. The BMW i3 alone has reached more than 60,000 units, making it the most successful electric vehicle in the premium compact segment. The BMW i8 ranks first among electrified sports cars, with more than 10,000 delivered since the middle of 2014. Additionally, there are the approximately 30,000 iPerformance plug-in hybrids sold.*
278. Jeff Cobb (2015-06-01). "Renault-Nissan And Leaf Lead All In Global EV Proliferation". HybridCars.com. Retrieved 2016-02-06. *Around 50,000 Mitsubishi i-MiEVs have been sold since 2009 under different nameplates.*
279. Bill Moore (2015-03-19). "Mitsubishi Firsts". *EV World*. Retrieved 2015-03-19.
280. "三菱 i-MiEVなどの2015年12月度 販売実績" [Mitsubishi i-MiEV production and sales results for December 2015]. *Electric Vehicle News* (in Japanese). 2016-01-28. Retrieved 2016-02-06. *A total of 6,061 Minicab vans and 940 mini truck versions have been sold in Japan through December 2015.*
281. "Nissan's "No Charge to Charge" program expands to 10 new Markets" (Press release). Nashville: Nissan USA. 2016-08-04. Retrieved 2016-08-13. *With more than 228,000 global sales and more than 95,000 in the U.S., Nissan LEAF is the world's best-selling electric car.*
282. Cobb, Jeff (2016-08-10). "Global 10 Best-Selling Plug-In Cars Are Accelerating Forward". *HybridCars.com*. Retrieved 2016-08-13. *As of June 2016, cumulative global sales of the top selling plug-in electric cars were led by the Nissan Leaf (over 228,000), followed by the Tesla Model S (129,393), Votl/Ampera family (about 117,300), Mitsubishi Outlander PHEV (about 107,400), Toyota Prius PHV (over 75,400), BYD Qin (56,191), Renault Zoe (51,193), BMW i3 (around 49,500), Mitsubishi i-MiEV family (about 37,600) and BYD Tang (37,509).*
283. Staff (2016-01-14). "Sales Ranking of China-made Pure-electric Cars in 2015". *China Auto Web*. Retrieved 2016-08-16. *A total of 16,488 BAIC E-Series EVs, and over 9,000 JAC iEVs were sold in China in 2015.*
284. Staff (2015-01-14). "2014 EV Sales Ranking". *China Auto Web*. Retrieved 2016-02-07. *A total of 5,234 E150 EVs (EV200), and about 1,000 J3 EVs were sold in China in 2014.*
285. Henry Lee; Sabrina Howell; Adam Heal (June 2014). "Leapfrogging or Stalling Out? Electric Vehicles in China". Belfer Center, Harvard Kennedy School. Retrieved 2016-08-16. *Download EVS in China (full report). See Table 2: Chinas's EV Sales by Brand, 2011-2013, p. 19. BAIC E150 EVs sales totaled 644 units in 2012 and 1,466 in 2013. JAC J3 EV sales totaled 2,485 units in 2012 and 1,309 in 2013*
286. Jose, Pontes (2016-07-17). "China June 2016". EVSales.com. Retrieved 2016-08-15. *A total of 9,977 BAIC E-series, and 7,862 JAC iEVs were sold in China during the first half of 2016.*
287. Cobb, Jeff (2016-07-05). "June 2016 Dashboard". *HybridCars.com and Baum & Associates*. Retrieved 2016-08-15.
288. Jeff Cobb (2016-01-06). "December 2015 Dashboard". *HybridCars.com and Baum & Associates*. Retrieved 2016-01-23.
289. Edelstein, Stephen (2016-08-16). "European electric and plug-in hybrid sales for Jan-June 2016". Green Car Reports. Retrieved 2016-08-16. *During the first half of 2016 European VW e-Golf sales totaled 3,912 units and VW Golf GTE sales totaled 5,692 units.*
290. Pontes, Jose (2016-01-30). "Europe December 2015". EVSales.com. Retrieved 2016-02-07. *European VW e-Golf sales totaled 11,214 units in 2015.*
291. Pontes, Jose (2015-01-31). "Europe December 2014". EVSales.com. Retrieved 2016-02-07. *European VW e-Golf sales totaled 3,328 units in 2014.*
292. Mat Gasnier (2013-01-14). "China Full Year 2012: Ford Focus triumphs". Best Selling Car Blog. Retrieved 2013-01-22.
293. Mat Gasnier (2014-01-14). "China December 2013: Focus on the all-new models". Best Selling Cars Blog. Retrieved 2014-01-16.
294. Staff (July 2016). "Chinese car sales data: BYD E6". carsalesbase.com. Retrieved 2016-08-14. *A total of 9,226 BYD e6s were sold in China during the first half of 2016.*
295. China Auto Web (2012-09-30). "JAC Delivers 500 J3 EVs ("ievs")". China Auto Web. Retrieved 2013-04-19. *A total of 1,585 of the first and second generation JAC J3 models were sold during 2010 and 2011.*
296. China Auto Web (2013-03-25). "Chinese EV Sales Ranking for 2012". China Auto Web. Retrieved 2013-04-19. *A total of 2,485 JAC J3 EVs were sold in 2012.*
297. Jeff Cobb (2015-09-16). "One Million Global Plug-In Sales Milestone Reached". HybridCars.com. Retrieved 2015-09-16. *Cumulative global sales totaled about 1,004,000 highway legal plug-in electric passenger cars and light-duty vehicles by mid-September 2015, of which, 62% are all-electric cars and vans, and 38% plug-in hybrids.*

298. Nic Lutsey (2015-09-29). "Global milestone: The first million electric vehicles". International Council on Clean Transportation (ICCT). Retrieved 2015-10-10.
299. Bloomberg New Energy Finance (2016-02-25). "Here's How Electric Cars Will Cause the Next Oil Crisis" (Press release). London and New York: PR Newswire. Retrieved 2016-02-25.
300. Argonne National Laboratory, United States Department of Energy (2016-03-28). "Fact #918: March 28, 2016 - Global Plug-in Light Vehicles Sales Increased By About 80% in 2015". Office of Energy Efficiency & Renewable Energy. Retrieved 2016-03-29.
301. Clark, Pilita; Campbell, Peter (2016-08-31). "Motor Industry: Pressure on the Pump". *Financial Times*. Retrieved 2016-09-01.
302. Cobb, Jeff (2016-01-18). "Top Six Plug-in Vehicle Adopting Countries – 2015". *HybridCars.com*. Retrieved 2016-01-23. *About 520,000 highway legal light-duty plug-in electric vehicles were sold worldwide in 2015, with cumulative global sales reaching 1,235,000. The United States is the leading market with 411,120 units sold since 2008, followed by China with 258,328 units sold since 2011. Japan ranks third (about 130,000), followed by the Netherlands (88,991), Norway (77,897), France (74,291), and the UK (53,254). Four of these countries achieved a PEV market share over 1% of new car sales in 2015: Norway (22.39%), the Netherlands (9.74%), France (1.2%), and the UK (1.1%)*
303. Berman, Brad (2016-02-13). "US Falls Behind Europe and China in Global Plug-in Vehicle Market". *Plugincars.com*. Retrieved 2016-02-16.
304. China Association of Automobile Manufacturers (2012-01-16). "5,579 electric cars sold in China in 2011". Wind Energy and Electric Vehicle Review. Retrieved 2014-01-12.
305. Cars21.com (2013-02-13). "EV sales increase 103.9% in China in 2012- Electric China Weekly No 17". Cars21.com. Retrieved 2014-01-12.
306. China Association of Automobile Manufacturers (CAAM) (2015-01-14). "The sales and production of new energy vehicles boomed". CAAM. Retrieved 2015-01-14.
307. China Association of Automobile Manufacturers (CAAM) (2016-01-20). "New energy vehicles enjoyed a high-speed growth". CAAM. Retrieved 2016-02-08.
308. Choi Dong (2016-01-10). "15年新能源乘用车销17.7万增2倍" [In 2015 with 177,000 units, new energy passenger car sales increased two-fold]. *Auto.sohu.com* (in Chinese). Retrieved 2016-02-08. *See the monthly sales graph/table in top of the article for an accurate figure of 2015 sales: 176,627 plug-in passenger cars.*
309. Petter Haugneland (2016-02-29). "Nasjonal transportplan: Elbil er klimaløsningen" [National Transport: EV is the climate solution] (in Norwegian). Norsk Elbilforening (Norwegian Electric Vehicle Association). Retrieved 2016-03-04.
310. "Number of electric cars worldwide climbs to 1.3 million" (PDF) (Press release). Stuttgart: Zentrum für Sonnenenergieund Wasserstoff-Forschung Baden-Württemberg (ZSW). 2016-02-26. Retrieved 2016-03-04. *Around 3% of some 2.64 million cars in Norway run on electricity by the end of 2015 (includes all-electric cars and plug-in hybrids).*
311. Roger Schreffler (2015-09-23). "PSA, Toyota Lead Way as European Cars Get Cleaner". *Ward's Auto*. Retrieved 2015-09-24. *Cumulative plug-in hybrid and all-electric sales in Europe totaled 233,022 units as of December 2014.*
312. Automotive Industry Data (AID) (2016-02-15). "PHEVs - Take off or transitory blip?". AID Newsletter. Retrieved 2016-02-19. *Market share only includes Western European countries. A total of 95,140 plug-in hybrid cars were sold in Europe in 2015.*
313. Association Nationale pour le Développement de la Mobilité Electrique - AVERE France (2016-03-24). "Quelle est la place de la France sur le marché européen du véhicule électrique ?" [What is the place of France in the European electric vehicle market] (in French). AVERE. Retrieved 2016-03-27. *A total of 97,687 all-electric vehicles, including vans, were registered in the European market in 2015, up from 65,199 in 2014 (+49.8%).*
314. European Automobile Manufacturers Association (ACEA) (February 2016). "New Passenger Car Registrations By Alaternative Fuel Type In The European Union Quarter 4 2015" (PDF). ACEA. Retrieved 2016-02-08. *See table Electric Vehicles: Total Europe (EU+EFTA), 186,170 registered units in 2015 (includes Norway and Switzerland). For Denmark and Romania only pure electric vehicles are included. Electric Vehicles = pure electric vehicles (BEV) + extended-range electric vehicles (EREV) + plug-in hybrid electric vehicles (PHEV) + fuel cell electric vehicles (FCEV).*
315. European Automobile Manufacturers Association (ACEA) (February 2015). "New Electric Vehicles Registrations In The European Union" (PDF). ACEA. Retrieved 2015-02-18. *See table "Total Electrically Charged Vehicles: Total Europe (EU+EFTA)", 65,071 registered units for 2013 and 97,791 units for 2014. For Denmark, Ireland and Romania includes only pure electric vehicles. Total Electrically Charged Vehicles = Pure Electric Vehicles + Extended-Range Electric Vehicles + Plug-In Hybrid Electric Vehicles.*
316. Ida Warner (2016-02-15). "Over 100.000 ladbare biler i Norden" [Over 100,000 plug-in cars in the Nordic countries]. *Insero.com* (in Norwegian). Norsk Elbilforening (Norwegian Electric Vehicle Association). Retrieved 2016-02-15. *Out of over 100,000 plug-in passenger cars registered in the Nordic countries at the end of 2015, a total of 74,883 were registered in Norway, 16,187 in Sweden, 7,926 in Denmark, and 1,479 in Finland (see graph).*
317. Cobb, Jeff (2016-02-16). "Nordic Countries Buy Their 100,00th Plug-in Car in 2015". *HybridCars.com*. Retrieved 2016-02-16.
318. Fergusson, Malcolm (October 2016). "Electric Vehicles in Europe - 2016: Approaching adolescence" (PDF). *Transport & Environment*. Retrieved 2016-10-13. *See pp. 15–16.*
319. Automobile Propre (August 2016). "Chiffres de vente & immatriculations d'utilitaires électriques en France" [Sales figures & electric utility van registrations in France] (in French). Automobile Propre. Retrieved 2016-10-02. *See "Ventes d'utilitaires électriques en 2016/2015/2014 for all-electric utility van registrations. Light-duty electric vehicles reached a 1.22% market share of new van sales in the country in 2014, and rose to 1.30% in 2015.*
320. Cobb, Jeff (2016-03-14). "Californians Will Buy 200,000th Plug-in Car By This Month". *HybridCars.com*. Retrieved 2016-03-15. *Sales of plug-in electric cars in California passed the 200,000 unit milestone in March 2016, , representing 47% of the 425,000 plug-in electric cars sold in the U.S. through February 2016.*
321. Reichmuth, David (2016-03-31). "California Zooms Past 200,000 Electric Cars". Union of Concerned Scientists. Retrieved 2016-04-03.
322. Tony Barboza (2015-10-11). "Cutting ozone will require radical transformation of California's trucking industry". *Los Angeles Times*. Retrieved 2015-10-11.
323. Dana Hull (2014-09-08). "California charges ahead with electric vehicles". *San Jose Mercury News*. Retrieved 2015-03-15.
324. Jeff Cobb (2015-03-18). "Californians Bought More Plug-in Cars Than China Last Year". *HybridCars.com*. Retrieved 2015-03-18.

325. California New Car Dealers Association (CNCDA) (February 2015). "California Auto Outlook Covering Fourth Quarter 2014: New Light Vehicle Registrations Likely to Exceed 1.9 million units in 2015" (PDF). CNCDA. Retrieved 2015-03-15. "Registrations through December 2014."
326. Jeff Cobb (2014-01-16). "Top 6 Plug-In Vehicle Adopting Countries". HybridCars.com. Retrieved 2014-01-18. "Over 172,000 highway-capable passenger vehicles have been sold in the U.S. between 2008 and December 2013."
327. Joly, David (2015-10-16). "Norway is A Model For Encouraging Electric Car Sales". *The New York Times*. Retrieved 2016-02-16.
328. Cobb, Jeff (2016-09-01). "Americans Buy Their Half-Millionth Plug-in Car: Concentration of plug-in electrified car registrations per 1,000 people". *HybridCars.com*. Retrieved 2016-09-04. *As of July 2016, Norway had a concentration of registered plug-in cars per 1,000 people of 21.52, the Netherlands of 5.63, California of 5.83, and the United States national average was 1.52.*
329. Cobb, Jeff (2016-08-09). "California Continues To Pull More Than Its Weight In Plug-in Car Sales". *HybridCars.com*. Retrieved 2016-09-01. *As of July 2016, California's plug-in car concentration was 5.83 registrations per 1,000 people, the U.S. was 1.51 per 1,000. Norway exceeds California by 3.69 times, California narrowly outpaces the Netherlands by 1.04 times.*
330. Matthew Klippenstein (2014-04-08). "One Percent Of Norway's Cars Are Already Plug-In Electrics". Green Car Reports. Retrieved 2014-04-09.
331. Jeff Cobb (2015-04-17). "Norway Electric Car Incentives Will Hit Sales Cap Next Week". *HybridCars.com*. Retrieved 2015-04-21.
332. Staff (2014-01-08). "Over 20.000 ladbare biler på norske veier" [Over 20,000 rechargeable electric cars on Norwegian road] (in Norwegian). Grønn bil. Archived from the original on 2014-01-23. Retrieved 2014-01-13.
333. Jeff Cobb (2015-02-18). "Top 6 Plug-In Vehicle Adopting Countries – 2014". HybridCars.com. Retrieved 2015-02-18.
334. Bil Sweden (2015-01-02). "Nyregistreringar december 2014 (prel)" [New registrations in December 2014 (preliminar)] (in Swedish). Bil Sweden. Retrieved 2015-01-03. *Download file "Nyregistreringar december 2014 (prel)" see tables: "Nyregistrerade supermiljöbilar december 2014" with summary of plug-in passenger car registrations by model for 2013 (revised) and 2014; table "Nyregistrerade eldrivna lätta lastbilar (högst 3,5 ton) per modell:" for plug-in utility vans registrations for the same two years; and table "Nyregistrerade miljöbilar per typ jan-dec 2014" for the distribution of registrations by alternative fuels. A total of 303,866 new passenger vehicles were registered in 2014, and a total of 4,656 super clean cars, resulting in a PEV market share of 1.53% of new car sales.*
335. Jose Pontes (2015-02-06). "Markets Roundup December 2014 (Special Edition)". EV Sales. Retrieved 2015-03-15. *See section "Engines of Growth - by EV share" Estonia's market shared in 2014 climbed to 1.57% from 0.68% in 2013. Iceland's market share grew from 0.21% in 2012, to 0.94% in 2013, to 2.71% in 2014.*
336. Jose, Pontes (2016-02-03). "Markets Roundup December 2015 (Special Edition)". EVSales.com. Retrieved 2016-02-17. *For countries with top PEV market share in 2015 see "Engines of Growth:" Hong Kong 4.84%, Denmark 2.29%, Sweden 2.62%, and Switzerland 1.98%.*
337. Jose, Pontes (2016-01-29). "Iceland December 2015". EVSales.com. Retrieved 2016-02-17. *Plug-in electric car sales in Iceland reached a market share of 2.93%f of new car sales in 2015.*
338. Zachary Shahan (2013-03-07). "Electric vehicle market share in 19 countries". ABB Conversations. Retrieved 2014-04-12.
339. Jose Pontes (2015-01-10). "Denmark December 2014". EVSales.com. Retrieved 2015-03-15. "Denmark's PEV market shared in 2014 was 0.88% of total new car sales."
340. Jose Pontes (2015-01-18). "Switzerland December 2014". EVSales.com. Retrieved 2015-03-15. "Switzerland's PEV market shared in 2014 was 0.75% of total new car sales."
341. Statistik Austria (2016-03-16). "Kraftfahrzeuge - Neuzulassungen: Neuzulassungen nach Jahren" [Motor vehicles - registrations: Registrations by year] (in German). Statistik Austria. Retrieved 2016-03-20. *Download the file "Kfz-Neuzulassungen Jänner bis Dezember 2015." A total of 2,778 passenger plug-in electric cars were sold in Austria in 2015 out of 308,555 passenger cars, resulting in a market share of 0.90% (see p. 78 PDF version).*
342. Jose, Pontes (2016-01-12). "China December 2015 (3rd Update)". EVSales.com. Retrieved 2016-02-08.
343. http://www.ev-sales.blogspot.com.au/search/label/Hong%20Kong
344. California New Car Dealers Association (CNCDA) (February 2016). "California New Vehicle Registrations Expected to Remain Above 2 Million Units in 2016" (PDF). CNCDA. Retrieved 2016-02-17. *Registrations through December 2015 since 2011. Revised figures for 2014.*
345. Staff (February 2016). "Europe Plug-in Sales Q4 and Full Year 2015". *EVvolumes.com*. Retrieved 2016-02-19.
346. International Council on Clean Transportation (ICCT) (2014). "European Vehicle Market Statistics Pocketbook" (PDF). ICCT. Retrieved 2016-02-21. *See page 88: EU-28 market share in 2013 was 0.42% (includes all-electric cars and plug-in hybrids). Adjusted to consider sales/registrations in Norway (5.79%) and Switzerland (0.57%) the market share rises to 0.49%.*
347. "State and Federal Incentives for EVs, PHEVs and Charge Stations". Plug In America. Retrieved 2010-05-29.
348. "Electric car grant: the lowdown on the changes for 2016". London: Go Ultra Low. 2016-03-02. Retrieved 2016-03-02.
349. Woodyard, Chris (2010-07-14). "Obama pushes electric cars, battery power this week". *USA Today*.
350. Paul Hockenos (2011-07-29). "Europe's Incentive Plans for Spurring E.V. Sales". The New York Times. Retrieved 2011-07-31.
351. "Overview of Purchase and Tax Incentives for Electric Vehicles in the EU" (PDF). European Automobile Manufacturers Association. 2011-03-14. Retrieved 2011-07-31.

Further reading

- Michael H. Westbrook."The Electric and Hybrid Electric Car", The Institution of Mechanical Engineers, 2001, London & SAE, USA. ISBN 0-7680-0897-2.
- Witkin, Jim. Building Better Batteries for Electric Cars (https://www.nytimes.com/2011/03/31/business/energy-environment/31BATTERIES.html), *The New York Times*, March 31, 2011, p. F4. Published online March 30, 2011. Discusses batteries and lithium ion battery.

External links

Wikibooks has a book on the topic of: ***Electric Vehicle Conversion/Technologies***

Look up ***electric car*** in Wiktionary, the free dictionary.

- Application of Life-Cycle Assessment to Nanoscale Technology: Lithium-ion Batteries for Electric Vehicles (http://www.epa.gov/dfe/pubs/projects/lbnp/final-li-ion-battery-lca-report.pdf), U.S. Environmental Protection Agency, April 2013.
- Competitive Electric Town Transport (https://www.toi.no/getfile.php?mmfileid=41196), Institute of Transport Economics (TØI), Oslo, August 2015.
- Cradle-to-Grave Lifecycle Analysis of U.S. Light-Duty Vehicle-Fuel Pathways: A Greenhouse Gas Emissions and Economic Assessment of Current (2015) and Future (2025-2030) Technologies (https://greet.es.anl.gov/publication-c2g-2016-report) (includes estimated cost of avoided GHG emissions from BEVs), Argonne National Laboratory, June 2016.
- Driving Electrification - A Global Comparison of Fiscal Incentive Policy for Electric Vehicles (http://theicct.org/sites/default/files/publications/ICCT_EV-fiscal-incentives_20140506.pdf), International Council on Clean Transportation, May 2014
- Effects of Regional Temperature on Electric Vehicle Efficiency, Range, and Emissions in the United States (http://www.greencarcongress.com/2015/02/20150218-michalek.html), Tugce Yuksel and Jeremy Michalek, Carnegie Mellon University. 2015
- History and Directory of Electric Cars from 1834 to 1987 (http://www.electriccarsociety.com/ev_hist.htm) Electric Car Society
- eGallon Calculator: Compare the costs of driving with electricity (http://energy.gov/articles/egallon-what-it-and-why-it-s-important), U.S. Department of Energy
- Global EV Outlook 2013 - Understanding the Electric Vehicle Landscape to 2020 (http://www.iea.org/publications/globalevoutlook_2013.pdf), International Energy Agency (IEA), April 2013
- Hybrid and Electric Vehicles - The Electric Drive Gains Traction (http://www.ieahev.org/assets/1/7/IA-HEV_Annual_Report_May_2013_3MB.pdf), IA-HEV, International Energy Agency (IEA), May 2013
- NHTSA Interim Guidance Electric and Hybrid Electric Vehicles Equipped with High Voltage Batteries - Vehicle Owner/General Public (http://www.nhtsa.gov/staticfiles/nvs/pdf/InterimGuide_Consumers_011912_v2a.pdf)
- NHTSA Interim Guidance Electric and Hybrid Electric Vehicles Equipped with High Voltage Batteries - Law Enforcement/Emergency Medical Services/Fire Department (http://www.nhtsa.gov/staticfiles/nvs/pdf/InterimGuide_EmergencyResponse_012012_v3.pdf)
- NOW on PBS investigates if electric cars will bring a new global climate change plan (http://www.pbs.org/now/shows/544/index.html#poll)
- Plug-in Electric Vehicles: Challenges and Opportunities (http://www.aceee.org/sites/default/files/publications/researchreports/t133.pdf), American Council for an Energy-Efficient Economy, June 2013
- Plugging In: A Consumer’s Guide to the Electric Vehicle (http://www.epri.com/abstracts/pages/productabstract.aspx?ProductID=000000000001023161) by the Electric Power Research Institute.
- Shade's of Green - Electric Car's Carbon Emissions Around the Globe (http://shrinkthatfootprint.com/wp-content/uploads/2013/02/Shades-of-Green-Full-Report.pdf), Shrink that Footprint, February 2013.
- Transport Action Plan: Urban Electric Mobility Initiative (http://www.un.org/climatechange/summit/wp-content/uploads/sites/2/2014/09/TRANSPORT-Action-Plan-UEMI.pdf), United Nations, Climate Summit 2014, September 2014
- When Will Electric Cars Compete in the Mainstream Market? (http://www.greencarreports.com/news/1093557_when-will-electric-cars-compete-in-the-mainstream-market), John Briggs, August 2014.
- Dissected (http://news.vattenfall.com/en/article/dissected), Dan Roupe, September 2015.

Categories: Electric cars | Automotive technologies | Battery electric vehicles | Sustainable technologies | 1884 introductions