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Exploring new electric vehicle roadmaps for China in a post-COVID-19 era

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Summary

China's long-term mitigation options have gathered increasing international interest and scrutiny in the last two years, as the country, currently the world's largest emitter, has announced and formalised a series of climate targets.

In 2020, China announced its aim to achieve carbon neutrality before 2060, a move that we estimated would lower global warming projections by around 0.2 to 0.3°C by the end of the century. The government then proposed strengthened NDC targets and issued the primary components of its 14th Five Year Plan (2021-2025), including a peak date for coal. It has not yet submitted a strengthened NDC to the UNFCCC.

China's economic stimulus response to the COVID-19 pandemic initially signalled a greener recovery than in previous economic downturns, but its response instead devolved into a carbon-intensive recovery based on heavy industry, construction, and further coal development.

China is currently the global leader in battery electric vehicle (BEV) sales annually, a position it has held since 2015 when it surpassed the US. The one positive policy priority in China's COVID-19 recovery focused on transitioning the transport sector towards development of public transport systems and electrified transport. New energy vehicles (NEVs), which include battery electric vehicles (BEVs), plug-in hybrid vehicles (PHEVs), and hydrogen cars, received large boosts in the form of extended purchase subsidy schemes, investment in charging infrastructure, and lowering market entry barriers for BEV producers.

Decarbonising the transport sector is critical to China's road to carbon neutrality as it is the country's second largest emitting sector after industry and accounts for almost 20% of national primary energy consumption. Within the sector, China's massive light-duty vehicle (LDV) car fleet is the primary consumer of energy and emitter of carbon dioxide (and other pollutants), and is projected to grow until 2050, where it remains the primary mode of transport. This subsector thus contains significant opportunities to help the country achieve its climate targets while attaining other socioeconomic benefits such as the reduction of air pollution.

In this study we explore several sets of scenarios for the evolution of the passenger vehicle stock in China, to inform on the emission reduction and electricity demand implications of increasing rates in market penetration of BEVs and PHEVs and the phase out of conventional fossil vehicles. For each of the three scenarios (Pre-COVID-19, Current Policies, 100% BEV) we explore two sets of separate emission pathways ("Renewable Electricity" and "Fossil Electricity"), which are based on developments in the carbon intensity of electricity in China's power sector and assumes either strict decarbonisation of the power sector until 2050 or decarbonisation at current rate.

- In our reference, **Pre-COVID-19 scenario**, which does not account for policy developments since the start of the pandemic, emissions from passenger cars peak in 2037 and result in levels of 250 to 790 $MtCO_2$/yr in 2050, depending on the carbon intensity of electricity. Electricity demand from the BEV and PHEV fleet reaches 1,320 TWh/yr in 2050; by way of comparison, this is roughly equivalent to India's current annual electricity consumption (**Figure 1**).
- In our **Current Policies scenario**, which accounts for both implemented and stated policies made since April 2020 until January 2021, emissions from passenger cars peak in 2032 and result in levels of 100 to 720 $MtCO_2$/yr in 2050, a 9% to 61% reduction under the pre-COVID-19 scenario. Electricity demand reaches 1,520 TWh/yr.
- In our **100% BEV scenario**, which explores the implications of China reaching 100% BEV sales by 2035, emissions from passenger cars peak in 2026 and result in levels of 0 to 680 $MtCO_2$/yr in 2050, a 13% to 100% reduction under the pre-COVID-19 scenario. Electricity demand reaches over 1,680 TWh/yr, which is roughly the current annual electricity consumption of both India and Germany combined.

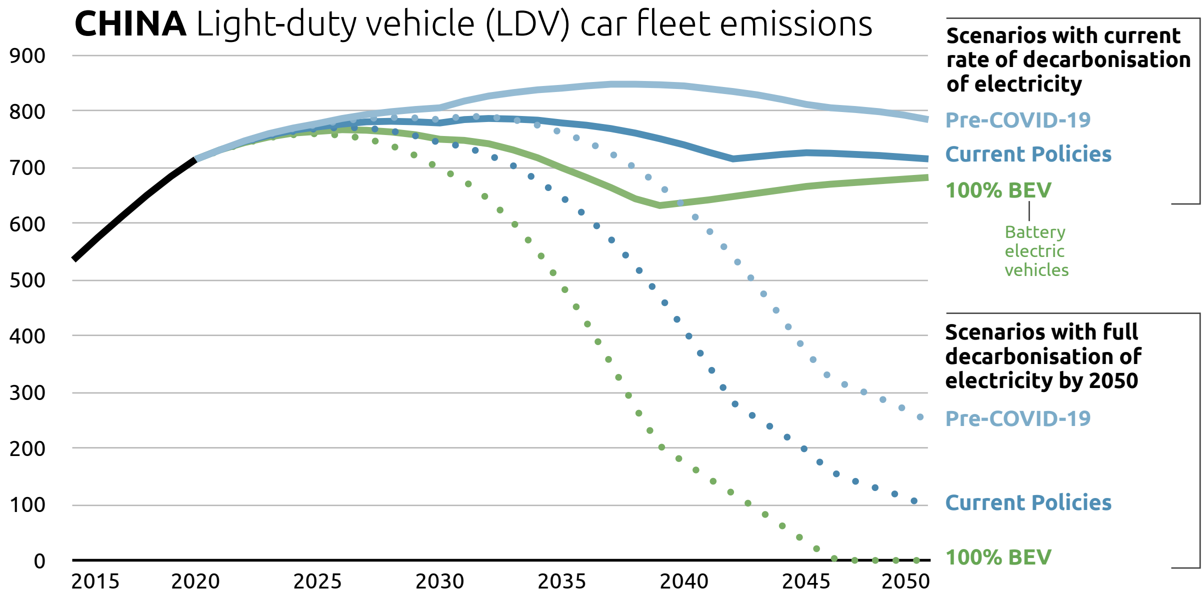

Figure 1 Emissions of China's LDV fleet for the pre-COVID-19, Current Policies, and 100% BEV scenarios under high and low electricity emission intensity developments.

Conclusions and recommendations from the analysis

1. **China's aggressive post-COVID-19 policies to support NEV penetration are positive, but more effort is required to make a large impact on reducing carbon emissions in the LDV sub-sector.**
   - All of China's new implemented and planned policies since April 2020 (Current Policies scenario) have the potential to substantially reduce carbon emissions from the LDV fleet.
   - However, LDVs emissions levels could still reach over 700 $MtCO_2$/yr in 2050 without additional mitigation action in NEVs or in decarbonising electricity, throwing China's carbon neutrality target into doubt.

2. **Decarbonisation of the LDV fleet will be a dedicated long-term effort in China on the timescale of several decades and requires immediate action to build momentum.**
   - Even in China's **Current Policies scenario** and **100% BEV scenario**, which would represent some of the most ambitious NEV penetration pathways internationally, emission reductions are negligible in the short term and minor in the medium, given the time needed to retire the immense size of the vehicle stock and low starting share of NEVs on the road.
   - In 2030, only a maximum of 110 $MtCO_2$/yr of emission reductions separate the least and most ambitious scenarios; we only start to see large impacts from NEV penetration and decreasing electricity emissions close to 2040. Rapid early retirement and replacement of ICE vehicles are needed.

3 **Emission reductions from ambitious electric vehicle policies in China are negligible unless coupled with a transformational shift to a low-carbon electricity sector**

- The future electricity demand of China's NEV fleet will be gargantuan (approximately 1,300 to 1,600 TWh/yr in the three scenarios) and their significance is driven by the emissions intensity of the power sector.
- Without also decarbonizing electricity production, the **Current Policies** and **100% BEV scenario** would only reduce emissions by 9% to 13% from the Pre-COVID-19 scenario by 2050, compared to 88% to 100% if the power sector is decarbonised.

4 **Achievement of a 100% BEV vehicle stock, coupled with power sector decarbonisation, is required for China to achieve its long-term carbon neutrality goal by 2060.**

- The most ambitious scenario in this analysis, the **100% BEV & Renewable Electricity** scenario coupling full modal share from BEVs with a fully decarbonised power sector, could reduce carbon emissions from LDVs to zero, and emissions in the transport sector by 790 $MtCO_2$/yr in 2050.
- Given the power sector is the most technologically mature sector ready to be decarbonised, China's policy intentions to transform its national LDV fleet, and existing market trends, this mitigation roadmap could be an attractive and feasible target for Chinese policymaking. If this roadmap were achieved, these emission reductions from one sub-sector intervention would be equivalent to around 15% of China's projected emissions in 2050.

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1 Introduction

China, the world's largest greenhouse gas (GHG) emitter, has played a significant and visible role in international climate politics over the past year. At the height of the economic downturn from the COVID-19 pandemic in 2020, China responded with policy and financial packages that showcased improved intent for a green recovery compared to previous national crises, but which ultimately resulted in carbon-intensive industry and construction activity.

In September 2020, President Xi Jinping announced that China will aim to achieve carbon neutrality before 2060, a move we estimated would lower global warming projections by around 0.2 to 0.3°C by the end of the century (CAT, 2020).

At the 2020 Climate Ambition Summit in December, China backed up its carbon neutrality pledge with proposed NDC targets (and a new renewable capacity installation target) not yet officially submitted to the UNFCCC, which are slightly stronger than its first NDC targets (CAT, 2021).

China's national ETS, initially covering the power sector and an estimated 40% of national carbon emissions, finally launched operations in July 2021 (IISD, 2021). China then followed up in March 2021 with the first segment of its 14th Five Year Plan, its short-term vision for social and economic development, which initially suggests the country's full-fledged transition towards carbon neutrality will be delayed to later years.

China's COVID-19 pandemic recovery, as for all countries, has been critically important for shaping the future of domestic climate policy. While the economy (along with emissions) was tanking during the first half of 2020, China issued broad stimulus packages to double down on existing priorities transitioning industry towards developing cutting-edge technologies and committed to continued acceleration of renewable energy systems, electric mobility, and electric vehicle deployment.

These strategies not only sought to reinforce existing economic and infrastructure objectives, but were amended to directly support critical sectors hit hard by the pandemic, such as new energy vehicles (NEVs, which include battery electric vehicles (BEVs), plug-in hybrid vehicles (PHEVs), and hydrogen cars).

By February 2020, NEV sales had plummeted by 80% from the same period in 2019, comparable to the sales slump of other vehicle types, prompting action from the government to extend purchase subsidy schemes to 2022, inject CNY 2.7 bn (approximately EUR 350m) in BEV charging infrastructure, and lower market entry barriers for electric vehicle (EV) producers (IEA, 2020) (Cheng, 2020).

China reinforced its commitment to developing the NEV sector in the 14th Five Year Plan (FYP) with mentions of EV battery swapping facilities and battery recycling (Shen, 2021). Of the policy directives issued from COVID-19 stimulus measures, China's post-COVID targets to continue electrifying the passenger vehicle fleet has not been fully explored in terms of potential emissions reductions impact.

In this analysis, we build several scenarios for China's passenger vehicle fleet with various pathways of accelerating NEV sales, explore the emissions reductions possible from each scenario, and discuss its implications for contributing to China's national climate targets.

Our **Pre-COVID-19 scenario** accounts for all policies prior to the full onset of the COVID-19 in 2020 and is used as the baseline scenario for this analysis. Our **Current Policies scenario** includes all implemented and stated policies during and after the COVID-19 pandemic recovery period until July 2021. Lastly, our **100% BEV scenario** explores the impacts where all sales of vehicles in 2035 consist of BEVs.

2 Effect of post-COVID-19 policies on China's greenhouse gas emissions outlook

The COVID-19 pandemic led to a lockdown of economic activity in China, with the carbon-intensive manufacturing, construction, and transportation sectors originally heavily affected. This led to an emissions drop of approximately 25% for CO_2 and over 30% for nitrous oxides and particulate matter in the first quarter of 2020, but quickly rebounded after the lockdown ended and according to Carbon Monitor, surpassed 2019 levels at the end of the year (ECMWF, 2020; Myllyvirta, 2020; NASA, 2020). Of the major-emitting economic sectors, only transportation sub sectors decreased in emissions with ground transportation decreasing emissions by 12.5% YOY (Carbon Monitor, 2021).

The CAT's [Current Policies projection for China]() with COVID-19 impacts (see Methodology and Assumptions), updated in September 2021, show GHG emissions levels (excl. LULUCF) are expected to reach between 13.2 to 14.5 $GtCO_2e$/yr in 2030 (CAT, 2021). The targets in China's proposed NDC update are well within its projected current policies emissions trajectory, including the non-fossil share target (around 25% in 2030) and the renewables installation target (1,200 GW additional solar and wind capacity by 2030). China could achieve these, and overachieve its existing NDC targets as well as the new proposed carbon intensity target (over 65% in 2030 compared to 2005 levels) without substantially increasing mitigation policy.

As of September 2021, our [latest analysis]() suggests China will continue to increase its emissions towards 2030; CO_2 emissions are projected to make up approximately 70% of national GHG emissions. China's pathway to its long-term carbon neutrality target assumes rapid decarbonisation after 2030 and is also wrought with uncertainty; we therefore assumed a linear decrease of emissions (excl. LULUCF) to 2060 (see Methodology and Assumptions).

According to our most recent economy-wide country analysis, China's emissions (excl. LULUCF) in 2030 would need to decrease by 36% to 41% from expected levels to be considered aligned with the 1.5°C Paris Agreement long-term temperature goal (**Figure 2**). This analysis explores possible emissions reduction contributions if China were to increase penetration of NEVs more aggressively than is currently planned.

The reduction range is derived from global model runs of the IPCC special report on 1.5°C that distribute emission reductions across countries and sectors in a cost optimal way to limit global temperature rise to below 1.5°C by the end of the century (Huppmann et al., 2019).

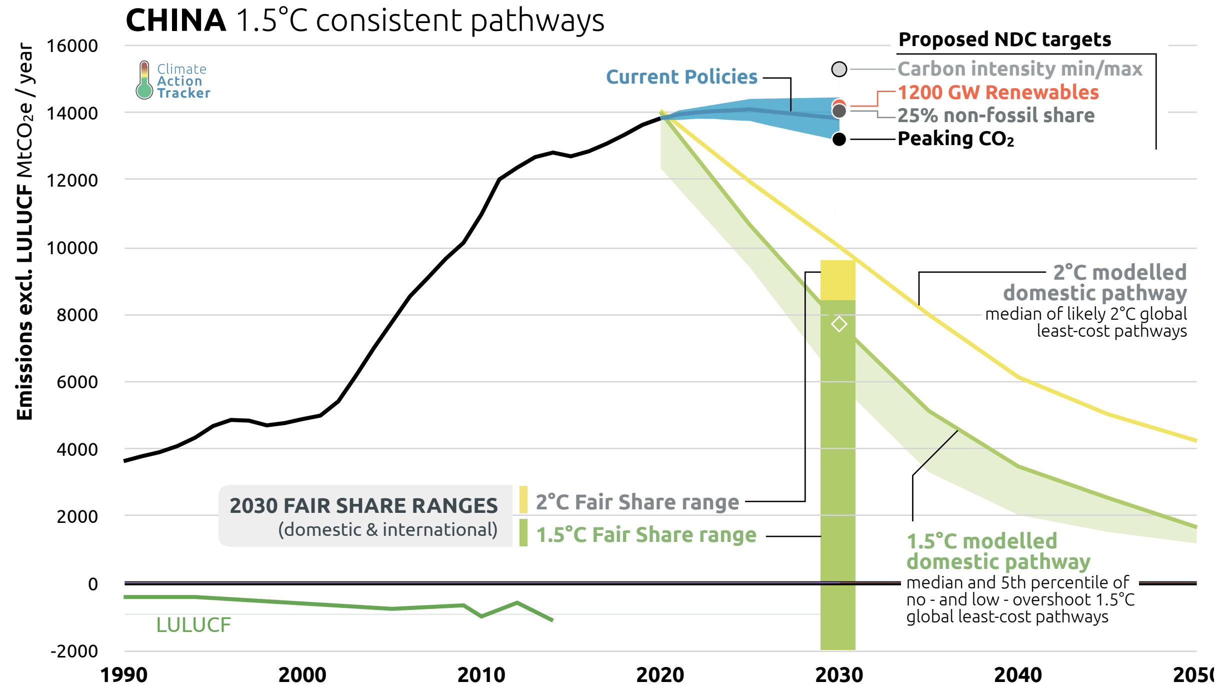

Figure 2 Emissions projections for China under current policies compared to proposed NDC targets, global least-cost pathways, and Fair Share emissions reduction ranges.

3 The role of passenger vehicles in China's road transport sector

China's transport sector is a vast consumer of energy (trailing only the industry sector) and accounts for almost 20% of national primary energy consumption (Zhou et al., 2020). Urban passenger transport is the primary end-use sub-sector, and passenger-kilometres driven increased 10-fold from 2005 to 2019. Road transport represented 77% of transport sector emissions in 2018, with the light-duty vehicle (LDVs) fleet (accounting for 30% of the modal share) dominated by petrol cars (Energy Foundation China, 2020).

As of the end of 2020, the national passenger LDV fleet reached 281 million vehicles, of which 4.9 million (1.7%) were NEVs, according to the Ministry of Public Security (Finance Sina, 2021). This represents an increase in over 29% from the 3.8 million NEVs in 2019, of which 3.4 million were BEVs (NBS, 2020).

China achieved its 'one million NEVs sold by 2020' goal two years earlier in 2018 (IEA, 2021). China is currently the global leader in BEV sales annually, a position it has held since 2015 when it surpassed the US (**Figure 3**). While growth in NEV penetration has been rapid, the share of NEV vehicles in the LDV fleet remains small compared to internal combustion engine (ICE) LDV modes such as petrol, which has represented over 95% of the stock since 2015 (**Figure 4**).

The NEV trend has been the result of the government's long history of effort to rapidly increase uptake, as summarised below from ICCT (Jin et al., 2020). Developing NEVs was first formally integrated into China's national strategy at the Political Consultative Conference in 2009 although policy signals dating back to the 1990s were recognised.

In the aftermath of the 2008 financial crisis with volatile oil prices, the NEV industry was prioritised with strategic importance when the State Council issued the "Auto Industry Adjustment and Revitalisation Plan" to reach 5% market sales by 2012, alongside large subsidies for city piloting programmes.

The next 12th FYP issued succeeding plans and rolled out an increased NEV R&D budget with special funding for implementation. From 2013, concerns on national air pollution and international competitiveness prompted further vehicle policies, with Beijing requiring a portion of annual car registration restrictions be dedicated to NEVs, ensuring an increasingly larger percentage of NEVs on the road. Demand-side policies, such as restricting conventional cars to alternate days of driving while NEVs faced no restrictions, were also implemented.

As reducing air pollution became a more prominent priority in national strategies, so did the NEV industry. In 2015, China released its "Made in China 2025" strategy, where President Xi Jinping announced NEVs as the next milestone in boosting the auto industry. In 2019, an implemented mandate required automakers to amass credits for the sale of their car fleets, with NEVs making up 10% of annual credits in 2019 and 12% in 2020. The system will also be continually tightened, with auto manufacturers needing to reach 14%, 16%, and 18% targets from 2021-2023.

Continuing loosening of market entry barriers of NEV automakers and increasing fuel quality standards for conventional vehicles since 2018 has given China's NEV industry an optimistic future of high growth.

Increasing urbanisation and household wealth is expected to further increase demand for private mobility through to 2050, where LDVs are still expected to be the primary mode of transport. While conventional vehicles are expected to give way to NEVs due to policy implementation and market forces, the sheer size of the existing fleet means it will take quite some time to phase out China's conventional fleet.

To be compatible with the Paris Agreement's goal to limit global warming to 1.5°C, electricity needs to supply 25-50% of transportation energy by 2050, where China's EV stock will need to make up 35% to 50% of the entire car fleet (Climate Action Tracker, 2020a; Energy Foundation China, 2020). Additionally, the last fossil fuel car will need to be sold before 2040. With NEVs only making up 1.7% of the national fleet in 2020, there is still a long road ahead for China, despite the positive outlook.

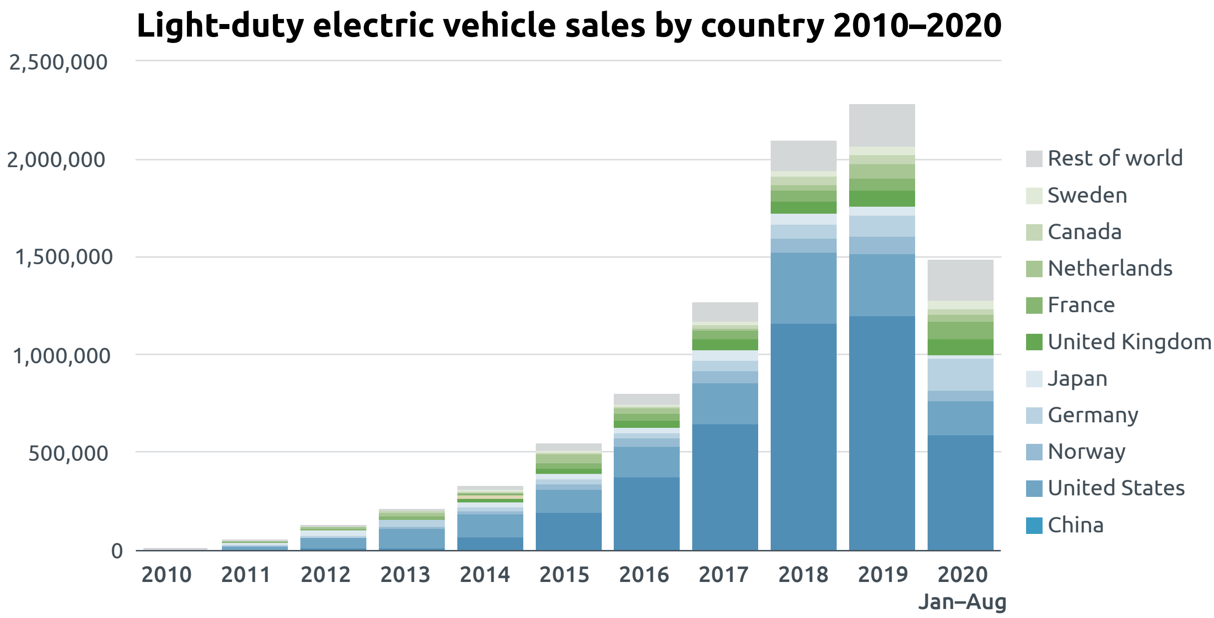

Figure 3 Global light-duty electric vehicle sales globally from 2010 to August 2020.

Source Taken from (Jin et al., 2020), based on (EV-Volumes, 2020).

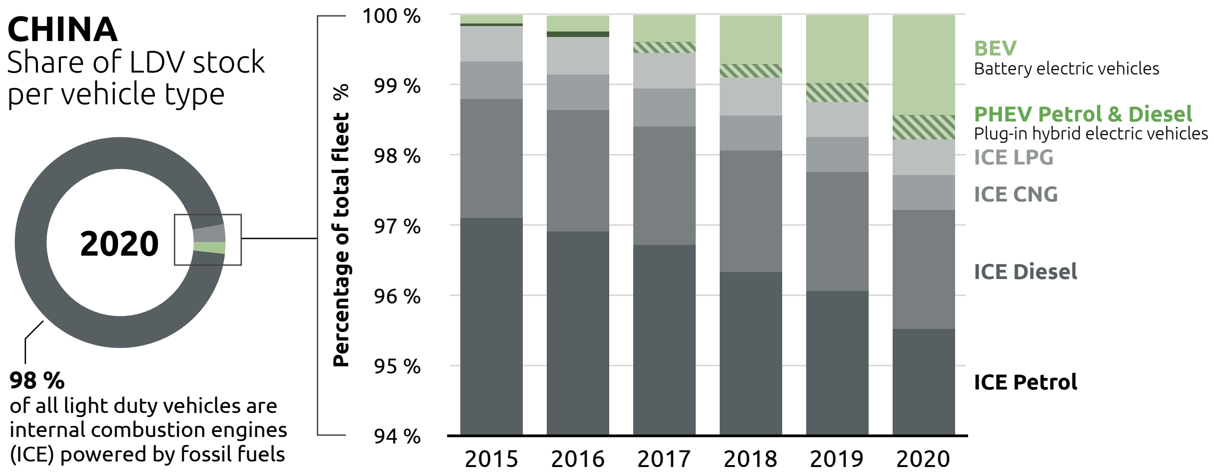

Figure 4 Share of LDV stock per vehicle type in China from 2015-2020.

Source Authors' calculation and elaboration based on data and literature from (ICCT, 2017; IEA, 2020a; Finance Sina, 2021). For more detail, see Methodology and Assumptions in the Annex.

4 Implications of scenarios on market shares, emissions and electricity demand

This section describes the major trends and differences in market shares and LDV activity per vehicle type across each of the policy scenarios explored, and discusses their implications for emissions and electricity demand.

The **Pre-COVID-19 scenario** accounts for all policies before April 2020, prior to the rollout of COVID-19 response policies that included NEV purchase subsidies and the New Infrastructure Plan, and serves as the reference scenario for this analysis.

The **Current Policies scenario** includes all implemented and stated policies during and after the COVID-19 pandemic recovery period until January 2021, such as the extension of subsidies for NEVs and policy signals from the New Infrastructure Plan. This scenario also includes most recent plans released by the State Council to increase the NEV sales target to 20% in 2025, and a proposed auto industry roadmap for transport from the Ministry of Industry and Information Technology to increase NEV sales target to between 50% to 60% by 2035 (Tabeta, 2020; Xinhua, 2020).

The roadmap proposal also included the intention that 90% of the NEV sales sold in 2035 should be BEVs (a 47.5% BEV market share). The proposal was discussed in 2020 in the aftermath of COVID-19 but has since been parked. The Current Policies scenario explores the impact if China were to fully implement its post-COVID-19 NEV policies, supplemented with another NEV industry boost in the form of its 2035 market share targets.

The **100% BEV scenario** is the most ambitious NEV penetration pathway explored, where 100% of LDV sales in 2035 are BEVs. For more detail on the methodologies and data behind this scenario, and the underlying country analysis on China's national emissions projections, see Methodology and Assumptions.

For all scenarios, transport activity demand from LDVs rises from 3,460 billion vehicle-kilometres (bn-vkm) in 2020 to 6,270 bn-vkm in 2035 and 9,240 bn-vkm in 2050, increasing almost three-fold over the period. The vehicle activity is driven by a growing national LDV fleet of 281 million cars in 2020 to 420 million in 2035 and 580 million in 2050 (ICCT, 2017; Finance Sina, 2021).

For China's passenger transport sub-sector to reduce emissions quickly in the long-term, along with switching to low-emission fleets, the country also needs to reduce its overall demand for passenger cars. Differences in projections for absolute national fleet stock and LDV activity are not modelled for this analysis and are assumed to be the same, given the focus of analysis is on increasing NEV penetration.

4.1 Market penetration of NEVs

Even in the **Pre-COVID-19 scenario**, the least ambitious NEV penetration pathway for LDVs in China, we find the market share of conventional ICE vehicles (including petrol, diesel, CNG, LNG) had already peaked in 2020 due to significant national and provincial policy incentives described in the previous section, although they retain the majority of market share until 2036.

Petrol vehicle sales phase out in 2045, with sales of remaining ICE vehicle types phased out in 2050. PHEVs (petrol and diesel) in 2020 represent 1.2% of the market share, but increase to peak at 26% in 2045, before declining towards 2050, where approximately 90% of PHEVs run a mix of electricity and petrol (as opposed to diesel). Market shares for BEVs rise rapidly in the baseline scenario due to existing policies and market trends, increasing from under 5% in 2020 to 20% in 2030, 50% in 2040, and 80% by 2050 (**Figure 5**).

In the **Current Policies scenario**, the market share of ICE follows a more aggressive phase-out due to the ramp up of NEV and particularly, BEV sales. ICE vehicles represent the majority of the market share until 2030, with sales of all ICE types assumed to be phased out by 2040, five years earlier than the reference scenario (Figure 5). In 2030, the market share of PHEVs reach 18% before peaking at 30% in 2040.

With all ICE vehicle sales phased out by this period, PHEV sales give way to the relentless uptake of BEV sales. The peak market share of PHEVs is earlier and larger in this scenario compared to the Pre-COVID-19 scenario, given that the increased penetration of BEVs does not fully absorb the earlier phase-out of ICE sales. The BEV market share reaches 35% in 2030 in this scenario and 47.5% in 2035 as stipulated by the proposed roadmap analysed, before reaching 70% in 2040 and 100% in 2050.

In the **100% BEV scenario**, sales of both PHEVs and ICE vehicles are phased out by 2035 with the market fully captured by BEVs (Figure 5). The aggressive uptake of BEVs leaves virtually no room for market share growth of other vehicle types from 2020, when they all start declining.

In the previous scenarios, fossil fuel cars decline in market share first, while PHEVs increase as the BEV market is not fully saturated. In this scenario, both ICE and PHEV vehicles decline from the beginning, and thus PHEV sales are phased out first due to the smaller initial market. Market share of BEVs in this scenario reaches 36% by 2025, 68% by 2030, and 100% in 2035. This is the only scenario that is Paris Agreement 1.5 °C compatible, which requires EV shares to reach 95-100% in 2030 and 100% by 2040 for China (Climate Action Tracker, 2020b).

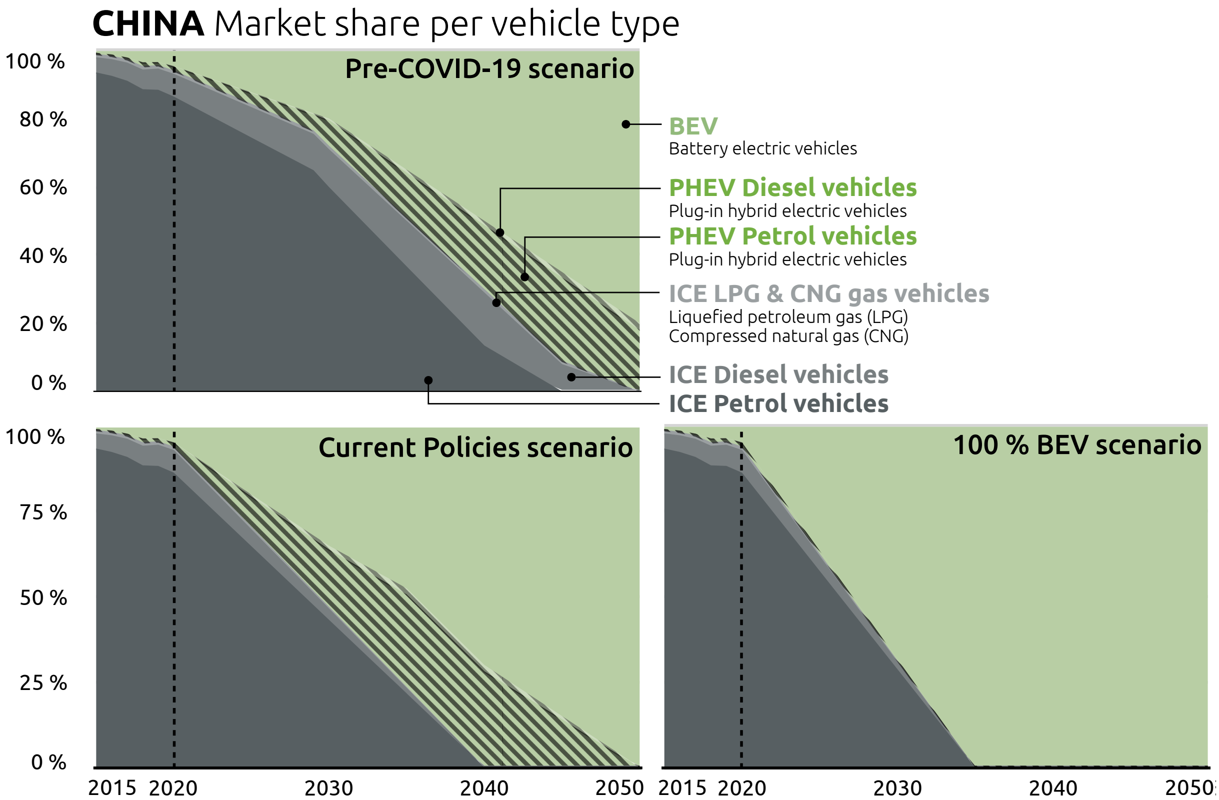

Figure 5 Historical and projected market share of China's passenger car fleet in the pre-COVID-19 scenario.

4.2 LDV activity per vehicle type

In the **Pre-COVID-19 scenario**, ICE vehicle activity in the national fleet peaks in 2031, represents the majority of the v-km driven until 2040 and still accounts for 9% of total LDV activity by 2050 (Figure 6). For ICE vehicle activity, petrol vehicles are dominant both historically and until the medium term and are phased out before other ICE vehicle types as it is assumed policy interventions target this mode first and most stringently.

The decline in modal share for ICE vehicle activity in the overall fleet (and increase in modal share for NEV activity) moves slower than the market share trends in new car registrations given the lagged effect of vehicle retirement. Road activity for PHEVs and BEVs increase steadily throughout the time horizon while replacing ICE activity. PHEVs achieve a modal share of 3% in 2030, 15% in 2040 and 24% in 2050, while BEVs increase more rapidly due to the larger annual market shares, and achieve a modal share of 11% in 2030, 39% in 2040 and 67% in 2050.

The increased uptake of NEVs in the **Current Policies scenario** is also reflected in overall LDV fleet activity, with a delayed retirement effect (**Figure 6**). Kilometres driven by ICE cars grows steadily until peaking in 2028, several years earlier than in the Pre-COVID-19 scenario, at approximately four trillion v-km. ICE vehicle activity then starts declining rapidly in between 2030 and 2040, decreasing by 73% over the period, due to the rapid projected uptake of BEVs in the period.

Conversely, the NEV fleet activity on the road increases more than three-fold over the period, accounting for 86% of vehicle activity by 2040. PHEV activity in this scenario has a larger peak as it is assumed PHEVs are more readily adopted during the phase out of LDVs but starts declining in 2045 as earlier PHEVs are retired and replaced by BEVs.

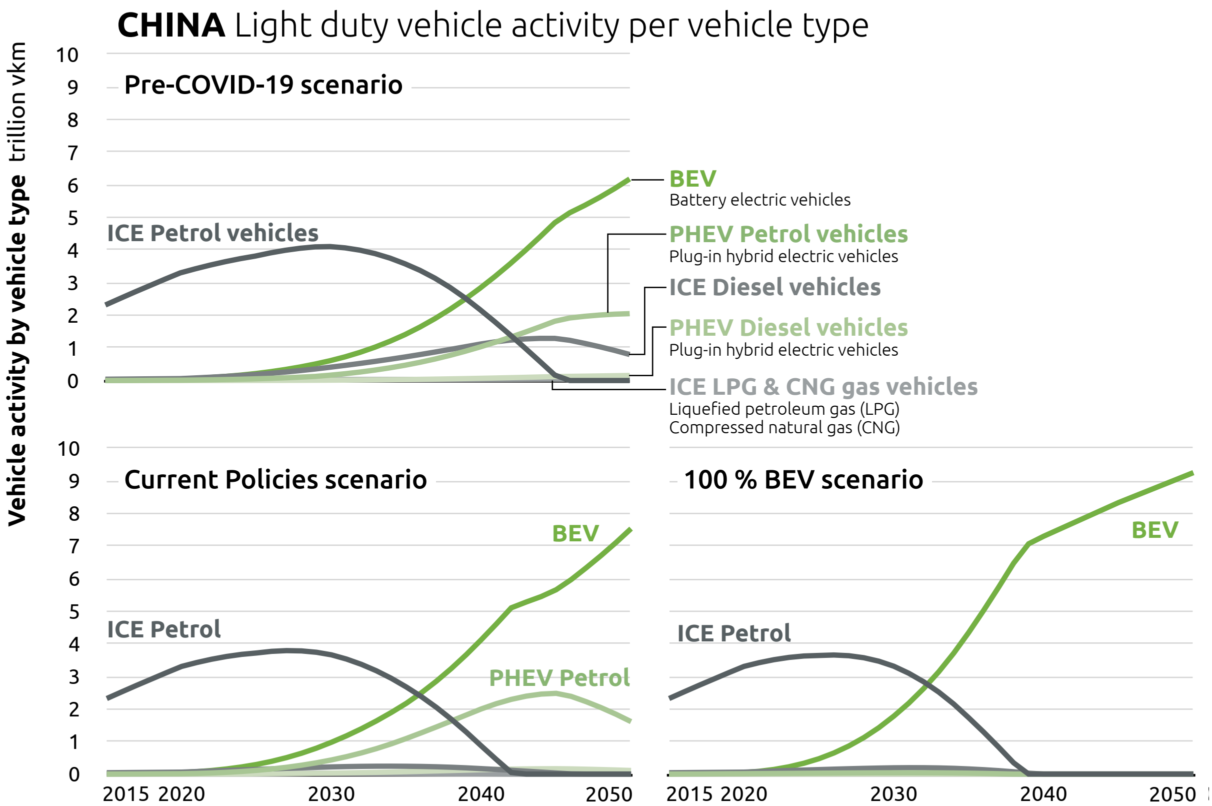

Figure 6 Historical and projected vehicle activity of China's passenger car fleet in the Pre-COVID-19 scenario

Source Authors' calculation and elaboration based on data and literature from (ICCT, 2017; IEA, 2020a; Finance Sina, 2021). For more detail, see Methodology and Assumptions in the Annex.

The **100% BEV scenario** is characterised by a rapid growth in activity from the BEV fleet. Due to the speed of uptake, LDV activity from ICE vehicles, particularly petrol, does not expand into the medium term but rather peaks in 2026 at approximately 3.85 trillion vkm and is completely phased out by 2040 (Figure 6). Given the steep decline in market share for all vehicle types (aside from BEVs) required under this scenario, this is the only scenario where petrol vehicle activity does not phase out before other vehicle types. Vehicle activity from BEVs increases exponentially until 2039, capturing a modal share of only 1% in 2020 but 33% in 2030, 69% in 2035 and 100% in 2040 and 2050.

4.3 Emissions and electricity

CO_2 emissions resulting from China's national LDV fleet, including the existing vehicle fleet and new vehicle registrations per fuel type, are presented in **Figure 7** for the Pre-COVID-19, Current Policies and 100% BEV scenario.

For each scenario, we explore two sets of emission pathways, depending on developments in the carbon intensity of electricity in China's power sector. For the high carbon-intensity scenario ("Fossil Electricity") and low carbon-intensity scenario ("Renewable Electricity"), we calculate the intensities from IEA WEO (2019b) and IEA WEO (2020c) respectively.

In addition to modelling the stock, sales, and activity of the LDV fleet, we also include projections on the technology developments, fuel efficiency and emissions-intensity improvements of vehicles from various sources (see Methodology and Assumptions).

Emissions under high projected carbon intensity of electricity

For the Fossil Electricity (high-carbon intensity) scenarios: The **Pre-COVID-19** scenario peaks at 850 $MtCO_2$ in 2038, the **Current Policies** scenario peaks at 790 $MtCO_2$ in 2032, and the **100% BEV scenario** peaks the earliest at 770 $MtCO_2$ in 2026, closely mirroring the timeline when more than 50% of vehicle activity is driven by low-carbon NEVs.

We find that the **Current Policies scenario** has a minor 3% reduction on CO_2 emissions compared to the **Pre-COVID-19 scenario** in 2030, due to the insufficient time for increasing NEV market penetration to replace large shares of the national fleet.

The largest impact on emissions is seen between 2039-2045 when the policy impacts of the **Current Policies scenario's** "50% NEVs by 2035 target" start to take effect, but before the NEV market saturates for the **Current Policies scenario** and continues expansion in the Pre-COVID-19 scenario.

The **Current Policies scenario** shows an 9% reduction in CO_2 emissions in 2050 compared to the baseline. The 100% BEV scenario shows a similar trend but with larger differences, with a -7% impact on CO_2 emissions compared to the **Pre-COVID-19 scenario** in 2030 (13% in 2050) and the most significant differences in emissions between 2037-2044.

The **100% BEV scenario** emissions trajectory shows an inflection point in 2040, when emissions start to increase again, reflecting the effects of when the entire stock has been electrified, yet increasing total LDV activity from new sales also increase emissions from electricity.

Emissions under low projected carbon intensity of electricity

For the Renewable Electricity (low-carbon intensity) scenarios: The **Pre-COVID-19** scenario peaks earlier at 790 $MtCO_2$ in 2031, the **Current Policies scenario** peaks at 770 $MtCO_2$ in 2026, and the **100% BEV scenario** peaks slightly earlier at 760 $MtCO_2$ in 2025.

As is visible in the figure, all three Renewable Electricity scenarios have a similar trend: decarbonising with increasing speed after the peaking year and reaching a first inflection point in 2046, 2043, and 2039 for the three scenarios respectively. These represent the years when the last petrol vehicles have been retired. The second milestone inflection point is only evident in the 100% BEV scenario, where the national fleet is comprised totally of BEVs and the carbon intensity of electricity reaches zero.

In Fossil Electricity and Renewable Electricity scenarios, emissions intensity of electricity reaches 530 and 385 gCO_2/kWh in 2030, 450 and 125 gCO_2/kWh in 2040, and 400 and 0 gCO_2/kWh in 2050 respectively. To be 1.5 °C Paris Agreement-compatible, China's emissions intensity of electricity would need to be at 100 to 110 gCO_2/kWh in 2030, and close to zero by 2040 (Climate Action Tracker, 2020b).

While absolute emissions from China's LDV fleet is massive, potentially reaching peak CO_2 levels that would rank among the largest carbon emitting countries today, it is also only a small percentage of China's economy-wide emissions. Potential LDV emissions reductions in 2050, if all passenger cars were replaced by BEVs and the electricity supply sector is completely decarbonised, this would only reduce around 6% of China's economy-wide GHG emissions in 2020 (CAT, 2021).

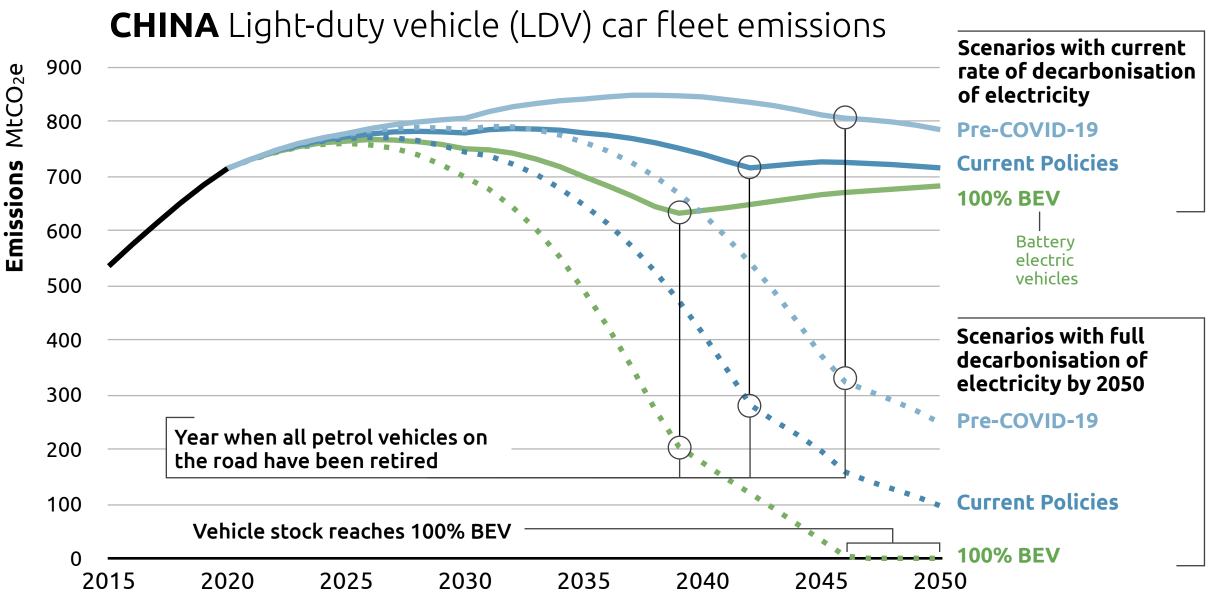

Figure 7 Emissions of China's LDV fleet for the pre-COVID-19, Current Policies, and 100% BEV scenarios under high and low electricity emission intensity developments.

Source Authors' calculation and elaboration based on sources described in Methodology and Assumptions.

Electricity demand from China's NEV fleet

The electricity demand from China's LDV fleet across the three scenarios grows with the increasing number of PHEVs and BEVs in the fleet (Figure 8).

- In the **Pre-COVID-19 scenario** and all other scenarios, the power generation needed to supply China's NEV fleet exceeds 1,300 TWh/yr in 2050, more than India's 2020 electricity consumption (Enerdata, 2016).
- In the **Current Policies scenario**, where there are 100 million PHEVs and 470 million BEVs on the road in 2050, electricity demand reaches 1,520 TWh in 2050.
- In the **100% BEV scenario**, where all 570 million cars are BEVs, electricity demand reaches 1,680 TWh in 2050, equivalent to the 2020 electricity consumption of India and Germany combined (Enerdata, 2016).

While electricity demand intuitively grows with increasing penetration of BEVs and PHEVs, this does not necessarily imply an increase in energy demand. Studies have shown that energy efficiency gains from switching from ICE (petrol and diesel) vehicles to BEVs are highly dependent on power plant efficiency (e.g., Albatayneh et al., 2020). However, there are shown to be significant efficiency gains when BEVs are powered by solar and wind technologies (the case in the Renewable Electricity scenarios with low carbon intensity of electricity), suggesting that aggressive NEV penetration alongside power sector decarbonisation would result in a decrease in total primary energy demand for China.

The inflection points seen in the three pathways, when electricity demand grows at a slower pace, counterintuitively mirror the years petrol vehicles are phased out of the national fleet. This is because prior to the phase-out of other vehicle types, larger stocks of BEV sales are required to compensate for both the decreasing sales and retirement of other vehicle types. After other modes are phased out, additional electricity demand only comes from growing sales of BEVs (as there is no change in electricity demand from BEVs replacing retired BEVs).

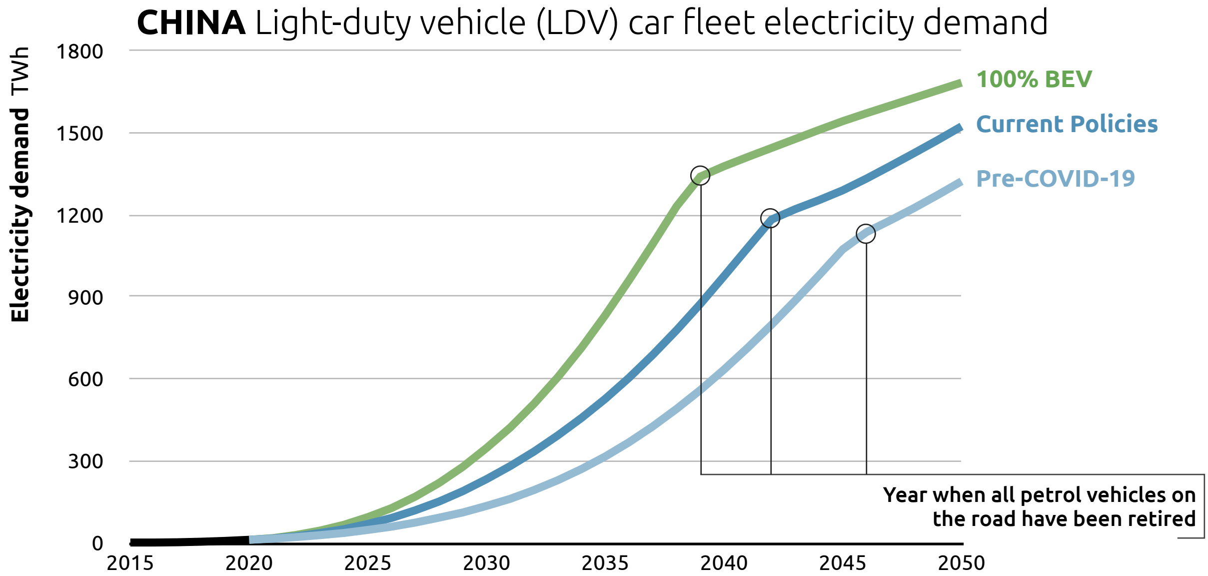

Figure 8 Electricity demand in the pre-COVID-19, Current Policies, and 100% BEV scenario.

Source Authors' calculation and elaboration based on (ICCT, 2017; ClimateWorks Foundation, 2018; IEA, 2020a). For more detail on methodologies, see Methodology and Assumptions in the Annex.

5 Conclusions and recommendations

There are several main takeaways and recommendations from the results of this analysis:

1. **China's aggressive post-COVID-19 policies to support NEV penetration are positive, but more effort is required to make a large impact on reducing carbon emissions in the LDV sub-sector.**
    - China is one of the world leaders in electric mobility, and its COVID-19 recovery package pushes NEV even further. All of China's new implemented policies since April 2020 (Current Policies Scenario), including new roadmap targets such as the 20% NEV sales target in 2025 and 50% NEV sales target in 2035, have the potential to substantially reduce carbon emissions from the LDV fleet by 9% to 61% from the reference scenario by 2050.
    - However, there is only a minor impact on emissions from the policy packages in the next decade. Even in the long-run, LDVs emissions levels could reach over 700 $MtCO_2$/yr in 2050 without additional mitigation action in NEVs or in decarbonising electricity, throwing China's carbon neutrality target into doubt.

2. **Decarbonisation of the LDV fleet will be a dedicated long-term effort in China on the timescale of several decades and requires immediate action to build momentum.**
    - Even in China's **Current Policies scenario** and **100% BEV scenario**, which would represent some of the most ambitious NEV penetration pathways internationally, emission reductions are negligible in the short term and minor in the medium, given the time needed to retire the immense size of the vehicle stock and low starting share of NEVs on the road.
    - In 2030, a maximum of 110 $MtCO_2$/yr of emission reductions separate all scenarios; we only start to see large impacts from NEV penetration and decreasing electricity emissions close to 2040. Rapid early retirement and replacement of ICE vehicles are needed, which is technically and economically feasible given the relatively short lifetime of vehicles when compared to other sectors such as buildings or industry.

3. **Emission reductions from ambitious electric vehicle policies in China are negligible unless coupled with a transformational shift to a low-carbon electricity sector**
    - The future electricity demand of China's NEV fleet will be gargantuan (ranging from approximately 1,300 to 1,600 TWh/yr in the three scenarios) and their significance is driven by the emissions intensity of the power sector.
    - Without also decarbonizing electricity production, the **Current Policies** and **100% BEV scenario** would only reduce emissions by 9% to 13% from the Pre-COVID-19 scenario by 2050, compared to 88% to 100% if the power sector is decarbonised.

4. **Achievement of an 100% BEV vehicle stock, coupled with power sector decarbonisation, is required for China to achieve its long-term carbon neutrality goal by 2060.**
    - The most ambitious scenario in this analysis, the **100% BEV & Renewable Electricity scenario** coupling full modal share from BEVs with a fully decarbonised power sector, could reduce carbon emissions from LDVs to zero, and emissions in the transport sector by 790 $MtCO_2$/yr in 2050 in the most optimistic case.
    - Given the power sector is the most technologically mature sector ready to be decarbonised, China's policy intentions to transform its national LDV fleet, and existing market trends, this mitigation roadmap could be an attractive and feasible target for Chinese policymaking. If this roadmap were achieved, these emission reductions from one sub-sector intervention would be equivalent to around 15% of China's projected emissions in 2050.

Annex: Methodology and Assumptions

New energy vehicle scenarios

We build and explore three scenarios for the pathways of LDVs for this analysis:

1. **Pre-COVID-19 scenario**, which accounts for all implemented and stated policies before the COVID-19 pandemic as of April 2020.
2. **Current Policies scenario**, which includes all implemented and stated policies during and after the COVID-19 pandemic recovery period until January 2021, such as the extension of subsidies for NEVs and policy signals from the New Infrastructure Plan for transport (Tabeta, 2020; Xinhua, 2020). This scenario additionally includes a proposed auto industry roadmap for transport from the Ministry of Industry and Information Technology to increase NEV sales target to at least 50% to 60% in 2035 (Tabeta, 2020). Of the NEVs sold, 95% of them would be BEVs.
3. **100% BEV scenario**, where all sales of vehicles in 2035 are BEVs.

We construct each scenario through bottom-up indicators including fleet stock and new sales, share of fuel type of vehicles, vehicle activity in kilometres travelled, and emissions intensity per vehicle type to assess the emission levels from the LDVs in the transport sector for the country from 2015 to 2050. Table 1 describes the main indicators developed for this analysis along with their methodological approach and sources. Vehicle fuel types covered in this analysis includes petrol (inc. hybrids), PHEV petrol, diesel (inc. hybrids), PHEV diesel, CNG, LNG and BEVs. Growth rates between data points in the time series are assumed linear unless stated otherwise.

Table 1 Data setup and assumptions for indicators used to construct the baseline data for scenario analyses.

Category	Indicator	Data and assumptions
LDV sales stock	Share (%) and stock of new vehicle sales per vehicle fuel type	Historical and projections for annual sales were taken from ICCT Roadmap (2017). The historical numbers for the share of vehicles per fuel type was broken down using ICCT (2012b) given this detail was not available in the updated 2017 modelling. This approach excluded PHEVs and BEVs, which were taken from IEA (2020a) for a more accurate representation of latest historical years. Under the pre-COVID policy scenario, projections for BEVs reaches a 20% market share in 2030 and 50% in 2040 based on IEA (2019a) and BNEF (2017) respectively. A 10-year trend is extrapolated to 2050. We assumed conventional vehicles sales phase out in the following order: petrol, diesel, CNG/LNG, while PHEV petrol and PHEV diesel vehicles grow at the same rate as BEVs until the phase out of the first conventional vehicle type. In this scenario, petrol vehicle sales are phased out completely by 2045 and BEVs reach a market share of 80% by 2050. Both the market share of BEVs and absolute number of BEVs in our scenarios are in line with other scenario exercises, such as in Energy Foundation China (2020).
LDV fleet stock	Share (%) and stock of total fleet per vehicle fuel type	The total fleet was established as 281 million vehicles for 2020, based on numbers cited by the Ministry of Public Security (Finance Sina, 2021). Historical numbers were extrapolated backwards based on the growth rate of sales from IEA (2020a) and ICCT (2017). Stock numbers for BEVs and PHEVs were also directly cited from the ministry, while the share of the remaining fleet were distributed to vehicle types based on the ratio of sales per type in 2010, assuming an average retirement lifetime of 10 years for LDVs. Projections per vehicle type was calculated as a sum of the stock from previous year and the new sales from the current year, with the additional assumption that 10% of the existing stock from 10 years prior is retired annually.

Category	Indicator	Data and assumptions
LDV activity	vkm travelled by new cars and total fleet	Historical and projected total vkm travelled by LDVs are taken from ICCT (2017) modelling and divided by the total LDV fleet numbers above to establish the average vkm travelled per LDV per year. Total activity vehicle fuel type was then derived for both new and existing LDVs, assuming each type on average travels the same distance per year. While this assumption can be challenged, particularly for BEVs in the short-term, the differences in results are minor until the share of BEVs in the stock grow in the long-term. It is thus also assumed that improvements in car battery technology as well as intracity and intercity charging infrastructure improve to accommodate the distances required to be travelled by (BEV) passenger cars.
LDV emission intensity	Carbon emission intensity and electricity intensity per vkm travelled per fuel type, for new and existing vehicles	Historical and projected developments in average emission intensities per fuel type for the existing fleet is taken from Climate Transparency Initiative (CTI) until 2030, except for PHEV and BEV vehicles (ClimateWorks Foundation, 2018). CTI (2018) is also based on various sources, such as IEA Mobility Model (2017b), ICCT (2017), BNEF (2017), IEA Energy Technology Perspectives (2017a), and Purohit et al., (2017). Post-2030 developments for these fuel types follow different assumptions given the limited time series of CTI until 2030. We assume the emissions performance of the petrol vehicle stock in 2050 to be on average reach the best-in-class levels of today (i.e., vehicle fleet are efficient and lightweight models). Petrol cars in 2050 linearly reach the benchmark of 110 gCO2/km, based on the CO2 performance of new efficient models from large manufacturers (e.g., Toyota, Peugeot) (European Environment Agency, 2021). In this case, the rate of technological efficiency improvements in petrol vehicles are faster pre-2030 and slower post-2030, which we find plausible due to the continued displacement from NEVs. We do not make explicit assumptions deviating from the trend for emission intensity improvement of diesel vehicles, as they occupy a minor share of the LDV fleet and are thus likely a lesser priority for innovation. We assume it follows a 10-year historical trend of minor improvements to 2050. LPG and CNG cars follow the growth rate of ICCT (2012) until 2050 , which assumes virtually no improvements. Their modal share in the LDV fleet is around 1%. As CTI (2018) had no data readily available for the average emission intensities per fuel type of new vehicles, historical numbers were harmonised by multiplying CTI emission intensities of the existing fleet with the ratio of emission intensity improvements between existing and new vehicles from ICCT (2012a). For emission intensity indicators, we preferred harmonisation to CTI (2018) numbers due to better capture of recent technology and policy trends. It is then assumed conservatively that the emission intensity of new vehicles improved at the same rate of the existing fleet. By 2050, new vehicles were 8% to 12% more efficient than the existing fleet average. Emission intensities for PHEVs were calculated by applying a utility factor (i.e., what % of vkm travelled were with electricity vs fuel). The portion of annual vkm travelled with conventional fuels for new and existing vehicles used emission intensities established above, while the emissions resulting from vkm travelled on electricity is calculated through the approach below (see Electricity supply). We apply the utility factor of 50% in this analysis, based off the global average from ICCT (2020). We use the global average rather than the 26% utility factor cited for China in the report, as we assume the factor will improve in the short-term through the expansive EV and transport logistics infrastructure and policy being planned in the country. Emission intensities for BEVs also utilised the electricity calculations described in (see Electricity supply).
Electricity supply	Electricity generation and emissions, and electricity emissions intensity	Electricity emission factors for the high- and low- carbon intensity pathways are established from power sector emissions and electricity generation from the Fossil Electricity (high intensity) and Renewable Electricity (low intensity) from the IEA WEO (2019b) and (2020c) respectively until 2040. The growth rate from 2040-2050 is extrapolated with the recent 10-year trend.

The Pre-COVID, Policy, and 100% BEV scenarios build off the data and time series methodology summarised above, and explore the emission impacts due to different developments of market shares for NEV. Differences in market shares affect the stock of individual vehicle fuel types for both new vehicle and existing fleet stocks, indirectly affecting the activity levels, energy demanded, and emissions from vehicles. We assume that the variation in new vehicle penetration does not affect the overall number of cars sold, cars in the existing fleet, the total activity level of the entire fleet, or the average emission intensity of an individual vehicle fuel type, per year. Each scenario contains an emissions range to reflect the possible carbon intensity pathways of the power sector in supplying electricity for BEVs and PHEVs.

The **Pre-COVID-19 scenario** utilises the data setup and methodology described in Table 1, with no further modifications. In the **Current Policies scenario**, the market share of new vehicles over time increases at a more ambitious rate as additional post-COVID policies are integrated in the modelled projections. The scenario also includes the targets discussed in the updated auto industry roadmap described above. The market share of this scenario for BEVs reaches 35% in 2030, 47.5% in 2035, and 70% in 2040 (BNEF, 2020; IEA, 2020a; Tabeta, 2020). It is assumed that sales of all conventional vehicles are completely phased out in 2040 (market consists of PHEVs and BEVs), and the market share of BEVs reaches 100% in 2050 due to trends leading to 2040. This phaseout trajectory if accomplished would be considered Paris-compatible for China (Climate Action Tracker, 2020a). The **100% BEV scenario** explores the emissions impact if the discussed policy increases targets to aim for a market share of BEVs reach 100% in 2035. All other vehicle types linearly decrease to zero sales from 2020 to 2035.

Economy-wide Current Policies projection

Energy-related CO_2 emissions:

We create two scenarios for energy-related CO¬2 emissions, a minimum and a maximum scenario.

For the high emissions scenario (higher bound), we start with the WEO (2019b) Current Policies scenario, which meets China's 58% cap on coal in the primary energy supply in 2020 and exceeds the 15% non-fossil share component of China's 2020 pledge. However, these projections do not achieve several prominent targets:

- 20% non-fossil share in 2025 (missed by 3%);
- 10% gas in primary energy supply in 2020 (missed by 3%), and 15% in 2030 (missed by 5%);
- 50% renewable energy capacity by 2025 (missed by 2%); and
- 35% electricity generation from renewables in 2030 (missed by 1%)

The high emissions scenario is adjusted to meet all the above targets, revising the emissions pathway downward. Most of these targets are newly-quantified due to the fact they are new policies (e.g. 14th FYP) or because we had previously deemed them implausible (e.g. 15% gas in TPED in 2030 seemed unlikely before high-level targets to reduce coal). In the projections gas is assumed to replace coal 1:1, as coal-to-gas switching is seen to be primarily driven by industry and buildings sectors, rather than in the power sector (Cornot-Gandolphe, 2019). While many targets have updates forthcoming or already in drafting stage, we only adjust for policies already implemented.

The scenario does not pass China's cap on total primary energy demand (TPED) targets of 5 billion tonnes coal equivalent in 2020 and 6 billion tonnes in 2030, but we choose not to quantify this as it is unlikely China achieves both this target and its gas targets. Under this scenario, energy-related CO_2 emissions continue to increase, reaching 10.1 $GtCO_2$ in 2030. For CO_2 emissions from fuel combustion, values in the IEA WEO 2019 Current Policies scenario were adjusted using the primary energy factors for renewable energy and nuclear power used in the Chinese accounting (different from IEA accounting).

For the minimum scenario, we adjust electricity capacity and generation outlook for renewables to the Stated Policies Scenario from the China Renewable Energy Outlook 2020 (CREO) (ERI and NDRC, 2021). As in the maximum scenario, we adjust the primary energy supply to meet current policies, although the CREO already meets all targets aside from the gas and total consumption targets.

This scenario exceeds China's proposed target of 35% electricity generation from renewables in 2030, reaching 44% in 2030. This is comparable to other modelling scenarios where China reaches a 37% share in 2027 (BloombergNEF, 2019). The scenario also reaches 24% non-fossil share in 2025 and 51% of renewable power capacity. Thus, the scenario is adjusted to meet the gas targets only. Coal consumption begins to decrease after 2025 in both ranges of Current Policies scenarios.

Industrial-process emissions:

We project industrial-process CO_2 emissions by applying growth rates from cement process emissions for the non-OECD region based on the IEA Energy Technology Perspectives 2016 report's 6DS scenario to our latest 2020 value estimates.

Other non-CO_2 emissions:

For non-CO_2 emissions from energy, fugitive emissions, agriculture, industrial processes, and waste, we apply sector-specific growth rates for non-CO_2 emissions from Lin et al., (2019) to our latest 2020 value estimates. This source considers recent policies implemented since 2015, leading to improved certainty on Chinese non-CO_2 emissions in 2030, compared to previous assessments. The reference scenario used assumes that no non-CO_2 mitigation measures will be implemented before 2050, except for efforts made to reach the Montreal Protocol targets for HFCs from HCFC-22 production, which are phased out. Other HFCs are assumed to grow without further implemented policies.

COVID-19 effect

In mid-2020, We applied a novel method to estimate the COVID-19 related dip in greenhouse gas emissions in 2020 and its impact until 2030. The uncertainty surrounding the severity and length of the pandemic creates a new level of uncertainty for current and future greenhouse gas emissions.

For emissions between 2020 and 2030, we first update the Current Policies projections using most recent projections, usually prepared before the pandemic. We then distil the emission intensity (GHG emissions/GDP) from this pre-pandemic scenario and apply to it most recent GDP projections that consider the effect of the pandemic. To capture a wide range, we usually use more than one GDP projection. For China, we have updated the following projections for 2021 GDP growth using China's national 2021 GDP target of 6% (Zhou, 2021), IMF's (2021) 8.4%, Oxford Economics (2021) 8.9%, and Bloomberg Economics (2021) 9.3% projections. The most recent GDP projections only provide values until 2026 (IMF); we then use the GDP growth rate that was used as a basis for the original pre-pandemic Current Policies scenario (WEO) until 2030.

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