The Lifecycle Emissions of Electric Vehicles

2024 edition

Corey Cantor

Nikolas Soulopoulos

March 11, 2024

BloombergNEF

Executive summary

Electric vehicles (EVs) have zero tailpipe emissions, yet the emissions associated with their manufacturing and use have raised questions regarding just how clean they really are. The answer: in all analyzed cases, EVs have lower lifecycle emissions than their internal combustion engine (ICE) counterparts. Just how much lower depends on how far they are driven, and the cleanliness of the grid where they charge. With zero-emission generation deployment rising globally, we expect that EVs will reach the breakeven emissions point with ICEs even earlier.

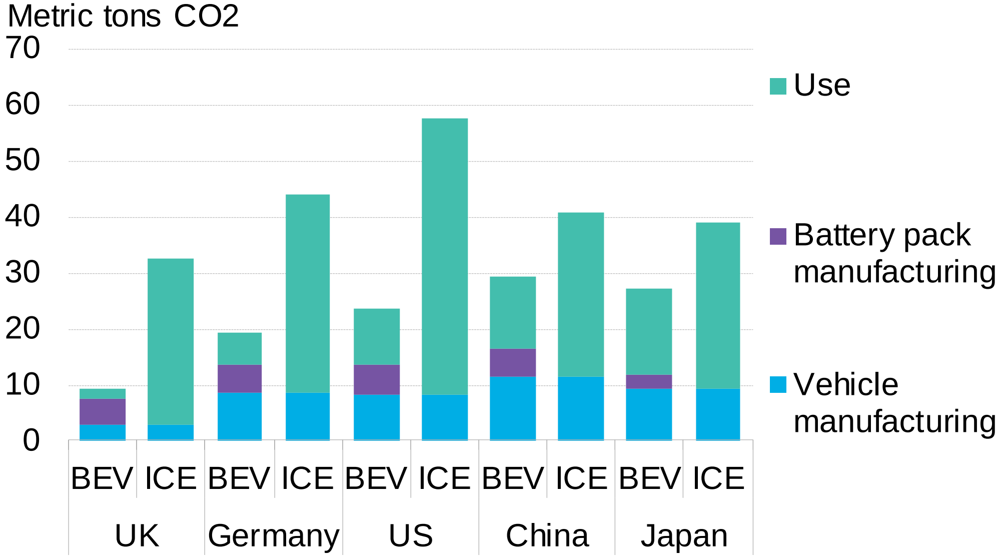
- The lifecycle CO_2 emissions of medium-sized battery electric vehicles (BEVs) produced in 2023 and used for 250,000 kilometers (km) would be 27-71% lower than those of equivalent ICEs in the five markets included in this report. Today, the breakeven point at which BEVs are cleaner than ICE comes after driving 41,000 km in the US, far sooner than the 118,000 km currently seen in China. By 2030, the breakeven point will have moved up significantly in all regions surveyed.
- BEV manufacturing emissions depend directly on the location of battery cell production and material refining. At the moment, importing EVs from China could increase the BEV-to-ICE CO_2 emissions breakeven distance by 9-17%. By 2030, that could more than double for some markets. Over time, lifecycle CO_2 emissions can be reduced by limiting transport emissions through on-shoring or near-shoring battery manufacturing, which laws like the US Inflation Reduction Act have encouraged through stringent policy requirements.
- We present estimates for the lifecycle emissions of battery-electric vehicles (BEV) and internal combustion engine cars (ICE) to 2030 for the US, China, the UK, Germany and Japan. Our full methodology, and details on how this edition of the report differs from the last one can be found in Section Four.

41,000 km Breakeven driving distance for lifecycle CO_2 emissions for BEVs and ICEs made in 2023 in the US

2.2 years Estimated time taken to pay back EV manufacturing emissions from driving an EV in the US in 2023

4.2 years Estimated time taken to pay back EV manufacturing emissions from driving an EV in China in 2030

Total CO_2 emissions of medium-segment ICEs and BEVs produced in 2023 and used for 250,000 kilometers



Source: BloombergNEF, New Energy Outlook 2022. Note: ICE= internal combustion engine, BEV = battery-electric vehicle.

Contents

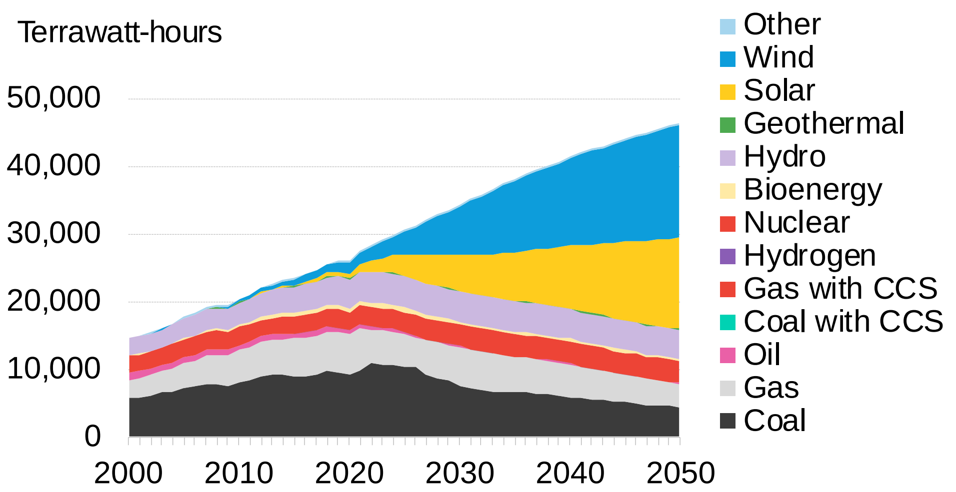
The lifecycle CO2 emissions of different types of vehicles

Comparing battery-electric and internal combustion engine cars

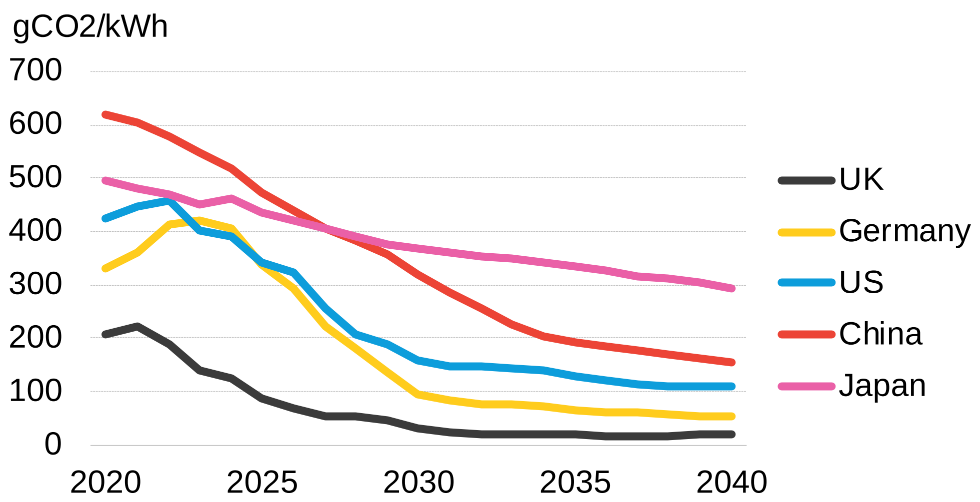
BloombergNEF

A changing global power generation mix is set to lower EV lifecycle emissions

Global electricity generation



Electricity grid emissions factors



Source: BloombergNEF New Energy Outlook 2022. Note: CCS is carbon capture and storage, gCO2/kWh is grams of CO2 per kilowatt-hour.

- Electric vehicles are only clean if the power they use is produced without emissions. Under the Economic Transition Scenario (ETS) in BNEF's *New Energy Outlook 2022* (web | terminal), the global share of zero-carbon electricity generation increases from 45% in 2023 to 74% by 2040. Zero-carbon generation shares differ widely across geographies, but for all five markets in this report, it accounts for at least half of generation by 2040.
- As renewable energy deployment increases, the average emissions intensity of most power grids across the world will trend downwards. Measured in grams of CO2 emitted per kilowatt-hour of electricity produced (gCO2/kWh, shown in the table), reductions range from 73% in the US to over 88% in Germany. Japan sees a less significant decline, as it maintains a heavy reliance on coal far into the 2030s.

Grid emissions factors

Market	2023 (gCO_2/kWh)	2040 (gCO_2/kWh)	Change, %
US	402	110	-73%
China	549	154	-72%
UK	138	19	-86%
Germany	421	51	-88%
Japan	450	294	-35%

Source: BloombergNEF New Energy Outlook 2022. Note: 2023 values are estimated.

Lifecycle CO2 emissions of ICEs and BEVs – key findings

- For the five markets included in this report, the total **lifecycle CO2 emissions** of a medium-segment battery-electric vehicle (BEV) produced in 2023 and used for 250,000 kilometers would be between 27-71% lower than the emissions of an equivalent internal combustion engine car (ICE). For cars produced in 2030, and used mostly in that decade, BEVs in Europe and the US would emit 77-86% less CO2 across their lifetimes than ICEs, while in China the difference would be about 50% and Japan about 42%.
- The **manufacturing CO2 emissions** of medium-segment BEVs in 2023 can be up to 2.7 times higher than those of equivalent ICEs in most major auto-producing countries. This calculation includes emissions associated with making both cars and batteries, as the location of battery production has a major impact on the final figure. We assume that raw materials and the battery precursors are produced in China, while other manufacturing occurs in the market where the EV is sold. In the US and China, BEV manufacturing emissions in 2023 were 1.6 and 1.4 times higher, respectively, than those for an ICE car. In Japan, they were 1.3 times higher. For more, see *Lithium-Ion Battery Manufacturing Emissions* (web | terminal) and *Lithium Battery Emissions Model (1.1.0)* (web | terminal), as well as the methodology section in this report.
- Yet after driving a car 250,000 km, **CO2 emissions from utilization** are far greater for ICEs than for BEVs, ranging from roughly twice as high in Japan and China, to 17 times as high in the UK.
- In the US and Europe today, it would take two to five years of using a medium BEV to close the gap in lifecycle emissions with an ICE vehicle. In Asia, it would take longer: nearly six years in Japan and nearly 10 years in China.
- Later this decade, as cleaner grid electricity mix takes hold, manufacturing and utilization emissions of BEVs will be significantly reduced. A less carbon-intensive grid mix means that it will take less time – or less driving distance – to reach an emissions breakeven point between BEVs and ICEs.
- Transport emissions, including delivery to the location of use account for up to 12% of battery manufacturing emissions. On-shoring or near-shoring efforts – like the US Inflation Reduction Act (web | terminal) – could also help reduce overall CO2 emissions.

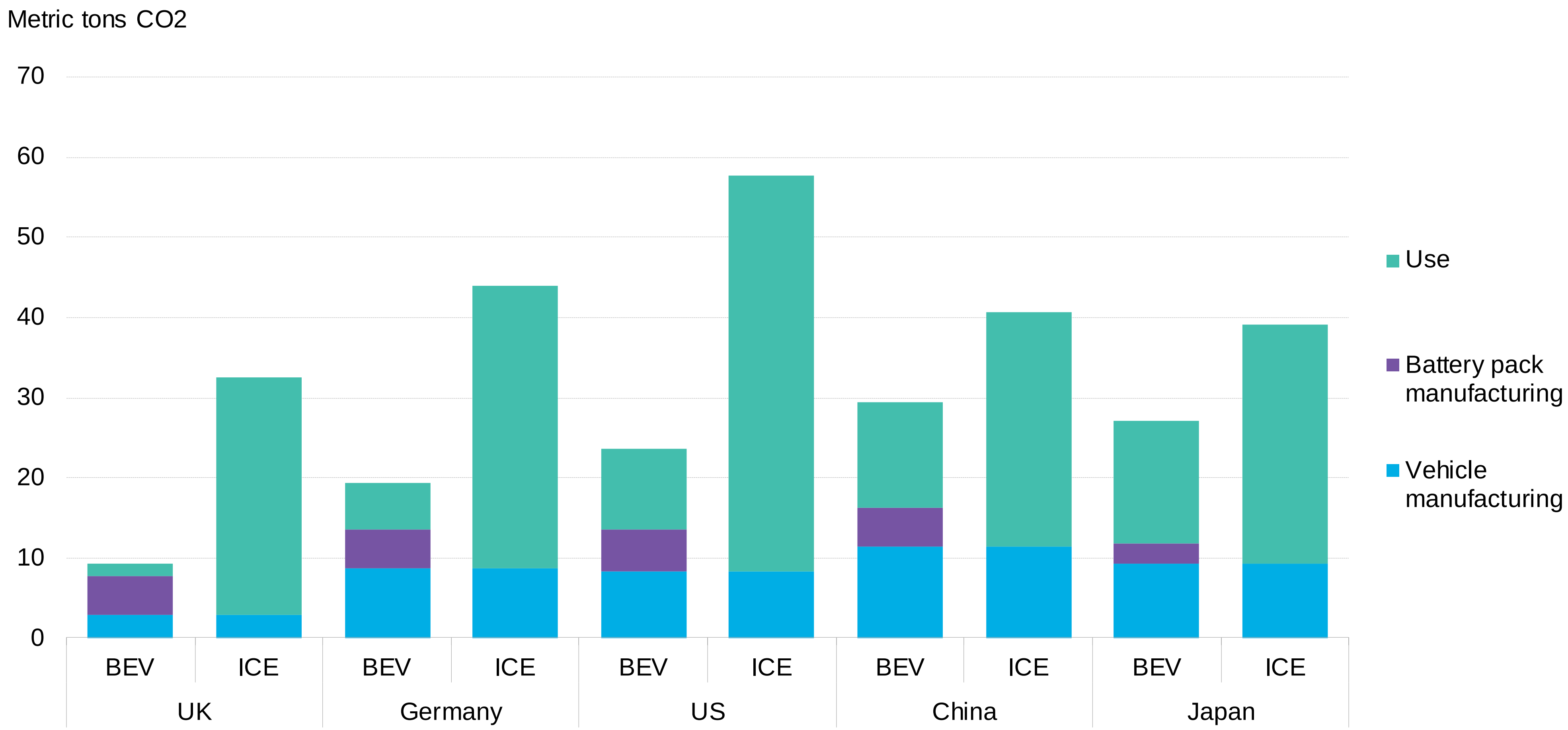
Breakeven points for BEV CO2 lifecycle emissions to be the same as those of ICEs, for cars and batteries produced in 2023 and 2030 and used thereafter

	2023		2030	
Market	Breakeven			
	Distance	Time	Distance	Time
US	41,000 km	2.2 years	21,000 km	1.1 year
UK	48,000 km	4.0 years	25,000 km	2.0 years
Germany	58,000 km	5.1 years	23,000 km	2.1 years
China	118,000 km	9.6 years	53,000 km	4.2 years
Japan	57,000 km	5.6 years	35,000 km	3.1 years

Source: BloombergNEF. Note: Break-even time rounded to first decimal.

The lifecycle CO_2 emissions of different types of vehicles

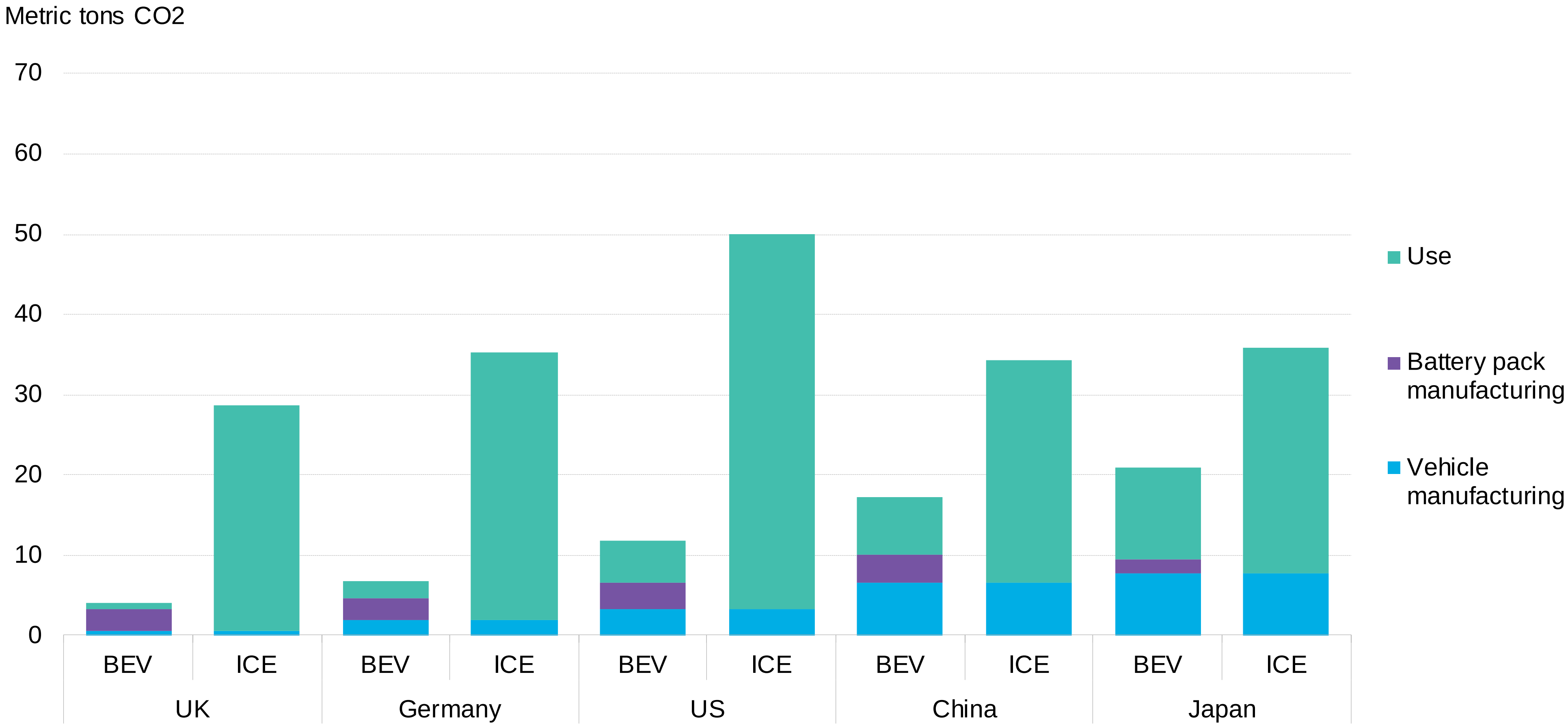
Total CO_2 emissions of medium-segment ICEs and BEVs produced in 2023 and used for 250,000 km



Source: BloombergNEF, International Council on Clean Transportation (ICCT). Note: We take into account the changing grid emissions over the time it takes to drive 250,000 km, which varies by market. For battery manufacturing, we assume that raw materials and precursor are produced in southeast China, while active materials, cells and packs are produced domestically in the US, Japan, Germany and China. The exception is the UK, for which we assume active materials and cells are produced in Germany, while the pack is produced in the UK. The battery size of a medium BEV varies by market. Vehicles are produced in the market of use, and we have scaled the emissions of vehicles produced in Germany to the grid emissions in other markets. ICE = internal combustion engine, BEV = battery-electric vehicle.

The lifecycle CO2 emissions of different types of vehicles

Total CO2 emissions of medium-segment ICEs and BEVs produced in 2030 and used for 250,000 km

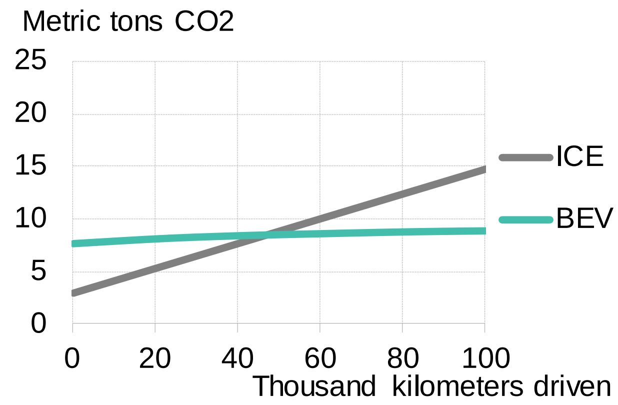


Source: BloombergNEF, International Council on Clean Transportation (ICCT). Note: We take into account the changing grid emissions over the time it takes to drive 250,000 km, which varies by market. For battery manufacturing, we assume that raw materials and precursor are produced in southeast China, while active materials, cells and packs are produced domestically in the US, Japan, Germany and China. The exception is the UK, for which we assume active materials and cells are produced in Germany, while the pack is produced in the UK. The battery size of a medium BEV varies by market. Vehicles are produced in the market of use, and we have scaled the emissions of vehicles produced in Germany to the grid emissions in other markets. ICE = internal combustion engine, BEV = battery-electric vehicle.

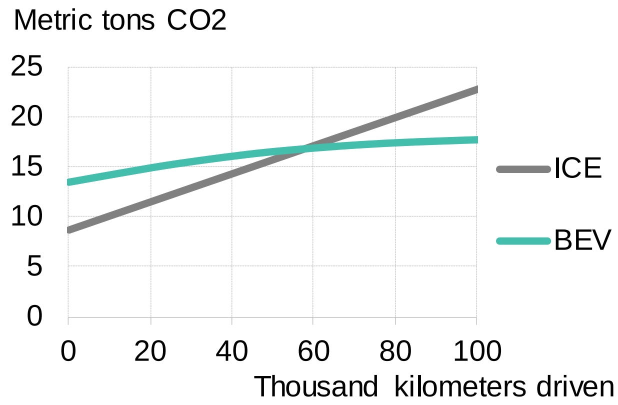
The lifecycle CO2 emissions of different types of vehicles

Lifecycle CO2 emissions of medium-segment ICEs and BEVs produced in 2023 and used thereafter

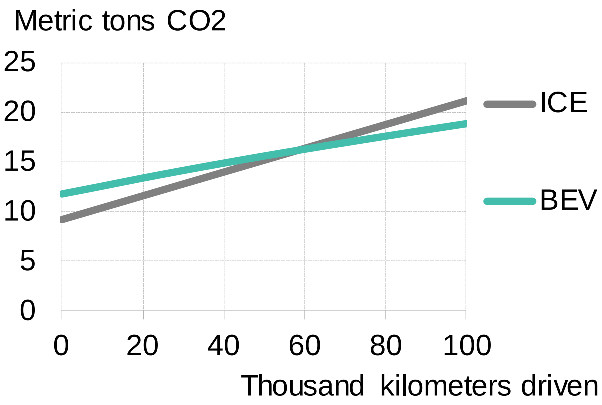
UK



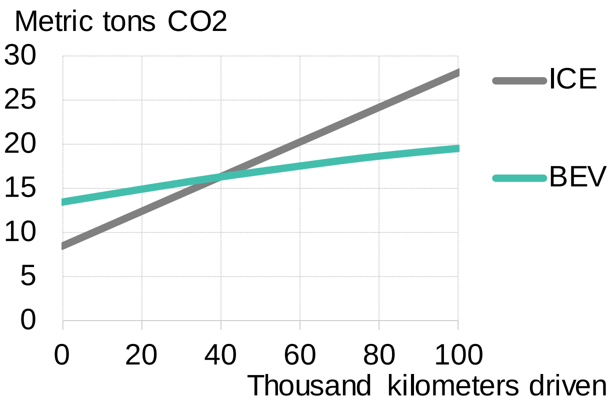
Germany



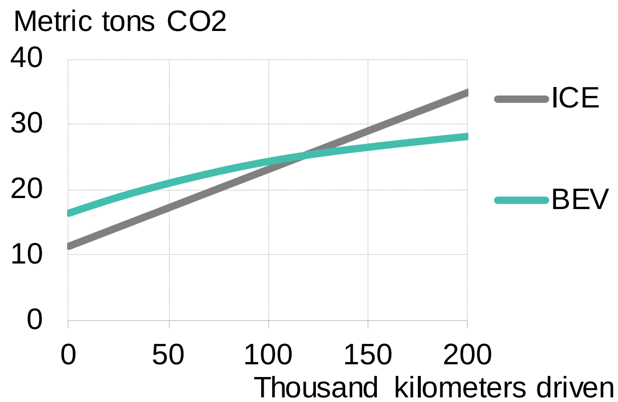
Japan



US



China

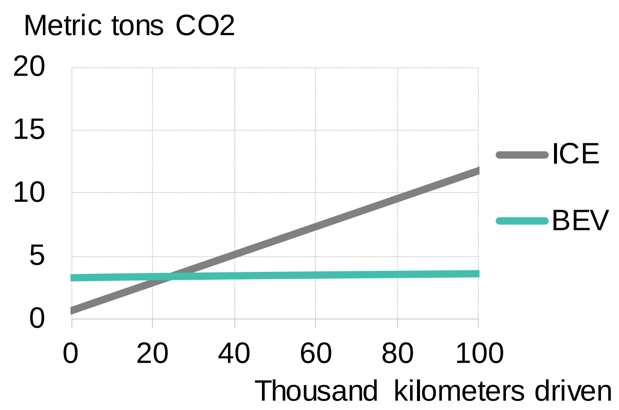


Source: BloombergNEF, ICCT. Note: We assume cars are driven for different annual distances in analyzed markets, meaning 25,000 km is reached in different years. We adjust the emissions factors to take this into account. For battery manufacturing, we assume that raw materials and precursors are produced in southeast China, while active materials, cells and packs are produced domestically in the US, Japan, Germany and China. The sole exception is the UK, for which we assume active materials and cells are produced in Germany, while the pack is produced in the UK. The battery size of a medium BEV varies by market. ICE = internal combustion engine, BEV = battery-electric vehicle.

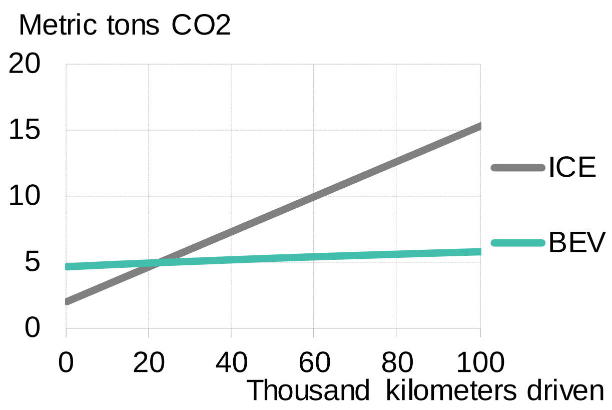
The lifecycle CO2 emissions of different types of vehicles

Lifecycle CO2 emissions of medium-segment ICEs and BEVs produced in 2030 and used thereafter

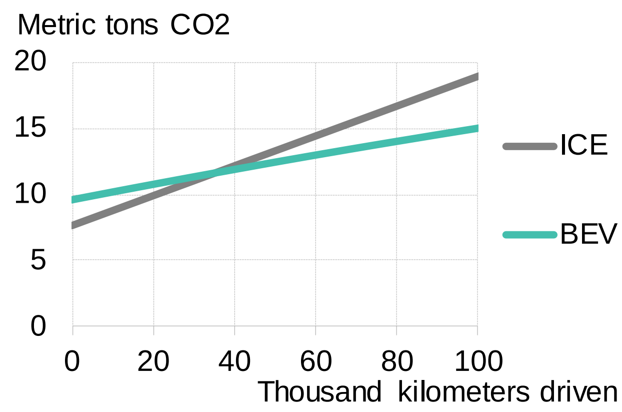
UK



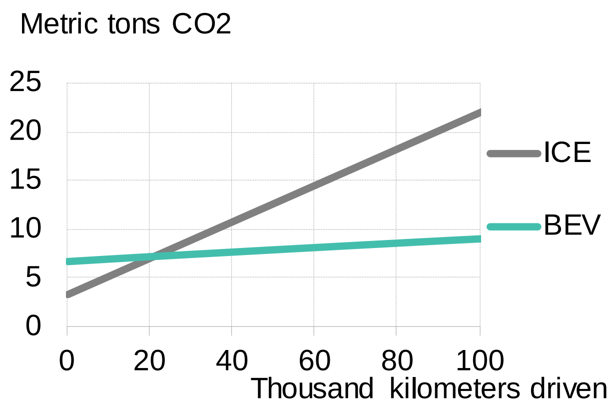
Germany



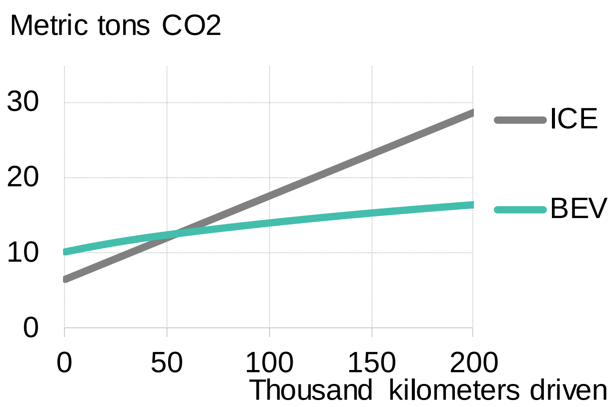
Japan



US



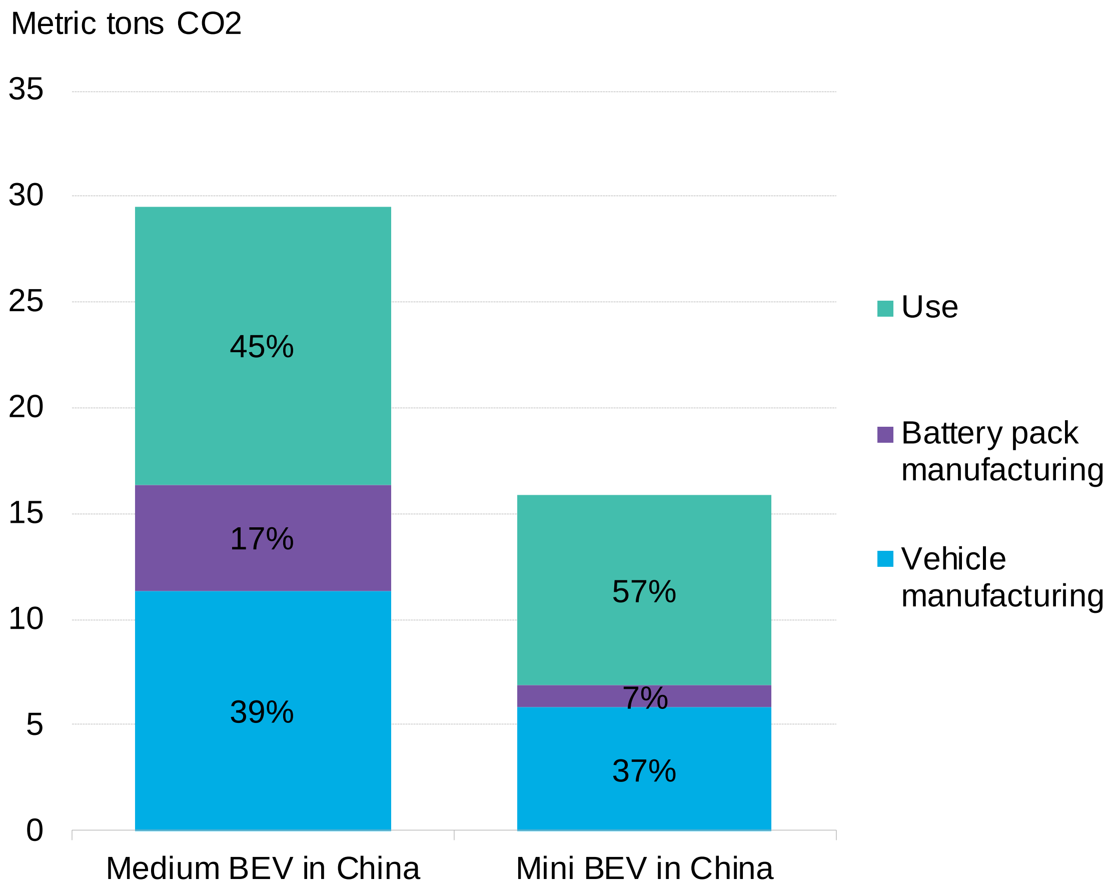
China



Source: BloombergNEF, ICCT. Note: We assume cars are driven for different annual distances in analyzed markets, meaning 25,000 km is reached in different years. We adjust the emissions factors to take this into account. For battery manufacturing, we assume that raw materials and precursors are produced in southeast China, while active materials, cells and packs are produced domestically in the US, Japan, Germany and China. The sole exception is the UK, for which we assume active materials and cells are produced in Germany, while the pack is produced in the UK. The battery size of a medium BEV varies by market. ICE = internal combustion engine, BEV = battery-electric vehicle.

Lifecycle CO2 emissions of mini electric vehicles in China

Total CO2 emissions of medium-segment and mini BEVs produced in China in 2023 and used for 250,000 km, and share of total lifecycle emissions



- The previous slides focused on the medium segment as an illustrative example of how lifecycle emissions vary between BEVs and ICEs. Yet lifecycle emissions will vary by vehicle segment, as each employs different battery sizes.
- In China, electric mini cars were one of the largest EV segments in 2023, accounting for over 10% of EVs sold in the market that year.
- China's mini electric cars have lower battery than their medium-sized counterparts. In general, batteries for this smallest segment range from 10kWH to above 30kWh; for this analysis, we assume a lithium iron phosphate (LFP) battery of 17kWh, with a real-world driving efficiency of around 0.12kWh/km.
- For Chinese EVs made in 2030 and driving 250,000 kilometers, the lifecycle emissions of mini EVs are around 46% lower than those of medium EVs. Manufacturing emissions are a key part of this difference: battery pack production for mini cars results in 79% fewer emissions than making packs for medium-sized cars, while manufacturing a mini vehicle body is about half as carbon-intensive as making a medium-sized BEV.
- The emissions benefits associated with driving a mini EV as opposed to a medium-sized one carry over to the use phase, as well. Emissions generated by minis car in China are 32% lower than those generated by a medium BEV for the same distance traveled.

Source: BloombergNEF, Chinese Automotive Technology and Research Center (CATARC). Note: BEV = battery-electric vehicle.

Market profiles and use-phase CO_2 emissions

ICEs are getting slightly cleaner, as BEVs pull farther and farther ahead

CO2 emissions per kilometer during the vehicle use-phase for ICE and BEV medium passenger vehicles

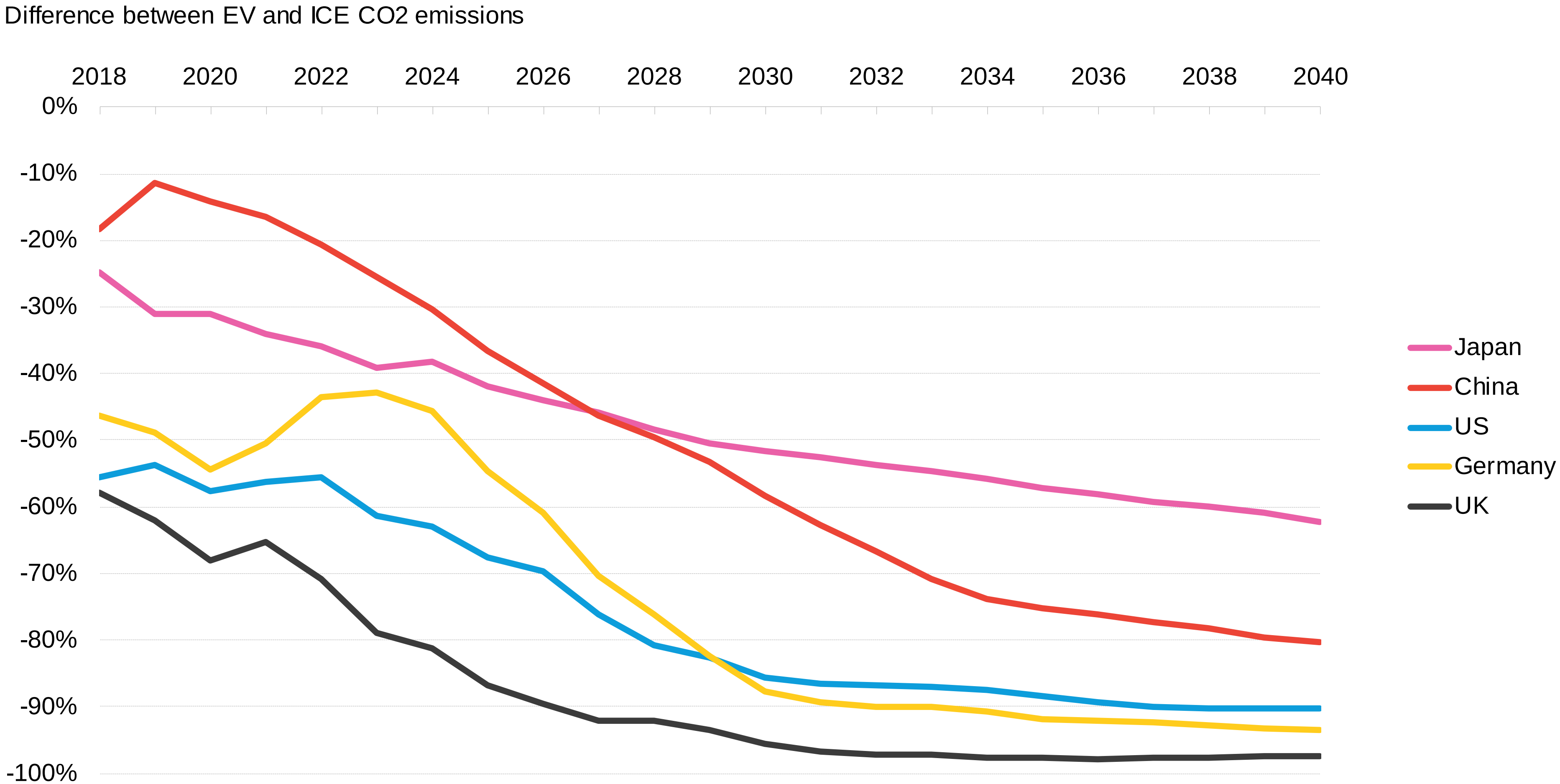
	ICE emissions, gCO_2/km			BEV emissions, gCO_2/km		
Market	2023	2040	CAGR, %	2023	2040	CAGR, %
US	201.6	175.3	-0.8%	87.1	17.2	-9.1%
China	136.4	119.3	-0.8%	120.7	23.3	-9.2%
UK	119.7	107.4	-0.6%	39.4	2.8	-14.4%
Germany	134.5	117.9	-0.8%	63.3	7.7	-11.7%
Japan	124.6	107.8	-0.8%	88.0	74.5	-4.5%

Source: BloombergNEF, ICCT. Note: Excludes emissions from manufacturing. CAGR = compound annual growth rate.

- Battery electric vehicles already emit less associated CO2 than combustion cars during use. As of 2023, BEVs emit about 40% less CO2 when driving than ICEs, and by 2040 that difference increases to 85%.
- Use-phase CO2 emissions from ICEs drop by about 1% per year between 2023 and 2040. In 2040, real-world driving emissions range from 107 gCO2/km in the UK to 175 gCO2/km in the US. These are not the highest levels of efficiency technically possible for an EV, but further improvements would be difficult and expensive.
- In order to meet fleet emissions regulations, we expect that mild and full hybrid drivetrains, advanced combustion engines and transmissions, and lighter materials will all be used in ICE drivetrains in the years ahead. But switching over to BEVs could be a more more palatable option for automakers.
- The decarbonization of electricity grids will result in a significantly greater drop in lifecycle emissions for BEVs over 2023-2040 than any improvements in engine efficiency will for ICEs. As the associated CO2 emissions from BEVs were already lower than those of ICEs in 2023, the gap will simply increase. Japan, due to a high use of coal on its grid, only sees a mild improvement in EV emissions – but these are still 62% lower than an ICE vehicle's in 2040.
- In the following analysis, we use average emissions factors over the whole day, and also for shorter periods around midday and at night. We expect that the majority of charging will take place at home at night. As EVs grow in use, utilities may encourage load-shifting to hours of more renewable energy penetration to reduce emissions.

As renewable energy deployment rises, EVs become CO2 heavy than ICE vehicles

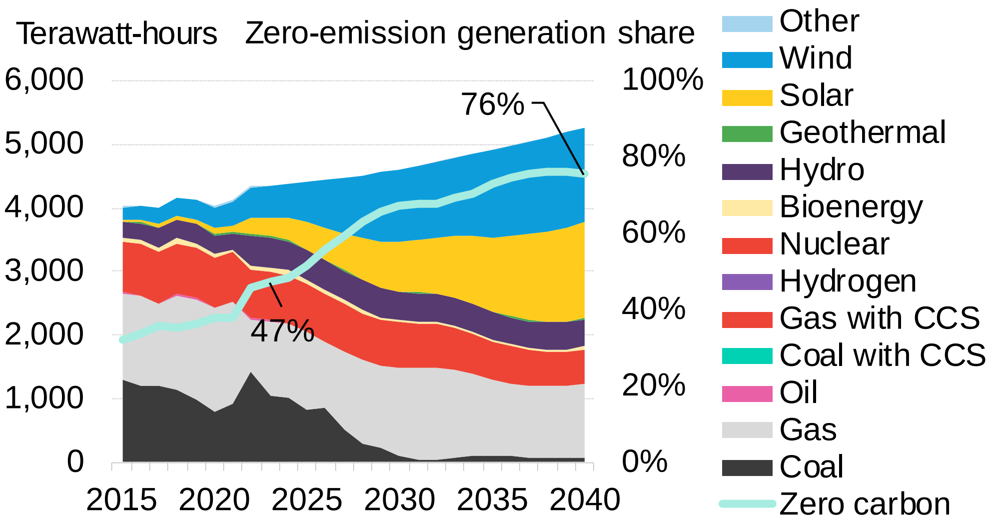
Emissions difference between ICE and BEV during use (normalized to the ICE emissions)



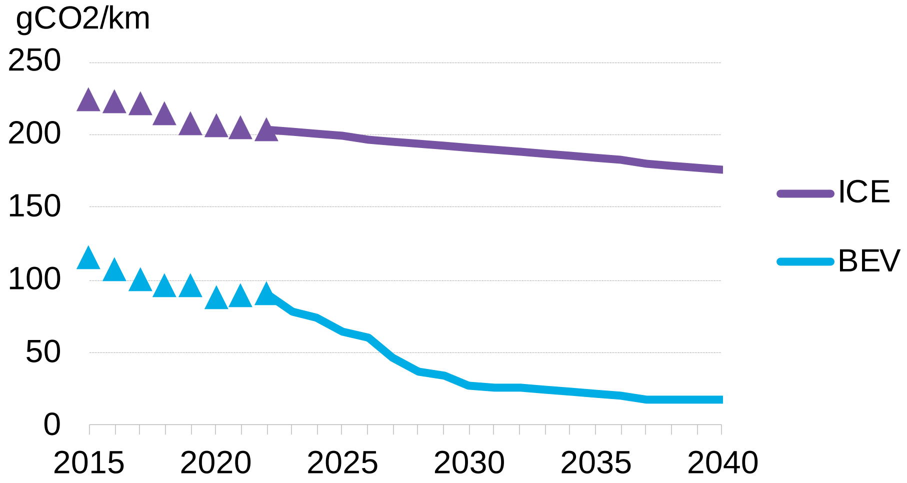
Source: BloombergNEF. Note: The difference in emissions is normalized to the emissions of an internal combustion engine vehicle (ICE), expressed in grams of CO2 per kilometer (gCO2/km). BEV = battery-electric vehicle.

US

Electricity generation and zero-carbon share



ICE and BEV CO2 emissions, use phase

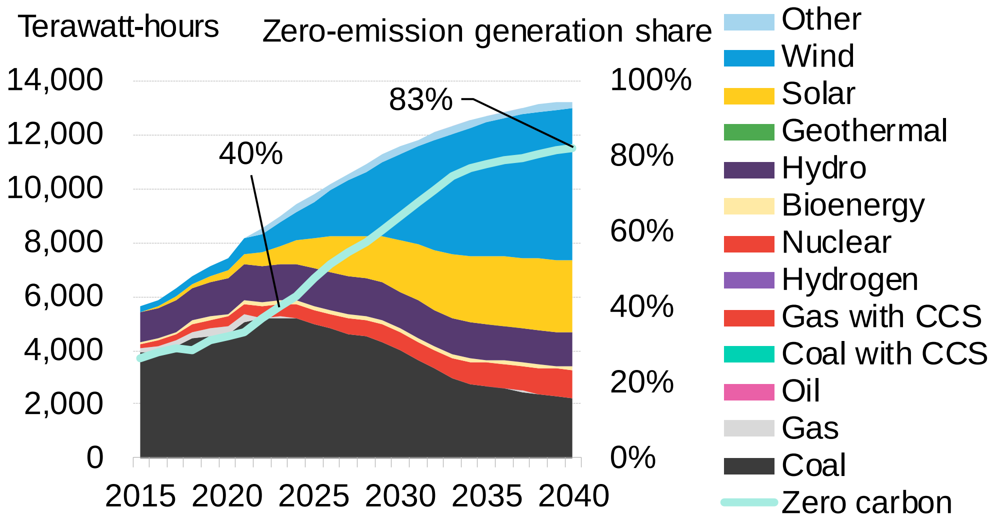


Source: BloombergNEF. Note: ICE results are normalized to the fuel economy test cycle; symbols correspond to historical performance until 2022. CCS = carbon capture and storage, gCO2/kWh is grams of CO2 per kilowatt-hour. ICE = internal combustion engine, BEV = battery-electric vehicle.

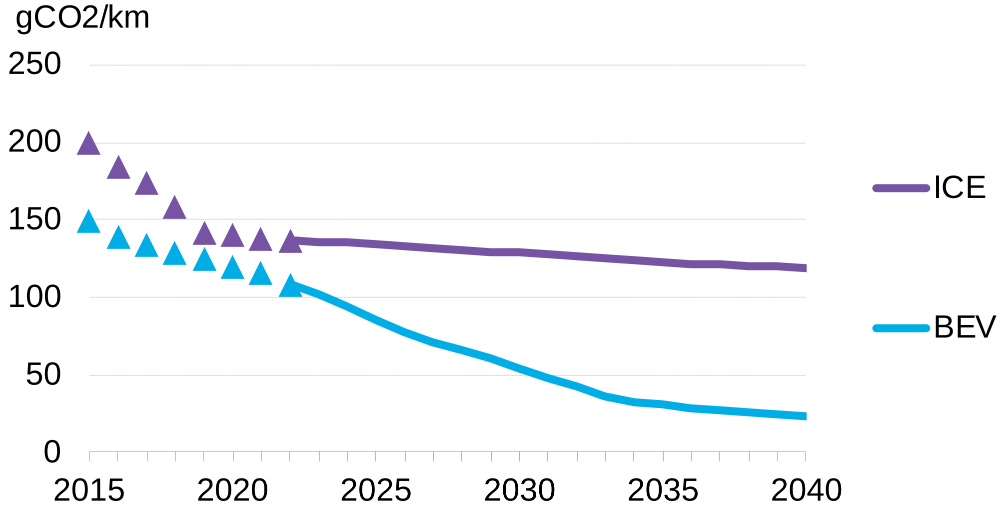
- The US power grid is set to rapidly decarbonize over the next two decades, according to BNEF's New Energy Outlook 2022 ETS (web | terminal). The share of power generation from zero-emission sources will grow from 47% in 2023 to 76% by 2040.
- Under the Biden administration, the US has implemented more stringent fuel economy standards, beginning with model years 2024-26. However, standards for the rest of the decade have not yet been finalized. The durability of these rules will likely be up in the air until after the next presidential election in 2024. Assuming these standards are not relaxed, automakers will have to sell more and more vehicles with alternative drivetrains – like BEVs and plug-in hybrids (PHEVs) – to meet these standards.
- Regions within the US continue to deploy renewables at different rates, meaning that where an EV charges within the US will dramatically impact its emissions footprint. There is no national carbon policy in place in the US that would impact all regions, although the passage of the Inflation Reduction Act offers a path forward through robust credits for solar and wind power.
- US EV sales in 2023 reached a record high of 1.46 million units, or around 9.4% of all car sales. US EV sales were up 50% compared to sales the previous year. Around 80% of all EV sales are fully electric thanks to Tesla's outsized market share, highlighting the importance of decarbonizing the grid to reduce emissions at a faster rate. US drivers typically drive more each year than drivers in either Europe or Asia.

China

Electricity generation and zero-carbon share



ICE and BEV CO2 emissions, use phase

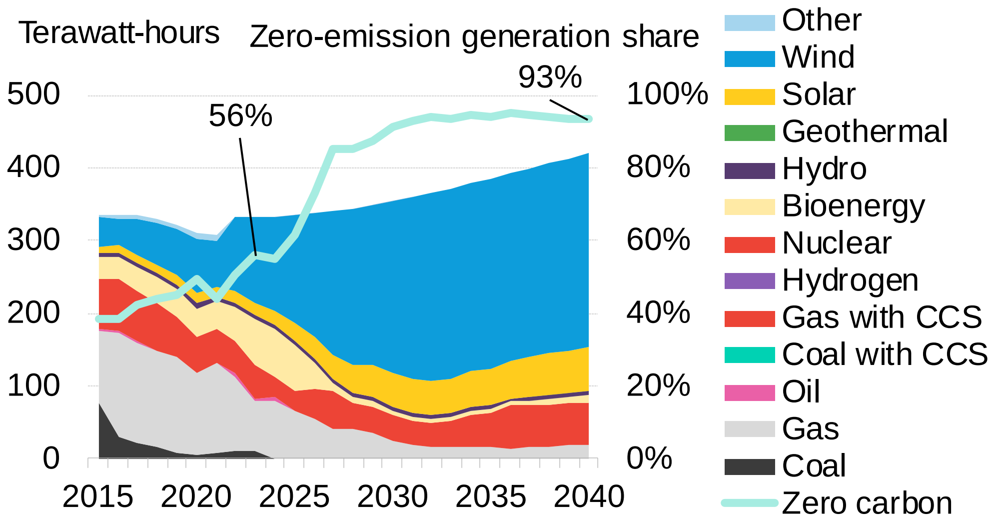


Source: BloombergNEF. Note: ICE results are normalized to the fuel economy test cycle; symbols correspond to historical performance until 2022. CCS = carbon capture and storage, gCO2/kWh is grams of CO2 per kilowatt-hour. ICE = internal combustion engine, BEV = battery-electric vehicle.

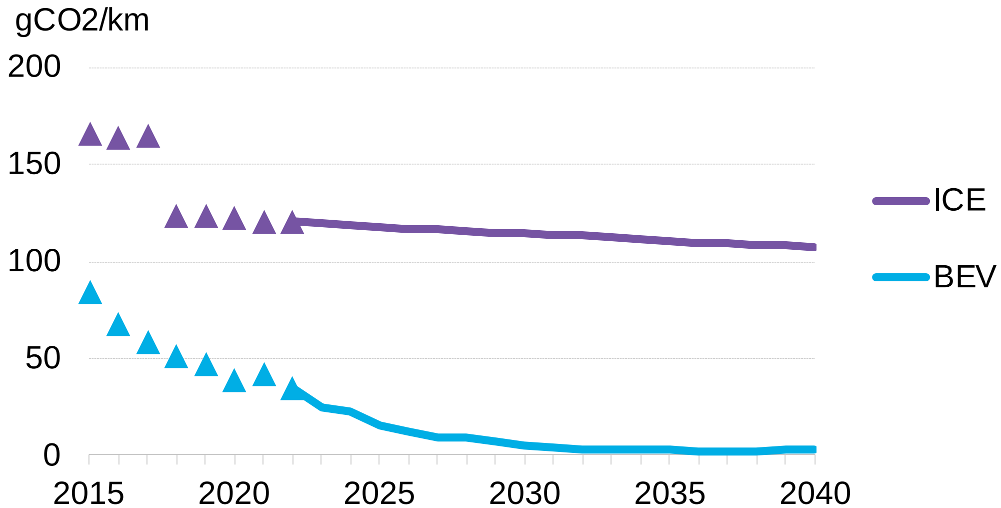
- In BNEF's ETS, China's grid undergoes a significant transformation over the next few decades. The zero-emission share of power generation grows from 40% in 2023 to 83% by 2040, driven by the rapid deployment of solar and wind energy. Coal generation, which made up 58% of the generation mix in 2023, falls to 17% by 2040. As a result, power grid emissions intensity falls from an average of 549 gCO2/kWh in 2025 to 154 gCO2/kWh in 2040.
- The lifecycle emissions of BEVs are higher in China than in other markets, due to the high share of fossil fuels in the generation mix. The average annual grid CO2 intensity decreases by ~8% from 2023 to 2040 on a compound annual growth rate (CAGR) basis, but even with the improved outlook for renewable energy deployment, China continues to see a more carbon-intensive grid mix in 2040 than the US, Germany and the UK.
- China's electricity mix differs region by region, and coal remains a major source of electricity in many parts of the market until the end of the decade. As renewables uptake accelerates in certain areas, an accelerated decrease in EV-linked emissions could follow.
- China continues to be the world's largest EV market. In 2023, 8.2 million passenger EVs (including both BEVs and PHEVs) were sold in China – representing around 60% of global EV sales. China's current push to electrify transport is being driven more by concerns around urban air quality, energy security and industrial policy than by a desire to cut emissions per se, but given the size of its EV market, cleaning its grid can have immense global climate benefits.

UK

Electricity generation and zero-carbon share



ICE and BEV CO2 emissions, use phase

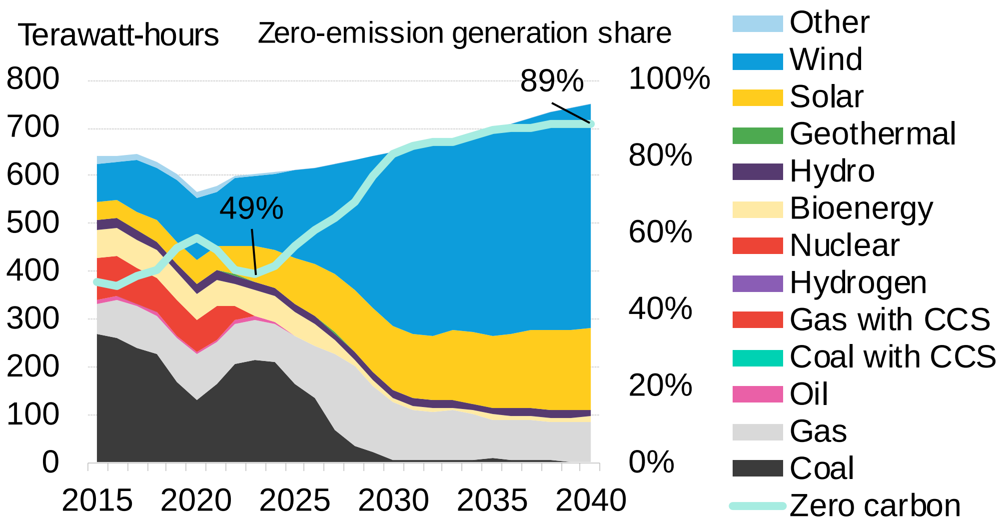


Source: BloombergNEF. Note: ICE results are normalized to the fuel economy test cycle; symbols correspond to historical performance until 2022. CCS = carbon capture and storage, gCO2/kWh is grams of CO2 per kilowatt-hour. ICE = internal combustion engine, BEV = battery-electric vehicle.

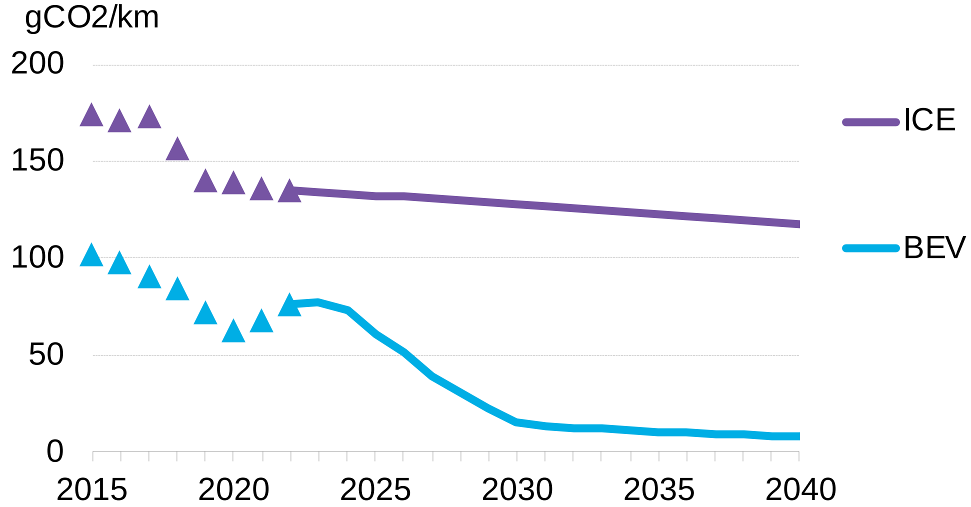
- By 2023, half of the UK's power generation was fueled by zero-carbon resources. Come 2040 under the ETS, zero-carbon sources will provide 93% of the market's electricity requirements, with offshore wind as the single largest generation source. Grid emissions intensity in the power sector tumbles from 138 gCO2/kWh in 2023 to 19 gCO2/kWh in 2040.
- It's not all downhill for power grid emissions in the UK as some nuclear closures will result in the carbon emissions intensity rising in the latter half of the 2030s. In addition, the UK announced in 2023 that it was delaying its plan to phase out sales of ICE vehicles from 2030 to 2035, to align with the EU's ICE phase-out target. Nevertheless, EVs sold in the UK after 2035 will be the closer to reaching "zero carbon" than those in any other market analyzed in this report. UK utilities have also shown innovation around smart charging, suggesting that the future EV fleet in the country can further help balance the grid and provide service as a backup to baseload generation.
- In 2023, passenger EV sales reached a new peak in the UK, at around 22% of all sales. Of the 476,000 EVs sold in the UK, around 67% were BEVs and 33% PHEVs.

Germany

Electricity generation and zero-carbon share



ICE and BEV CO2 emissions, use phase

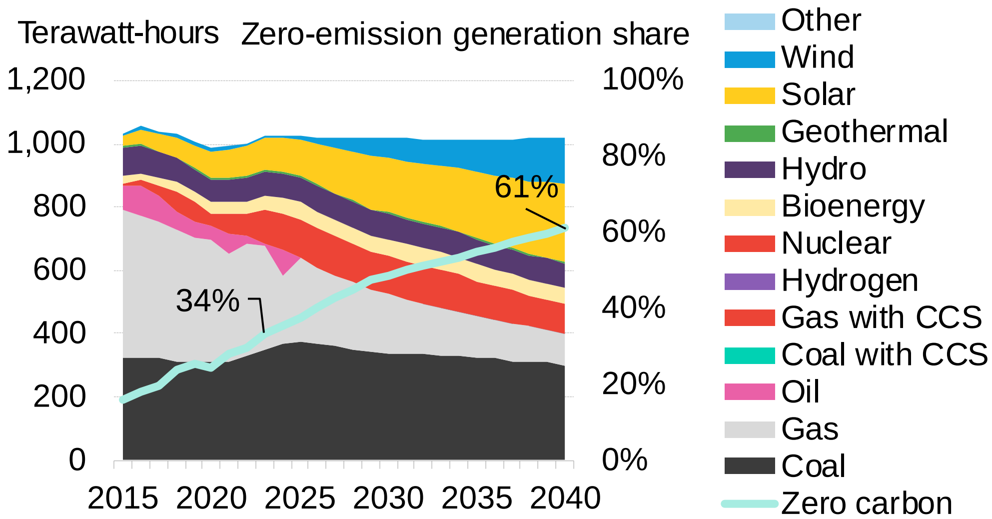


Source: BloombergNEF. Note: ICE results are normalized to the fuel economy test cycle; symbols correspond to historical performance until 2022. CCS = carbon capture and storage, gCO2/kWh is grams of CO2 per kilowatt-hour. ICE = internal combustion engine, BEV = battery-electric vehicle.

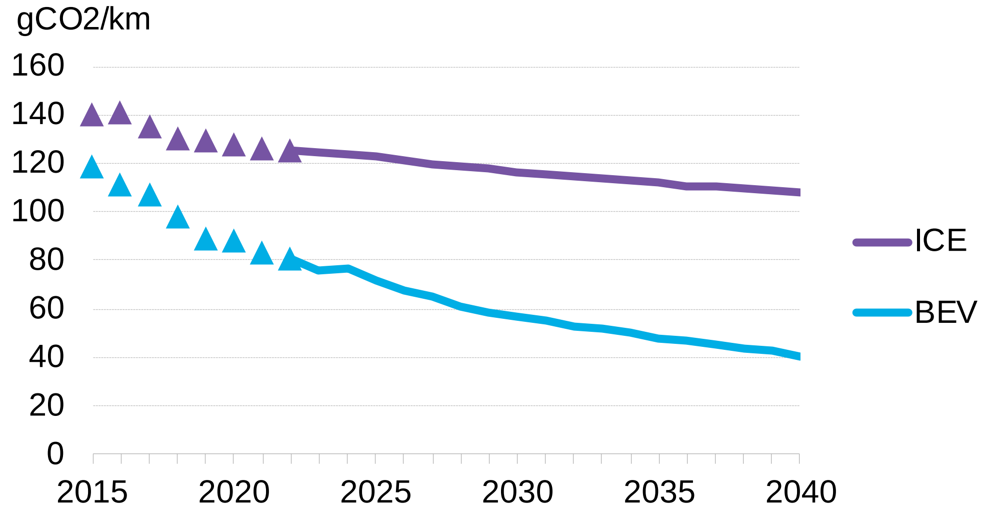
- Coal continues to be the most important source of electricity generation in Germany, providing 35% of the market's energy. This has increased since 2020, when coal contributed only 28%. Coal's share of the German market declines to zero by 2040 under BNEF's ETS as Germany focuses on adding renewable energy technologies, mainly solar and wind over the next decade. The zero-emission share of electricity generation rises from 49% in 2023 to 89% by 2040. Germany's power sector grid emissions drop substantially as a result, from 338 gCO2/kWh in 2025 to 51 gCO2/kWh in 2040.
- Charging an EV on Germany's grid in 2023 would emit 57% of the CO2 that an ICE vehicle would emit during the use-phase: 77gCO2/km for a medium BEV compared to 134.5 gCO2/km for a medium ICE car, according to our analysis. As the grid in Germany decarbonizes, EV emissions will fall even further: by 2040, BEVs in Germany are forecast to emit 7% of the per-kilometer emissions of their ICE counterparts.
- In 2023, German EV sales reached a new high of 713,000 units, including 532,800 BEVS and 180,600 PHEVs. While a subsidy cut at the end of 2023 will likely hamper sales in 2024, EV adoption is expected to accelerate again in 2025 as automakers gear up to comply with the region's fuel economy targets. Long-term targets, like the EU's plan to phase out sales of ICE vehicles by 2035, will underpin the market in the long term.

Japan

Electricity generation and zero-carbon share



ICE and BEV CO2 emissions, use phase



Source: BloombergNEF. Note: ICE results are normalized to the fuel economy test cycle; symbols correspond to historical performance until 2022. CCS = carbon capture and storage, gCO2/kWh is grams of CO2 per kilowatt-hour. ICE = internal combustion engine, BEV = battery-electric vehicle.

- Of the markets covered in this report, Japan had the lowest level of zero-emission generation in 2023, with nearly a third of its electricity from coal. Solar and wind energy, which are growing rapidly, are on track to supply 39% of electricity generation by 2040, but coal will still account for 29% of Japan's generation – highlighting that further innovation is needed to drive down emissions.
- By 2040, EV charging emissions in Japan will be the highest of the five surveyed markets. Still, Japan's EVs will get significantly cleaner as the share of zero-emission technologies in the power generation mix grows over time, rising from just 34% in 2030 to 61% by 2040.
- Japanese automakers, like Toyota and Honda, focused on hydrogen fuel cell vehicles as a potential drivetrain for years – with government support. As a result, EVs have struggled to gain ground in the market. In 2023, only 140,000 vehicles, or about 3% of all cars sold in the Japan, were electric.

CO2 emissions from vehicle use

Variation throughout the day

BloombergNEF

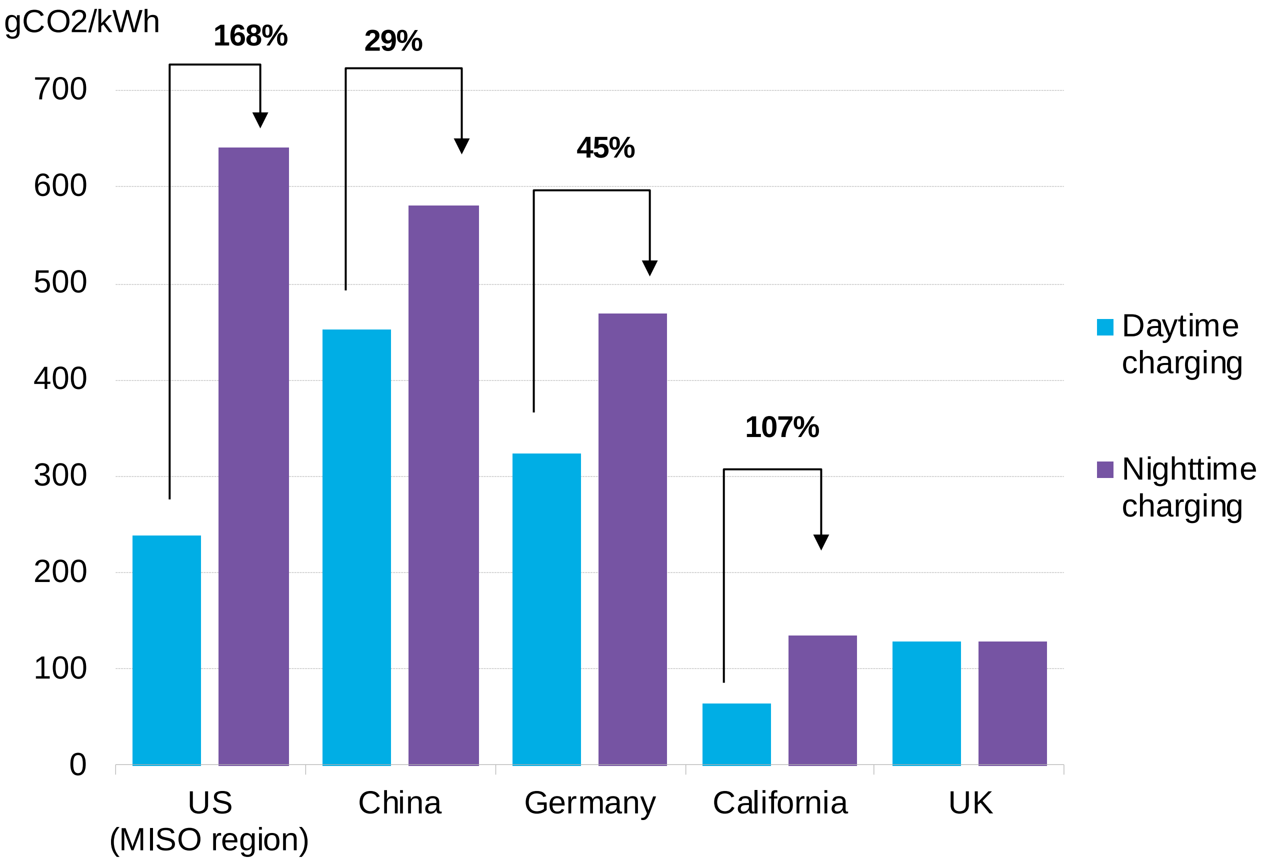
The variation of EV CO_2 emissions throughout the day

- As renewable energy generation varies throughout the day, so too will the emissions from EV charging. We expect the majority of charging in the short term to take place at home at night. However, we believe that the shift to solar and wind energy, and their varying generation profiles, will incentivize more flexible charging that allows better use of excess generation from renewables at specific times of day. An increasing number of commercial EVs with different use patterns will also lead to a greater variety of charging profiles. As utilities become more sophisticated, they will also aim to shift passenger EV charging to times when emissions are lower – often during the day – although this shift will depend on the prevalence of renewable resources. Such efforts to shift consumer habits often come in the form of specialized tariffs to lower-rates offered for charging during peak renewables hours.
- In the following slides, we use the emissions factors that correspond to nighttime and daytime charging to quantify this variation. For this analysis, we define nighttime as 7 p.m. to 5 a.m., and daytime as 10 a.m. to 2 p.m.
- In these charts, we use a regional breakdown for the US to account for differences in installed capacity. In particular, we show results for California and for the the Midcontinent Independent System Operator (MISO), which controls electricity generation in the Midwest, including parts of states such as Illinois, Missouri, Wisconsin, Iowa and others.
- We also show the change in charging emissions intensity in China, Germany and the UK, using our New Energy Outlook 2022 (web | terminal) to determine average emissions intensity across each market.
- We find that the CO_2 emissions associated with BEV charging are lower than those of ICEs irrespective of the time of charging for all markets included in this report. The BEV-ICE emissions gap tends to be larger with daytime charging, when solar panels generate a larger share of total electricity generation. This effect increases between 2023 and 2030. In the US, daytime and nighttime charging emissions differ less than elsewhere, as the MISO region is slower to decarbonize. By contrast, California has already enjoyed strong penetration of renewables, thanks to the rapid growth of solar.

CO2 emissions from vehicle use

EV emissions at different times during the day – 2023

BEV CO2 emissions for nighttime and daytime charging in 2023



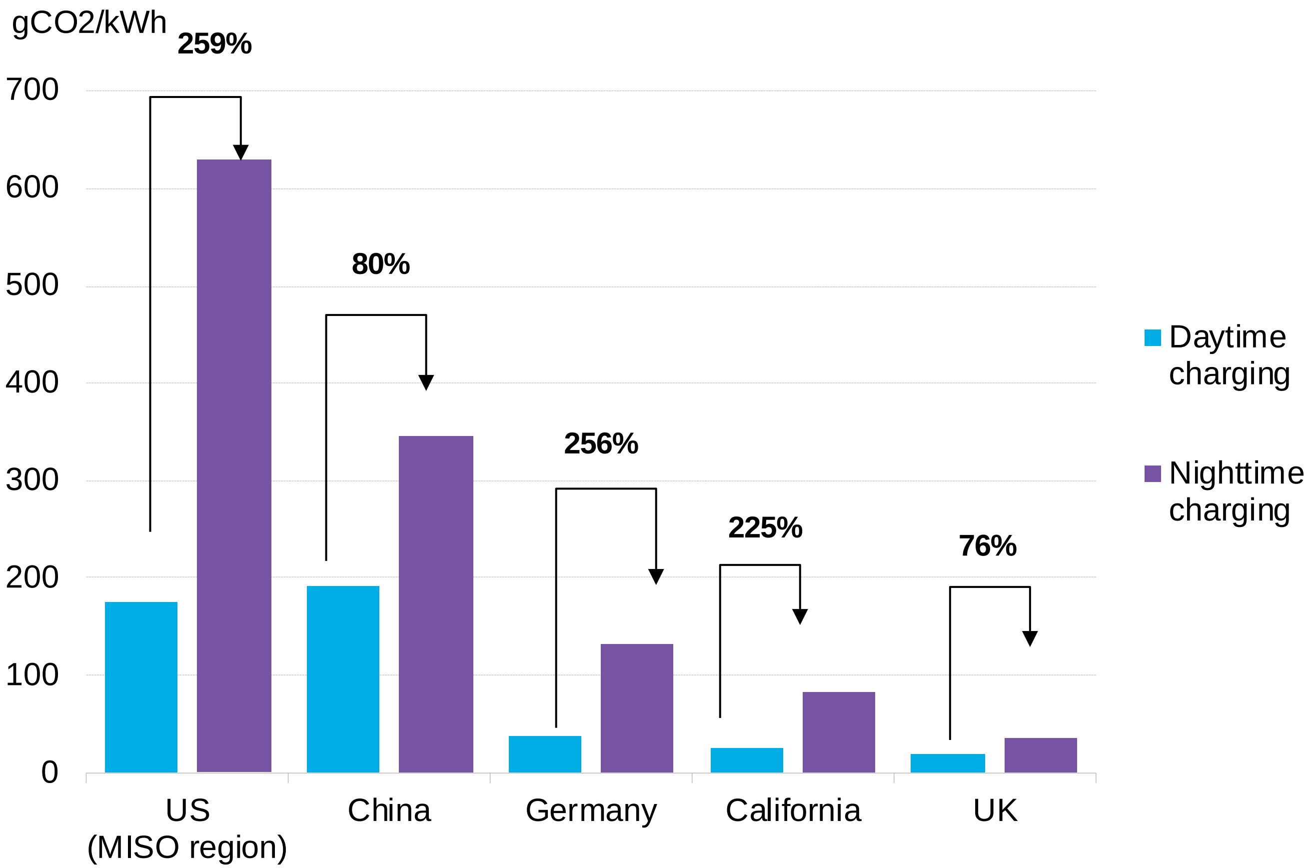
Source: BloombergNEF. Note: US (MISO region) refers to the Midcontinent Independent System Operator, which controls electricity generation in a region in the Midwest, including parts of states such as Illinois, Missouri, Wisconsin, Iowa and others. Day refers to charging between 10 a.m. and 2 p.m., while night is 7 p.m. to 5 a.m., and gCO2/kWh is grams of CO2 per kilowatt-hour. BEV = battery-electric vehicle.

- Daytime BEV charging is an attractive option for grid operators as a way to use excess renewable energy. However, the benefits associated with charging during the day vary by region. The percentages in this figure (and on the following slide) represent the percent change when daytime charging is compared with charging at night.
- Daytime solar generation in California, for example, makes daytime charging very attractive from a CO2 emissions point of view, while the high use of coal in Germany results in relatively high emissions from charging during the nighttime hours.
- There is close to no difference between daytime and nighttime charging in the UK due to high generation of both solar (day) and wind (night).
- Where charging takes place also matters. For example, an EV charging in the Midcontinent Independent System Operator (MISO) region in the US at day generates almost seven times as much CO2 emissions (from charging) as an EV charging in California.
- On a market-wide level, China has the highest level of charging emissions, at 452 gCO2/kWh. At night, emissions intensity rises by 29% to 582 gCO2/kWh.

CO2 emissions from vehicle use

EV emissions at different times during the day – 2030

BEV CO2 emissions for nighttime and daytime charging in 2030



- Carbon dioxide emissions associated with BEV charging drop in all countries by 2030, thanks to a rapid uptake of renewables.
- The CO2 emissions gap associated with EV charging widens even further between daytime and nighttime by 2030. In the US (MISO) region and California, the emissions intensity of daytime charging falls by 27% and 61% respectively from 2023 levels by the end of the decade.
- While emissions intensity remains quite high in China in absolute terms, there is a improvement in daytime emissions intensity by 2030, falling by 57% from 2023.
- Germany and the UK see their daytime charging emissions intensity drop by 89% and 81%, respectively, compared with 2023 figures.

Source: BloombergNEF. Note: US (MISO region) refers to the Midcontinent Independent System Operator, which controls electricity generation in a region in the Midwest, including parts of states such as Illinois, Missouri, Wisconsin, Iowa and others. Day refers to charging between 10 a.m. and 2 p.m., while night is 7 p.m. to 5 a.m., and gCO2/kWh is grams of CO2 per kilowatt-hour. BEV = battery-electric vehicle.

Methodology

Methodology and data sources

- We use the following data sets to derive the results in this report:
  - Grid emissions intensity factors
  - Real-world driving efficiencies for battery electric and internal combustion engine vehicles
  - Vehicle and battery manufacturing emissions
  - Average vehicle utilization rates, expressed in kilometers driven per year
- We calculate battery manufacturing emissions using the *Lithium Battery Emissions Model (1.1.0)* (web | terminal), which takes into account the energy used in the production of cells and packs, extracting and processing raw materials, and transportation. That energy is then converted to CO2 emissions using market-specific grid emission factors. In this year's report, we updated some assumptions around battery manufacturing in order to better reflect the global EV supply chain as it exists today.
- We assume that raw materials and battery precursors are manufactured in southeast China, and are then transported to the other four markets by sea. We assume that the active materials, cell and battery pack are assembled in the market where the car is sold. The exception is the UK, where we assume that only the pack is made domestically, while the cell and active materials are produced in Germany. An example of our main inputs from the battery emissions model is shown in the table below (although grid emissions intensity has been updated from the model's initial publication).

Production emissions inputs into lifecycle emissions models by market

Market	2023 battery production emissions (kgCO2/kWh)	2030 battery production emissions (kgCO2/kWh)
UK	65.19	40.42
Germany	65.65	40.49
US	61.01	43.50
China	70.77	54.50
Japan	59.59	49.49

Source: BloombergNEF. Note: Values are rounded.

Methodology and data sources (cont.)

- We assume that the vehicle is produced in the market of use, and we collect literature values for its manufacturing emissions from industry and academic studies. We estimate that a medium-segment vehicle emitted 6.8 metric tons of CO2 during manufacturing in Germany in 2020. We scale that using the ratio of grid emissions factors in different markets and years to arrive at the market-specific vehicle manufacturing emissions. We adjusted this for 2023 vehicles across the board. One main assumption during this calculation is that combustion and electric vehicles are practically the same in design, materials used and manufacturing methods. Many companies are trying to reduce the space and time required to manufacture EVs, which could change this.
- The BEV efficiency (in kWh/km) comes from our work on vehicle pricing (web | terminal). The efficiency of the ICE vehicles (gCO2/km) is our estimate of real-world CO2 emissions (web | terminal) – for more details see the next slide.
- For the market- and time-of-day-specific emissions factors of the electricity grid (in grams of CO2 per kWh of energy generated) we use the results of BNEF's New Energy Outlook 2022 (web | terminal). We calculate generation-weighted emissions factors throughout the day and for two-time windows: 10 a.m. to 2 p.m., and 7 p.m. to 5 a.m.
- Market-specific average vehicle utilization, in terms of annual distance driven, affects the CO2 emissions breakeven points between ICEs and BEVs. For vehicles produced in 2023 and 2030, as used in this report, the usage emissions of BEVs change over the vehicle's lifetime. We use the same inputs as in our Long-Term Electric Vehicle Outlook 2023 (web | terminal) for the average annual distance driven in different markets.
- In the Long-Term Electric Vehicle Outlook 2023 (web | terminal), we updated our approach around battery capacity based on the conditions in each of the separate regions that we surveyed. This allowed the final results to better reflect the marketplace as consumers were facing it.
- These battery capacities are important to lifecycle analysis, as the needs of consumers in each region vary – with US drivers for example preferring larger battery packs. Medium BEVs may look different in two regions as a result. The pack sizes used for 2023 and 2030 in this analysis are on the table to the right.

Battery pack sizes used for lifecycle emissions analysis (medium BEVs)

Market	2023 battery pack size (kWh)	2030 battery pack size (kWh)
UK	73.6	66.8
Germany	73.6	66.8
US	85.2	76.9
China	70.3	63.8
Japan	41.8	38.4

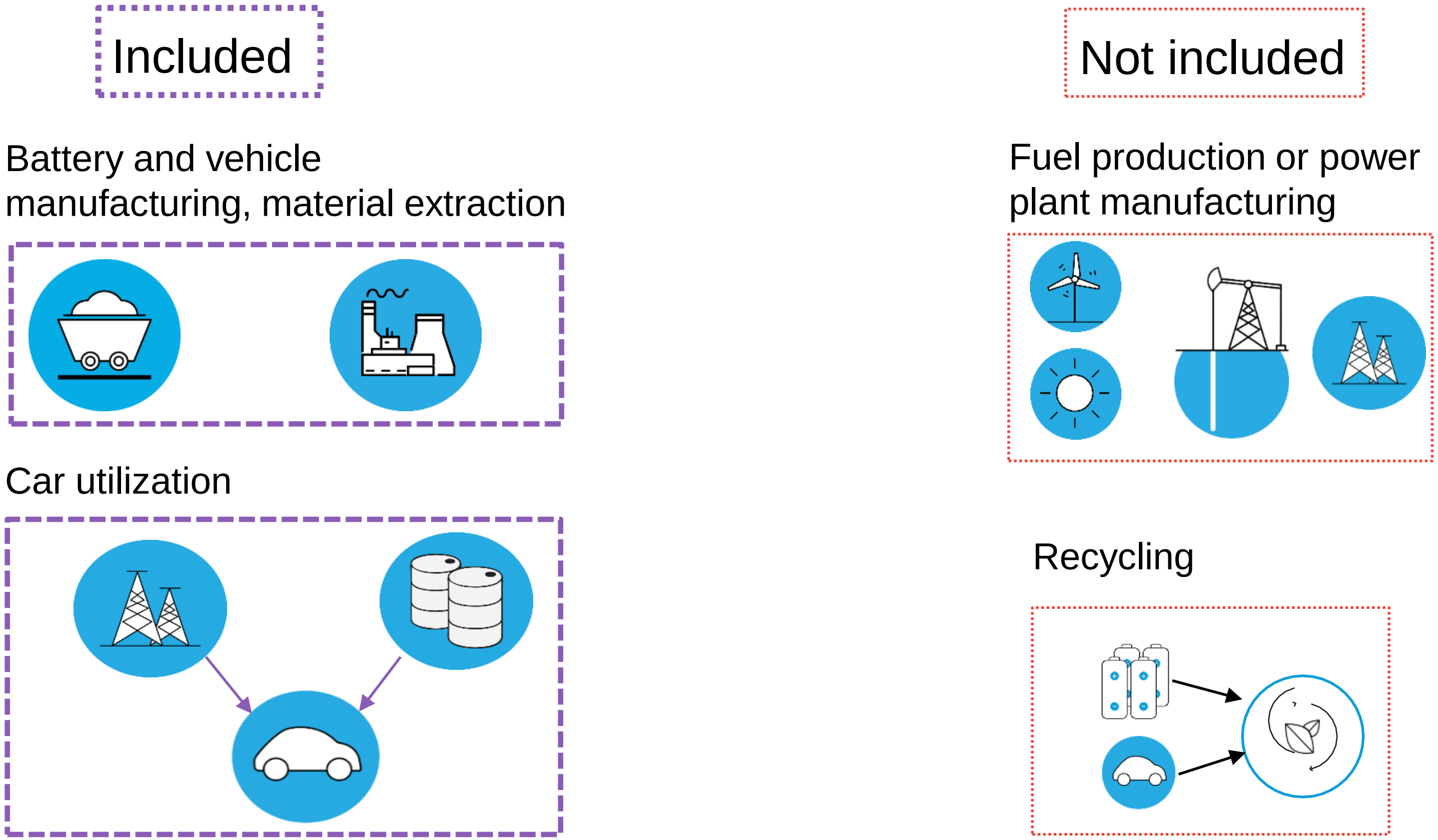
A note on vehicle efficiency

- The efficiency of a new car is typically measured in a laboratory as part of a regulatory approval process, which includes tests for fuel economy, CO2 or pollutant emissions targets. In these measurements, the vehicle follows a driving cycle (ie, a combination of vehicle speed, selected gear, aerodynamic and road resistance, etc), which attempts to mimic average driving conditions in different situations. These testing procedures differ between markets, and efficiency measurements are not directly comparable.
- However, these testing cycles are no longer representative of real-world driving conditions. Regulatory agencies and other organizations are thus using laboratory tests as a basis for estimating the real-world efficiencies of new cars.
- In the **US,** the EPA estimates real world vehicle efficiencies using additional testing cycles on top of those required for compliance. Real-world driving fuel economy can be 20-25% lower than the compliance value – in other words, CO2 emissions can be 25-33% higher.
- In **Europe**, the testing cycle has recently changed from the New European Driving Cycle (NEDC) to the Worldwide Harmonized Light Vehicle Test Procedure (WLTP), which attempts to better represent actual driving conditions. While the regulating agency does not publish estimates of real world driving efficiency, studies from the International Council on Clean Transportation (ICCT) estimate that in 2017, CO2 emissions from real-world driving were on average 37% higher than the NEDC results. In **China**, a modified version of the WLTP is about to be adopted.
- At BNEF, we also estimate real-world driving efficiency using a top-down approach, which stems from our 2023 Road Fuel Outlook (web | terminal). We start with the amount of diesel and gasoline fuel consumed, and the fleet of passenger vehicles – these are generally well documented quantities in most markets. We combine those with statistics on vehicle distance traveled, and we adjust that and the efficiency of new sales, within reasonable bounds, to arrive at estimates of real world fuel use from new cars. We find that our estimates are within 10% of those published by the US Environmental Protection Agency (EPA) or the ICCT for the US, Japan and Europe. We use these real-world estimates in our emissions calculations.

Source: BloombergNEF, EPA, EU Commission, ICCT.

What’s not included in this report

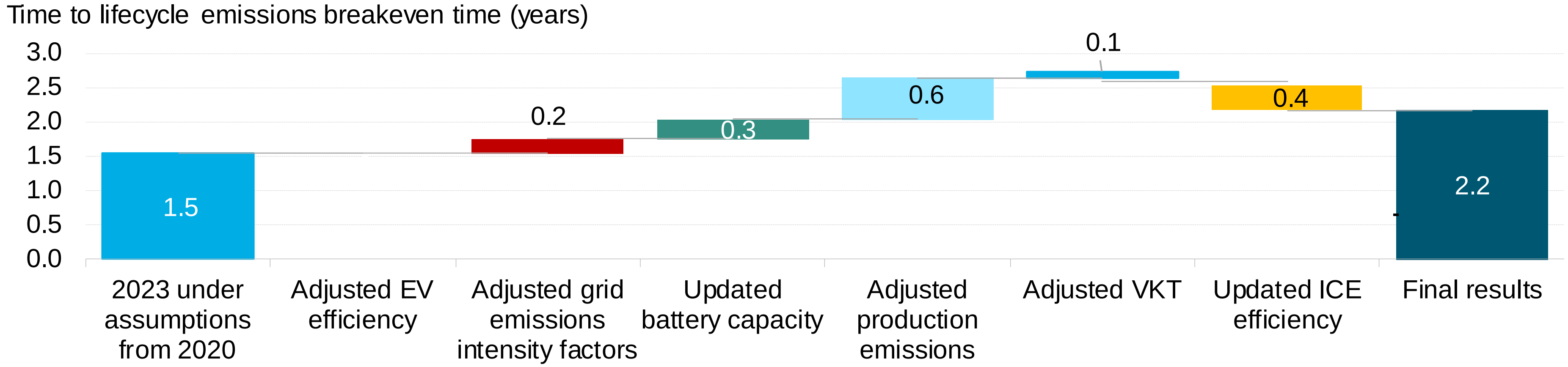
Lifecycle emissions analysis – included and excluded



- We do not include emissions from refining and shipping diesel or gasoline in our lifecycle analysis. We also do not include emissions from extraction and transport of coal, or building renewable generation in our grid emissions intensity factors. Their effect will depend on whether such additions reduce the manufacturing emissions gap, which would be favorable for EVs, or increase it, which could be favorable for ICEs. Recycling, which could reduce battery manufacturing emissions moving forward, is also not considered.

Changes from the 2023 edition of this report

Impacts of modeling changes on time to lifecycle emissions breakeven in the US, compared to previous report



- To better reflect that state of the global passenger EV market, we have updated the following topics:
  - Grid emissions intensity factors
  - BEV and ICE real-world driving efficiencies, informed by our latest research on fuel economy
  - Vehicle- and battery-manufacturing emissions
  - Average vehicle utilization rates, expressed in kilometers driven per year
  - Battery sizes for medium electric vehicles; these now vary by market
- To illustrate the impact of these updates, the chart shows how each step change impacted the lifecycle breakeven point between BEVs and ICEs, compared with our previous work. Adjusted grid intensity factors and updated battery capacity had the largest impact on delaying breakeven, while a diminishment in ICE efficiency in the US brought the breakeven point forward.
- This edition focuses on Japan rather than France, which was covered in previous reports. This has allowed us to expand our coverage to a region with both distinct EV dynamics and slower trajectory for decarbonization than Europe's.
- As noted, we now have China as the location for the refining of critical minerals and precursor. Previously, all manufacturing was assumed to be done in each market domestically.

Source: BloombergNEF. Note: VKT = vehicle kilometers traveled, ICE = internal combustion engine.

Copyright and disclaimer

BloombergNEF (BNEF) is a strategic research provider covering global commodity markets and the disruptive technologies driving the transition to a low-carbon economy.

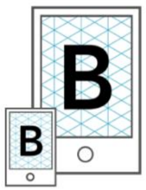
Our expert coverage assesses pathways for the power, transport, industry, buildings and agriculture sectors to adapt to the energy transition.

We help commodity trading, corporate strategy, finance and policy professionals navigate change and generate opportunities.

BloombergNEF

Corey Cantor,
ccantor11@bloomberg.net

Get the app



On IOS + Android
about.bnef.com/mobile

Client enquiries:

Bloomberg Terminal: press <Help> key twice
Email: support.bnef@bloomberg.net

Learn more:

about.bnef.com | @BloombergNEF