Carbon Performance assessment of automobile manufacturers: Note on methodology

January 2023

Simon Dietz, Hayli Chiu, Tess Sokol-Sachs

With contributions from Valentin Jahn, Nikolaus Hastreiter, and Sidonie Commarmond

Transition Pathway Initiative

CONTENTS

1. INTRODUCTION

The Transition Pathway Initiative (TPI) is a global initiative led by asset owners and supported by asset managers. Established in January 2017, TPI is now supported by 133 investors globally with over $50 trillion of assets under management.[1]

On an annual basis, TPI assesses how companies are preparing for the transition to a low-carbon economy in terms of their:

- *Management Quality* – all companies are assessed on the quality of their governance/management of greenhouse gas emissions and of risks and opportunities related to the low-carbon transition.
- *Carbon Performance* – in selected sectors, TPI quantitatively benchmarks companies' carbon emissions against international climate targets made as part of the 2015 UN Paris Agreement.

TPI publishes the results of its analysis through an open access online tool hosted by the Grantham Research Institute on Climate Change and the Environment at the London School of Economics (LSE): www.transitionpathwayinitiative.org .

Investors are encouraged to use the data, indicators and online tool to inform their investment research, decision making, engagement with companies, proxy voting and dialogue with fund managers and policy makers, bearing in mind the Disclaimer that can be found in section 6. Further details of how investors can use TPI assessments can be found on our website at www.lse.ac.uk/GranthamInstitute/tpi/about/how-investors-can-use-tpi/ .

The purpose of this note is to provide an overview of the latest methodology being followed by TPI in its assessment of the Carbon Performance of automobile manufacturers. The methodology is an evolution of previous versions (most recently December 2020), but this note has been written to stand alone.

[1] As of January 2023.

2. THE BASIS FOR TPI'S CARBON PERFORMANCE: SECTORAL DECARBONISATION APPROACH

TPI's Carbon Performance assessment is based on the Sectoral Decarbonization Approach (SDA)[2]. The SDA translates greenhouse gas emissions targets made at the international level (e.g., under the 2015 UN Paris Climate Agreement) into appropriate benchmarks, against which the performance of individual companies can be compared.

The SDA is built on the principle that different sectors of the economy (e.g., oil and gas production, electricity generation and automobile manufacturing) face different challenges arising from the low-carbon transition, including where emissions are concentrated in the value chain, and how costly they are to reduce. Other approaches to translating international emissions targets into company benchmarks have applied the same decarbonization pathway to all sectors, regardless of these differences [1].

Therefore, the SDA takes a sector-by-sector approach, comparing companies within each sector against each other and against sector-specific benchmarks, which establish the performance of an average company aligned with international emissions targets.

Applying the SDA can be broken down into the following steps:

- A global carbon budget is established, which is consistent with international emissions targets, for example keeping global warming below 2°C. To do this rigorously, some input from a climate model is required.
- The global carbon budget is allocated across time and to different regions and industrial sectors. This typically requires an integrated economy-energy model, and these models usually allocate emissions reductions by region and by sector according to where it is cheapest to reduce emissions and when (i.e., the allocation is cost-effective). Cost-effectiveness is, however, subject to some constraints, such as political and public preferences, and the availability of capital. This step is therefore driven primarily by economic and engineering considerations, but with some awareness of political and social factors.
- In order to compare companies of different sizes, sectoral emissions are normalised by a relevant measure of sectoral activity (e.g., physical production, economic activity). This results in a benchmark path for emissions intensity in each sector:

  $$\text{Emissions intensity} = \frac{\text{Emissions}}{\text{Activity}}$$

  Assumptions about sectoral activity need to be consistent with the emissions modelled and therefore should be taken from the same economy-energy modelling, where possible.
- Companies' recent and current emissions intensity is calculated, and their future emissions intensity can be estimated based on emissions targets they have set (i.e.,

[2] The Sectoral Decarbonization approach (SDA) was created by CDP, WWF and WRI in 2015 (https://sciencebasedtargets.org/wp-content/uploads/2015/05/Sectoral-DecarbonizationApproach-Report.pdf).

this assumes companies exactly meet their targets).[3] Together these establish emissions intensity paths for companies.

- Companies' emissions intensity paths are compared with each other and with the relevant sectoral benchmark pathway.

[3] Alternatively, future emissions intensity could be calculated based on other data provided by companies on their business strategy and capital expenditure plans.

3. HOW TPI IS APPLYING THE SDA

3.1. Deriving the benchmark paths

TPI evaluates companies against benchmark paths, which quantify the implications of the Paris Agreement goals at the sectoral level. For each sector benchmark path, the key inputs are:

- A time path for economy-wide carbon emissions, which is consistent with meeting a particular climate target (e.g., limiting global warming to 1.5°C) by keeping cumulative carbon emissions within the associated carbon budget.
- A breakdown of this economy-wide emissions path into emissions from key sectors (the numerator of sectoral emissions intensity), including the sector in focus.
- Consistent estimates of the time path of physical production from, or economic activity in, the sector in focus (the denominator of sectoral emissions intensity).

TPI uses three sectoral benchmark pathways/scenarios for the auto manufacturing sector, based on modelling by the International Energy Agency (IEA):

- *A National Pledges scenario*, which is consistent with the global emissions reductions pledged by countries as of mid-2020. This scenario is derived from the IEA's Stated Policies Scenario, as presented in the ETP2020 report. Commitments made close to or after the publication of IEA scenarios are not included. According to the IEA, this aggregate is currently insufficient to put the world on a path to limit warming to 2°C or below, even if it will constitute a departure from a business-as-usual trend. This scenario is expected to lead to a global temperature increase of 2.7°C by 2100 with a probability of 50%. [2]
- *A Below 2 Degrees scenario*, which is consistent with the overall aim of the Paris Agreement to hold "the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels", albeit at the lower end of the range of ambition. This scenario is derived from the IEA's Sustainable Development Scenario. It gives a probability of 50% of holding the global temperature increase to 1.65°C. [2]
- *A 1.5 Degrees* scenario, which is consistent with the overall aim of the Paris Agreement at the high end of the range of ambition. This is derived from the IEA's Net Zero by 2050 scenario and requires virtually all new passenger vehicles sold to have zero tailpipe emissions by 2035. The scenario gives a probability of 50% to limiting the global temperature increase to 1.5°C. [3]

The IEA's economy-energy model simulates the supply of energy and the path of emissions in different sectors burning fossil fuels, or consuming energy generated by burning fossil fuels, given assumptions about key inputs, such as economic and population growth. In low-carbon scenarios, the IEA model minimises the cost of adhering to a carbon budget by always allocating emissions reductions to sectors where they can be made most cheaply, subject to some constraints as mentioned above. These scenarios are therefore cost-effective, within some limits of economic, political, social and technological feasibility.

For the automobile manufacturing sector, TPI uses inputs from the IEA Mobility Model (MoMo), its specific module for the transport sector [2], combined with other inputs from the

IEA via its Energy Technology Perspectives 2020 (ETP2020) [4], EV Outlooks 2019-2022 [5], Net Zero by 2050 (NZE 2050) report, [3] and World Energy Outlooks 2020-2021 [6]. The MoMo projects fuel economy data for light-duty vehicles (LDVs) while other IEA reporting provides data on the projected share of EV sales under different low-carbon scenarios.

A central feature of automobile manufacturing is that the majority of the sector's lifecycle emissions, of the order of three quarters,[4] originates downstream, i.e., from fuel combustion as the vehicles that have been manufactured and sold are driven (these emissions are categorised as "use of sold products", a subset of Scope 3 emissions). Therefore, it is most appropriate to measure companies according to the performance of their vehicles. Companies' operational emissions from manufacturing (i.e., companies' Scope 1 and 2 emissions) are less important, but not unimportant, and TPI is looking into options for integrating these in future versions of the methodology. New vehicles are also the most appropriate focus, as existing stock usage is not normally within the scope of influence of manufacturers' sustainability policies.

It has thus been suggested that a suitable measure of carbon performance in the automobile manufacturing sector is the **average emissions intensity of a company's fleet of new vehicles** [9]. This is the approach being followed by TPI. By measuring the average emissions intensity of the new passenger car fleet, our benchmarks in effect test if companies are on track to phase in zero-tailpipe-emissions vehicles, the key lever for decarbonising the sector, fast enough to meet the Paris temperature goals. In the 1.5 Degrees scenario, virtually all new passenger vehicles sold – with some minor exceptions for hybrids – must have zero tailpipe emissions by 2035.

The scope of TPI's analysis is limited to passenger cars, due to the greater availability of manufacturer data on this subset of LDVs. In order to ensure the benchmarks are comparable with data on fleet emissions intensity commonly reported by manufacturers, **the precise measure of fleet emissions intensity that TPI uses is Tank-to-Wheel CO_2 emissions per kilometre**. Tank-to-Wheel emissions based on real-world driving conditions are converted into equivalent emissions in test-cycle conditions. Following the industry's progress in adopting a test procedure that better reflects driving conditions in the real world, **TPI now uses the Worldwide harmonized Light duty driving Test Procedure (WLTP)** as the common basis for comparison across global manufacturers.

In order to obtain the average emissions intensity of new vehicles using output from IEA modelling, the following calculation steps are necessary:

- For the National Pledges and 1.5 Degrees scenarios, MoMo provides fuel economy values (Lge/100km, WLTP) for new LDVs for the years 2005-2050, in five-year increments. The fuel economy values in Lge/km are converted to gCO2/km using factors published by the International Council on Clean Transportation (ICCT) [7]. Because battery electric vehicles (BEVs) and fuel-cell electric vehicles (FCEVs) have zero tailpipe emissions, the MoMo fuel economy values are multiplied by the share of internal combustion engine (ICE) vehicles and plug-in hybrid vehicles (PHEVs) in the sales fleet under different scenarios. The sales share of these vehicle classes is

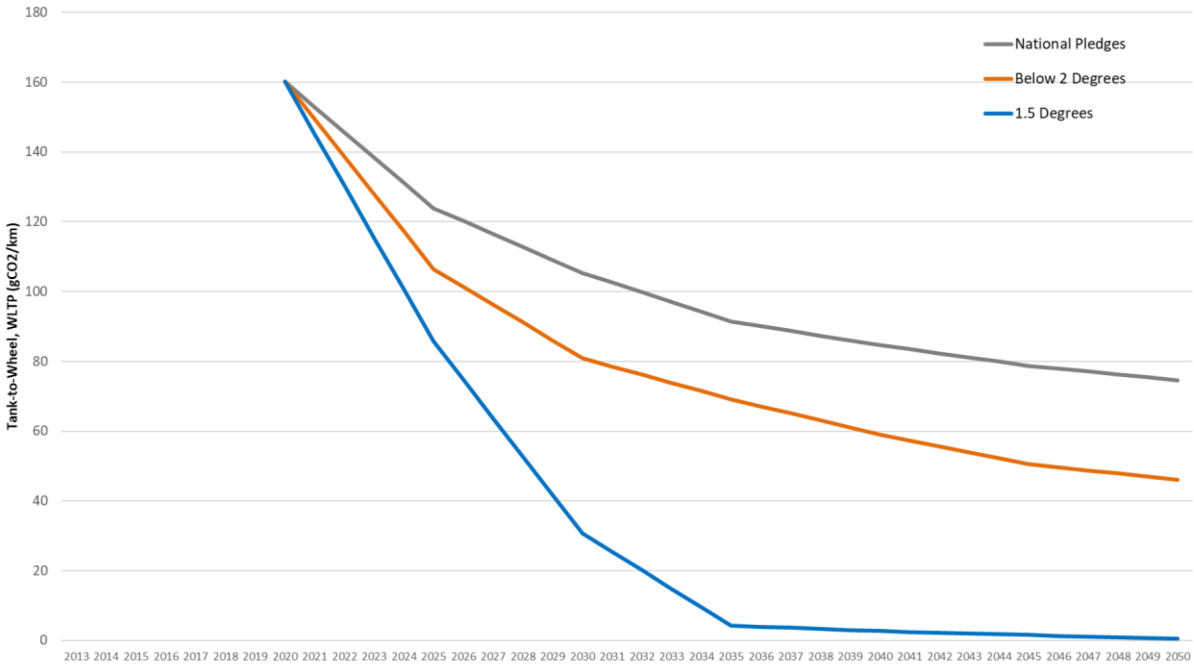
[4] Source: ICCT.

obtained from other IEA reporting (ETP 2020 [4], EV Outlooks 2019-22 [5], NZE2021 [3] and WEO 2020-21 [6]).

- For the Below 2 degrees scenario, ICE and PHEV sales fleet intensity are projected using IEA data from their EV 30@30 scenario (equivalent to below 2 degrees) [8]. We then weight the intensities by their commensurate share of new passenger car sales obtained from IEA publications (ETP 2020 [4], EV Outlooks 2019-22 [5], NZE2021 [3] and WEO 2020-21 [6]). The remaining share of the new sales fleet is comprised of zero-tailpipe-emission vehicles.

Figure 1 shows the benchmark emissions intensity paths for automobile manufacturers.

Figure 1 Benchmark global carbon intensity paths for automobile manufacturers' fleets of new passenger cars (grams of CO2 per kilometre)



Tank-to-Wheel, WLTP (gCO2/km)	2020	2025	2030	2035	2040	2045	2050
National Pledges	160.16	123.89	105.36	91.45	84.65	78.73	74.58
Below 2 Degrees	160.16	106.46	80.91	69.13	59.06	50.45	46.12
1.5 Degrees	160.16	85.69	30.68	4.25	2.67	1.56	0.44

3.2. Data sources and validation

In automobile manufacturing, the primary sources of company data are companies' own disclosures (e.g., sustainability reports), responses to the annual CDP questionnaire, as well as publicly available information held by regulators. Sales data mostly come from company disclosures, whereas emissions data mostly come from regulators.

Given that TPI's Carbon Performance assessment is both comparative and quantitative, it is essential to understand exactly what the data in company disclosures refer to. Company reporting varies not only in terms of what is reported, but also in terms of the level of detail and explanation provided. The following cases can be distinguished:

- Some companies provide data in a suitable form, and they provide enough detail on those data for analysts to be confident that appropriate measures can be calculated or used.
- Some companies also provide enough detail, but from the detail it is clear that their disclosures are not in a suitable form for TPI's Carbon Performance assessment (e.g., they do not report the measure of company activity needed). These companies cannot be included in the assessment.
- Some companies do not provide enough detail on the data disclosed and these data are also excluded from the assessment (e.g., the company reports an emissions intensity estimate but does not explain precisely what it refers to).
- Some companies do not disclose their carbon emissions and/or activity.

Once a company's preliminary performance assessment has been made based on the principles and procedures described above, it is subject to the following quality assurance:

- *Internal review*: the preliminary assessment is reviewed by analysts who were not originally involved in making it.
- *Company review*: once the initial findings review is complete, TPI writes to companies with their assessment and requests companies to review it and confirm the accuracy of the company disclosures being used. The company review is done for all companies, including those who provide unsuitable or insufficiently detailed disclosures.
- *Final assessment*: company assessments are reviewed and, if it is considered appropriate, revised.

3.3. Responding to companies

Allowing companies, the opportunity to review, and if necessary, correct their assessments is an integral part of TPI's quality assurance process. We send each company its draft TPI assessment and the data that underpins the assessment, offering them the opportunity to review and comment on the data and assessment. We also allow companies to contact us at any point to discuss their assessment.

If a company seeks to challenge its result/representation, our process is as follows:

- TPI reviews the information provided by the company. At this point, additional information may be requested.
- If it is concluded that the company's challenge has merit, the assessment is updated, and the company is informed.
- If it is concluded that there are insufficient grounds to change the assessment, TPI publishes its original assessment.
- If the company requests an explanation regarding its feedback after the publication of its assessment, TPI explains the decisions taken.

- If a company requests an update of its assessment based on data publicly disclosed after the research cut-off date communicated to the company, TPI can note the new disclosure on the company's profile on the TPI website.
- If a company chooses to further contest the assessment and reverts to legal means to do so, the company's assessment is withheld from the TPI website, and the company is identified as having challenged its assessment.

3.4. Presentation of assessment on TPI website

The results of the Carbon Performance assessment are posted on the TPI website, within the TPI tool (https://www.transitionpathwayinitiative.org/sectors). On each company page, its emissions intensity path will be plotted on the same chart as the benchmark paths for the relevant sector. Different companies can also be compared on the tool's main page, with the user free to choose which companies to include in the comparison.

4. ASSESSMENT OF AUTOMOBILE MANUFACTURERS' CARBON PERFORMANCE

4.1. Measure of emissions intensity

As discussed, TPI measures emissions intensity in the automobile sector according to the average Tank-to-Wheel CO_2 emissions per kilometre of newly registered passenger cars globally, measured in terms of the WLTP. For individual manufacturers, the average is calculated at the fleet level. For the sectoral benchmarks, the average is taken across all manufacturers' fleets.

The scope of TPI's analysis is limited to passenger cars. Vehicle manufacturers are subject to different regulatory regimes covering vehicle performance in different jurisdictions.[5] In each one, a designated driving cycle is used to test vehicle emissions. TPI uses the test standard applied by the European Union, the WLTP, as it directly measures CO_2 emissions per kilometre.[6] Other major regions use test cycles that report fuel efficiency instead (e.g., the Corporate Average Fuel Economy or CAFE standard that is used in the US and China, replaced by the WLTC standard in 2021, and the JC08 cycle that is used in Japan).

In addition to passenger cars, data are sometimes published for LDVs, a classification that includes smaller commercial vehicles, such as pick-ups, vans and minibuses. As mentioned in the previous section, TPI focuses on passenger cars, since data are available for a wider range of countries than data on the broader category of LDVs.[7] However, there are slight variations in vehicle classification between regulatory regimes. In the EU, the passenger car classification (category M1) covers vehicles "designed…for the carriage of passengers and not exceeding eight seats".[8] By contrast, under the CAFE standards in the US and China, classification is primarily made by weight, meaning that sports utility vehicles (SUVs) are classified as light trucks.[9] These variations are accepted, because data are not available to adjust for the small discrepancies that result.

4.2. Calculating company emissions intensities

TPI estimates companies' future fleet emissions intensity on the basis of their published targets to reduce new vehicle emissions or improve new vehicle fuel efficiency. However, there are variations in the way in which companies specify targets, which require certain assumptions to be applied for target estimation.

- Targets set relative to a base year before 2013: in these cases, we estimate base-year emissions by back-casting from our most recently available company figure using the recorded change in the company's vehicles' emissions for that period.

---

[5] Source : ICCT (http://www.theicct.org/chart-library-passenger-vehicle-fuel-economy).

[6] Since 1st September 2017, vehicle testing and type approval of vehicles in the EU has applied the World Harmonised Light duty driving Test Procedure (WLTP). TPI's methodology reflect this update from previous NEDC test cycle as the new WLTP test cycle is suggested to better reflect real-world emissions.

[7] In some cases, LDV results are used as a basis to calculate a representative figure for passenger cars.

[8] European Union Regulation (EC) No 443/2009 of the European Parliament and of the Council of 23rd April 2009 (http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32009R0443), Article 2 (Scope)

[9] EPA Emission Standards for LDVs, Trucks and Motorcycles (https://www.epa.gov/emission-standards-reference-guide/epa-emission-standards-light-duty-vehicles-and-trucks)

- Targets published for classes of vehicles that are broader than just passenger cars: in these cases, TPI assumes that targets apply equally to all vehicle sub-classes.
- Targets published for Well-to-Wheel rather than Tank-to-Wheel emissions: we assume that targets apply proportionally to Tank-to-Wheel emissions.
- Different lengths of emissions intensity pathways: the length of companies' emissions intensity paths will vary depending on how much information companies provide on their recent emissions, as well as the time horizon for their emissions targets.

4.3. Estimating autos manufacturers' historical and current emissions intensities

4.3.1. Overview

To estimate the current global average emissions intensity of manufacturers' new passenger car fleets, TPI combines regulatory data on emissions test results in different jurisdictions with individual companies' regional sales figures. Emissions or fuel economy data for new car registrations are published by regulators in the EU, US and China.[10] These data are often published by companies too, in their annual reports, sustainability reports, or CDP disclosures, in some cases complemented by coverage of other jurisdictions. Sales data are published by companies in annual reports, sales reports, or CDP disclosures.

4.3.2. Test cycle standardisation

Regulatory agencies in the US and China regulate and report fuel efficiencies rather than emissions intensities, and US regulators do so according to a different test cycle than WLTP. US and Chinese data must therefore be harmonised into gCO2/km as measured by the WLTP. This is done using a methodology published by the ICCT, which involves regression analysis of data on test cycle results [9]. ICCT's report normalised fuel economy and efficiency data across test cycles based on an analysis of New Zealand's imported LDVs. This analysis established relationships TPI can use to convert regional test cycle data from the EU, US, China, and Japan to the WLTP CO_2-equivalent basis. The ICCT methodology also allows for emissions intensity conversions according to the proportion of sales that are diesel versus petrol (diesel vehicles emit more CO_2 per unit volume than petrol vehicles).

Conversion from different test cycles to the WLTP involves the following steps:

1. Unit conversion; [10]
2. Test-cycle conversion; [9]
3. Weighting of fuel efficiency conversions according to the proportion of sales that are diesel versus petrol.

4.3.2.1. Unit conversion

The fuel type coefficient conversion method of ICCT [10] is used to harmonise test cycles' units across regions in gCO_2/km separately for petrol and diesel cars.

[10] For the EU, this is the EU Environment Agency. In China, data are published by the Ministry of Industry and Information Technology (MIIT) and reproduced in English language reports by the Innovation Center for Energy and Transportation (iCET). For the US, data are published by the National Highway Traffic Safety Administration (NHTSA).

For US fuel efficiency data, published in miles per gallon (mpg) according to the CAFE test cycle, we apply the following formula:

$$Y = Fuel\ type\ coefficient / X$$

where Y is emissions per kilometre (gCO2/km, WLTP), X is fuel efficiency in mpg according to CAFE, and the fuel type coefficients are 5,497 for petrol and 6,315 for diesel, respectively. Some Japanese automobile companies publish fuel efficiency data and these must also be converted using the above formula. Japanese regulation covers fuel efficiency in kilometres per litre (km/L) according to the JC08 test cycle. The fuel type coefficients are 2,337 for petrol and 6,315 for diesel, respectively.

Chinese fuel efficiency results are published in litres per 100 km (L/100 km) according to the WLTP test cycle from 2021 onwards and NEDC test cycle up to and including 2020. We apply the following formula, noting the Chinese fuel efficiency data are the inverse of the US and Japanese data:

$$Y = Fuel\ type\ coefficient * X$$

The fuel type coefficients are 23.4 for petrol and 26.8 for diesel, respectively.

4.3.2.2. Test cycle conversion

Test cycle conversions are based on a methodology from ICCT [9]. This methodology describes the relationship between different test cycles and 3P-WLTP, the 3-Phase Worldwide harmonized Light Vehicles Test Procedures currently used for certification in Japan. This is because ICCT analysis was conducted on vehicle sales in New Zealand, where the majority of passenger car imports are from Japan [10]. Europe uses the 4P-WLTP cycle, so we first convert all 3P-WLTP figures into 4P-WLTP, which is the test cycle adopted to harmonise emissions intensities across TPI's company assessments. The conversion relationship for petrol cars and diesel cars also differs, hence the conversions are conducted separately based on the following relationships.

For petrol cars,

$$4PWLTP = \frac{[\alpha(from\ cycle) + \beta] + 31.0519}{1.1569}.$$

For diesel cars,

$$4PWLTP = \frac{[\alpha(from\ cycle) + \beta] + 14.4674}{1.0497}.$$

For the US, conversion from CAFE to 4P-WLTP is required for all historical years. For China, conversion from NEDC to 4P-WLTP is required for data up to and including 2020. For the EU, conversion from NEDC to 4P-WLTP is required for data up to and including 2019.[11] For Japan, conversion from JC08 to 4P-WLTP is required for all historical years.

[11] For some companies, disclosures in 2020 were still in NEDC hence conversion from NEDC to WLTP is involved for 2020 data as well.

Table 1. Conversion factors used for test cycle conversions

from cycle	**Fuel type**	α	β
NEDC	Petrol	1.1194	-1.1618
JC08		0.9695	24.6742
CAFE		1.2094	-16.4856
NEDC	Diesel	1.0871	12.7300
JC08		0.9695	27.4167
CAFE		1.1589	-16.5771

4.3.2.3. Weighting fuel efficiency conversions according to the proportion of sales that are diesel versus petrol

Diesel vehicles emit more CO_2 per unit volume than petrol vehicles. We therefore weight the test cycle conversions according to the proportion of sales that are diesel versus petrol.

We assume 1% of sales in the US & China and 4% of sales in Japan are diesel (this is our assumption for all companies' sales, based on the typical share of diesel car sales in the Chinese and US markets [11, p. 3] [12, p. 4]. For the EU, as the proportion of diesel car sales dropped significantly from 2011 to 2020 (Table 2), we calculated annual percentage shares of diesel cars by interpolating datapoints from ICCT's analysis [13, p. 4]. We assume the sales proportion remains constant at 29% after 2020.

Table 2. Annual percentage of Sales of diesel cars

2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
55%	52.11%	49.22%	46.33%	43.44%	40.56%	37.67%	34.78%	31.89%	29%

For all other regions, we assume 100% of sales are petrol cars. Although some proportion of passenger car sales in other regions likely consists of diesel cars, this would minimally impact our final intensity calculation as global car sales are highly concentrated in China, Europe, and North America.

4.3.3. Using regional data to calculate a global average for companies

The availability of EU, US and Chinese emissions data is a good starting point for calculating manufacturers' global-average fleet emissions intensity, as these three markets make up about two thirds of the global market for new cars.[12] However, most companies sell cars outside these three markets, where emissions data are generally unavailable.[13]

Companies often disclose sales data that cover a number of countries and/or regions, typically reflecting where their sales are concentrated. For almost all companies, verified sales data are available for some markets outside the EU, US and China. For other markets, TPI estimates

[12] Based on CY2016 data (EFTA sales included with EU) (OICA, http://bit.ly/1Ljltdh).

[13] The exceptions companies include Xpeng for example, whose sales are focused on China, and BMW, for whom global emissions data are available.

average fleet emissions intensity using ratios of how regional emissions intensities relate to the US and EU over the period 2013-2021 (Table 3).[14,15]

Table 3. Regional passenger car average CO_2/km relative to the EU and US

		Africa	Australia	Latin America	Canada	China	EU-28	India	Japan	Mexico	Middle East	Other Europe	Eurasia	South Korea	Other Asia Pacific	U.S.
Relative to EU-28	**2013**	1.149	1.302	1.239	1.209	1.198	1.000	0.777	1.014	1.250	1.405	1.046	1.369	1.074	1.149	1.368
	2014	1.167	1.304	1.258	1.209	1.190	1.000	0.778	1.026	1.241	1.427	1.062	1.390	1.074	1.167	1.351
	2015	1.185	1.306	1.278	1.208	1.181	1.000	0.778	1.037	1.231	1.449	1.079	1.412	1.074	1.185	1.333
	2016	1.234	1.360	1.299	1.223	1.162	1.000	0.789	1.042	1.271	1.466	1.092	1.429	1.051	1.200	1.344
	2017	1.288	1.419	1.322	1.238	1.142	1.000	0.801	1.048	1.314	1.484	1.106	1.448	1.026	1.215	1.356
	2018	1.346	1.483	1.347	1.256	1.120	1.000	0.814	1.055	1.361	1.504	1.121	1.468	0.999	1.232	1.369
	2019	1.410	1.553	1.374	1.274	1.096	1.000	0.828	1.062	1.412	1.525	1.138	1.490	0.969	1.251	1.383
	2020	1.480	1.630	1.405	1.295	1.069	1.000	0.844	1.069	1.468	1.549	1.156	1.514	0.936	1.272	1.399
	2021	1.460	1.609	1.385	1.277	1.055	1.000	0.832	1.055	1.448	1.528	1.140	1.494	0.923	1.255	1.380
Relative to US	**2013**	0.840	0.951	0.906	0.884	0.876	0.731	0.568	0.741	0.913	1.027	0.764	1.001	0.785	0.840	1.000
	2014	0.864	0.965	0.931	0.895	0.881	0.740	0.576	0.759	0.918	1.056	0.786	1.029	0.795	0.864	1.000
	2015	0.889	0.979	0.958	0.906	0.885	0.750	0.583	0.778	0.924	1.087	0.809	1.059	0.806	0.889	1.000
	2016	0.918	1.011	0.966	0.910	0.864	0.744	0.587	0.775	0.945	1.090	0.812	1.063	0.782	0.892	1.000
	2017	0.950	1.046	0.975	0.913	0.842	0.737	0.591	0.773	0.969	1.094	0.815	1.068	0.757	0.896	1.000
	2018	0.983	1.083	0.984	0.917	0.818	0.730	0.594	0.770	0.994	1.098	0.819	1.072	0.730	0.900	1.000
	2019	1.019	1.123	0.994	0.921	0.792	0.723	0.599	0.768	1.021	1.103	0.822	1.077	0.701	0.904	1.000
	2020	1.058	1.165	1.004	0.926	0.764	0.715	0.603	0.764	1.050	1.107	0.826	1.083	0.669	0.909	1.000
	2021	1.058	1.166	1.005	0.925	0.764	0.725	0.603	0.764	1.050	1.107	0.826	1.083	0.669	0.909	1.000

Still, very few companies provide a comprehensive breakdown of regional sales, meaning that some portion of sales remains unallocated to any particular market. When this is the case, we assume that the average emissions intensity that we are able to calculate for countries/regions where sales data are available is representative of the manufacturers' global sales. This is unlikely to be problematic, as companies usually report the location of more than 85% of their sales.

4.4. Worked example[16]

4.4.1. Historical emissions intensity

Company A publishes tailpipe new vehicle emissions data covering vehicles sold in the EU in gCO_2/km according to the NEDC for 2019-2020 and the WLTP for 2021. The company reports fuel efficiency data for new vehicles sold in the US (mpg, CAFE), China (L/100km, NEDC for 2019-2020 and WLTP for 2021), and Japan (L/km, JC08). These data can be used alongside a sales breakdown to calculate Company A's new vehicle average emissions intensity between 2019 and 2021.

---

[14] Source: ICCT data on annual Well-to-Wheel CO_2/km for 2013-2020.

[15] Where sales data are available for countries that have very similar fleet emissions intensity to the EU, US or China, these data are apportioned to the EU, US or China respectively. In particular, any sales in NAFTA countries are apportioned to the US. When no distinction was made between sales in China and in 'other Asia', sales were assumed to refer to China only; hence, Chinese emissions were assumed to apply. All countries that might be reported as being within Europe are apportioned to the EU, apart from Russia, whose average emissions intensity is closer to the US.

16 In the following examples various numbers are rounded for ease of presentation.

The emissions data available for company A are:

		2019	2020	2021
EU	gCO_2/km, NEDC for 2019-2020; WLTP for 2021	113.70	96.00	118.00
US	mpg, CAFE	41.40	40.70	41.70
China	L/100km, NEDC for 2019-2020; WLTP for 2021	5.80	5.50	6.00
Japan	L/km, JC08	22.60	23.10	23.60

The EU data do not need conversion. US, Chinese and Japanese fuel efficiencies are converted to emissions intensities in gCO_2/km.

Petrol cars	US emissions intensity (gCO_2/km, CAFÉ) (Y)	= $5{,}497/X$
	Japanese emissions intensity (gCO_2/km, JC08) (Y)	= $2{,}337/X$
	Chinese emissions intensity (gCO_2/km, WLTP for 2021, NEDC for 2019-2020) (Y)	= $23.4 * X$
Diesel cars	US emissions intensity (gCO_2/km, CAFÉ) (Y)	= $6{,}315/X$
	Japanese emissions intensity (gCO_2/km, JC08) (Y)	= $6{,}315/X$
	Chinese emissions intensity (gCO_2/km, WLTP for 2021, NEDC for 2019-2020) (Y)	= $26.8 * X$

Emissions intensities in a common unit (gCO_2/km) but still according to different test cycles are then converted into the harmonised WLTP.

Petrol cars	US emissions intensity (gCO_2/km, WLTP)	$= \frac{[1.2094 * Y - 16.4856] + 31.0519}{1.1569}$
	Japanese emissions intensity (gCO_2/km, WLTP)	$= \frac{[0.9695 * Y + 24.6742] + 31.0519}{1.1569}$
	Chinese and EU emissions intensity (gCO_2/km, WLTP for 2019-2020)	$= \frac{[1.1194 * Y - 1.1618] + 31.0519}{1.1569}$
Diesel cars	US emissions intensity (gCO_2/km, WLTP)	$= \frac{[1.1589 * Y - 16.5771] + 14.4674}{1.0497}$
	Japanese emissions intensity (gCO_2/km, WLTP)	$= \frac{[0.9695 * Y + 27.4167] + 14.4674}{1.0497}$
	Chinese and EU emissions intensity (gCO_2/km, WLTP for 2019-2020)	$= \frac{[1.0871 * Y + 12.7300] + 14.4674}{1.0497}$

These conversions result in the following regional emissions data for petrol and diesel cars respectively:

			2019	2020	2021
EU	Petrol	gCO_2/km, WLTP	136	119	118[17]
	Diesel	gCO_2/km, WLTP	144	125	

[17] No units nor test cycle conversions is required for 2021 EU data as it has already been reported in gCO2/km, WLTP

US	Petrol	gCO_2/km, WLTP	151	154	150
	Diesel	gCO_2/km, WLTP	166	169	165
China	Petrol	gCO_2/km, WLTP	157	150	140
	Diesel	gCO_2/km, WLTP	187	170	161
Japan	Petrol	gCO_2/km, WLTP	135	133	131
	Diesel	gCO_2/km, WLTP	150	147	145

The emissions intensities for petrol and diesel cars are then weighted by their sales shares. Diesel sales shares in the US and China are estimated at 1%; in Japan at 4%. In the EU, the diesel sales share is estimated at 32% for 2019 and 29% for 2020 respectively.

This results in the following average regional emissions intensities:

		2019	2020	2021
EU	gCO_2/km, WLTP	138	121	118
US	gCO_2/km, WLTP	152	154	151
China	gCO_2/km, WLTP	157	150	140
Japan	gCO_2/km, WLTP	135	134	132

These intensities are then weighted by the company's regional sales data to provide global averages. The company's sales data are:

000' vehicles	2019	2020	2021
EU	521	391	340
NAFTA	1,620	1,213	1,183
China	1,547	1,457	1,381
Japan	534	478	428
Volume covered by sales breakdown	4,222	3,539	3,332
Global Total	4,930	4,052	3,876
% of total sales covered by regional breakdown	86%	87%	86%

It is assumed that NAFTA emissions are the same as the US. For companies selling in markets not covered by published emissions data, the corresponding regional emissions intensity is estimated from ICCT's Well-to-Wheel historical country new vehicle average gCO_2/km emissions (Table 3). The coefficient used would be the ratio relative to the largest sales market for the assessed company.

After applying sales weightings across all regional emissions intensities (gCO2/km, WLTP), we can calculate Company A's global average emissions intensity:

		2019	2020	2021
Company A new passenger vehicle registrations	Average gCO_2/km, WLTP	150	146	141

4.4.2. Future emissions intensity

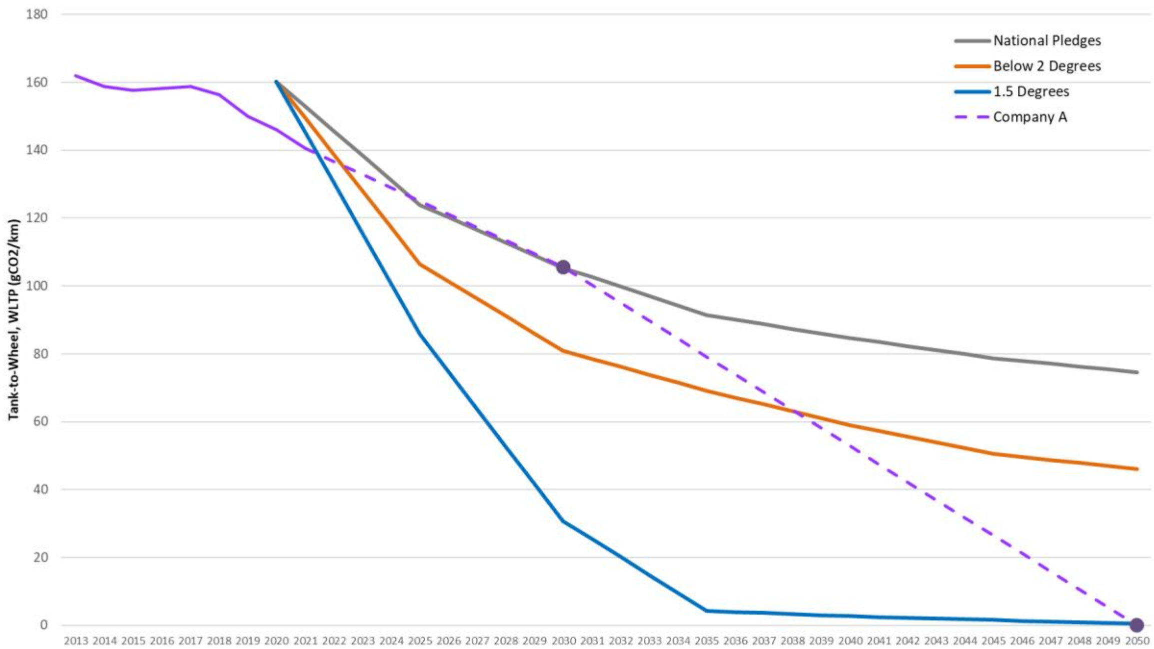
Company A disclosed a target to reduce its fleet average CO2 emissions of all new vehicles in 2030 by 32.5% from a 2018 base year and achieve net-zero emissions for all new vehicles in 2050. The company specifies these targets cover tank-to-wheel emissions, which is in line with our methodology. We assume these targeted reductions for Company A's total new vehicle sales can be applied proportionally to new passenger vehicle sales. In this case, the 2018 base year value can be calculated using the approach listed above for 2019-2021 emissions intensities. The value estimated is 156 gCO_2/km, WLTP.

Therefore, Company A's 2030 and 2050 new vehicle emissions target can be calculated as:

$$2030\ target = 156\ *(1 - 32.5\%) = 106\ \mathrm{gCO2/km}$$

$$2050\ target = 156\ *(1 - 100\%) = 0\ \mathrm{gCO2/km}$$

4.4.3. Carbon Performance Pathway



5. DISCUSSION

This note describes the methodology followed by TPI in assessing the Carbon Performance of the auto manufacturing sector. The approach aims to be both easy to understand and use, while also being robust. However, there are unavoidable uncertainties and judgements made in the development of the methodology, as well as in individual company assessments. Investors may wish to dig deeper in their engagements with companies to understand these.

5.1. General Issues

The methodology builds on the Sectoral Decarbonization Approach (SDA), which compares a company's emissions intensity with sector-specific benchmarks that are consistent with international targets (i.e., limiting global warming to 1.5°C, well below 2°C, and the sum of National Pledges).

TPI uses the modelling of the IEA to calculate the benchmark paths. The IEA modelling has several advantages, but it is also subject to limitations, like all other economy-energy modelling. Model projections often turn out to be wrong. This could impact the accuracy of the benchmark and potentially lead to investors drawing inaccurate conclusions about a company's alignment. The IEA frequently updates its modelling and TPI plans to update its benchmark calculations accordingly. Nevertheless, in such a forward-looking exercise there is no way to avoid the uncertainty created by projecting into the future.

TPI predominantly uses disclosed emissions and activity data to derive emissions intensity paths. While much of this data is audited, the emissions intensity estimates can only be as accurate as the underlying disclosures.

Estimating the recent, current, and especially the future emissions intensity of companies involves several assumptions. Therefore, it is important to bear in mind that, in some cases, the emissions path drawn for each company is an estimate made by TPI, based on information disclosed by companies, rather than the companies' own estimate or target. In other cases, the information disclosed by companies is sufficient on its own to completely characterise the emissions intensity path.

5.2. Issues specific to the autos sector

Within the context of the SDA, automobile manufacturing has required a distinctive approach to carbon performance assessment, compared with other sectors that TPI has covered so far, e.g., electricity, cement, and steel. In particular, the assessment focuses on the emissions performance of automobile manufacturers' new vehicles, rather than the emissions intensity of the manufacturing process itself. This is justified on the grounds that it is downstream of manufacturing where automobile makers' lifecycle carbon footprint is concentrated.

In order to derive company paths for new vehicle emissions, we have combined regulatory data on emissions performance or fuel efficiency with company data on sales. The main challenges encountered here include converting regulatory emissions data to a common basis, which involves some uncertainties but still rests on strong empirical data. In addition, imputing emissions performance data for countries and regions outside of the EU, US, and China is achieved by assuming variations at the company level mirror variations at the sector level.

As in other sectors, TPI's analysis is highly dependent on company disclosure. In the automobile sector, this poses three particular challenges:

- First, passenger cars are defined differently by the different regional regulatory bodies, to whom companies report their emissions intensities, as well as by the companies themselves. For instance, Chinese and US industry bodies classifies some SUVs, mini-vans, and pickups as light trucks rather than regular passenger cars. On the other hand, companies may classify these cars as passenger cars in their disclosed sales volumes. Consequently, for certain regions there can be a discrepancy between a company's car sample used to calculate the company's average emissions intensity (excluding light trucks) and the sample of cars used for the regional sales weighting (including some light trucks). This can result in an underestimate of a company's overall intensity, especially for automobile manufacturers that sell a larger number of big passenger cars such as SUVs and pickups in the US.
- Second, there have been controversies around automakers efforts to minimize their intensities in official emissions tests. Research by the ICCT [14] has shown that there is an increasing divergence between real-world performance and official emissions test intensities, leading to an underestimation. This is partially addressed by TPI's shift towards adopting the World Harmonized Light Vehicles Test Procedure (WLTP) in our assessments. The new WLTP cycle is believed to better reflect real-world performance by reducing the gap with real-world emissions to approximately 14% (previous NEDC test cycle is suggested to have a 40% gap with real-world emissions) [15].
- Third, TPI acknowledges that the phase-in of zero-tailpipe emission vehicles in low-carbon scenarios increases the significance of operational and upstream emissions in the automobile manufacturing value-chain. At the time of publishing this methodology note, the large majority of new passenger car sales were still ICE vehicles[18], meaning the bulk of value chain emissions from new car sales still occur in the use phase. The availability of modelling and company disclosure that reports Scope 1 and 2, as well as Scope 3 upstream emissions for new passenger car sales also poses a challenge as it is very limited or even non-existent. Currently electric vehicles (EVs) are treated as having zero emissions. This is consistent with how regulators around the world have decided to treat EVs and how it is accounted for in the benchmark scenarios. However, as long as countries' electricity grids are not delivering electricity with zero emissions, charging EVs cannot be carbon-free.

These three limitations are currently accepted as they cannot be solved with more accurate and comprehensive data. For these reasons, we conclude that our estimates should be considered as a lower-bound estimate for most companies.

[18] Source: https://www.iea.org/reports/electric-vehicles (IEA, 2022)

6. DISCLAIMER

1. Data and information published in this paper and on the TPI website is intended principally for investor use but, before any such use, you should read the TPI website terms and conditions to ensure you are complying with some basic requirements which are designed to safeguard the TPI whilst allowing sensible and open use of TPI data. References in these terms and conditions to “data” or “information” on the website shall include the carbon performance data, the management quality indicators or scores, and all related information.
2. By accessing the data and information published in the report and on this website, you acknowledge that you understand and agree to these website terms and conditions. In particular, please read paragraphs 4 and 5 below which details certain data use restrictions.
3. The data and information provided by the TPI can be used by you in a variety of ways – such as to inform your investment research, your corporate engagement and proxy-voting, to analyse your portfolios and publish the outcomes to demonstrate to your stakeholders your delivery of climate policy objectives and to support the TPI in its initiative. However, you must make your own decisions on how to use TPI data as the TPI cannot guarantee the accuracy of any data made available, the data and information on the website is not intended to constitute or form the basis of any advice (investment, professional or otherwise), and the TPI does not accept any liability for any claim or loss arising from any use of, or reliance on, the data or information. Furthermore, the TPI does not impose any obligations on supporting organisations to use TPI data in any particular way. It is for individual organisations to determine the most appropriate ways in which TPI can be helpful to their internal processes.
4. Subject to paragraph 3 above, none of the data or information on the website is permitted to be used in connection with the creation, development, exploitation, calculation, dissemination, distribution or publication of financial indices or analytics products or datasets (including any scoring, indicator, metric or model relating to environmental, climate, carbon, sustainability or other similar considerations) or financial products (being exchange traded funds, mutual funds, undertakings collective investment in transferable securities (UCITS), collective investment schemes, separate managed accounts, listed futures and listed options); and you are prohibited from using any data or information on the website in any of such ways and from permitting or purporting to permit any such use.
5. Notwithstanding any other provision of these website terms and conditions, none of the data or information on the website may be reproduced or made available by you to any other person except that you may reproduce an insubstantial amount of the data or information on the website for the uses permitted above.
6. The data and information on the website may not be used in any way other than as permitted above. If you would like to use any such data or information in a manner that is not permitted above, you will need TPI’s written permission. In this regard, please email all inquiries to tpi@unpri.org.

7. BIBLIOGRAPHY

[1] J. Randers, "Greenhouse gas emissions per unit of value added ('GEVA'): a corporate guide to voluntary climate action," *Energy Policy,* vol. 48, pp. 46-55, 2012.

[2] IEA, "MoMo Model," September, 2021.

[3] IEA, "Net Zero by 2050 - A Roadmap for the Global Energy Sector," Paris, 2021.

[4] IEA, "Energy Technology Perspective 2020," Paris, 2020.

[5] IEA, "Global EV Outlook," Paris, 2019-2022.

[6] IEA, "World Energy Outlook 2021," Paris, 2021.

[7] ICCT, "GLOBAL TRANSPORTATION ENERGY AND CLIMATE ROADMAP," 2005, 2012.

[8] IEA, "Electric vehicle stock in the EV30@30 scenario, 2018-2030," 2022. [Online]. Available: https://www.iea.org/data-and-statistics/charts/electric-vehicle-stock-in-the-ev3030-scenario-2018-2030.

[9] ICCT, "Methods of converting the type-approval fuel economy and CO2 emission values of light vehicles: An analysis for New Zealand," 2021.

[10] ICCT, "Development of test cycle conversion factors among worldwide light-duty vehicle CO2 emission standards," 2014.

[11] ICCT, "The New Passenger Car Fleet in China 2010".

[12] ICCT, "Shifting Gears: the effects of a future of decline in diesel market share on tailpipe CO2 and NOx emissions in Europe".

[13] ICCT, "European Vehicle Market Statistics, Pocketbook 2021/22".

[14] ICCT, "On the way to real world CO2 values: The European passenger car market in its first year after introducing the WLTP," 2020.

[15] SBTi, "Sectoral Decarbonization Approach (SDA): A Method for Setting Corporate Emission Reduction Targets in line with Climate Science," 2015.

GLOSSARY

ICE	Internal combustion engine vehicles
BEV	Battery electric vehicles
FCEV	Fuel cell electric vehicles
PHEV	Plug-in hybrid electric vehicles
NEDC	New European Driving Cycle A driving cycle, last updated in 1997, designed to assess the emission levels of car engines and fuel economy in passenger cars.
WLTP	Worldwide harmonized Light vehicles Test Procedures New test designed by the EU to better assess the emission levels of car engines. It is believed that fuel economy values estimated through the WLTP cycle better reflects real-world emissions compared to NEDC.
CAFE	Corporate Average Fuel Economy standards Regulations in the US, first enacted in 1975, to improve the average fuel economy of cars and light trucks produced for sale in the US.
JC08	Test cycle introduced by the Japanese 2005 emission regulation to determine fuel economy of automobiles for sale in Japan.