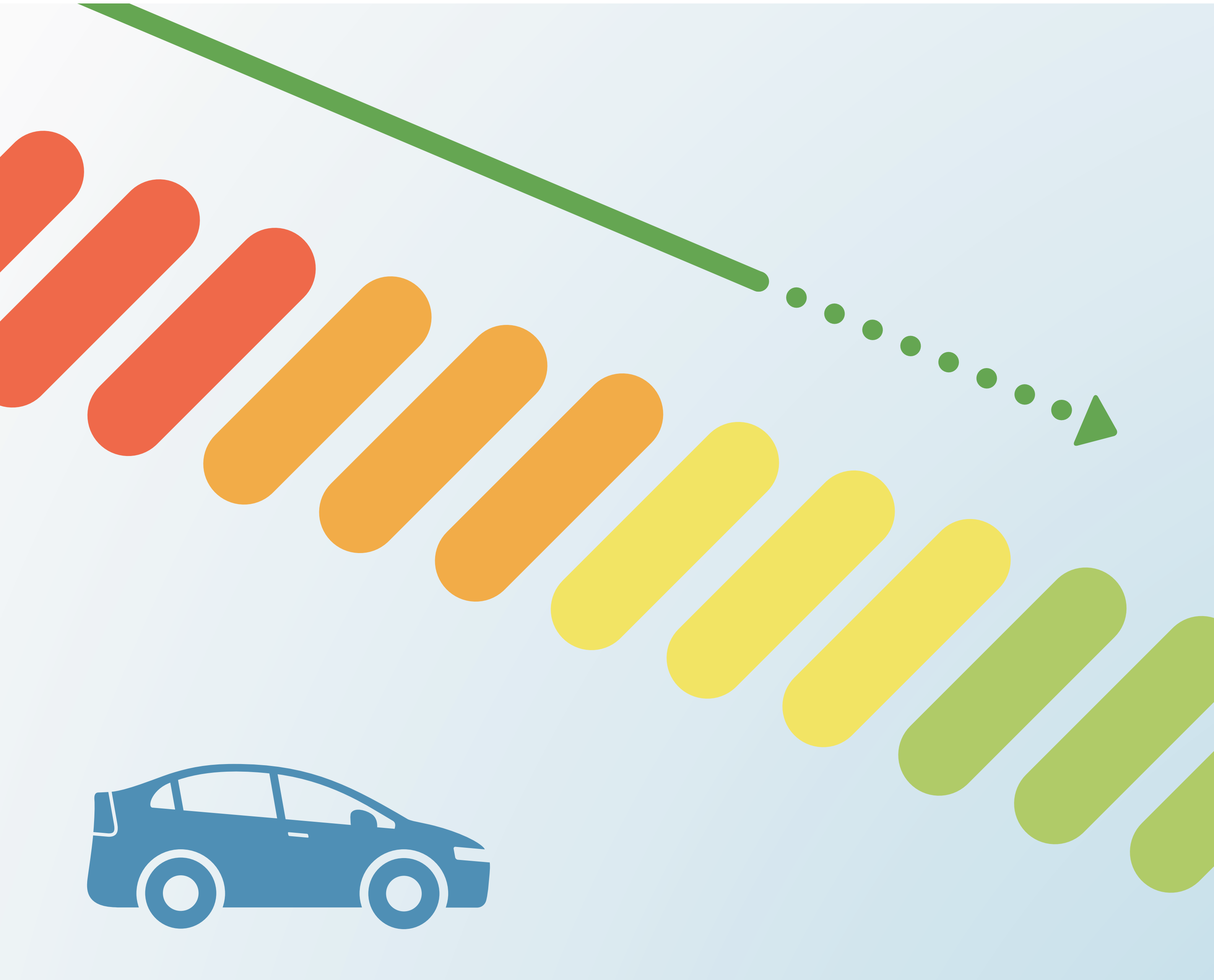
Climate Action Tracker



Climate Action Tracker

Decarbonising light-duty vehicle road transport

Paris-aligned benchmarks for the transport sector

October 2024

CLIMATE ANALYTICS

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Summary

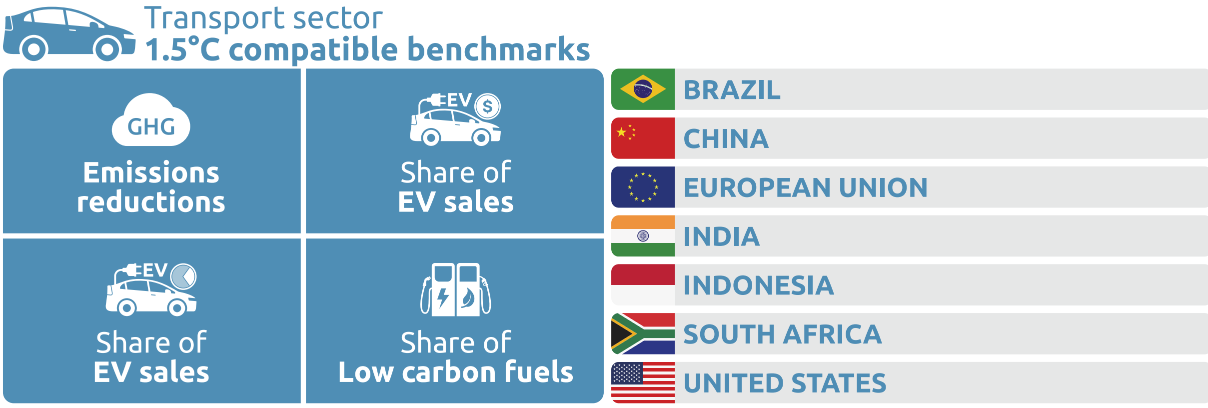
The broad strokes of a Paris Agreement-aligned roadmap are clear: we need to roughly halve emissions by 2030, achieve net zero CO2 emissions by 2050 and net zero greenhouse gas emissions soon after. However, the details at the national and sectoral level are often still unclear.

Transport demand and associated emissions continue to grow around the world. The mass electrification of light-duty passenger vehicles will play a major role in cutting road transport emissions, which represent 72% of total transport sector emissions.

Developed countries and China are the largest global emitters of GHG emissions and given their wealth and advanced EV industries, will need to do most of the heavy lifting in the global EV market and stock transition.

While positive signs can be seen in some countries, greater effort will be needed to accelerate EV market and fleet penetration. If current uptake rates continue, EV sales could well be on track to reach 90% by 2030 (Boehm et al., 2023), but continued and additional policy support will be needed to ensure that this growth continues and targets are reached.

However, national governments will need to raise their 2030 EV targets to be 1.5°C compatible. Internal combustion engine (ICE) vehicles are still being sold, posing a growing problem for the future as stranded assets that will need to be removed from the roads.



In this report, the Climate Action Tracker (CAT) provides updated 1.5°C compatible benchmarks for the transport sector, building on the CAT's previous 2020 benchmark report (Climate Action Tracker, 2020a), for the world as a whole and for seven individual countries; the US, EU, China, India, Brazil, South Africa and Indonesia.

Our new benchmarks show how the share of EV sales, and EV stocks needs to evolve out to 2050, and what this means for emission reductions in the light-duty vehicle sector.

We also provide a benchmark on the share of low and zero emission fuels in the whole domestic transport sector. This will be crucial for understanding the scale and pace of transition needed by countries to transition their fuel systems, and highlights the need to phase out fossil fuels in the transport sector.

The CAT finds that, to align with 1.5°C, the world should reach 100% EV sales by 2035

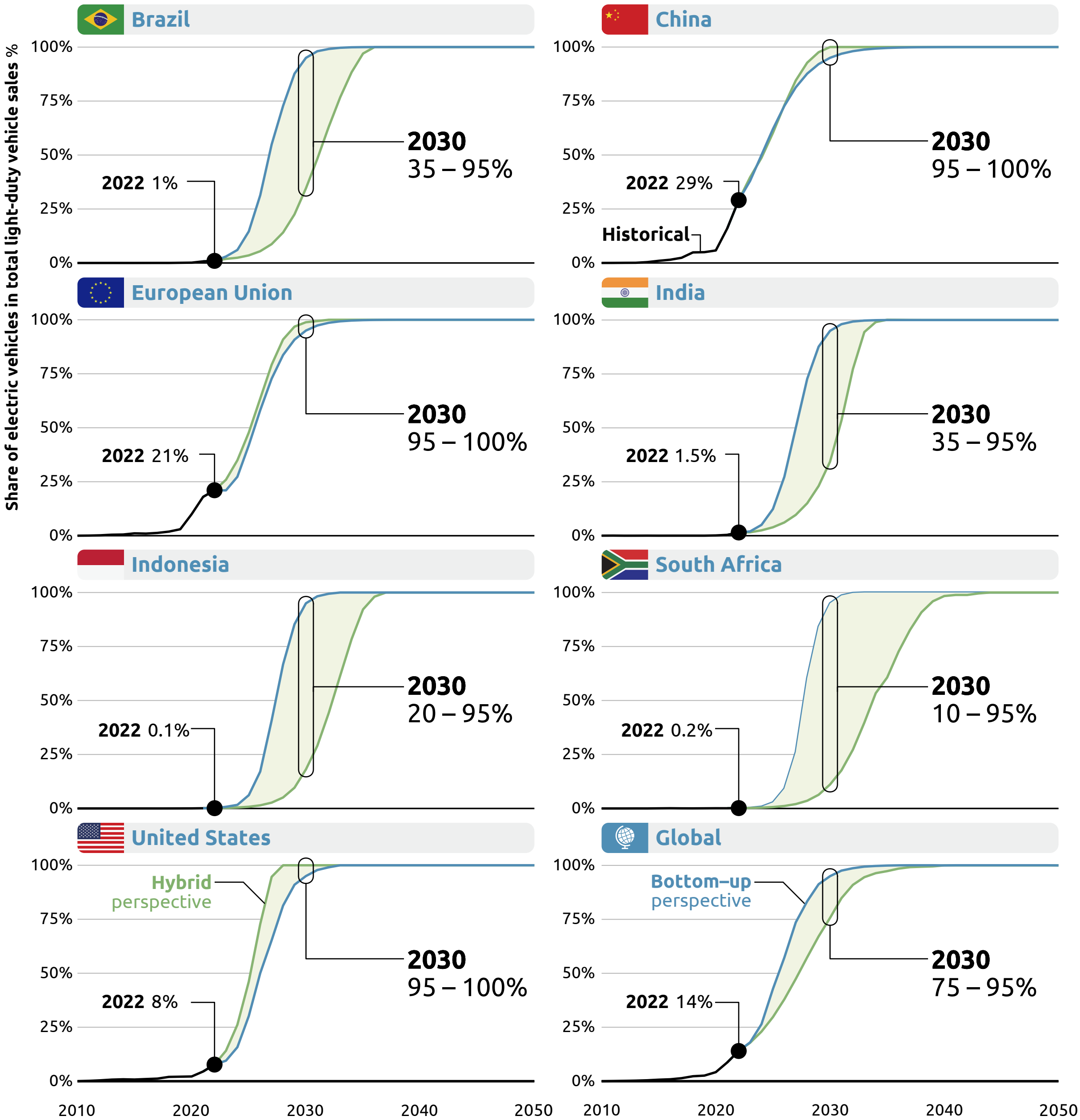
Globally, electric vehicles should achieve 75-95% of the light-duty vehicle market by 2030 and 97-100% by 2035.

Developed countries and China should take the lead, phasing out the sale of internal combustion vehicles as early as 2030.

While the pace of action could be slower in developing countries than in wealthier nations, developing countries should still aim to achieve 100% EV sales share by 2040 at the latest.

Developed countries must achieve close to 100% of light-duty vehicle sales by 2030 and global market must reach at least 75%

Country-level 1.5°C compatible benchmarks for share of light-duty electric vehicle sales in national vehicle markets



Even if countries were to achieve 100% EV sales as soon as possible, it will not be enough to make the necessary emissions reductions without also taking aggressive measures to scrap or retire existing fossil fuel cars — or take them off the roads. In some countries, **the annual retirement rate of ICE vehicles would need to roughly increase by a factor of seven in 2040 compared to historical retirement rates**.

Worryingly, in 2023, half of new car sales were large resource and emission intensive SUVs. In the US, resource demand for EVs would be higher than in other countries due to the popularity of large SUVs. In Europe, passenger cars are becoming bigger and heavier, catering to new consumer preferences. This will prove challenging to meet their EV demand if fewer resources are available to manufacture them.

While not quantified here, increasing electric vehicle production and sales will put more pressure on critical material resources. Encouraging smaller, less resource-intensive electric vehicles and reduced overall demand for private vehicles through alternative transport modes will be essential to curbing the demand for critical minerals, helping ensure that supply chains can scale in a sustainable manner to meet demand. While this report focuses on light-duty vehicles, the CAT is clear that fewer cars, as well as electrifying the remaining fleet, will be essential for limiting warming to 1.5°C.

To achieve these targets, governments will need to implement cross-cutting policies for EVs, their infrastructure necessary to support them, and alternative zero emission public transport to lay the foundations of a zero-carbon future for all.

While all governments need to act, the US, EU and China will need to take the lead globally as these countries have some of the highest transport emissions and are also equipped with the established markets and resources to scale up EV transition this decade as early movers.

They will need to increase action toward decarbonising national grids through the deployment of more renewable energy to fuel the forthcoming demand for electric vehicles, **coupled with a clear commitment to end the sales of traditional fossil fuel vehicles by 2035 and remove current vehicles from their national fleets**. Further policy interventions from governments to incentivise EVs, while disincentivising the sale and use of ICE vehicles and expanding EV changing infrastructure will come at a high cost.

This has hindered the EV transition in lower income communities and developing countries, but in the long term has the potential to increase competitiveness, improve air quality and come closer to achieving a net zero future. To this end, **developed country governments should account for equity and fair considerations to support the transition to EVs and zero emission fuels in developing countries so that no one is left behind.**

In recent months, the politics surrounding the global EV trade has shifted. In May 2024, the United States increased tariffs on imported Chinese EVs from 25 % to 100 %. The European Union has also recently decided to move forward with setting their own tariffs on imported Chinese battery EVs sold within Europe, with duties ranging between 17.4 % and 37.6 %. The justification behind these tariffs from the US and EU is to counter the subsidies provided by the Chinese government to their domestic manufacturers, which the EU and US claim go against WTO rules and create an unfair playing field for US and EU auto manufacturers. How this will play out over the coming years is uncertain, but there is a risk that this could slow EV adoption within the US and EU by raising prices, despite the global need for rapid, affordable EV growth to meet climate goals.

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1 Introduction

Transforming transportation systems will be a central pillar of the zero-carbon transition. The transport sector represents about 15% of global greenhouse gas (GHG) emissions, of which 72% comes from road transport (or 10% of global GHG emissions) (Boehm et al., 2023). Cutting emissions from the transport sector is therefore essential.

At the core of this transition will be accelerating the shift away from traditional vehicle fleets to electric vehicles (EVs), which have zero tailpipe emissions. To achieve this, market sales will need to increase significantly. Increased EV sales will need to be complemented with additional actions to further cut light-duty vehicle (LDV) emissions in line with 1.5°C. This includes:

- Rapidly decarbonising the power grid, which supplies electricity for EVs;
- Increasingly removing existing internal combustion engine (ICE) vehicles from current national vehicle stocks.;
- Reducing total distance travelled by private vehicles by reducing the demand for vehicles, increasing car-sharing, and shifting passenger travel to other modes of sustainable transport;
- Improving energy and carbon intensity of EVs and ICE vehicles (i.e. improved fuel economy).

In this report, the CAT explores what a 1.5°C aligned transport sector transition would require. We provide benchmarks for the future shares of electric vehicles in LDV sales and LDV fleet stocks, and the emissions reductions from the LDV fleet relative to 2020. Light-duty vehicles (LDVs) refer to passenger and light commercial duty vehicles.

Our analysis only looks into passenger light duty vehicles (LDVs). We also provide the share of zero and low emission fuels in the total domestic transport sector (i.e. including road, rail, aviation and maritime navigation but excluding international aviation and shipping). These benchmarks can help individual countries align their transport sector transitions with a 1.5°C temperature limit goal.

We assess the current status of the transport sector transition, specifically for light-duty vehicles , analysing the pace of EV market and fleet penetration.

This report defines global benchmarks as well as national benchmarks for seven countries; the USA, EU, China, India, Brazil, Indonesia and South Africa. Countries are categorised as developed vs. developing along Annex I / non-Annex I lines. For China, India and Indonesia, two-wheeler vehicles are included in the benchmarks as they are dominant in these national vehicle fleets.

1.1 Approach

This report uses two main lines of evidence to define benchmarks for the share of EVs in total LDV sales and total LDV stocks, as well as the corresponding emission reductions.

The lower range of the benchmarks is defined by the hybrid top down - bottom up optimisation FLEX model. In this model, LDV emissions, energy demand and passenger kilometres at the global and country level are constrained to 1.5°C compatible levels using data from global integrated assessment model (IAM) pathways. A bottom-up vehicle stock turnover model is then parameterised to fit these top down constraints, and from this the EV sales and stock dynamics are calculated.

In our hybrid approach, the top down IAM pathways are taken from the IPCC AR6 assessment report, filtered for Paris-compatibility and sustainability constraints (Climate Analytics, 2023b). Filtering resulted 24 pathways meeting 1.5°C compatibility constraints. However, for the EV sales and stock share benchmarks, not all the 24 pathways provided the necessary data on the LDV subsector to enable their use in the LDV benchmarks. As a result, the CAT has selected these two illustrative pathways for analysis. These two pathways are both part of the wider set of 24 pathways which are used later to provide benchmarks on the share of zero-carbon fuels in the transport sector.

The alternative range of the EV benchmarks are defined by a bottom-up EV model derived from the PROSPECTS tool as presented in the Climate Action Tracker's 2020 sectoral benchmarks report

(Climate Action Tracker, 2020a). This EV model is an S-curve model constrained by historical data and the target of a fully electrifying the light-duty vehicle fleet by 2050. Additional assumptions regarding the retirement age of fossil-fuel powered vehicles constrain the year for ending sales of fossil fuel powered vehicles.

For our benchmarks on the share of zero emission fuels in domestic transport, we take the collective share of electricity, hydrogen and biofuels directly from the full set of 24 IAM pathways. Unlike with the other indicators for EV sales and stock share, which only could use two pathways due to limited available data, the data on the share of zero emission fuels indicator were available across several IAM pathways. We present the 50th percentile of the 24 pathways as representing the lower range of the benchmarks and the 95th percentile to represent the upper range.

For a more detailed explanation of the methodology refer to the Climate Action Tracker Methodology for 1.5°C compatible sectoral benchmarks.

1.2 Pathway narratives for EV sale and stock benchmarks

Benchmark lower range: FLEX Model

To provide the top-down constraints for the stock turnover model, two illustrative pathways from the REMIND-MAgPIE model were selected; the Sustainable Development Pathway and the SSP1 Minimal CDR pathway (Soergel et al., 2021; Strefler et al., 2021). Both pathways provide narratives of how global efforts to reduce emissions in line with 1.5°C can unfold, and are compatible with reaching net zero GHGs before 2100. These selected pathways represent the top down element of the hybrid FLEX model, providing the overall constraints on emissions, energy demand and passenger kilometres which guide the emission reductions pathway of the bottom-up model.

The selected pathways emphasise shifts to more sustainable consumption patterns, rapid development, and the promotion of less energy-intensive lifestyles, as both use the 'SSP1' socio-economic pathway (van Vuuren et al., 2017).

The pathways also have some differences in global narrative. The Sustainable Development Pathway focuses on achieving the Sustainable Development Goals alongside limiting warming to 1.5°C. Most importantly for this report, in the Global North there are significant reductions in transport demand per capita to facilitate increased space for transport demand growth in the Global South.

Meanwhile the Minimal CDR pathway focuses on minimising CDR reliance across the energy system, and therefore exhibits deeper cuts in fossil fuel usage than other pathways. However, while there are deeper overall cuts in fossil fuels than in the Sustainable Development Pathway, this is not particularly observable in the LDV fleet (where emissions fall to zero around mid-century in both pathways).

These two IAMs emission pathways are used as a top down constraint in the FLEX bottom up model, which calculates the vehicle stock turnover of a country and the resultant emissions. Optimisation variables are used to adjusted the stock turnover model, and therefore the EV fleet size calculations, to produce emission pathways that align with the top down IAMs emission pathways. The final benchmark from this hybrid FLEX model approach takes the average of the outputs from both of the selection IAMs pathways.

2 Results: the roadmap to clean transport

2.1 Emission reductions from light-duty vehicles

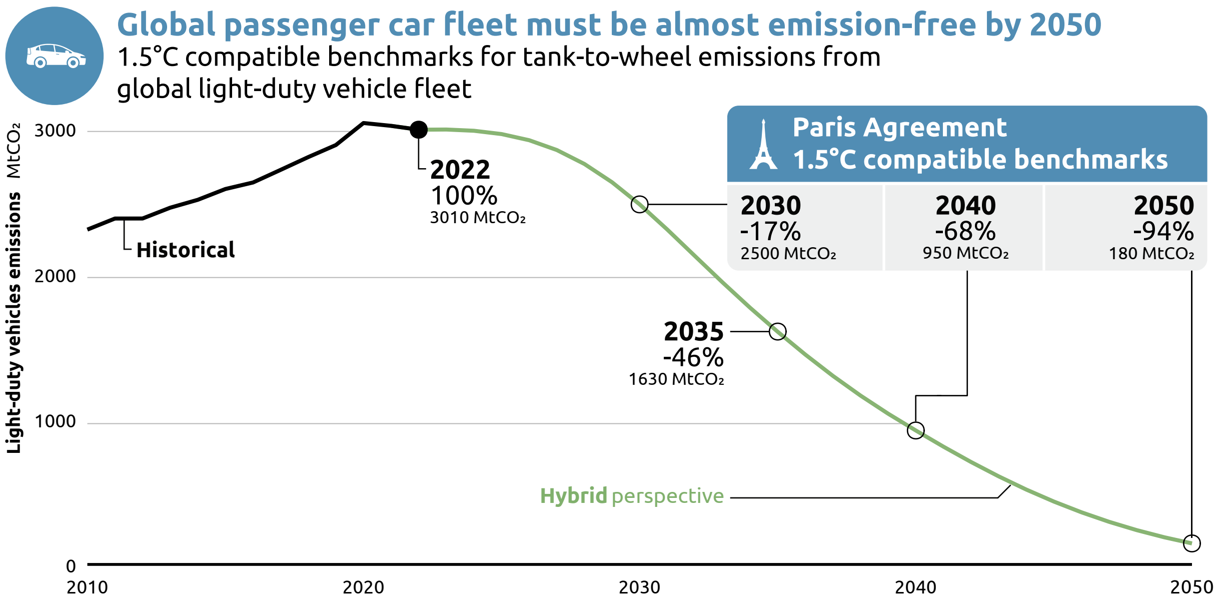

Figure 1: 1.5°C compatible tank-to-wheel emissions pathways for global light-duty passenger vehicle fleet.

These results represent the average calculated emissions fitting the selected top down IAM derived pathways in the hybrid FLEX model.

Road transport accounts for 72% of total transport emissions, for which light-duty passenger vehicle make up the majority (Boehm et al., 2023). Globally, the tank-to-wheel emissions (i.e. tailpipe emissions directly from cars) from light-duty passenger vehicles reached 3.1 $GtCO_2$ in 2022. The well-to-wheel emissions, which include power sector emissions for the electricity demand of electric vehicles, is roughly the same as tank-to-wheel emissions because the present fleet is predominantly made up of internal combustion engine (ICE) vehicles running on fossil fuels.

We present the expected emissions reductions computed by the hybrid FLEX model, which generally represented the lower range (i.e. more conservative) benchmarks. Emission reduction pathways could not be extracted from the bottom-up EV model, however the model assumes that by 2050 emissions reductions will be 100% and therefore more ambitious than the FLEX model.

Our 1.5°C compatible benchmarks for emissions from the LDV fleet show that global LDV emissions need to peak around 2024 and fall fast in this sector to limit warming to 1.5°C. This was also found to be the case in other recent analysis (ICCT, 2023a). By 2050, tank-to-wheel emissions from the global passenger vehicle fleet must be almost emission free and fall by at least 94% from 2020 levels (Figure 1). Emissions would need to roughly halve by 2035.

By 2030 global tank-to-wheel emissions need to fall by at least 17% below 2022 levels (Table 1). In the near-term these reductions are driven primarily by developed countries as they rapidly decarbonise their fleets (Figure 2). Decarbonising these fleets may come with mass electrification of transport and promoting greater modal shifts to more shared transport. With more EVs in the fleet, the well-to-wheel emissions accounting for EV electricity consumption would fall by 16% in 2030 compared to 2022 levels.[1] This 2% gap between the relative reductions in tank-to-wheel and well-to-wheel emissions stem for the carbon intensity of the power grid powering EVs (see Table A1). For transport to fully decarbonise, the power sector must also rapidly move away from fossil fuels (Climate Action Tracker, 2023a)

1 It should be noted that while the IAMs model produce pathways for the tank-to-wheel emissions for the transportation sector, the model envelope accounts for the upstream emissions (i.e. the electricity demand emissions) under the power sector – so the full scope of emissions are accounted.

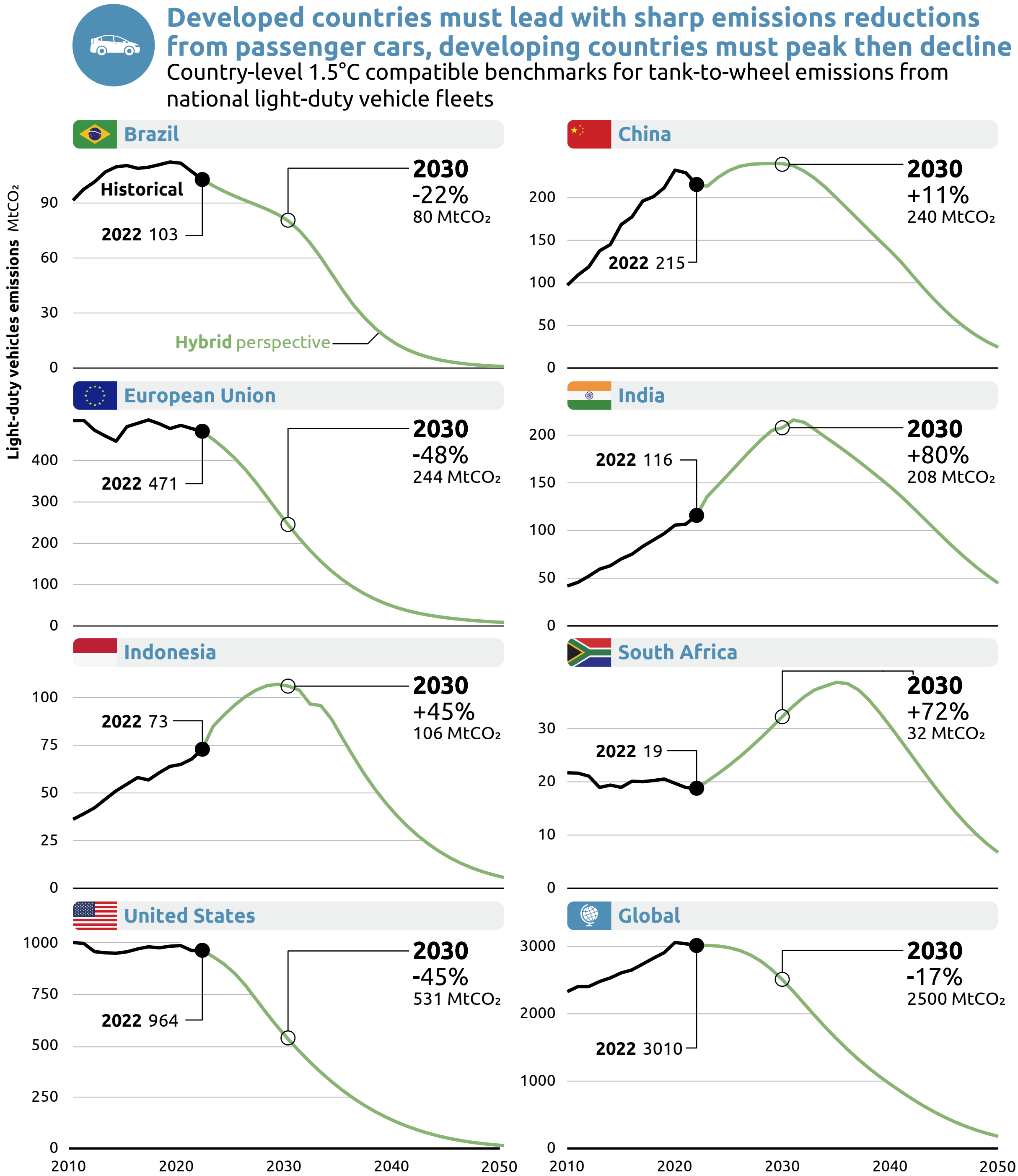

Figure 2: 1.5°C compatible share of coal in global electricity generation

Under 1.5°C compatible benchmarks for the power sector, all countries should reach 0 gCO_2/kWh emissions intensity of their power grid by 2040 (Climate Action Tracker, 2023a). As a result, this 2% gap in emissions between tank-to-wheel and well-to-wheel emissions disappears as early as 2030 in most countries. EVs already have lower lifecycle emissions than ICE cars, even with the current electricity mix in most countries (Knobloch et al., 2020). As renewables continue to grow their generation share, the emissions benefit of EVs will continue to grow.

By 2050, well-to-wheel emissions need to fall by at least 94% from 2022 levels, according to the hybrid FLEX model (see Appendix). Remaining emissions in 2050 are likely due to the small proportion of remaining internal combustion cars in the fleet. However, these represent a very small proportion of the overall fleet, that would be rapidly replaced in the years following 2050. In the bottom-up EV model, well-to-wheel emissions fall 100% by 2050, as all ICEs are fully replaced. In both perspectives,

Table 1: 1.5°C compatible national and global emission reductions for light-duty passenger vehicle tank-to-wheel emissions

Emissions reductions from only the FLEX model (i.e. lower range of all benchmarks), presented as the average of the selected 1.5°C compatible pathways. Historical 2022 emissions taken from FLEX model estimate. China, India and Indonesia include two-wheelers.

1.5°C compatible benchmarks for light-duty vehicle emission reductions					
Country	**2022**	**2030**	**2035**	**2040**	**2050**
Brazil	103 MtCO2	-22%	-58%	-87%	-99%
China	215 MtCO2	11%	-7%	-36%	-89%
EU27	471 MtCO2	-48%	-76%	-90%	-98%
India	116 MtCO2	80%	64%	26%	-61%
Indonesia	73 MtCO2	45%	8%	-47%	-92%
South Africa	19 MtCO2	72%	106%	62%	-64%
United States	964 MtCO2	-45%	-71%	-87%	-99%
Global	3012 MtCO2	-17%	-47%	-69%	-94%

it is clear that emissions from the LDV fleet need to fall to zero by or soon after 2050, as the age of the internal combustion engine comes to a close.

Light-duty vehicle emissions are expected to begin decreasing globally, most rapidly in developed countries. In developing countries, light-duty vehicle emissions are anticipated to continue rising before reaching a peak and subsequently dropping rapidly before 2050. From the FLEX model's stock turnover perspective, increasing the ICE retirement rate was shown to be a major driver to achieving these emission reductions.

The timing of peak transport emissions varies by country and pathway; for instance, in China, it may occur as late as 2030, while in India, it could be as late as 2040. This delay in emission peaking stems from the fact that both countries have large vehicle fleets to electrify. Despite China's rapid progress in EV sales and shrinking share of ICE vehicle sales, the projected stronger in the total fleet in the coming years will still result in growth of ICE vehicles, and therefore the total fleet emissions.

Even if full EV market penetration is achieved as early as possible, the dominant ICE vehicle fleet will remain in the stock longer as the countries continue to develop. From the top down perspective, the IAMs are assuming that more leeway is given in the Global South to facilitate increased space for transport demand growth in the Global South.

Based on our lower range benchmarks for EV stock share derived from the FLEX model, the US, EU, Brazil, and Indonesia may achieve zero tank-to-wheel emissions by 2050. While not an output of the bottom-up EV model, the EV model does assume that every country reaches zero emissions by 2050 representing a higher reduction benchmark of 100%.

Reducing emissions will involve increased electrification of fleets, alongside measures such as improving fuel standards through policy interventions. While many countries already have regulatory measures in place, others have yet to introduce them.

Additionally, promoting a shift towards shared modes of transport, such as high-speed rail and active transportation, will be crucial (Boehm et al., 2023). Our bottom up model scenarios indicate that to align with 1.5°C compatible pathways, measures to retire or replace internal ICE vehicles will be necessary. Based on the bottom up scenarios used, in some countries ICE retirement rates will need to increase by as much as seven times current levels by 2050.

From a policy perspective, governments would need to explore ways to take ICE vehicles off the roads, such as through financial incentives or disincentive schemes, tied with higher emissions standards. This illustrates the financial burden that ICE vehicles will have in the future for governments and car owners, which further supports a phase-out of fossil fuel car sales as early as possible.

2.2 Share of EV sales (percentage of vehicle sales)

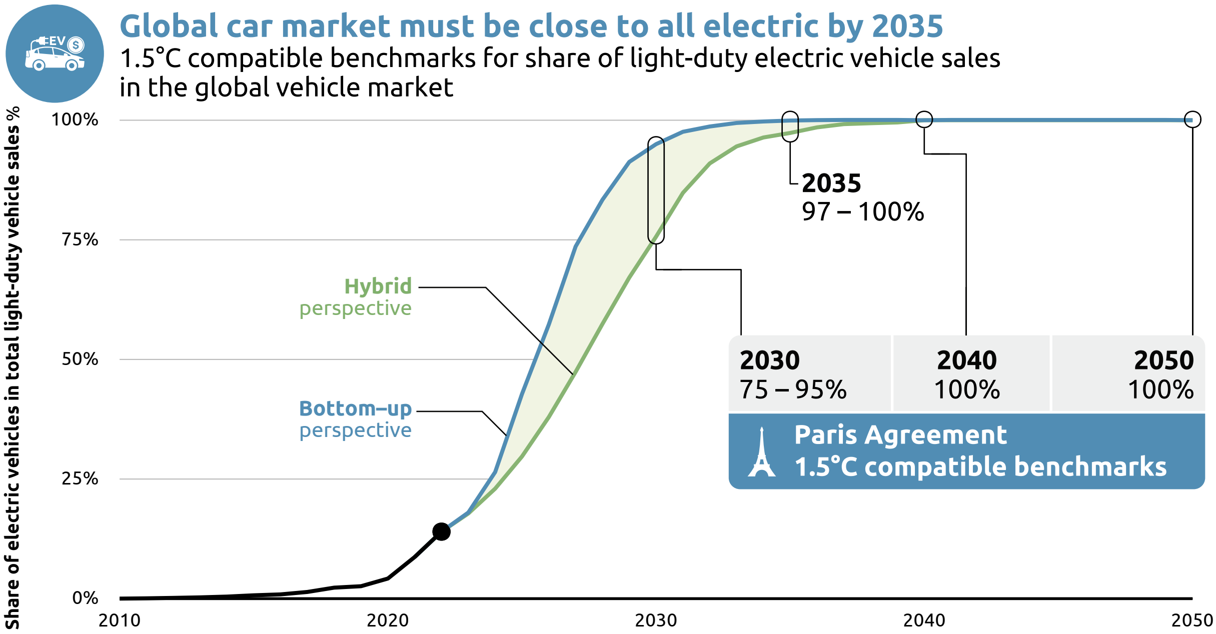

Figure 3: 1.5°C compatible share of light-duty electric vehicle sales in global vehicle markets

*Benchmark ranges from hybrid FLEX model (as an average of the two IAM pathways) and bottom-up EV model. *Historical data from IEA EV Data Explorer 2022*

An accelerated uptake of electric vehicles will be essential to cut emissions in the transport sector. To align with the Paris Agreement 1.5°C limit, the world must phase out the sale of ICE passenger light-duty vehicles completely by 2040, with EVs reaching close to 100% of market share in 2035 (Figure 3). By 2030, EV sales would need to represent 75 – 95% of the global vehicle market.

EV sales have rapidly increased in the past years. Of the 78 million passenger vehicles sold in 2023, EVs accounted for 18% of global vehicle sales (IEA, 2024b) and there is no signal that this is slowing down.[2] Many countries are demonstrating the feasibility of rapid rollout of EVs.

Developed countries were early movers in the EV market and some now have some of the highest national EV sales shares, (Jaeger, 2023b). However, developing countries are catching up and have experienced rapid growth in their EV markets. Taking the average growth rate in sales between 2015 and 2022, EV markets are booming faster in emerging and developing economies. South Africa, Brazil, India and China are experiencing the fastest annual gross sales with 218%, 162%, 118% and 85% average annual growth rates respectively (IEA, 2022) compared to developed countries like the USA and the EU with only 37% and 64%.

A key barrier to scaling up EV sales has been the high upfront costs. Positively, the cost of EV batteries could halve this decade from $151 per kWh to $60-90 per kWh, increasing the cost competitiveness with fossil combustion vehicles. Purchase price parity of EVs is expected to be reached by 2031 across all markets (RMI, 2023), and has already been achieved in Chinese markets (IEA, 2023). This will be a critical development to accelerate the uptake of EVs.

All countries reach 100% EV sales between 2030 and 2040 in 1.5°C compatible pathways (Table 2). In the hybrid FLEX model, China, the EU27 and the US lead the race to zero-carbon transport by reaching 100% EV sales by 2030.

India and Brazil reach this milestone by 2035, but with strong growth by 2030. Our results from the FLEX model allow for slower EV market growth in South Africa and Indonesia compared to other countries, but both will still need to reach about 100% EV sales in 2040. Meanwhile in the EV model, all regions reach 95% EV sales by 2030, and 100% EV sales by 2035 (see Appendix for model specific results).

2 Battery electric vehicles remain the most popular type of zero emission vehicle (ZEV), where other definitions also include plug-in hybrid and hydrogen fuel cell EVs (BNEF, 2023b).

Developed countries must achieve close to 100% of light-duty vehicle sales by 2030 and global market must reach at least 75%

Country-level 1.5°C compatible benchmarks for share of light-duty electric vehicle sales in national vehicle markets

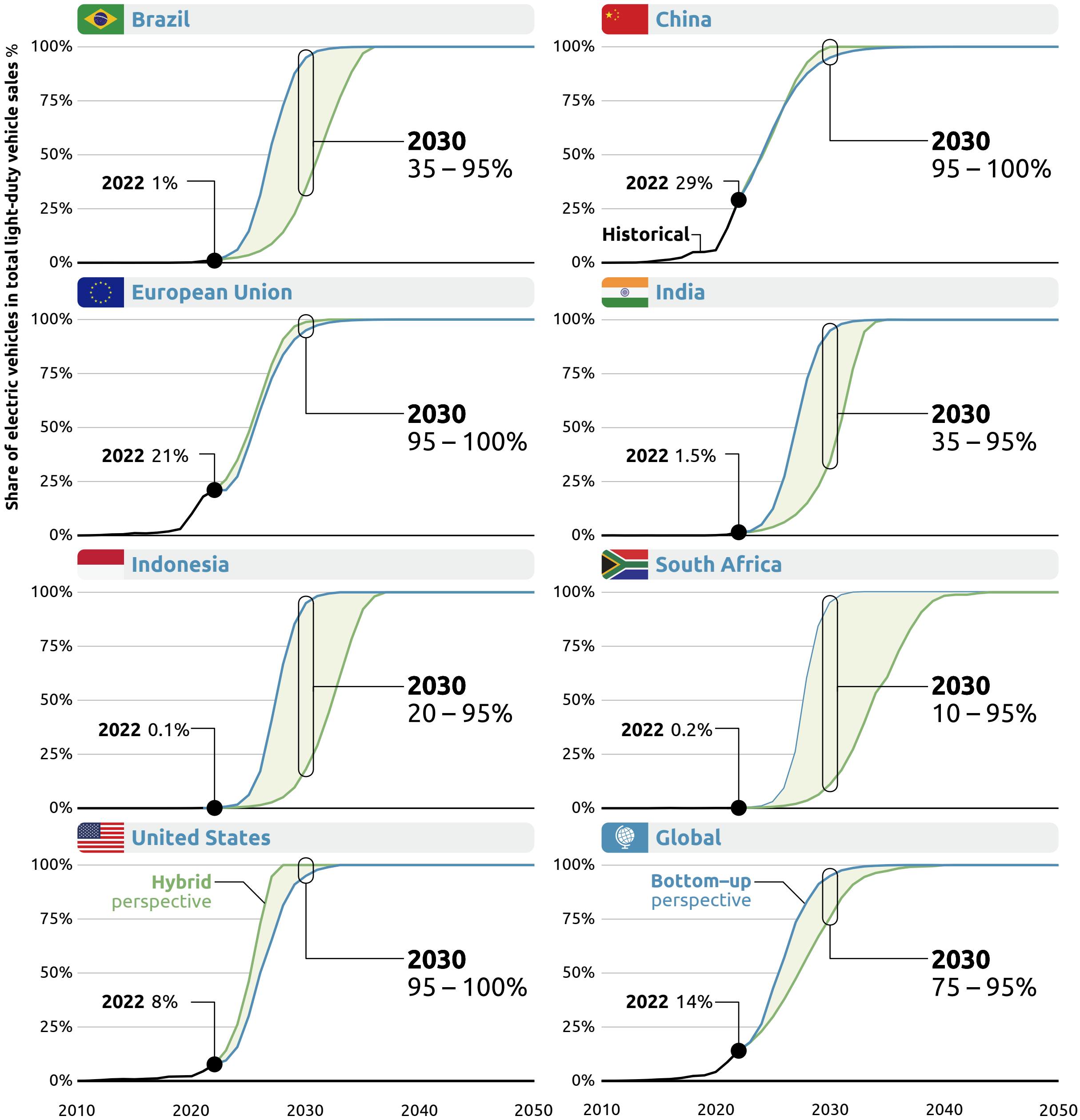

Figure 4: 1.5°C compatible share of light-duty electric vehicle sales in national-level vehicle markets

Benchmark ranges from hybrid FLEX model (as ana average of the two IAM pathways) and bottom-up EV model.
**Historical data from IEA EV Data Explorer 2022*

We compare our benchmarks to other global 1.5°C compatible pathways. In the IEA's Net Zero Emission scenario, global EV sales reach 65% in 2030 (IEA, 2024b), lower than our benchmark range of 75-95%. On the other hand, other literature estimates that global BEV sales (for all LDVs) would need to reach 100% by 2030, about five years earlier than our estimate (Teske et al., 2022).

Our 2030 benchmark falls short of 100% at the global level because of the equitable transition assumptions made in the selected pathways which show a slower uptake of EVs in developing countries as reflected in our national benchmarks from the FLEX model. Under the BNEF Net Zero Scenario, global EV sales also reach 100% by 2040 accompanied with a peak in the demand for passenger cars (BNEF, 2022), aligning closely with our benchmark.

Table 2: 1.5°C compatible benchmarks for share of electric vehicle sales.

For the lower range, the average of the selected pathways from the hybrid FLEX model is presented. China, India and Indonesia include two-wheelers. The 2035 EV model benchmark values are calculated as the average between the 2030 and 2040 values.

1.5°C compatible benchmarks for electric light-duty passenger vehicles sales					
Country	**2022**	**2030**	**2035**	**2040**	**2050**
Brazil	1%	35 – 95%	100%	100%	100%
China	29%	95 – 100%	100%	100%	100%
EU27	21%	95 – 100%	100%	100%	100%
India	1.5%	35 – 95%	100%	100%	100%
Indonesia	0.1%	20 – 95%	90 – 100%	100%	100%
South Africa	0.2%	10 – 95%	60 – 100%	100%	100%
United States	8%	95 – 100%	100%	100%	100%
Global	14%	75 – 95%	95 – 100%	100%	100%

China is an outlier as an emerging economy country needing to reach 100% of EV sales (for both four-wheelers and two-wheelers combined) by 2030. China's car manufacturing industry has grown rapidly. Part of this success can be traced to the Chinese government's strategic planning in anticipating the need for growing demand for EVs, coupled with large subsidies to support the growth of the EV industry. Comparatively, the ICCT's High Ambition Scenario for China estimates 70% EV sales by 2030 and 100% by 2035 (ICCT, 2021). While the ICCT's benchmark includes technical feasibility aspects and assumes a similar level of ambition as taken by the UK, it is not consistent with our benchmarks which suggests that a great level of ambition would be needed to align with the 1.5°C warming limit.

2.3 Share of light duty EVs in total vehicle stock

By 2035, almost two-thirds of all cars on the road need to be electric

1.5°C compatible benchmarks for share of light-duty electric vehicles in global vehicle stock

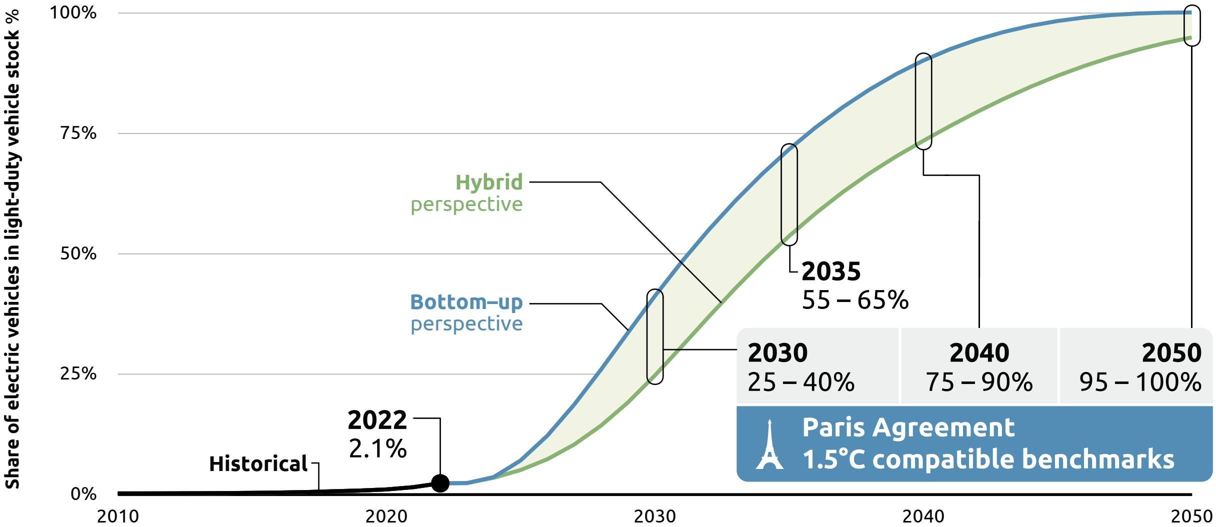

Figure 5: 1.5°C compatible share of light-duty electric vehicle stock in global vehicle fleet

*Benchmark ranges from hybrid FLEX model (as an average of the two IAM pathways) and bottom-up EV model. *Historical data from IEA EV Data Explorer 2022 (IEA, 2022)*

The share of EVs in the Global vehicle stock, like the EV market share, has also been gaining traction but at a much slower pace. In 2022, about 3% of the global fleet were electric vehicles (IEA, 2024a). In our 1.5°C compatible benchmarks, the global share of EVs in the LDV fleet grows to about 25 - 40% by 2030 and 95-100% by 2050 (Figure 5). By 2035, almost two-thirds of all cars on the road need to be electric. A significant proportion of this share will need to come from the US, EU and China.

Figure 6 shows the share of EVs in total vehicle stocks at the country level. The pace of EV penetration into national fleets needs to grow rapidly to align with 1.5ºC limit of warming.

In almost all countries, the current share of EV stocks remains low, less than 3% in 2022. China leads the world with about 5% of EVs in its national fleet (IEA, 2022). Critically, the tipping point must be achieved this decade. For this to happen, drastic policy actions and financing measures will be required. Table 3 provides benchmarks for the share of EVs penetrating the vehicle stock on the roads in each country analysed.

In the hybrid FLEX model, our share of EV stock benchmarks follow the same principles enshrined in top-down pathway narratives whereby faster action is taken in developed countries (Global North) to enable the Global South further leeway in their development.

This is evident in our 2030 benchmarks for India, South Africa, Brazil and Indonesia which are characterised by low values in the FLEX model benchmark for LDV stocks.

While this accounts for a more equitable pace of EV uptake in the Global South, developing country governments can still set national benchmarks beyond these lower ranges to instil a clear commitment and signal to industry and consumers of the country's intention of scaling up EVs. Notably, while benchmarks are low in 2030, in the following decades further effort will be needed to achieve almost 100% of EV stock by 2050.

(Milovanoff et al., 2020) estimate that the USA will need to achieve 90% EV stock share by 2050 to be consistent with 2°C of warming. In contrast, we find that the stock share would need to reach 98 - 100% stock share to be 1.5°C compatible (see Appendix). The feasibility of maintaining a 2% share of non-EV stock is questionable, given the infrastructure that would be necessary (e.g. fuelling stations). However, whether this negligible stock of non-EV cars remains or not, the end point of the US car stock is clear – moving towards 100% EVs by 2050.

Developed countries need to transition their fleets to EVs earlier and faster than developing countries

Country-level 1.5°C compatible benchmarks for share of light-duty electric vehicles in national vehicle stocks

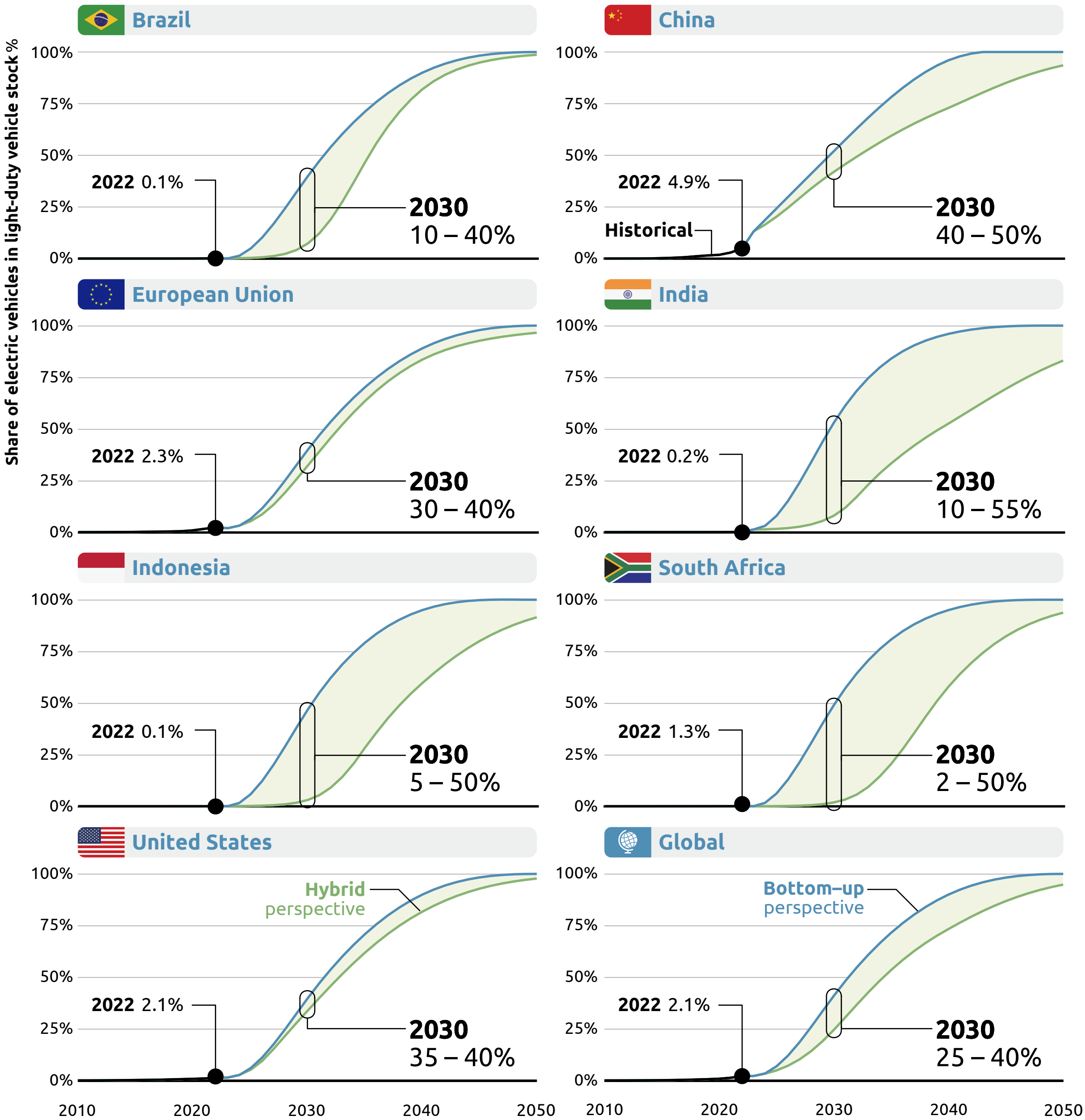

Figure 6: 1.5°C compatible share of light-duty electric vehicle stock in national-level vehicle fleet

Benchmark ranges from hybrid FLEX model (as ana average of the two IAM pathways) and bottom-up EV model.
**Historical data from IEA EV Data Explorer 2022*

In fact, our benchmarks show that by 2050 most countries would need to achieve at close to 100% EV stock share by 2050. In the bottom-up EV model, all countries achieve 100% EV stocks by 2050. Meanwhile in the FLEX model, which models a slower pace of EV uptake in developing countries, some developing countries have a lower EV stock in 2050. In particular, India is an outlier with about 85% EV stock share in 2050.

In general our 2030 benchmarks align closely with other studies such as (Teske, 2019), for countries were data is available. The one exception is India for which the FLEX model estimates a 10% EV stock share, more in line with the IEA's APS and STEP scenarios (IEA, 2022). Comparatively, alternative 2050 outlooks forecast lower EV stock share benchmarks but these scenarios are not 1.5°C compatible.

Table 3: 1.5°C compatible benchmarks for share of EVs in total vehicle stock

*For the lower range, the average of the selected pathways from the hybrid FLEX model is presented. China, India and Indonesia include two-wheelers. The 2035 EV model benchmark values are calculated as the average between the 2030 and 2040 values. Historical data from IEA EV Data Explorer (IEA, 2022), *Indonesia 2022 data is an estimate from FLEX model.*

1.5°C compatible benchmarks for electric light-duty passenger vehicle stock share					
Country	**2022**	**2030**	**2035**	**2040**	**2050**
Brazil	0.1%	10-40%	50-65%	80-90%	100%
China	5.0%	40-50%	60-75%	75-95%	95-100%
EU27	2.3%	30-40%	65%	85-90%	100%
India	0.2%	10-55%	35-75%	55-95%	85-100%
Indonesia	0.1% *	5-50%	30-70%	60-95%	90-100%
South Africa	0.0%	2-50%	20-70%	60-95%	95-100%
United States	1.3%	35-40%	60-65%	80-90%	100%
Global	2.1%	25-40%	55-65%	75-90%	95-100%

For example, BNEF's Economic Transition Scenario forecasts that globally, under no new policies and technological-economic markets driving change, zero emission vehicle fleet will reach 70% by 2050 (BNEF, 2023a). The IEA's 2022 APS and STEPS projections reach only 15% EV stock share by 2030 which fall below our 1.5°C compatible 25-40% EV stock share benchmarks (IEA, 2022).

As the total vehicle fleet is still expected to continue growing, increasing scrappage rates of ICEs may be needed to meet decarbonisation goals. Even with 100% EV market share and no new ICEVs entering fleets, more ICE vehicles will need to be retired earlier going forward.

Other studies have also found that removing ICE vehicles from the road will be necessary to make the necessary emission reductions by 2050 (ICCT, 2023a; Transport & Environment, 2018). The historical baseline for the retirement (i.e. de-registration of vehicles and removal from fleet) floats between 3% (RMI, 2023) and 5% (Teske et al., 2022) for vehicles that are on average 15 years old.

To meet the necessary emission reductions, the scenarios from our optimised bottom up model assumes that retirement rates for ICE vehicles would need to double by 2030 in developed countries and then increase by seven times current levels by 2040 in order to phase out ICE vehicles by 2050.

In developing countries increasing ICE vehicle retirement rates will also be required but to a lesser degree, reaching 8% of vehicles per year in 2030 and 20% in 2050. This may require government policies to drive scrappage, but could also occur organically, consumer demand switches wholesale towards EVs, driven by falling prices and increased cost competitiveness (RMI, 2023).

To this point, any further investment into ICE vehicles represents an enormous source of stranded assets that governments and consumers will need to reconcile in the future. While we have assumed a relatively strong growth in the global car fleet of 3-4% per year, if this growth can be reduced due to greater car-sharing, and modal shift to active and public transport, then the pressures on EV scale-up and associated critical mineral requirements could be reduced

2.4 Share of low emission fuels in domestic transport

Use of low and zero emission fuels needs to at least double by 2030

1.5°C compatible benchmarks for share of electricity, hydrogen and biofuels in all domestic transport (excluding only international aviation and shipping)

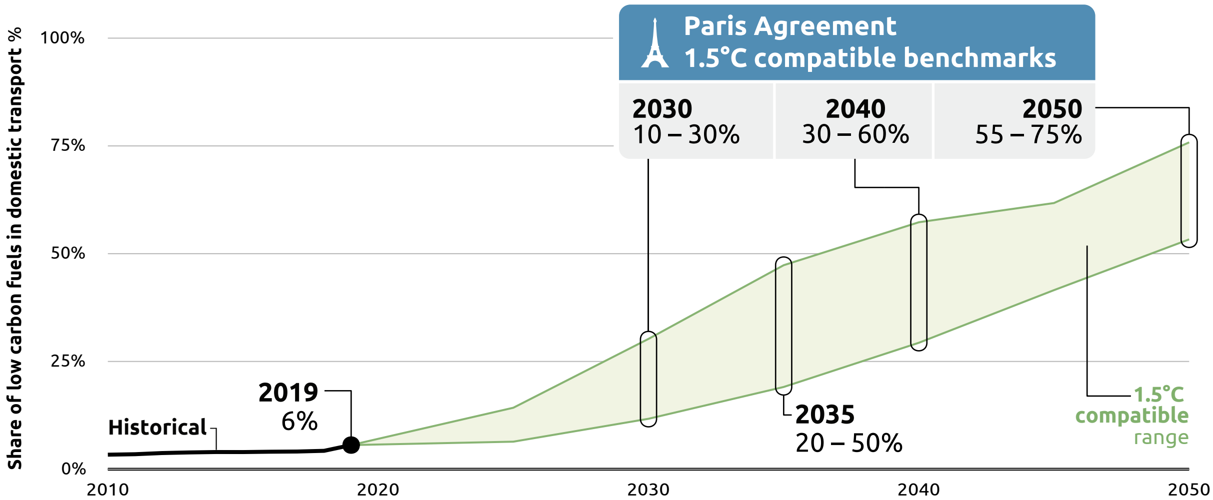

Figure 7: 1.5°C compatible share of zero and low carbon fuels in all modes of global domestic transport.

Low carbon fuels refer to electricity, hydrogen and biofuels. Domestic transport refers to road, rail, aviation, and maritime navigation within the borders of a country. The lower and upper ranges presented as the 50th and 95th percentiles of the 24 1.5°C compatible IAMs pathways. Shares taken from regional level of the respective country.

The first three benchmarks in this report focus on the LDV fleet, a significant component of total transport emissions, but the transition to zero-carbon mobility involves the entire transport sector.

In this final benchmark therefore, we report the share of zero and low emission fuels in the domestic transport sector (including road, rail, domestic aviation and shipping) in the 1.5ºC compatible pathways assessed. Here, we consider zero and low emission fuels to include electricity, hydrogen and biofuels. This provides an overview of how much clean energy is required to fuel the transport sector as a whole (excluding international aviation and shipping). This includes both passenger and freight transport.

In 2020, the global share of low carbon fuels accounted for about 5% of domestic transport fuel (IRENA, 2023). Our 1.5°C compatible benchmarks show that low emission fuels will need to reach about 55 – 75 % of domestic transport fuel demand by 2050 (Figure 7). By 2030, low and zero carbon fuels would need to almost double from currently levels, with our benchmarks showing shares reach 10 – 30 % low emission fuels.

While the IAMs often assume quite large biomass utilisation, this may not be compatible with sustainable considerations. At the same time the IAMs often underestimate the potential for electrification (Luderer et al., 2021) and the scenarios assessed by AR6 do not represent synthetic fuels as a decarbonisation option in transport.

The CAT expects that electricity would dominate surface transport modes, with long-distance and energy-dense transportation such as aviation and shipping requiring greater use of hydrogen and synthetic fuels, and relatively limited deployment of biomass, due to the strong sustainability limits that will prevent large-scale scaling of biomass (Transport & Environment, 2023).

The pace of transition to low and zero mission fuels will vary across countries (Figure 8). The IAMs pathways for low emission fuels in developed countries are more certain than in developing countries, as seen through the wide benchmark ranges in some countries, such as South Africa, India and Indonesia.

However, it should be noted that in defining policy targets, aspiring for the highest level of ambition helps set a clear commitment and signal to both industry and consumers. If higher levels of ambition can be achieved, this will also bring large-scale co-benefits to citizens, in the form of cleaner air and reduced deaths from air pollution.

Domestic transport of US, EU, China & India alone would require half of global demand for low & zero emission fuels

Country-level 1.5°C compatible benchmarks for share of electricity, hydrogen and biofuels in all domestic transport (excluding only international aviation and shipping)

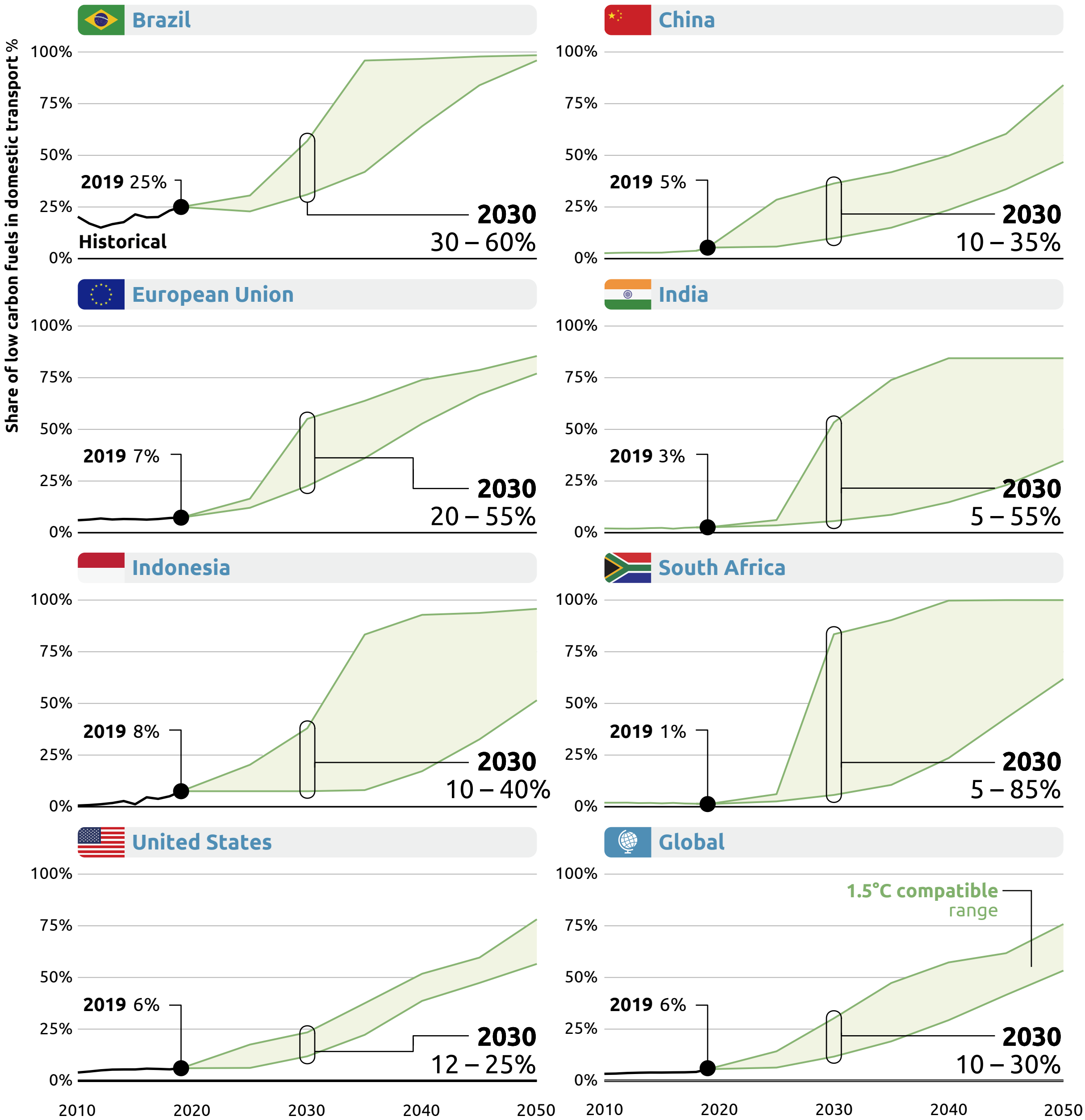

Figure 8: 1.5°C compatible share of zero and low emission fuels in all modes of domestic transport.

Low emission fuels refer to electricity, hydrogen and biofuels. Domestic transport refers to road, rail, aviation, and maritime navigation within the borders of a country. The lower and upper ranges presented as the 50th and 95th percentiles of the 24 1.5°C compatible IAMs pathways. Shares taken from regional level of the respective country.

The USA, EU, China and India would collectively provide about half of the global low emission fuel demand in domestic transport between 2030 and 2050. These four countries alone account for most of the global responsibility to advance the uptake of low emission fuels. This comes on the back of their large populations, socio-economic conditions and expected growth in demand for passenger travel. Action in these countries to fast track the electrification of transport will go a long way to meeting the global goal.

Table 4: 1.5°C compatible benchmarks for share of low emission fuels (electricity, hydrogen and biofuels) in total domestic transport energy consumption.

Lower and upper ranges presented as the 50th and 95th percentiles of the 24 1.5oC compatible IAMs pathways. Shares taken from regional level of the respective country. World historical data point taken from IRENA (2023). National historical data (2019) taken from IAM model.

** In defining the final benchmark range, we assume that benchmarks can only increase or remain constant with time. Therefore for India (2050) and Indonesia (2030), values were amended.*

1.5°C compatible benchmarks for the share of low carbon fuels in domestic transport					
Country	**2022**	**2030**	**2035**	**2040**	**2050**
Brazil	25%	30-60%	40-95%	65-100%	95-100%
China	5%	10-35%	15-40%	25-50%	50-85%
EU27	7%	25-55%	35-65%	55-75%	80-85%
India	3%	5-55%	10-75%	15-85%	35-85%*
Indonesia	8%	10-40%*	10-85%	20-95%	50-95%
South Africa	1%	5-80%	10-90%	25-100%	60-100%
United States	6%	10-25%	20-40%	40-50%	60-80%
Global	5%	10% – 30%	20% - 50%	30% - 60%	55% - 75%

In developing countries such as South Africa, Indonesia and Brazil, there is a consensus that zero emission fuels should provide at least 50% of the transport energy mix by 2050, looking at the lower end of the benchmarks. At the higher end of ambition, the share of zero emission fuels could reach around 90% by 2035. Action to cut fossil fuels from the transport sector this fast would require substantial international support, but would bring large-scale co-benefits, particularly around air pollution.

Low and zero emission fuels in China and India could take longer to replace fossil fuels and, by 2050, could attain levels as low as 45% and 35% respectively. This could likely be due to the large population size and the increasing mobility as both countries develop, posing additional challenges for governments. Again, aiming for the highest possible ambition can help minimise the need for carbon dioxide removal (CDR) to compensate for residual emissions, and bring health co-benefits in the form of cleaner air.

For developed countries, the US and EU still account for a small share of low emission fuels in their domestic transport with 6% and 7% respectively in 2019. The EU has introduced several new policies to increase this share through its REPowerEU plan calling for 32% share of renewable fuels (which includes electricity, biofuels and hydrogen) in the transportation sector by 2030 (European Commission, 2022a). This would put it within the range of our 1.5°C compatible benchmarks of 20 – 55%. However, the plan implies the majority of this share will come from conventional biofuels, which could present sustainability challenges down the line.

In all pathways, some fossil fuels remain by 2050. This will largely be consumed by aviation and shipping. While a small amount of electricity may be expected to power some domestic navigation (i.e ferries) and short haul aviation as new battery technology evolves, alternative low and zero carbon fuels are anticipated to be the main fuel source for aviation and maritime navigation in the future. In the maritime sector, hydrogen and ammonia are expected to play a key role in the sector's decarbonisation. Aviation will likely account for the bulk of the remaining fossil fuels in the transport sector. Synthetic fuels could help further displace fossil fuels from aviation, but are not represented in the pathways

While fossil fuels remain in transport by 2050, they are expected to continue being phased out beyond 2050. By 2050 and beyond, enough momentum in the zero and low carbon fuel transition should be realised to make fossil fuel technology increasingly unattractive. In the meantime, to account for the remaining emissions, from the hard to abate, some investment in CDR would be needed. This should be linked to the hard to abate aviation and maritime sectors which are expected to be some of the last sectors to fully decarbonise.

3 Progress towards EV Sales benchmarks

Across all countries, EVs have been gaining momentum. China, the EU and the USA remain the top three largest EV markets, with China selling more EVs in 2022 than the rest of the world (Jaeger, 2023a). Compared to any other country China leads in national markets, with EVs making up almost a third of total light-duty vehicle sales in 2022 (IEA, 2023), with market forecasts for 2024 expecting EVs to reach 50% of total sales (Johnson, 2024).

If the uptake of EVs continues at current growth levels, global EV sales could be on track to achieve 90% of sales by 2030 (Boehm et al., 2023). However, policies needed to set commitments in line with the Paris Agreement and create the enabling conditions for EV uptake to continue are not necessarily in place to achieve the 1.5°C compatible benchmarks.

The IEA's Announced Pledge Scenario (APS) projects that based on current policies the global share of EV sales will reach 44-48% by 2030 which falls short of our 1.5°C compatible benchmarks of 95-100%. This highlights an ambition gap between current policies and 1.5°C compatible levels of 51-56%. Countries would need to increase the ambition of their national targets and policy measures to close this gap.

EV purchase subsidies and investment into interconnected charging infrastructure and fuel emission standards have been shown some of the most effective policy instruments (IEA, 2021; Jaeger, 2023b). In China, for example, aggressive financial support, strict emission standards and large investments into changing infrastructure, culminating in the Dual Credit Policy, has effectively helped the bullish growth of China EV car manufacturers nationally and globally. This has manifested in China being the global leader in EV sales (ICCT, 2022; Jaeger, 2023b).

The EU has set a date to phase out ICE sales by 2035, (European Commission, 2022b) setting a clear signal to the car manufacturing industry and market. However, exceptions have been made for alternative fuel vehicles. Meanwhile, some EU countries (the Netherlands, Ireland, Slovenia, and Sweden) have already implemented a faster deadline for 2030 (4i-TRACTION, 2022). Our analysis shows that the EU as a whole should bring forwards the ICE sales ban to 2030.

The US has announced it will target 50% of zero emission vehicle sales by 2030, facilitated by support measures under the Inflation Reduction Act (The White House, 2023a). However, the government's own projections suggest it is only on track to reach 23% of EV sales by 2030 (Climate Action Tracker, 2023c; U.S. Energy Information Administration, 2024). The IEA projects that the US will achieve 55% share of EV sales in 2030 (IEA, 2024a). Based on its targets and current policy projections, the US is far off track from the required to meet our determined Paris compatible benchmark of 100% EV sales by 2030.

Some countries are setting good examples. In 2023, Indonesia joined developed countries in the Major Economies Forum (MEF), committing to a global collective goal to achieve 50% of LDV sales from zero-emission vehicles by 2030[3] (ICCT, 2023b; The White House, 2023b). If Indonesia adopts a similar national target, it would go well beyond what our 1.5°C compatible benchmarks require.

India has also gone further by setting ambitious targets to reach 30% of EV sales for private use passenger cars and 80% for two and three-wheelers by 2030 (Clean Energy Ministerial, 2023). This puts India's policies within the range of our 1.5°C compatible 2030 benchmarks for 27-41% share of EV sales. India has introduced financial incentives such as purchase subsidies and tax exemptions to non-fiscal policies to give EV drivers preferential on-road use, more efficient charging infrastructure rollouts and preferential market access (ICCT, 2024).

South Africa has taken some steps to decarbonise its transport, such as incentivising electric buses and attempting to grow its domestic manufacturing industry of EVs to compete with growing demand globally (Khan et al., 2022). However to date, it has still not set clear targets or policies for EV sales or stock into law (Climate Action Tracker, 2023b). Setting such targets and incentives will be important for setting the impetus for EV sales to grow in the nation (Tongwane & Moeletsi, 2021) if it is to reach at least a 20% share EV sales by 2030, the minimum level necessary to be 1.5°C compatible.

3 This includes battery, plug-in hybrid and fuel cell electric vehicles.

4 Conclusion

Our benchmarks offer a guide for policy makers in setting national EV market share targets in line with emissions reductions aligned with the goals of Paris Agreement to limit warming by 1.5°C by the end of the century. It is clear that time is running out to cut economy-wide emissions globally.

This has culminated in the need for greater ambition in EV uptake within a shorter period globally, but mostly coming from developed countries. Great progress in pushing EVs has been made but a lot more policy action will be required if this momentum is to be maintained. Now more than ever, it is critical that the ball is not dropped.

Developed countries and China should take most of the action, initially at least, and should seek to reach 100% EV sales by 2030, earlier than the intention of their current policies.

The analysis presented here highlights two key shifts:

- First, countries must stop the supply of new ICE vehicles to prevent further emissions
- Second, to effectively cut transport emissions fast enough to keep in line with the Paris Agreement goal to limit warming to 1.5˚C, countries need to increasingly take ICE vehicles off the road.

Another major challenge in reaching the number of electric vehicles needed to decarbonise LDV transport will be the limitation of critical raw materials needed in EV batteries (Jones et al., 2020). To this end, supplementary policies to decrease the size of vehicles (and therefore material demand), increase recyclability rates of EV batteries and reduce vehicle ownership and usage will be imperative (Milovanoff et al., 2020).

Worryingly, in 2023, half of new car sales were large resource and emission intensive SUVs (Carrington, 2024). In the US, resource demand for EVs would be higher than in other countries due to the popularity of large SUVs.

In Europe, passenger cars are becoming bigger and heavier, catering to new consumer preferences. This will prove challenging to meet their EV demand if fewer resources are available to manufacture them (GFEI, 2023). The EU recently adopted the Batteries Regulation (EU 2023/1542), which will seek to reduce the security and carbon intensity of the critical raw materials required for EV batteries, and which sets requirements for increasing the recycling of batteries for materials such as nickel, cobalt and lithium (European Commission, 2023). Recycling of batteries, setting standards on vehicle sizes and taking action to reduce the overall demand for private passenger cars will be key in the long term viability of the EV transition.

When looking at low carbon fuels, electricity should power the bulk of domestic road transport. While some modelling suggests that biofuels could play a role in the other sectors such as shipping and aviation, significant caution must be exercised here.

Biofuels come with many challenges, mainly sustainability and scalability challenges. They risk competing with agriculture land, jeopardising food security and may spur further deforestation. In their worst form, biofuels can be worse than fossil fuels from a life-cycle emissions point of view, and come with significant impacts on biodiversity and local populations who live on or near bioenergy plantations. The role of biofuels should be minor at best, and limited only to those biofuels produced from sustainable feedstocks.

The EV transition is gaining a lot of traction but further work is - and will be -required to maintain this progress. Developed countries are further along, but developing countries are transitioning quickly. However, the current momentum must to be maintained to meet 1.5°C compatible 2030 benchmarks.

Further policy interventions from governments to incentivise EVs while disincentivising the sale and use of ICE vehicles will be required, while simultaneously expanding EV changing infrastructure.

This will come at a high cost which has hindered the EV transition in lower income communities and developing countries, but in the long term has the potential to increase competitiveness, improve air quality and come closer to achieving a net zero future. To this end, developed country governments should account for equity and fair considerations to support the transition to EVs and zero emission fuels in developing countries so that no one is left behind.

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Annex: 1.5°C benchmarks

Table A1: 1.5°C compatible national and global emission reductions for light-duty passenger vehicle tank-to-wheel and well-to-wheel emissions

Emissions reductions from only the FLEX model (i.e. lower range of all benchmarks), presented as the average of the selected 1.5°C compatible pathways. Historical 2022 emissions taken from FLEX model estimate. China, India and Indonesia include two-wheelers.

Country	Scenario	2022	2030	2035	2040	2050
Brazil	Tank to wheel	103 $MtCO_2$	-22%	-58%	-87%	-99%
	Well to wheel	103 $MtCO_2$	-22%	-58%	-87%	-99%
China	Tank to wheel	215 $MtCO_2$	11%	-7%	-36%	-89%
	Well to wheel	222 $MtCO_2$	13%	-8%	-37%	-88%
EU27	Tank to wheel	471 $MtCO_2$	-48%	-76%	-90%	-98%
	Well to wheel	472 $MtCO_2$	-48%	-76%	-90%	-98%
India	Tank to wheel	116 $MtCO_2$	80%	64%	26%	-61%
	Well to wheel	117 $MtCO_2$	82%	67%	25%	-61%
Indonesia	Tank to wheel	73 $MtCO_2$	45%	8%	-47%	-92%
	Well to wheel	73 $MtCO_2$	46%	9%	-47%	-92%
South Africa	Tank to wheel	19 $MtCO_2$	72%	106%	62%	-64%
	Well to wheel	19 $MtCO_2$	73%	106%	62%	-63%
United States	Tank to wheel	964 $MtCO_2$	-45%	-71%	-87%	-99%
	Well to wheel	966 $MtCO_2$	-44%	-70%	-87%	-99%
Global	Tank to wheel	3012 $MtCO_2$	-17%	-47%	-69%	-94%
	Well to wheel	3031 $MtCO_2$	-15%	-45%	-68%	-94%

Table A2: 1.5°C compatible benchmarks for share of electric vehicle sales.

For the lower range, the average of the selected pathways from the hybrid FLEX model is presented. China, India and Indonesia include two-wheelers. The 2035 EV model benchmark values are calculated as the average between the 2030 and 2040 values.

Country	Scenario	2022	2030	2035	2040	2050
Brazil	FLEX Model (hybrid approach)	1.0%	35%	97%	99%	100%
	EV Model (bottom-up approach)	1.0%	95%	98%	100%	100%
	Final Benchmark Range	1.0%	35 – 95%	100%	100%	100%
China	FLEX Model (hybrid approach)	32%	100%	100%	100%	100%
	EV Model (bottom-up approach)	32%	95%	98%*	100%	100%
	Final Benchmark Range	32%	95 – 100%	100%	100%	100%
EU27	FLEX Model (hybrid approach)	21%	99%	100%	100%	100%
	EV Model (bottom-up approach)	21%	95%	98%*	100%	100%
	Final Benchmark Range	21%	95 – 100%	100%	100%	100%
India	FLEX Model (hybrid approach)	1.5%	34%	100%	100%	100%
	EV Model (bottom-up approach)	1.5%	95%	98%*	100%	100%
	Final Benchmark Range	1.5%	35 – 95%	100%	100%	100%
Indonesia	FLEX Model (hybrid approach)	0.1%	18%	92%	100%	100%
	EV Model (bottom-up approach)	0.1%	95%	98%*	100%	100%
	Final Benchmark Range	0.1%	20 – 95%	90 – 100%	100%	100%
South Africa	FLEX Model (hybrid approach)	0.2%	11%	61%	98%	100%
	EV Model (bottom-up approach)	0.2%	95%	98% *	100%	100%
	Final Benchmark Range	0.2%	10 – 95%	60 – 100%	100%	100%
United States	FLEX Model (hybrid approach)	8%	100%	100%	100%	100%
	EV Model (bottom-up approach)	8%	95%	98%*	100%	100%
	Final Benchmark Range	8%	95 – 100%	100%	100%	100%
Global	FLEX Model (hybrid approach)	14%	76%	97%	100%	100%
	EV Model (bottom-up approach)	14%	95%	100%	100%	100%
	Final Benchmark Range	14%	75 – 95%	95 – 100%	100%	100%

Table A3: 1.5°C compatible benchmarks for share of EVs in total vehicle stock

*For the lower range, the average of the selected pathways from the hybrid FLEX model is presented. China, India and Indonesia include two-wheelers. The 2035 EV model benchmark values are calculated as the average between the 2030 and 2040 values. Historical data from IEA EV Data Explorer (IEA, 2022), *Indonesia 2022 data is an estimate from FLEX model.*

Country	Scenario	2022	2030	2035	2040	2050
Brazil	FLEX Model (hybrid approach)	0.1%	7%	47%	82%	99%
	EV Model (bottom-up approach)	0.1%	40%	65%*	90%	100%
	Final Benchmark Range	0.1%	10-40%	50-65%	80-90%	100%
China	FLEX Model (hybrid approach)	5.0%	42%	59%	73%	94%
	EV Model (bottom-up approach)	5.0%	52%	74%*	96%	100%
	Final Benchmark Range	5.0%	40-50%	60-75%	75-95%	95-100%
EU27	FLEX Model (hybrid approach)	2.3%	32%	64%	84%	97%
	EV Model (bottom-up approach)	2.3%	40%	65%*	89%	100%
	Final Benchmark Range	2.3%	30-40%	65%	85-90%	100%
India	FLEX Model (hybrid approach)	0.2%	8%	33%	53%	83%
	EV Model (bottom-up approach)	0.2%	53%	75%*	96%	100%
	Final Benchmark Range	0.2%	10-55%	35-75%	55-95%	85-100%
Indonesia	FLEX Model (hybrid approach)	0.1%	3%	29%	60%	92%
	EV Model (bottom-up approach)	0.1%	47%	71%*	95%	100%
	Final Benchmark Range	0.1%	5-50%	30-70%	60-95%	90-100%
South Africa	FLEX Model (hybrid approach)	0.0%	2%	21%	58%	94%
	EV Model (bottom-up approach)	0.0%	49%	72%*	95%	100%
	Final Benchmark Range	0.0%	2-50%	20-70%	60-95%	95-100%
United States	FLEX Model (hybrid approach)	1.3%	34%	62%	82%	98%
	EV Model (bottom-up approach)	1.3%	40%	65%*	90%	100%
	Final Benchmark Range	1.3%	35-40%	60-65%	80-90%	100%
Global	FLEX Model (hybrid approach)	2.1%	24%	53%	73%	95%
	EV Model (bottom-up approach)	2.1%	41%	66%*	90%	100%
	Final Benchmark Range	2.1%	25-40%	55-65%	75-90%	95-100%

Table A4: 1.5°C compatible benchmarks for share of low emission fuels (electricity, hydrogen and biofuels) in total domestic transport energy consumption.

Lower and upper ranges presented as the 50th and 95th percentiles of the 24 1.5oC compatible IAMs pathways. Shares taken from regional level of the respective country. World historical data point taken from IRENA (2023). National historical data (2019) taken from IAM model.

** In defining the final benchmark range, we assume that benchmarks can only increase or remain constant with time. Therefore for India (2050) and Indonesia (2030), values were amended.*

Country	Scenario	2022	2030	2035	2040	2050
Brazil	50th percentile	25%	31%	42%	64%	96%
	90th percentile	25%	57%	96%	97%	98%
	Final Benchmark Range	25%	30-60%	40-95%	65-100%	95-100%
China	50th percentile	5%	10%	15%	24%	47%
	90th percentile	5%	36%	42%	50%	84%
	Final Benchmark Range	5%	10-35%	15-40%	25-50%	50-85%
EU27	50th percentile	7%	23%	36%	53%	77%
	90th percentile	7%	55%	64%	74%	85%
	Final Benchmark Range	7%	25-55%	35-65%	55-75%	80-85%
India	50th percentile	3%	6%	9%	15%	35%
	90th percentile	3%	53%	74%	84%	84%*
	Final Benchmark Range	3%	5-55%	10-75%	15-85%	35-85%*
Indonesia	50th percentile	8%	8%*	8%	17%	52%
	90th percentile	8%	38%	83%	93%	96%
	Final Benchmark Range	8%	10-40%*	10-85%	20-95%	50-95%
South Africa	50th percentile	1%	6%	11%	24%	62%
	90th percentile	1%	83%	90%	100%	100%
	Final Benchmark Range	1%	5-80%	10-90%	25-100%	60-100%
United States	50th percentile	6%	12%	22%	39%	57%
	90th percentile	6%	23%	38%	52%	78%
	Final Benchmark Range	6%	10-25%	20-40%	40-50%	60-80%
Global	50th percentile	5%	12%	19%	29%	53%
	90th percentile	5%	30%	47%	57%	76%
	Final Benchmark Range	5%	10% – 30%	20% - 50%	30% - 60%	55% - 75%

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climateactiontracker.org

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Climate Analytics is a non-profit institute leading research on climate science and policy in relation to the 1.5°C limit in the Paris Agreement. It has offices in Germany, the United States, Togo, Australia, Nepal and Trinidad and Tobago.

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