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# Japan and the global transition to zero emission vehicles

Research report summary

May 2022

# Introduction

In 2021, international non-profit Climate Group commissioned independent reports from two expert researchers on the current status of zero emission vehicles (ZEVs)<sup>1</sup> in Japan and the economic impacts of hybrid electric vehicles (HEVs) for the Japanese automotive industry.

This paper provides a summary of the key findings and arguments presented in the reports.<sup>2</sup> Both call for a rapid shift in Japanese automotive manufacturing away from traditional internal combustion engine vehicles (ICEVs) and HEVs to ZEVs and discuss the potential negative economic,

environmental, and societal impacts for Japan if its automotive industry fails to alter its current path.

**The two reports were written by:**

**Kenichiro Wada**, former Head of Development, Mitsubishi iMiev and founder and CEO of the Japan Electrification Institute

**Professor Masahiro Inoue**, former Design Director of the first-generation Nissan Leaf and professor at the Italian University of Design in Turin

**This summary is structured as follows:**

**Part 1:** The current situation in Japan

**Part 2:** Environmental impact of HEVs and BEVs

**Part 3:** Estimates of economic impact

**Part 4:** Policy suggestions

<sup>1</sup> The term "ZEVs" in this report primarily refers to battery electric vehicles (BEVs), although it also includes fuel cell electric vehicles (FCEVs) and plug-in hybrid vehicles (PHEVs). The Japanese government frequently uses the term "xEVs" which includes all of these as well as non-plug-in hybrid vehicles (HEVs). For this reason, this report does not use the term "EVs" to refer to "BEVs" as in Japan this is widely understood to also include HEVs.

<sup>2</sup> This summary has been compiled for Climate Group based on the two expert reports by team members at the government relations consultancy, GR Japan: Austin Smith, Debbie Warrenner, Izumi Fujiwara, Kayako Kobayashi and Yuri Iwaya. Data and references used include both those available at the time the two reports were written in summer-autumn 2021 and the latest available data from 2022.

An online event to present the findings from the research was hosted during COP26 on 11 November 2021, the day after Transport Day, with simultaneous translation in Japanese and English.

In addition to the two expert researchers, Wada and Inoue, presenters at the event included: Japanese Parliamentary Vice-Minister for Foreign Affairs, Shingo Miyake; (chair) Meryam Omi, Head of Sustainability and Responsible Investment Strategy, Legal & General Investment Management; Angela Hultberg, Road Transport Lead for UN Climate Champions; Tomohiko Ikeya, Central Research Institute of Electric Power Industry (CRIEPI); Hideaki Kawano, TEPCO Holdings EV Promotion Office Manager; and Sandra Roling, Head of Transport, Climate Group.

On Transport Day at COP26 a declaration on accelerating the transition to 100% zero emission cars and vans was launched. It was signed by national governments (including the UK, Chile, and New Zealand); state governments (including Chungcheongnam-do Province, Jeju Special Self-Governing Province, and Seoul Metropolitan Government); cities (including City of São Paulo, City of Buenos Aires, and City of Los Angeles); automakers (including Ford, General Motors, and Volvo Cars) and fleet operators (including SK Networks, Uber, SIEMENS). The total list contains markets representing two billion people and automakers representing more than a quarter of car sales globally, committed to working towards 100% of all vehicle sales being zero emission by 2040 or earlier.

## Part 1:

# The current situation in Japan

### Japan: a major automotive nation

Japan is the third largest automotive manufacturing nation in the world and boasts one of the largest automotive markets, surpassed in size only by the United States and China. Japan is also the world's second-largest car exporter, behind Germany, supplying nearly 13% of passenger vehicles around the world in 2019. As such, the automotive industry is vital for the Japanese economy, constituting around 18.8% of all manufacturing in Japan, with cars and car products the nation's largest exports. Japanese automotive manufacturers are also major players in the global industry: Toyota is the world's largest automotive manufacturer by sales, with Honda fourth and Nissan fifth.

Both Wada and Inoue note that Japan's economy is now regarded as "one-legged" due to its substantial reliance on the automotive sector. Until recently, the economy had three substantial pillars: semiconductors, home appliances, and automotive vehicles. But Japan has lost its dominance of the first two sectors to competition from elsewhere, particularly South Korea, China, and Taiwan. The question of whether the Japanese automotive sector will just survive or actually thrive in the current global transition to ZEVs therefore cuts to the very heart of Japanese economic strength and stability.

**Table 1:** 2021 vehicle sales figures in Japan according to type

Year	ICEVs	HEVs	PHEVs	BEVs	FCEVs	Total
2020	3,275,991	1,347,535	14,741	14,604	761	4,653,632
2021	2,959,919	1,441,487	22,777	21,693	2,464	4,448,340

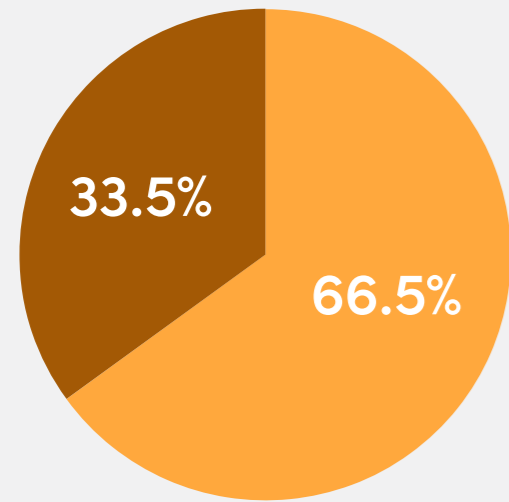
Source: Automotive Business Association of Japan (ABA)<sup>3</sup> and (ABA)<sup>4</sup>

<sup>3</sup> [www.aba-j.or.jp/info/industry/16777/](http://www.aba-j.or.jp/info/industry/16777/)

<sup>4</sup> [www.aba-j.or.jp/info/industry/16684/](http://www.aba-j.or.jp/info/industry/16684/)



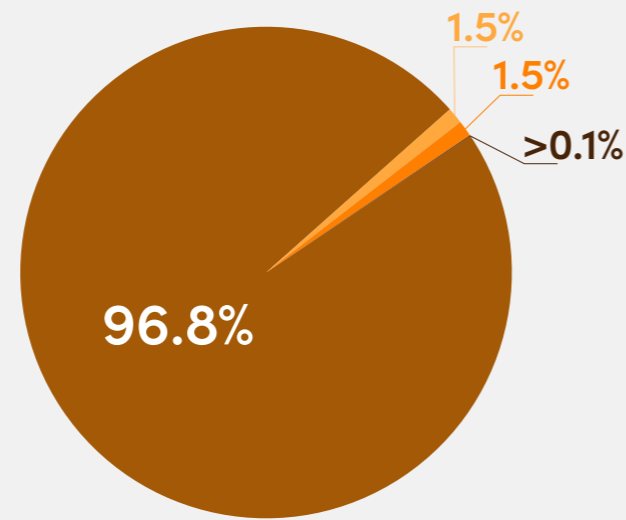
**Graph 1: Domestic sales of xEVs and ICEs in Japan in 2021**



■ xEVs (Includes HEV, PHEV, BEV, FCEV) 2,959,919 units  
 ■ ICE 3,275,991 units

Source: Automotive Business Association of Japan (ABA)<sup>5</sup>

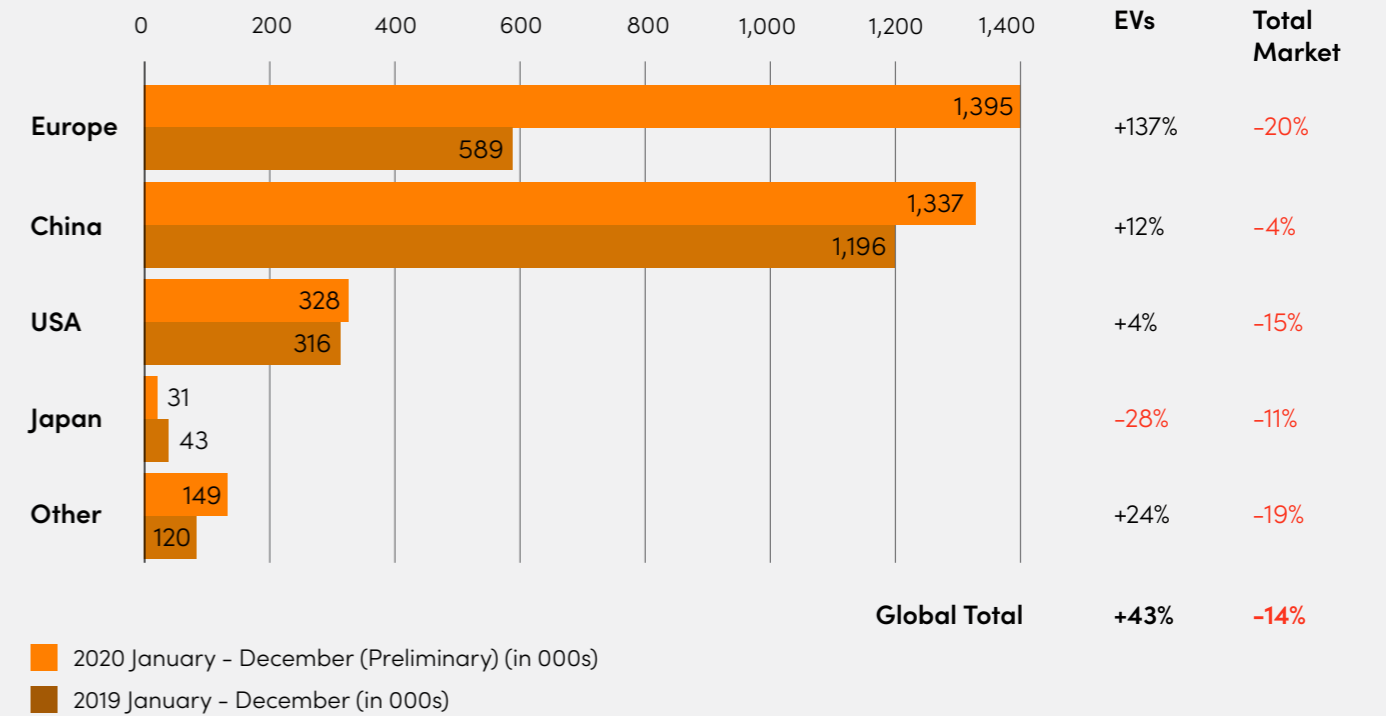
**Graph 2: Sales of xEVs in Japan according to type in 2021**



■ HEVs  
 ■ PHEVs  
 ■ FCEVs

Source: Automotive Business Association of Japan (ABA)<sup>6</sup>

**Graph 3: Growth of BEV and PHEV sales by region**



Source: EV Volumes<sup>8</sup>

### Very low domestic ZEV sales

Sales of ZEVs in Japan are currently very low. Wada cites data provided by the Automotive Business Association of Japan (ABA) and illustrated in Table 1 and Graphs 1 and 2. As can be seen, electric-powered “xEVs” account for 30% of the domestic market. However, within this, HEVs (i.e. non-ZEVs) make up 98% of those sales.

#### Wada shares three reasons for such low ZEV sales in Japan:

- Consumers have limited options as few companies sell ZEVs;
- There are few battery manufacturers and batteries are expensive – large investments have been made by Toyota and Panasonic in nickel-metal hydride batteries for HEVs, but until very recently fewer investments have been made in lithium-ion batteries for BEVs and PHEVs; and
- 7,600 quick chargers are installed in Japan, but more than 40% of them are installed at car dealerships which makes them difficult to access.

<sup>5</sup> [www.aba-j.or.jp/info/industry/16684/](http://www.aba-j.or.jp/info/industry/16684/)

<sup>6</sup> [www.aba-j.or.jp/info/industry/16777/](http://www.aba-j.or.jp/info/industry/16777/)

<sup>7</sup> “xEV” is the term generally used by the Japanese government to refer to any vehicles that are not solely powered by an internal combustion engine, including HEVs, BEVs, PHEVs, and FCEVs (see Footnote 1).

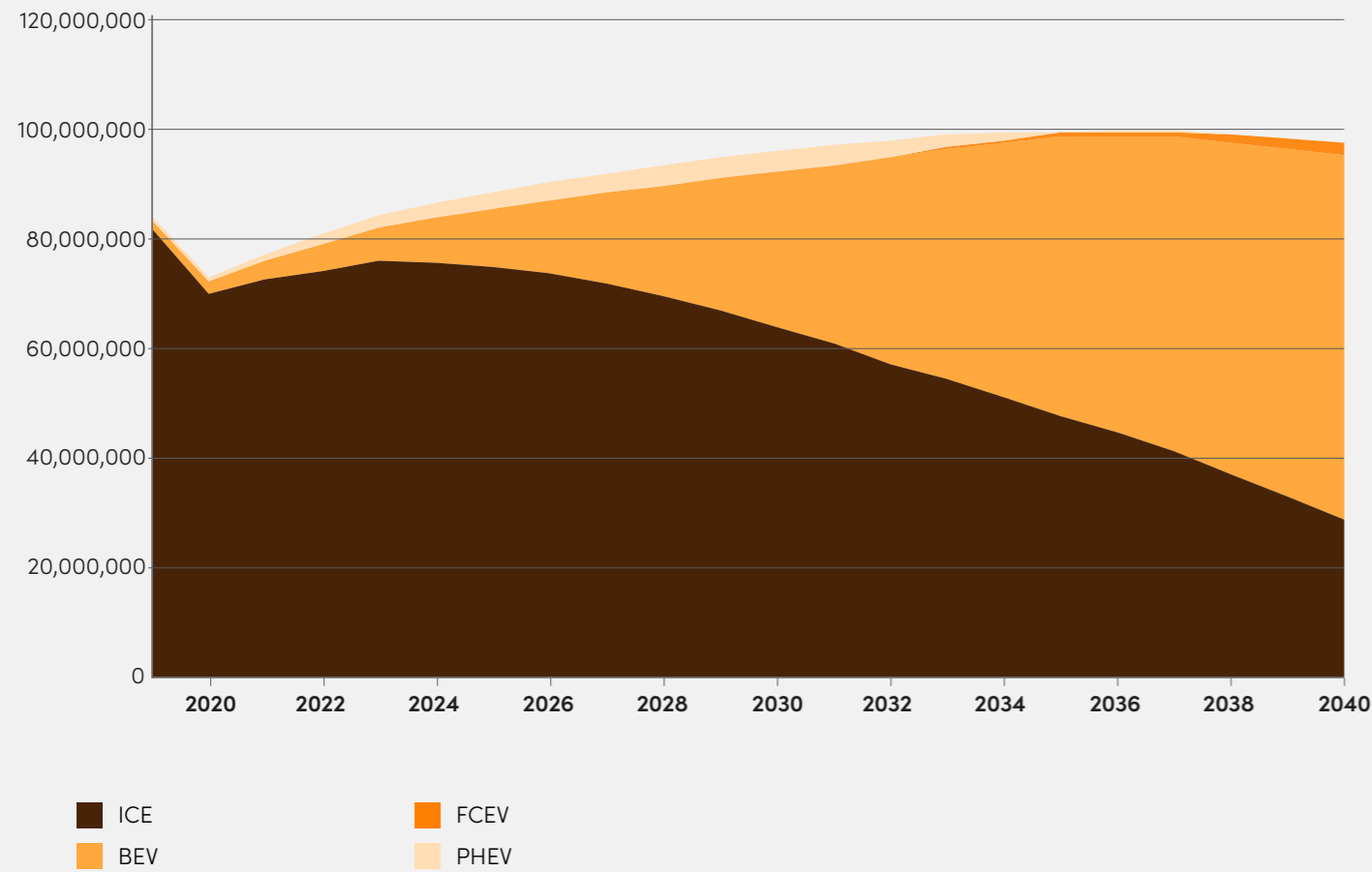
<sup>8</sup> [www.ev-volumes.com/country/total-world-plug-in-vehicle-volumes/](http://www.ev-volumes.com/country/total-world-plug-in-vehicle-volumes/)

**Table 2: Growth of BEV and PHEV sales by Region (2019-Q3 2021)**

	Drive train	2019	2020	2021	Δ% (2019/20)	Δ% (2020/21)	Δ% (2019/21)
Europe	FCV	572	676	576	18.2%	-14.79%	0.7%
	PHEV	187,907	680,162	804,427	262%	18.27%	328.1%
	BEV	350,596	752,540	818,163	114.7%	8.72%	133.4%
China	PHEV	226,018	239,447	356,911	6%	49.06%	58%
	BEV	861,572	970,556	1,642,431	12.7%	69.23%	90.6%
USA	FCV	2,089	809	2,743	-61.3%	239.06%	31.3%
	PHEV	84,062	65,340	112,457	-22.3%	72.11%	33.8%
	BEV	235,492	259,424	322,710	10.2%	24.39%	37%
Japan	FCV	644	717	2,165	11.3%	201.95%	236.2%
	PHEV	14,855	14,413	17,442	-3%	21.02%	17.4%
	BEV	20,424	16,558	14,964	-19%	-9.63%	-26.7%
Rest of World	FCV	0	0	35	N/A	N/A	N/A
	PHEV	480	8,105	13,347	1588.5%	64.68%	2680.6%
	BEV	43,852	60,948	41,327	39%	-32.19%	-5.8%

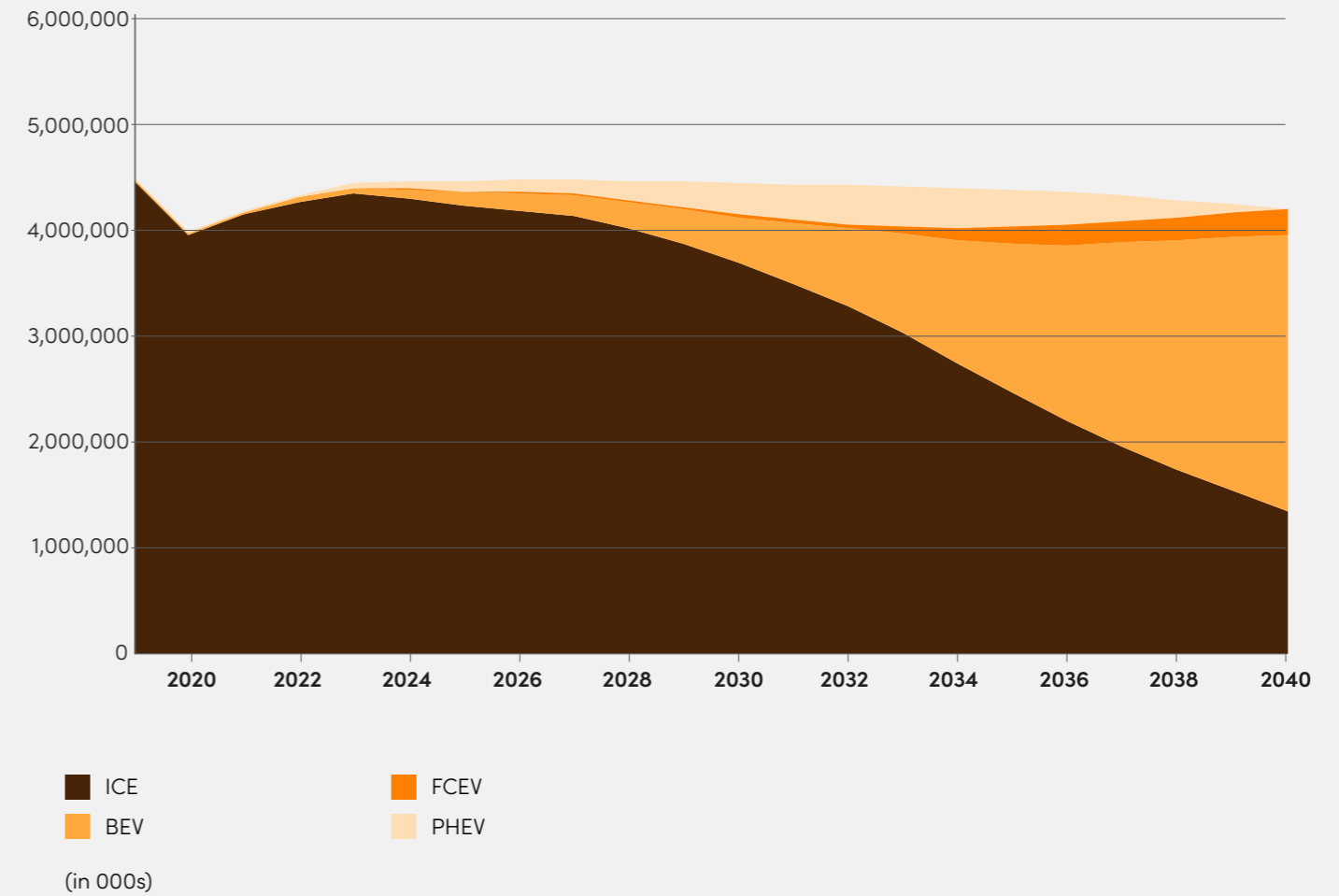
Source: BNEF (accessed 10 March 2022) [www.ev-volumes.com/country/total-world-plug-in-vehicle-volumes/](http://www.ev-volumes.com/country/total-world-plug-in-vehicle-volumes/)

**Graph 4: Global car sales projection – 2019–2040**



Source: BNEF (accessed 14 March 2022)

**Graph 5: Japan car sales projection – 2019–2040**



(in 000s)

Source: BNEF (accessed 14 March 2022)

### Domestic market lags behind the global trend

Such low ZEV sales in Japan contrast with recently increasing ZEV sales trends in major markets such as Europe, China and the US (Graphs 4 and 5.) Wada cites data provided by EV Volumes and set out in Table 2, to illustrate this. Globally BEV and PHEV sales went up by 43% between 2019 and 2020 with particularly strong growth in Europe (plus 137%). Japan, on the other hand, showed minus 28% growth in BEVs and PHEVs during the same time period. Furthermore, total sales volumes of BEVs

and PHEVs are tiny in Japan relative to the growing volumes elsewhere, particularly in Europe and China, but also in the US.

Table 2 and Graphs 4 and 5 draw from the latest available BNEF data and show this trend is very much continuing. Table 2 shows BEV sales increases between 2019 and Q3 2021 of 133.4% in Europe, 90.6% in China and 37.0% in the US. Japan is clearly the outlier as BEV sales declined by 26.7% over this period. BNEF data plotted in Graphs 4 and 5 show how the changes

in Japan are predicted to be much more gradual and later than the global trends.

As a further indication of how Japan is falling behind internationally, Inoue notes that only two Japanese vehicles were in the top 20 most popular BEVs globally in 2020 – the Nissan Leaf and the Mitsubishi Outlander PHEV. In the latest data from 2021, shown in Table 3, now only the Nissan Leaf is included, in 14th place. Inoue also quoted a July 2021 report by the Fuji Keizai Group that showed global sales of BEVs

are expected to overtake global HEV sales by 2022.

Japan's poor take-up of ZEVs and continuing focus on HEVs in the domestic market is therefore clearly lagging behind global trends. The Japanese automotive industry, which relies on overseas business for around 75% of its profit base, must adapt to the shifting tides that increasingly favour ZEVs.

**Table 3: 2021 BEV global sales ranking (Q1-Q3 2021)<sup>9</sup>**

	Model Name	Q3 2021	Q1-Q3 2021
1	Tesla Model 3 BEV	142,271	395,331
2	SAIC Wuling Hongguang Mini BEV	103,269	286,036
3	Tesla Model Y BEV	126,956	258,212
4	BYD Han BEV	19,901	58,580
5	ChangAn Benni EC 260 BEV	24,054	53,244
6	Volkswagen ID 3 BEV	21,897	52,603
7	Volkswagen ID.4 BEV	19,418	50,377
8	Chery EQ1 BEV	19,355	50,294
9	Renault Zoe ZE BEV	16,104	48,475
10	Kia Niro BEV	19,571	47,724
11	GAC Aion S BEV	17,989	47,527
12	ORA R1 BEV	15,093	47,087
13	Hyundai Kona BEV	14,254	43,569
14	Nissan Leaf BEV	13,376	42,174
15	BMW iX3 BEV	17,689	39,749
16	Xpeng P7 (E28) BEV	19,731	39,227
17	Ford Mach E BEV	17,222	37,795
18	BYD Qin BEV	26,967	35,960
19	SAIC Roewe Clever BEV	16,305	34,998
20	Audi e-tron SUV BEV	9,095	33,484

Source: BNEF (accessed on 10 March 2022)

<sup>9</sup> Names of the models in the table are as listed in the original source.

## Limited commitments to full electrification by Japanese manufacturers

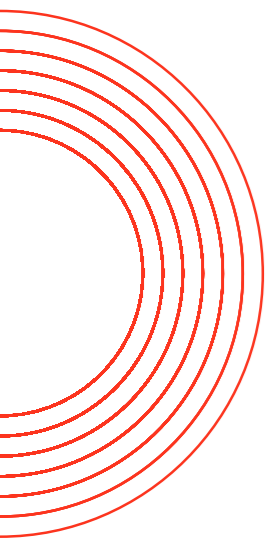
Japanese automotive manufacturers have historically promoted HEVs over ZEVs. They have successfully led and dominated the global HEV market and are therefore reluctant to move away from this technology and the investments made throughout the supply chain and in manufacturing facilities.

In October 2020, then Prime Minister, Yoshihide Suga, committed Japan to reaching net zero carbon emissions by 2050. Japanese automotive manufacturers have responded with commitments to decarbonise but most of these still involve a major commitment to HEVs. Wada summarised the latest commitments – these are outlined in Table 4. Although Honda’s 2040 commitment to full electrification is more aggressive than others, all Japanese manufacturers are behind the global trend: the more

ambitious targets set by key rival manufacturers are set out in Table 5.

In his role as chair of the highly influential Japanese automotive industry association, the Japan Automotive Manufacturers Association (JAMA), Toyota’s CEO, Akio Toyoda, has historically been a vocal opponent of shifting too rapidly away from the production of HEVs. He has argued that a substantial shift to ZEVs in the near future is untenable, citing the costs of infrastructure investments and training required to mass produce ZEVs as roadblocks for the industry.





**Table 4: Japanese automotive industry commitments to electrification**

Company	Report	Additional info or update (if any)
Toyota	Global sales of 3.5 million BEVs per year by 2030 and will roll out 30 BEV models by 2030 (December 2021 announcement) (Toyota sold just over 9.5 million vehicles globally in 2020)	<ul style="list-style-type: none"> <li>• USD 35 billion (2030) on electrification</li> <li>• 3.5 million BEV sales by 2030</li> <li>• 30 BEV models across Lexus and luxury brands (2030)</li> </ul>
Honda	Increase the ratio of BEVs and FCEVs in all major markets to 100% by 2040	<ul style="list-style-type: none"> <li>• USD 46.3 billion (2026) on R&amp;D (incl. electrification)</li> <li>• 40% EV sales (2030), 100% EV sales in major markets (2040)</li> </ul>
Nissan	100 of all new vehicle offerings in key markets to be electrified by the early 2030s (includes HEVs) and to be fully carbon neutral across the entire life cycle by 2050	<ul style="list-style-type: none"> <li>• USD 10 billion (2025) on electrification</li> <li>• 50% EV sales by 2030 and 23 EV models by 2030</li> </ul>
Suzuki	Develop small-frame and passenger HEVs and PHEVs by 2025 and enter the “electrified car” market in the same year	No change
Mazda	Develop small-frame and passenger HEVs and PHEVs by 2025 and enter the “electrified car” market in the same year	<ul style="list-style-type: none"> <li>• 100% of its products will have “some level of electrification” and 25% of its vehicle lineup in 2030 will be EV</li> <li>• Will roll out 5 HEVs, 5 PHEVs and 3 BEVs (2025)</li> </ul>
Subaru	More than 40% of global sales to include BEVs or HEVs by 2030	• 100% EVs by mid-2030s
Mitsubishi	Increase the ratio of “electrified car” sales (includes HEVs) to 50% globally by 2030	• As part of the Renault-Nissan-Mitsubishi alliance, Mitsubishi will contribute to a EUR 23 billion investment in electrification and help roll out 35 new EV models by 2030.

Source: Wada plus recent announcements

**Table 5: Other international automotive manufacturers’ commitments to electrification**

Company	Stated corporate goals shifting to electric vehicles	Additional info or update (if any)
Daimler (Mercedes Benz)	Mercedes-Benz will sell only electric vehicles by 2030	<ul style="list-style-type: none"> <li>• EUR 40 billion (2026) on electrification</li> <li>• Will be ready to go all-electric (BEV) within a decade</li> <li>• 13 new BEV models (2030)</li> </ul>
General Motors	Completely phase out vehicles using internal combustion engines by 2035	<ul style="list-style-type: none"> <li>• USD 35 billion (2025) on electrification</li> <li>• 100% EV sales (2035)</li> <li>• 30 new EV models (2025)</li> </ul>
Stellantis	Increase the ratio of BEVs and PHEVs to 70% in Europe and 40% in the US by 2030	<ul style="list-style-type: none"> <li>• EUR 30 billion (2025)</li> <li>• 5 million BEV sales [~ 68%] (2030)</li> <li>• 100% BEV sales in European markets and 50% BEV sales in US markets</li> <li>• 75 BEV models (2030)</li> </ul>
Volkswagen	Increase the ratio of BEVs in the European market to 70% by 2030	<ul style="list-style-type: none"> <li>• USD 82 billion (2025) on “future technologies”, including electrification</li> <li>• 60% BEV sales in European markets (2030)</li> <li>• 70 BEV models (2030)</li> </ul>

Source: Toyo Keizai plus recent announcements<sup>10</sup>

For example, in response to Suga’s net-zero commitment, Toyota expressed his concerns, suggesting:<sup>11</sup>

- Japan’s automotive industry business model may collapse if the transition to net zero is too fast;
- Japan would run out of electricity in summer if all cars ran on electric power;
- The cost of installing the necessary charging infrastructure is prohibitively high;
- BEVs will be too expensive for the average consumer; and
- Japan’s energy is not clean enough, so shifting to BEVs will not reduce emissions – “the more EVs we build, the worse carbon dioxide gets”.

However, recently this has changed. In an announcement in December, Toyota announced that Toyota would offer 30 BEV models globally by 2030 as part of their ‘showroom of the future’<sup>12</sup> and invest \$35 billion (4 trillion yen) in the process. The change in position from one year to the next shows how fast this space is changing – and the real risk of being left behind. Similarly, in January 2022, Renault, Nissan and Mitsubishi Motors announced that they plan to invest \$26.3 billion (3 trillion yen) to launch 35 new EV models by 2030 as part of their future roadmap.<sup>13</sup> Following that, it is expected that “Nissan Motor will end development of new internal combustion engines in all its major markets except the US and focus its resources on electric vehicles, becoming the first major Japanese automaker to make such a break”.<sup>14</sup>

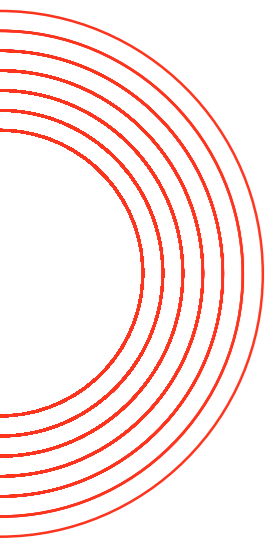
<sup>10</sup> “The EV Industrial Revolution.” Toyo Keizai Weekly, 9 Oct. 2021, p. 40

<sup>11</sup> Japan Automobile Manufacturers Association (JAMA) online press conference on 17 December 2020: [www.youtube.com/watch?v=6zozn1VU0VU](https://www.youtube.com/watch?v=6zozn1VU0VU)

<sup>12</sup> [global.toyota/en/newsroom/corporate/36428993.html#presentation](https://global.toyota/en/newsroom/corporate/36428993.html#presentation)

<sup>13</sup> [global.nissannews.com/en/releases/alliance-digital-conference-2022](https://global.nissannews.com/en/releases/alliance-digital-conference-2022)

<sup>14</sup> [asia.nikkei.com/Business/Automobiles/Nissan-to-end-most-development-of-new-gasoline-engines](https://asia.nikkei.com/Business/Automobiles/Nissan-to-end-most-development-of-new-gasoline-engines)



**Table 6:** Comparison of automotive-related targets and regulations by region

Countries	Automotive-related target
EU	Sales of new vehicles with ICEs to be banned by 2035
UK	Sales of new vehicles with ICEs to be banned by 2030
USA	50% of new vehicle sales to be ZEVs and PHEVs by 2030
China	50% of new vehicle sales to be NEVs (BEVs, FCEVs, PHEVs) and 50% to be HEVs by 2035
Japan	All new vehicle sales to be electrified vehicles by 2035

Source: Wada plus recent announcements

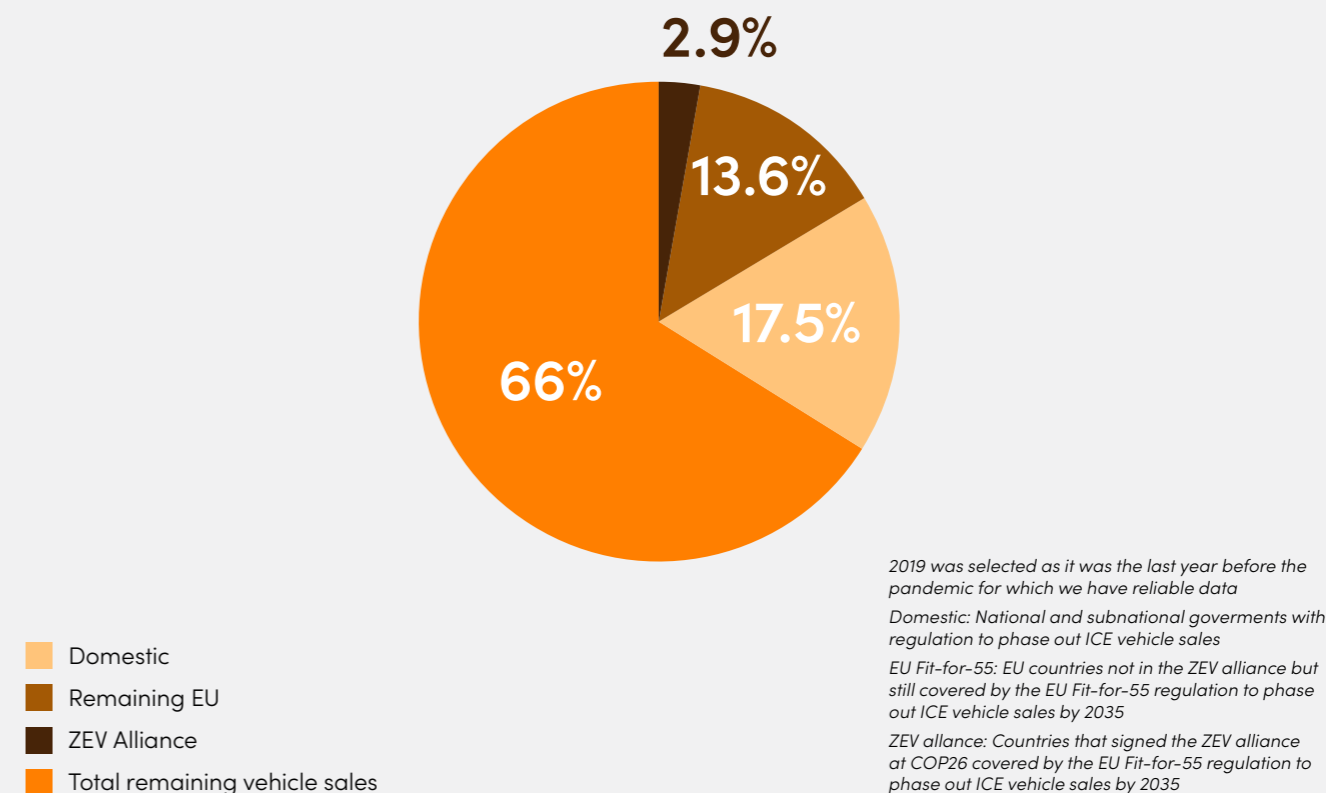
### Major markets rapidly phasing out ICEVs including HEVs

Despite the international trends, the Japanese government typically sticks to a similar position to industry on the ongoing importance of HEVs. Its latest policy goal, set out in the Green Growth Strategy launched following Suga's net zero commitment, is to achieve 100% xEV sales by 2035. This includes HEVs, where sales are already almost 30% of the total in Japan.

Whilst most of the domestic automotive industry and government remain reluctant to budge from their focus on HEVs, other major markets are increasingly implementing incentives to promote ZEV use and curtail HEV and ICEV sales.

Wada highlights the EU taxonomy for sustainable activities, published by the European Commission in April 2021, as particularly significant, as this is the first regulation set that explicitly excludes PHEVs from the sustainable investment target after 2025. The Fit for 55 package, which the European Commission published in July 2021, also follows a similar logic. This package plans to prohibit sales of ICEVs, including HEVs and PHEVs, in the EU by 2035.

**Graph 6:** COP26 ZEV alliance



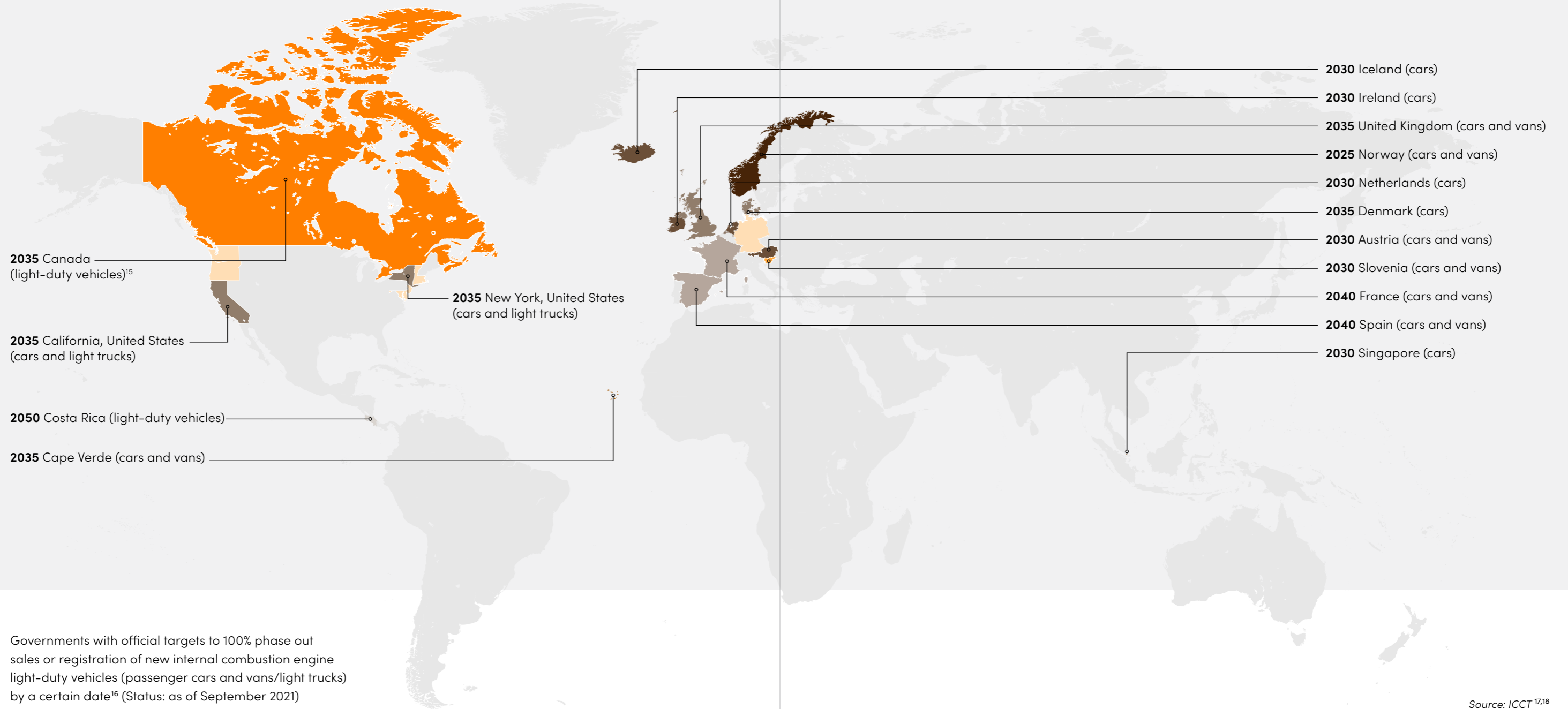
As the major markets move forward with efforts to ban HEVs and PHEVs, as part of wider moves away from ICEVs, Wada states only Japan and China will be left allowing HEV sales among major markets – see Table 6 and the latest regional targets on the map on the next page.

Inoue suggests that this wave of commitments is underpinned by rapid advances in technology and the business case for going electric. He states that when the world's first mass-produced BEV, the

Nissan Leaf, came out in 2010 the battery cost was US\$600 per kWh and predictions were made that prices would reach US\$100 per kWh after 2030. The significance of this US\$100 price point is that this is widely regarded as the tipping point for the economic competitiveness of BEVs versus ICEVs. In light of innovation and regulatory changes, however, the shift is actually accelerating far ahead of predictions and the industry is on track to reach that benchmark in 2023.



## Illustration of automotive-related targets and regulations by region



Source: ICCT<sup>17,18</sup>

### Target to allow the sale or registration of new BEVs and FCEVs only

- 2025
- 2030
- 2035
- 2040
- 2050
- 2050 International Zero-Emission Alliance (IZEVA)

### Target to allow the sale or registration of new BEVs, FCEVs and PHEVs only

- 2030
- 2035

<sup>15</sup> The Canadian province of British Columbia has set its 2040 target into binding regulations and the Canadian province of Québec has also set a target for 2035.

<sup>16</sup> Includes countries, states and provinces that have set targets to only allow the sale or registration of new battery electric vehicles (BEVs), fuel cell electric vehicles (FCEVs) and plug-in hybrid electric vehicles (PHEVs). Countries such as Japan with pledges that include hybrid electric vehicles (HEVs) and mild hybrid electric vehicles (MHEVs) are excluded as these vehicles are non plug-in hybrids.

<sup>17</sup> [theicct.org/publications/pvs-global-phase-out-FS-oct21](https://theicct.org/publications/pvs-global-phase-out-FS-oct21)

<sup>18</sup> Since this graphic was published in October 2021, a number of new markets have come forward with proposals to phase out combustion engine vehicles, including Chile that aims to achieve this by 2035. An even greater number of governments came together at COP26, covering a population in excess of 2 billion people, expressing the global ambition to achieve 100% ZEV car and van sales by 2040, and in leading markets by 2035 ([cop26transportdeclaration.org/](https://cop26transportdeclaration.org/)).

## Governments and companies making major investments

Currently, the biggest battery manufacturers for BEVs are located in China (CATL and BYD) and South Korea (LG Chem and SK Innovation). Inoue shared the latest data available from BloombergNEF on the top ten global battery manufacturers in 2020. China hosted 80% of all battery cell manufacturing capacity and five of the top ten were Chinese: CATL, BYD, A123, Guoxuan and Farasis. Graph 7 shows the latest 2021 data. Now seven of the top ten manufacturers are Chinese with CATL's planned capacity particularly surging ahead.

In the face of China's dominance in lithium-ion battery manufacturing, Europe

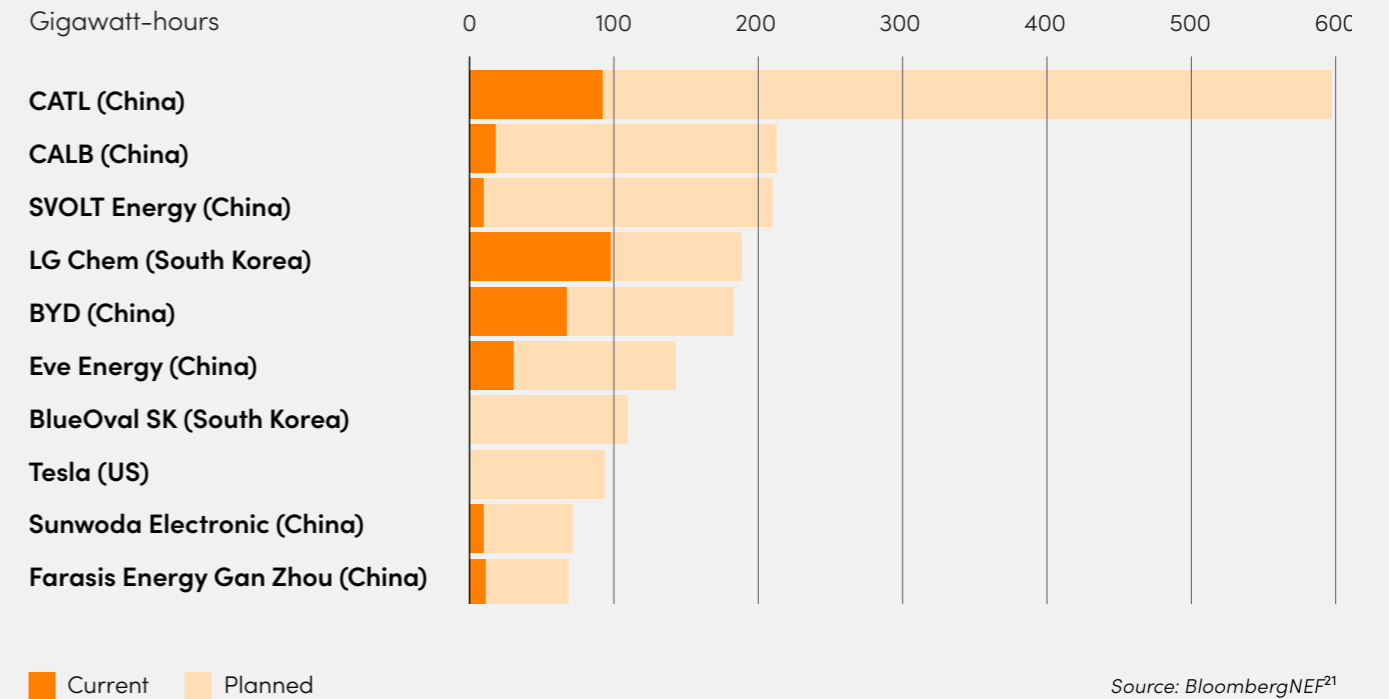
and the US are increasingly working to implement measures to develop their own production capabilities to decrease their reliance on imports from China. Inoue notes that Toyota's biggest rival, Volkswagen, is investing in 240 GWh battery manufacturing capacity by 2025-30, General Motors is investing US\$33.4 billion (3.8 trillion yen) in battery factories by 2025, Ford is putting in US\$29 billion (3.3 trillion yen) by 2030 and Tesla plans 3 TWh annual capacity by 2030. These investments are all being supported by government subsidies in their respective jurisdictions.

For example, in August 2021, the US government passed the Infrastructure Investment and Jobs Act, containing a US\$550 billion infrastructure investment plan. Within this, the government allocated US\$7.5 billion for battery charging infrastructure along America's highways and an additional US\$7.5 billion for zero emission buses and ferries.<sup>19</sup> The EU also recently announced €20 billion (US\$23 billion) climate-focused recovery budget. Budget allocations for grants and guarantees aim to foster the development of the BEV industry and as part of this, the EU plans to install 2 million electric and hydrogen vehicle charging stations by 2025.<sup>20</sup>

In contrast, Japan's response has been limited so far, and Inoue argues that Japan's current strategy for the sustainability of the automotive industry lacks focus and is spread too thin, attempting to incorporate an overly broad range of technology including HEVs, FCEVs, e-fuel, and hydrogen internal combustion vehicles.

Japan's government and industry do not appear to have the same sense of urgency

Graph 7: Top battery manufacturers capacity to 2025



Source: BloombergNEF<sup>21</sup>

to change as other leading automotive nations and manufacturers. Both Wada and Inoue warn that because Japan is lagging behind with investments in battery factories, the government needs to step in to support industry much more if Japan is to have a chance of maintaining its international competitiveness.

For example, Japan's lithium-ion battery production capacity – which currently constitutes just 2% of the global supply chain – is expected to decline further in the coming years. Current projections indicate that lithium-ion batteries produced in Japan will comprise merely 1% of the world's

cell capacity by 2025 if it continues on its current trajectory.

Summarising the overall context, Wada compares the Japanese automotive industry and government to a frog in slowly boiling water, seemingly not fully aware of the risk it faces as the situation becomes increasingly dangerous. With an ongoing focus on HEVs, Japan is at risk of becoming a "Galapagos" market,<sup>22</sup> out of step with and left behind in these global trends. Failing to shift more rapidly away from HEVs will put this vital Japanese industry at a significant competitive disadvantage.

<sup>19</sup> [www.whitehouse.gov/briefing-room/statements-releases/2021/08/02/updated-fact-sheet-bipartisan-infrastructure-investment-and-jobs-act/](https://www.whitehouse.gov/briefing-room/statements-releases/2021/08/02/updated-fact-sheet-bipartisan-infrastructure-investment-and-jobs-act/)

<sup>20</sup> [www.reuters.com/article/us-eu-budget-recovery-climate-factbox-idUSKBN2331RB](https://www.reuters.com/article/us-eu-budget-recovery-climate-factbox-idUSKBN2331RB)

<sup>21</sup> [www.bloomberg.com/toaster/v2/charts/342e80eeb9a44cc287bf0051a059adaf.html?brand=businessweek&webTheme=businessweek&web=true&hideTitles=true](https://www.bloomberg.com/toaster/v2/charts/342e80eeb9a44cc287bf0051a059adaf.html?brand=businessweek&webTheme=businessweek&web=true&hideTitles=true)

<sup>22</sup> This phrase is used in Japan to refer to a market that goes through a unique process of evolution unlike the rest of the world, due to isolation and specific local circumstances. It is most often used to refer to "Galapagos Japan".

## Part 2:

# Comparing the environmental impact of HEVs and BEVs

### BEVs have lower greenhouse gas emissions (even under current energy mix)

Many industry commentators<sup>23</sup> and journalists have argued that there is an environmental case against rolling out BEVs in an economy that is still largely dependent on thermal power generation. In 2020, coal, gas, oil and other fossil fuels accounted for 76% of Japan's electricity mix and renewables for 19%.<sup>24</sup>

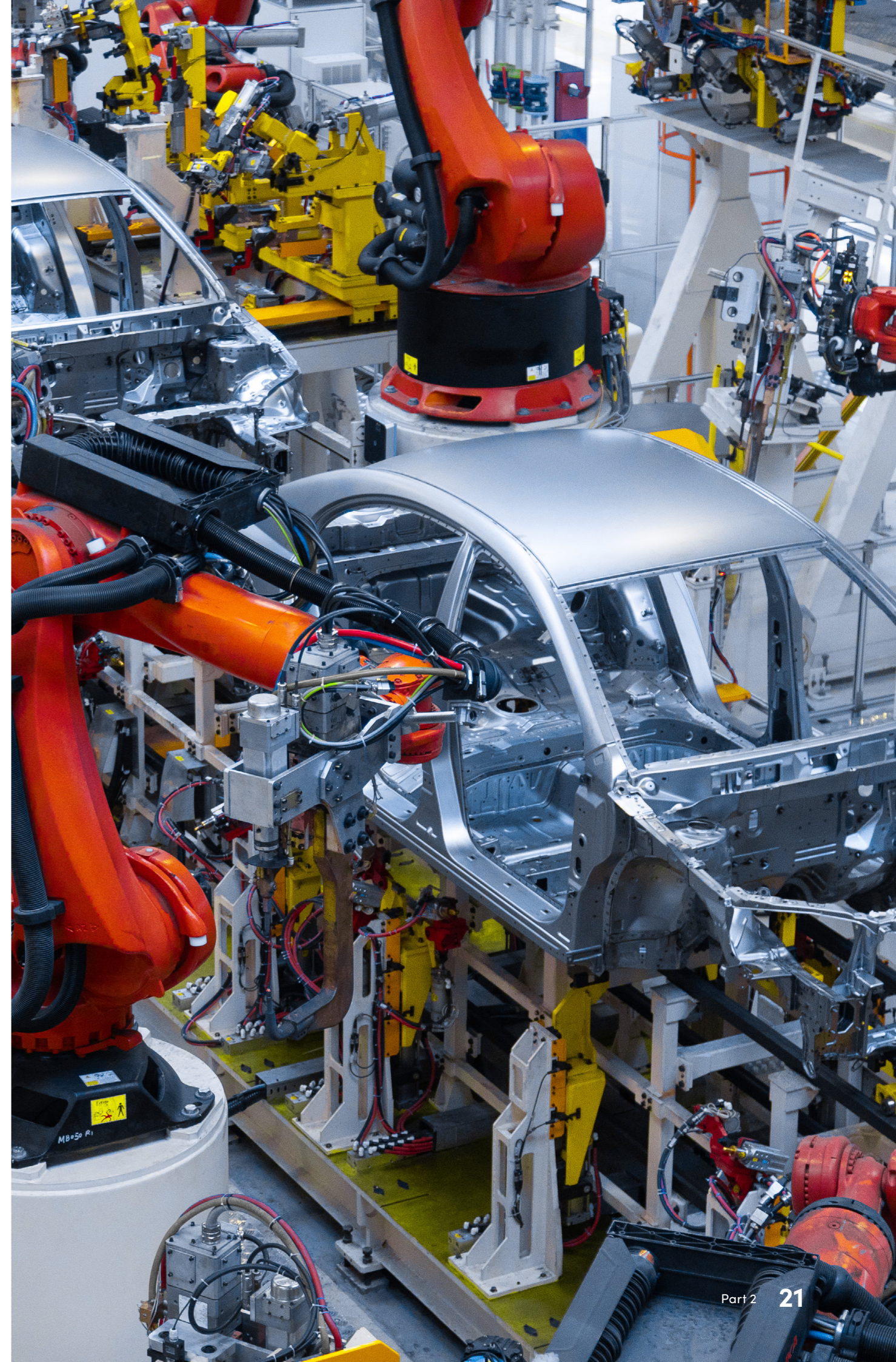
However, recent reports show that such claims are no longer valid. Both Wada and Inoue cite a June 2021 research report<sup>25</sup> from the Central Research Institute of Electric Power Industry (CRIEPI), Japan's electricity industry research organisation, to illustrate this point.

CRIEPI's research calculates the life-cycle greenhouse gas emissions released during vehicle manufacturing, transport of materials for assembly, and gasoline or electricity production. This data was then combined with emissions data for four different types of passenger vehicle all travelling 100,000km: ICEVs, HEVs, PHEVs and BEVs. The research showed that while BEVs tend to emit more greenhouse gases than ICEVs or HEVs during the manufacturing process, even where thermal power accounts for 90% of the energy mix, BEVs produce fewer emissions throughout their whole life cycle due to a far lower impact during their operational phase (Graph 8).

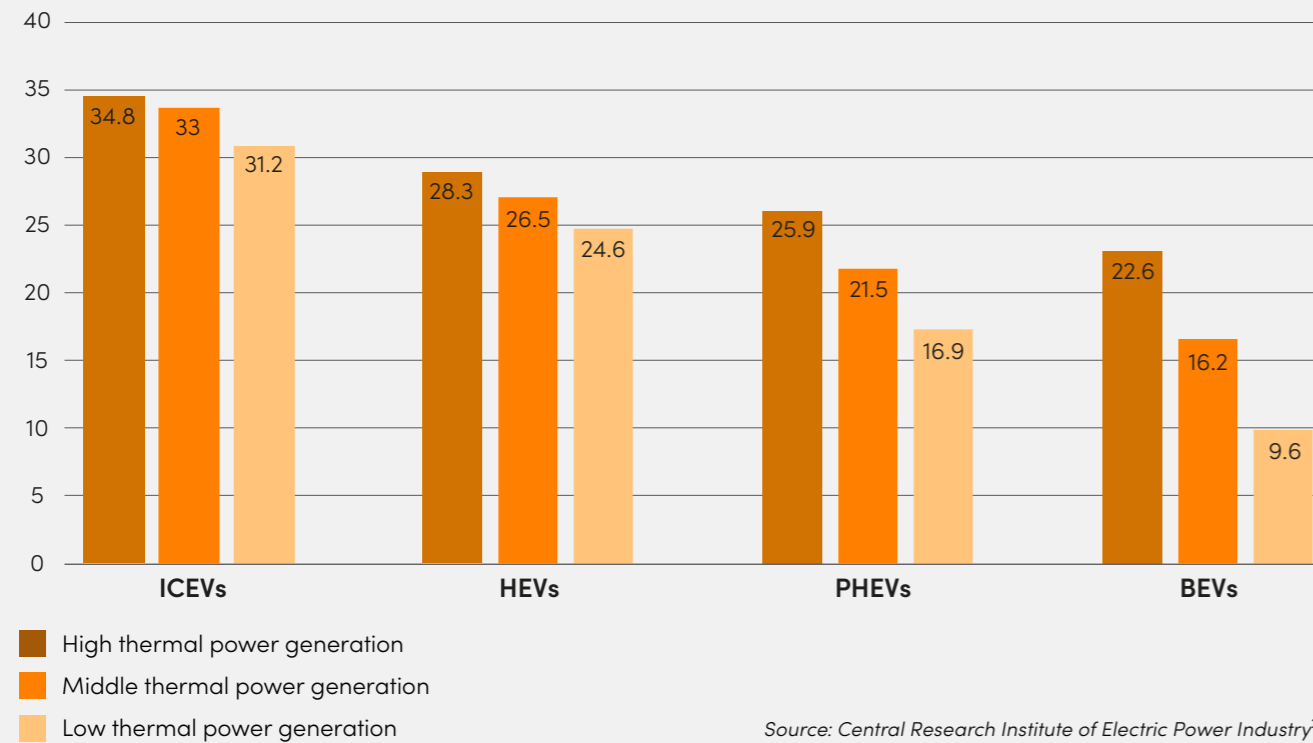
<sup>23</sup> Including JAMA chair, Toyoda, quoted above.

<sup>24</sup> [www.enecho.meti.go.jp/statistics/total\\_energy/pdf/gaiyou2020fyr.pdf](http://www.enecho.meti.go.jp/statistics/total_energy/pdf/gaiyou2020fyr.pdf)

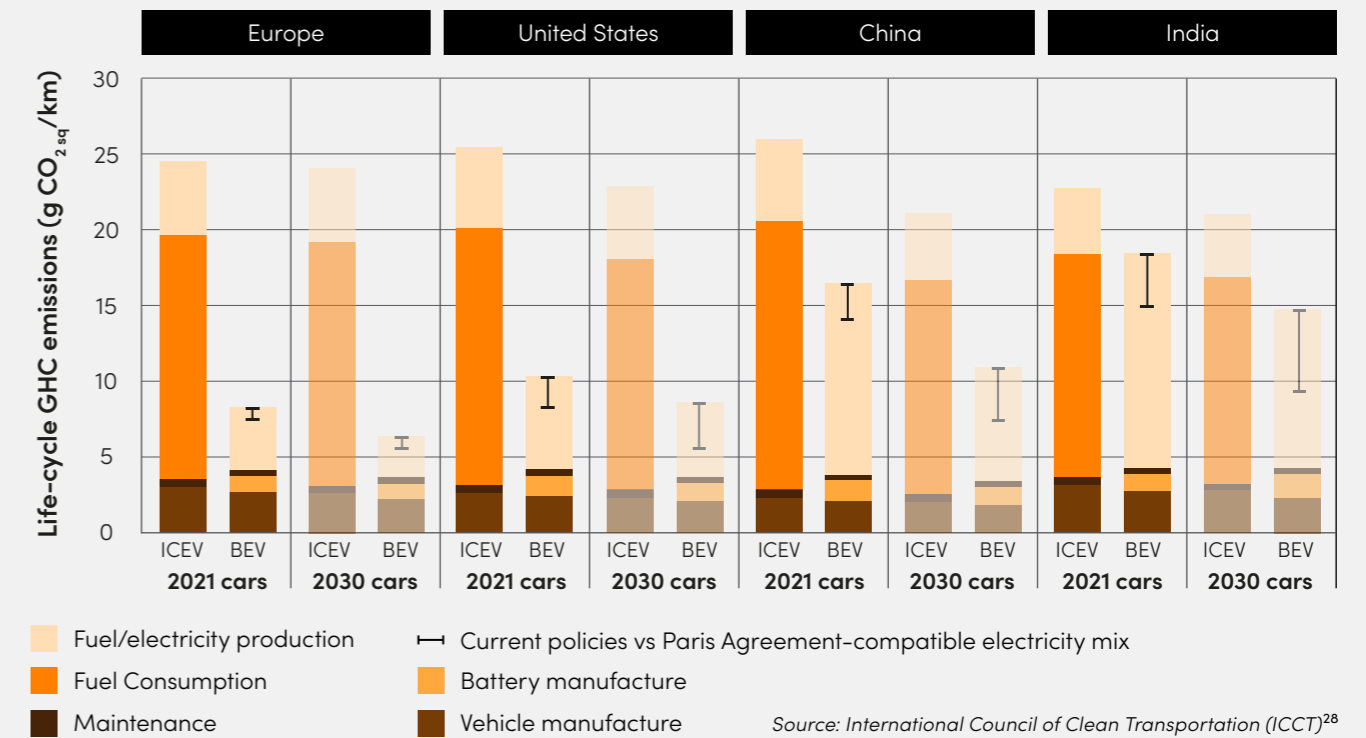
<sup>25</sup> [criepi.denken.or.jp/jp/serc/source/pdf/Y21503.pdf](http://criepi.denken.or.jp/jp/serc/source/pdf/Y21503.pdf)



**Graph 8: Life-cycle greenhouse gas emissions for passenger vehicles under different energy mixes**



**Graph 9: Life-cycle greenhouse gas emissions of average medium-size ICEVs and BEVs in 2021 and 2030**



Recent international research has also reached similar conclusions on the relative life-cycle emissions of ICEVs and BEVs. For example, the International Council of Clean Transportation (ICCT) published its findings in July 2021,<sup>27</sup> looking at four major economies: Europe, the US, China, and India (Graph 9). In all four markets, BEVs have lower life-cycle emissions than ICEVs.

The International Energy Agency (IEA) also published similar results in May 2021 (Graph 10).

These findings serve to profoundly challenge the widespread view in Japan that BEVs are not better for the environment under the current energy mix. In addition, as technology improves, battery production is expected to become increasingly efficient in material and energy use, leading to a reduction in life-cycle greenhouse gas emissions and further undermining this argument.

<sup>26</sup> [criepi.denken.or.jp/jp/serc/source/pdf/Y21503.pdf](http://criepi.denken.or.jp/jp/serc/source/pdf/Y21503.pdf)

<sup>27</sup> [theicct.org/publications/global-LCA-passenger-cars-jul2021](http://theicct.org/publications/global-LCA-passenger-cars-jul2021)

## BEVs are more fuel efficient

In his report, Inoue also cites data that shows that, again, contrary to popular perceptions in Japan, BEVs are also superior to HEVs in terms of their fuel efficiency. This is important because this is an issue that often garners more attention in Japan than emissions data. JAMA, for example, traditionally emphasises its commitment to fuel efficiency alongside its commitment to “next-generation” vehicles.

For example, according to fuel economy calculations based on data provided by the US Department of Energy, a 2020 Toyota Prius HEV can travel 23.8km on one litre of gasoline.<sup>29</sup> A similar calculation for a 2020

Tesla Model 3 BEV shows it can actually travel slightly further – 24.8km – on the energy equivalent of one litre of gasoline – a 4% improvement in relative energy efficiency.

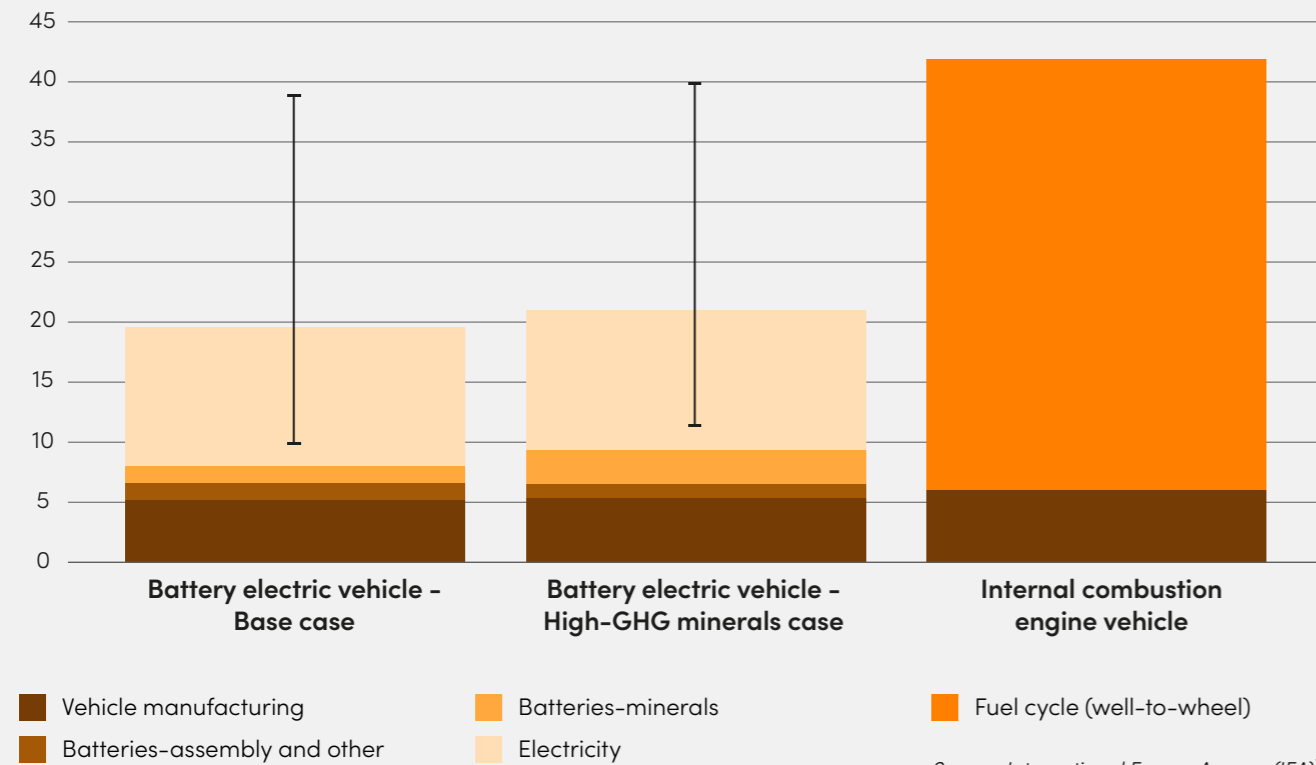
Inoue further develops the case by noting the substantial amounts of energy lost when one litre equivalent of oil is converted into electricity and then transported through the grid to charge a BEV. Inoue concludes that the relative efficiency is in reality higher than this calculated 4% difference and that, as the technology progresses, efficiency will increase further still.

<sup>28</sup> [theicct.org/publications/global-LCA-passenger-cars-jul2021](http://theicct.org/publications/global-LCA-passenger-cars-jul2021)

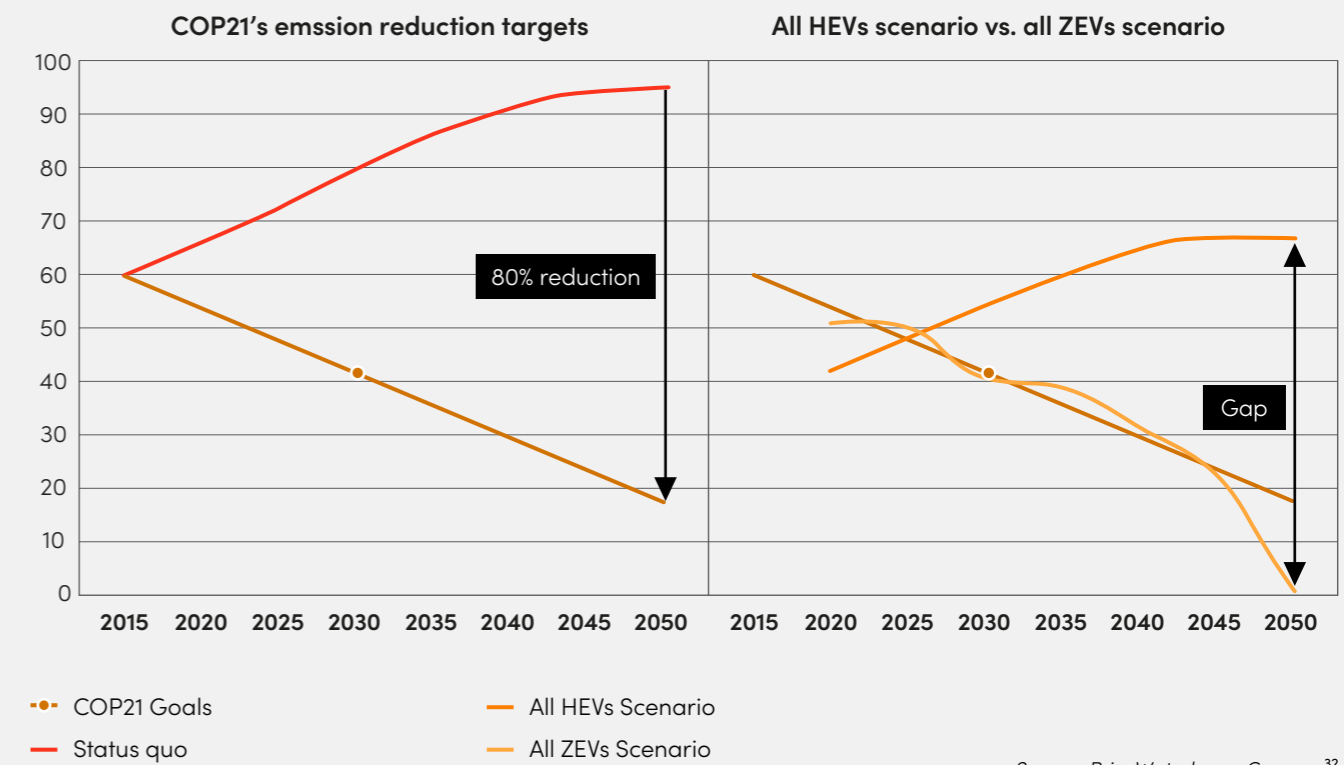
*The error bar shows the difference between the current energy mix and what is needed to align with the Paris Agreement.*

<sup>29</sup> [www.fueleconomy.gov/feg/Find.do?action=sbs&id=41915&id=42278](http://www.fueleconomy.gov/feg/Find.do?action=sbs&id=41915&id=42278)

**Graph 10: Comparative life-cycle greenhouse gas emissions of a mid-size BEV and ICEV<sup>30</sup>**



**Graph 11: HEVs and all EVs contribution to meeting the COP21 emission reduction targets**



## ZEVs contribute substantially and incrementally to decarbonisation

Inoue examined the role of ZEVs in meeting the commitments to reduce global emissions made at COP21 in Paris in 2015.

In line with global population growth, demand for automotive vehicles is projected to rise, leading to nearly 20 billion more passenger vehicles by the year 2050. Consequently, CO<sub>2</sub> emissions from the transportation sector are expected to constitute around a quarter of all human-produced carbon emissions.

At COP21 in Paris, participating nations committed to an agreement that would require reducing the total amount of

global CO<sub>2</sub> emissions by at least 82% by 2050 to maintain even the lower threshold of ambition of keeping global warming well below 2 degrees centigrade. On the assumption that the energy mix will gradually improve to achieve 100% decarbonised power generation by 2050, Inoue provides a scenario analysis based on data from PwC Japan. This compares the case where all vehicles in Japan are replaced by HEVs with a case where all vehicles are replaced by BEVs and examined how these would help contribute towards the Paris target.

<sup>30</sup> The ranges shown for BEVs represent cases for charging with a static low-carbon (50 g CO<sub>2</sub>-eq/kWh) and high-carbon electricity mix (800 g CO<sub>2</sub>-eq/kWh).

<sup>31</sup> [www.iea.org/data-and-statistics/charts/comparative-life-cycle-greenhouse-gas-emissions-of-a-mid-size-bev-and-ice-vehicle](http://www.iea.org/data-and-statistics/charts/comparative-life-cycle-greenhouse-gas-emissions-of-a-mid-size-bev-and-ice-vehicle)

In the scenario where all vehicles are replaced by HEVs, the reduction in CO<sub>2</sub> emissions will consistently fail to contribute towards the necessary required reduction trajectory after 2027 and will therefore substantially hinder the long term decarbonisation process. However, where all vehicles are replaced by ZEVs, CO<sub>2</sub> emissions will continue to be reduced in line with the commitment so that, by 2050, full decarbonisation of automotive emissions will be achieved (Graph 11). This is because BEV emissions continue to fall as the energy mix becomes progressively cleaner – a positive knock-on effect for decarbonisation that HEVs do not offer.

<sup>32</sup> [www.pwc.com/jp/ja/knowledge/thoughtleadership/automotive-insight/vol6.html](http://www.pwc.com/jp/ja/knowledge/thoughtleadership/automotive-insight/vol6.html)

<sup>33</sup> Approved by Cabinet on 24 December 2021.

This is important as Japan's latest energy mix targets<sup>33</sup> are likely to lock in a substantial move towards renewables and away from fossil fuels: the latest target of 36-38% renewable energy by 2030 is an increase of 19% from actual 2020 generation figures, and the new target of 41% fossil fuel generation by 2030 is down 35% from actual 2020 figures. In light of this, a widespread move to BEVs is the only viable way Japan can realistically meet its domestic and international commitments to rapidly decarbonise the transportation sector.

# Understanding the economic impact

## Risk of replicating decline of Japanese semiconductor industry

Inoue offers a comparison between what happened to the Japanese semiconductor industry and what is at risk of happening to the Japanese automotive sector.

In the 1980s, Japanese semiconductor manufacturers were clear leaders who controlled 50% of the global market. Under the Japanese model, each semiconductor company would handle all aspects of manufacturing – from production to sales of the final product. However, Japanese manufacturers were overconfident in the superiority of their products and failed to notice important changes in global business models for computers.

A significant change occurred when Dell introduced its “Build to Order” approach which was more cost-effective than the Japanese production model. In this, a range of specialised manufacturers could focus on improving performance and price, and the Japanese semiconductor industry lost its foothold in the global market. In particular, Intel semiconductors came to dominate the global computer market due to the company’s ability to respond flexibly and deliver exactly on schedule. Japan’s current share of the global semiconductor market is now only 10%, due to the industry’s

inability to adapt quickly and their apparent overconfidence.

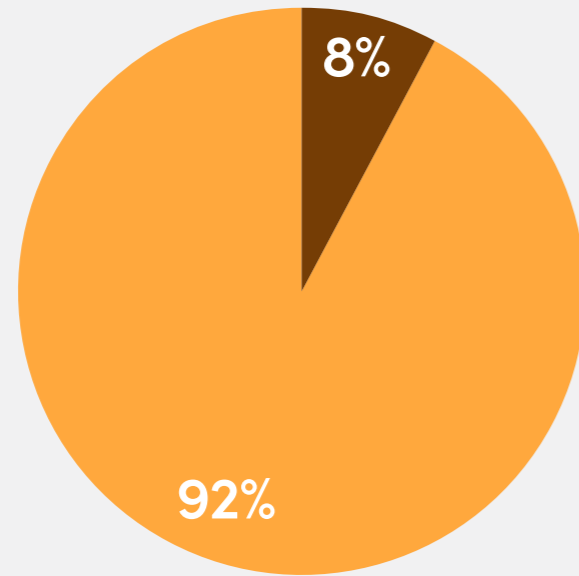
Inoue’s report warns the Japanese automotive industry may be headed down a similar path, if it does not rapidly respond to wider global trends. He sees Japanese automotive manufacturers as overconfident in the superiority of their technology and out of step with wider international trends – just as they were previously in the semiconductor industry.

He also warns of the risk of continuing to depend on battery manufacturers in foreign countries, particularly those in China. He makes the point that computers shifted to having *Intel Inside* across the board and there is a risk that BEVs will become dominated by *CATL inside* if Japan, and others, do not proactively invest now to counteract China’s growing dominance.

As noted above, both Wada and Inoue emphasise the importance of further government support and investment to address this. For example, Wada argues that Japan should accelerate its efforts to transition from liquid-state batteries to solid-state batteries (Toyota holds more than 1,000 patents in this technology<sup>34</sup>).



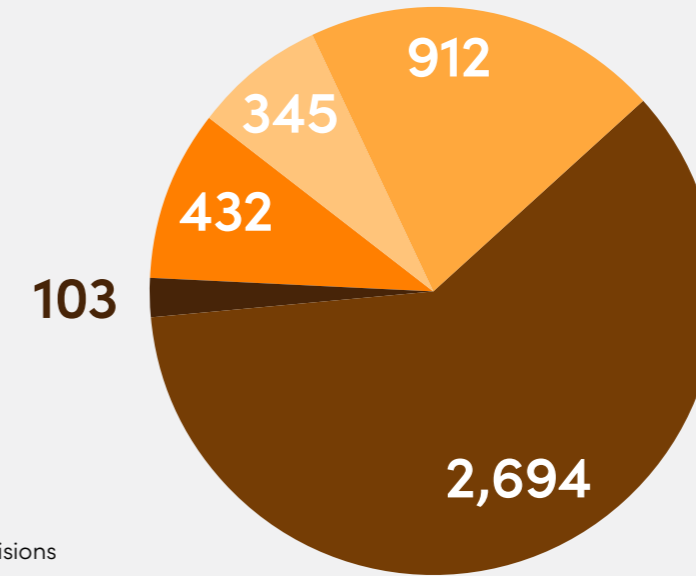
**Graph 12: Automotive-related industry workers within the Japanese labour force**



■ Automotive industry workers  
■ Other sectors of the labour force

Source: Ministry of Health, Labour and Welfare and Ministry of Internal Affairs and Communications<sup>36</sup>

**Graph 13: Population employed in automotive-related industries by division**



■ Other relevant divisions  
■ Documentation  
■ Sales division  
■ Manufacturing division  
■ Operations division

(in 000s)

Source: Ministry of Health, Labour and Welfare and Ministry of Internal Affairs and Communications<sup>36</sup>

He also proposes that Japan should increase its R&D in rechargeable lithium-sulphur batteries, fluoride-ion batteries, and lithium-air batteries that are currently being considered as potential alternatives to lithium-ion batteries, and which have the potential to require significantly less rare earth materials to mass produce.

Several projects are currently underway in Japan looking into the viability of these replacements for lithium-ion batteries. However, the level of commitment is still limited. For example, in 2021 the New Energy and Industrial Technology Organisation (NEDO) allocated just 20 million yen (US\$175,000) to fund research on new rechargeable battery

types for BEVs, including fluoride-ion and lithium-air batteries.<sup>35</sup>

It is also worth noting that Japan's new administration under Prime Minister Kishida has established a new ministerial position in the Japanese Cabinet – the Minister of Economic Security. The new minister will consider issues relating to supply chain security and procuring rare earth materials.

While welcoming these developments, both researchers want to see government and industry significantly step up the introduction of supportive policies, investments, regulations and show a greater sense of urgency in the face of the potential threat to Japan's key industry.

<sup>34</sup> [asia.nikkei.com/Spotlight/Most-read-in-2020/Toyota-s-game-changing-solid-state-battery-en-route-for-2021-debut](https://asia.nikkei.com/Spotlight/Most-read-in-2020/Toyota-s-game-changing-solid-state-battery-en-route-for-2021-debut)  
<sup>35</sup> [www.nedo.go.jp/content/100905385.pdf](https://www.nedo.go.jp/content/100905385.pdf)

### Potential loss of employment from not moving faster to ZEVs

In his report, Wada estimates the impact on employment in the automotive industry, where the shift by industry to BEVs is too slow. Currently in Japan, the employed population is about 66.8 million, of which 10.45 million (16% of the total) are in manufacturing and 5.42 million (8% of the total) are in the automotive industry.<sup>36</sup> Graphs 11 and 12 illustrate this and the types of work done by those employed in the automotive industry.

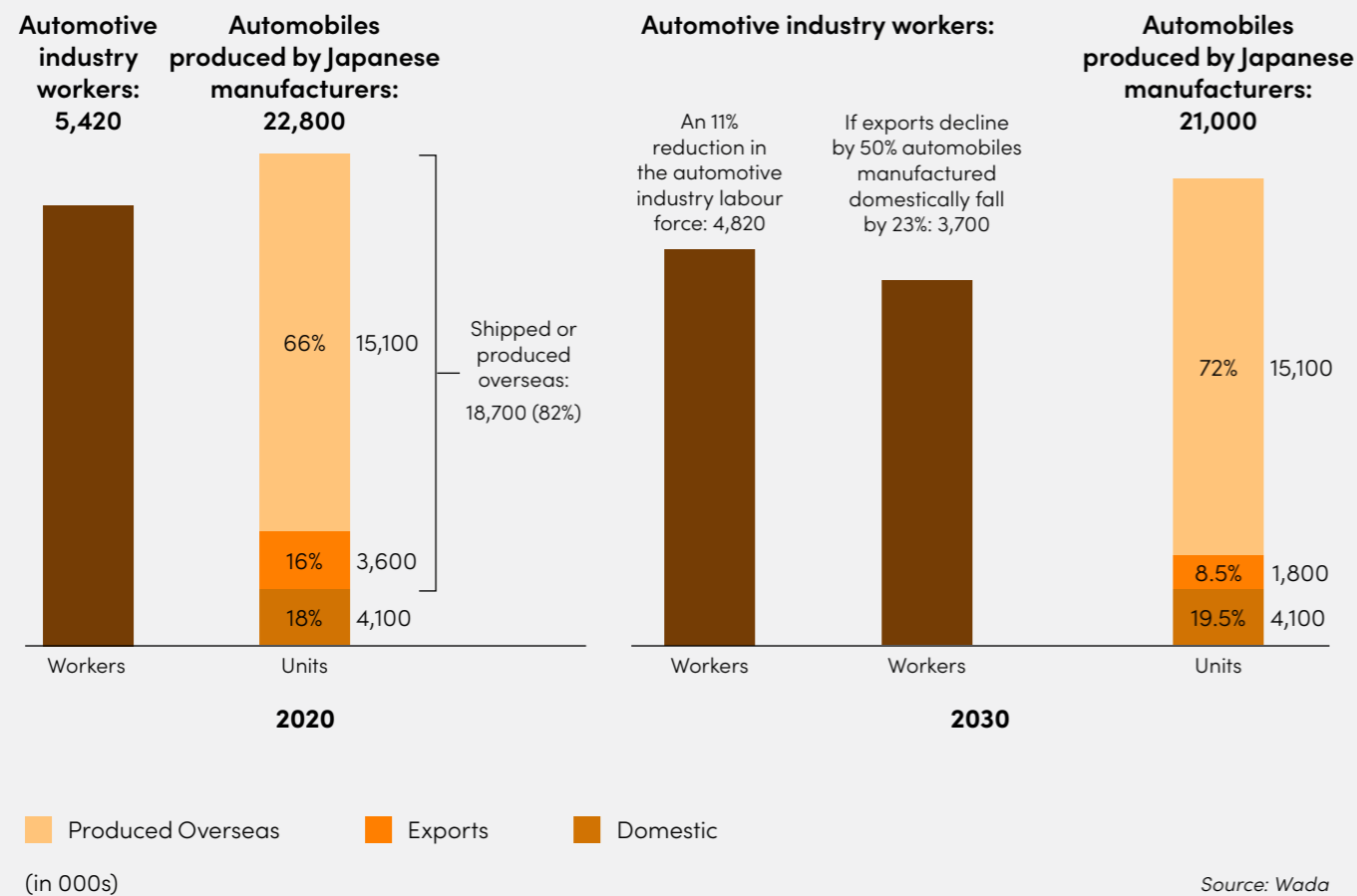
Wada then juxtaposes the 2020 automotive industry figures with the location of

Japanese manufacturing (Graph 14). As can be seen on the left-hand side, 82% of automotive vehicles produced by Japanese manufacturers are for overseas markets, which includes vehicles produced in Japan and exported, as well as those produced overseas.

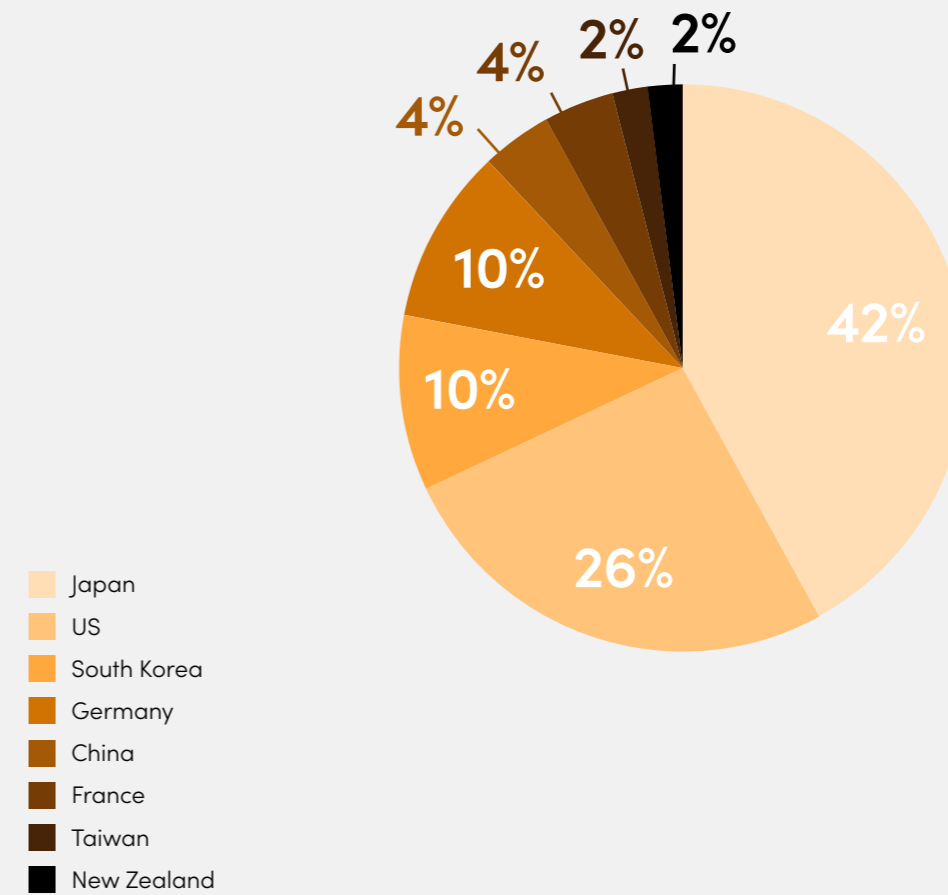
Wada estimates that over the next ten years the demographics of an ageing workforce suggest there will be an 11% decline in those employed by the automotive industry in Japan, bringing the figure down to 4.82 million.

<sup>36</sup> Figures from Japan Institute for Labour Policy and Training, Ministry of Internal Affairs and Communications (MIC) and Ministry of Economy, Trade and Industry (METI).

**Graph 14: Predicted employment changes as Japan's automotive exports fall<sup>37</sup>**



**Graph 15: xEV-related patents held in the US according to country**



However, he predicts that exports overseas will fall by 50% if the automotive industry continues to rely on gasoline, diesel and HEVs. This 50% decline in domestic production for export would then lead to a further 23% reduction in industry employees – to 3.7 million in 2030, a loss of 1.72 million jobs from the current level of 5.42 million.

Inoue also addresses the potential impact on employment of a sluggish transition to BEVs. As noted above, the Fuji Keizai Group project that global BEV sales will overtake HEV sales by 2022. Inoue notes that BEVs already exceed 20% of total automotive sales in Germany, while they only accounted for a mere 1.7% of automotive sales in Japan in June 2021.

Unlike Japan, Germany is increasingly working to transition the core of its world-renowned automotive industry away from ICEVs, retraining its engineers to reorient their skills and knowledge towards the production of BEVs. If the Japanese automotive industry fails to make a similar transition in the near future, Japanese engineers will face distinct disadvantages when compared to their global counterparts, limiting their opportunities outside Japan and their capacity for cooperation with overseas makers. A focus on HEVs risks putting the country on a “Galapagos” development path, making workers’ engineering skills less relevant elsewhere in the world.

### Job creation opportunities from a faster shift to ZEVs

Wada expands his analysis on employment by noting the considerable employment opportunities available to Japan from a faster pivot to ZEVs. He cites a July 2021 survey on xEV-related patents in the US conducted by Nikkei and patent research company, Patent Result.<sup>39</sup> This showed that Japanese companies outrank US companies in terms of technology development, with 21 of the top 50 ranked companies being Japanese compared to 13 US companies (Graph 13).

Although some of these patents cover HEV technologies, this nevertheless shows that relevant R&D is occurring in Japan, forming a basis for a stronger pivot by government and industry that could create new employment opportunities.

Wada also references measures implemented in Europe to facilitate the automotive industry shift to ZEVs. For example, he states that the roll out of charging infrastructure is estimated to lead to the creation of more than 100,000 jobs in

<sup>37</sup> Wada assumes the number of units sold in the domestic market stays constant at 4,100.

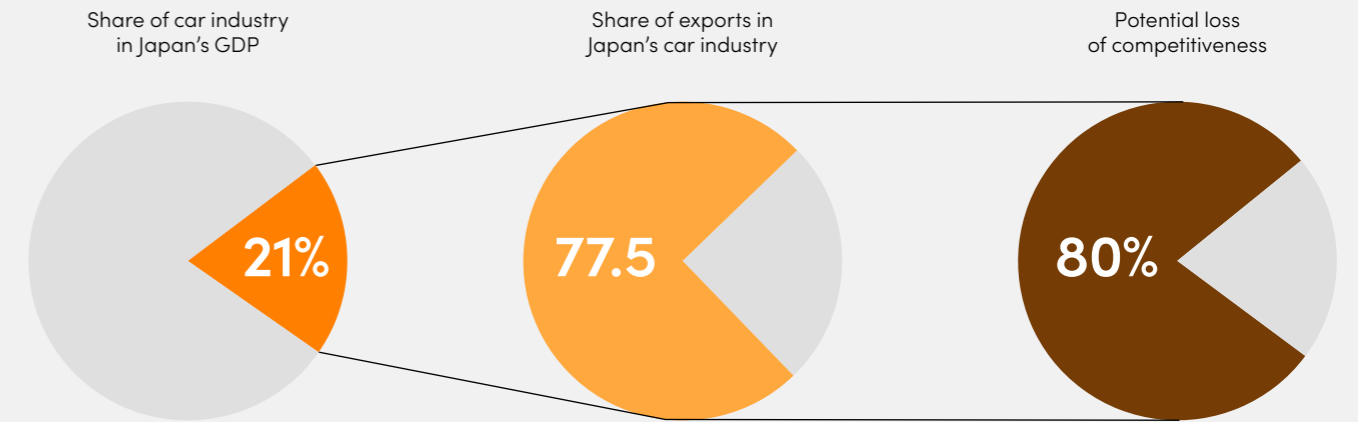
<sup>38</sup> [www.nikkei.com/article/DGXZQOUC05CR00V00C21A8000000](http://www.nikkei.com/article/DGXZQOUC05CR00V00C21A8000000)

<sup>39</sup> Ibid.





**Graph 16: Key data and assumptions in Inoue's calculations**



Source: Inoue

### Potential loss of GDP from not moving faster on ZEVS

In his report, Inoue provides a broad-brush estimate of the financial risks that may arise from Japanese automotive companies not shifting more rapidly to ZEV production. His analysis is based on the two scenarios outlined in the Bloomberg NEF Electric Vehicle Outlook 2021.

The first scenario, called the "Economic Transition Scenario", involves industry largely continuing under business-as-usual conditions, resulting in the transition to ZEVs being shaped by market forces, without substantial policy intervention by governments.

areas such as manufacturing, installation, and operational management.

Moreover, new factories for BEV-related parts and batteries are expected to further contribute to substantial employment opportunities. He refers to the transition as "an industrial revolution" – and as with past industrial revolutions, the exact impact on employment is difficult to estimate but it is likely to result in a host of new employment opportunities, many of which may be in new businesses and business models, including wireless power

supply, use of block chain, and automatic driving technology.

A July 2021 report<sup>40</sup> by Boston Consulting Group comes to a similar conclusion regarding the impact on employment opportunities in Europe from e-mobility. Although it acknowledges jobs will be lost in traditional automotive industries and supply chains, it estimates that overall employment created in BEV manufacturing and related industries has the potential to mostly offset those losses.

**Table 7: BNEF projected market share for ZEVs in 2030 and 2040**

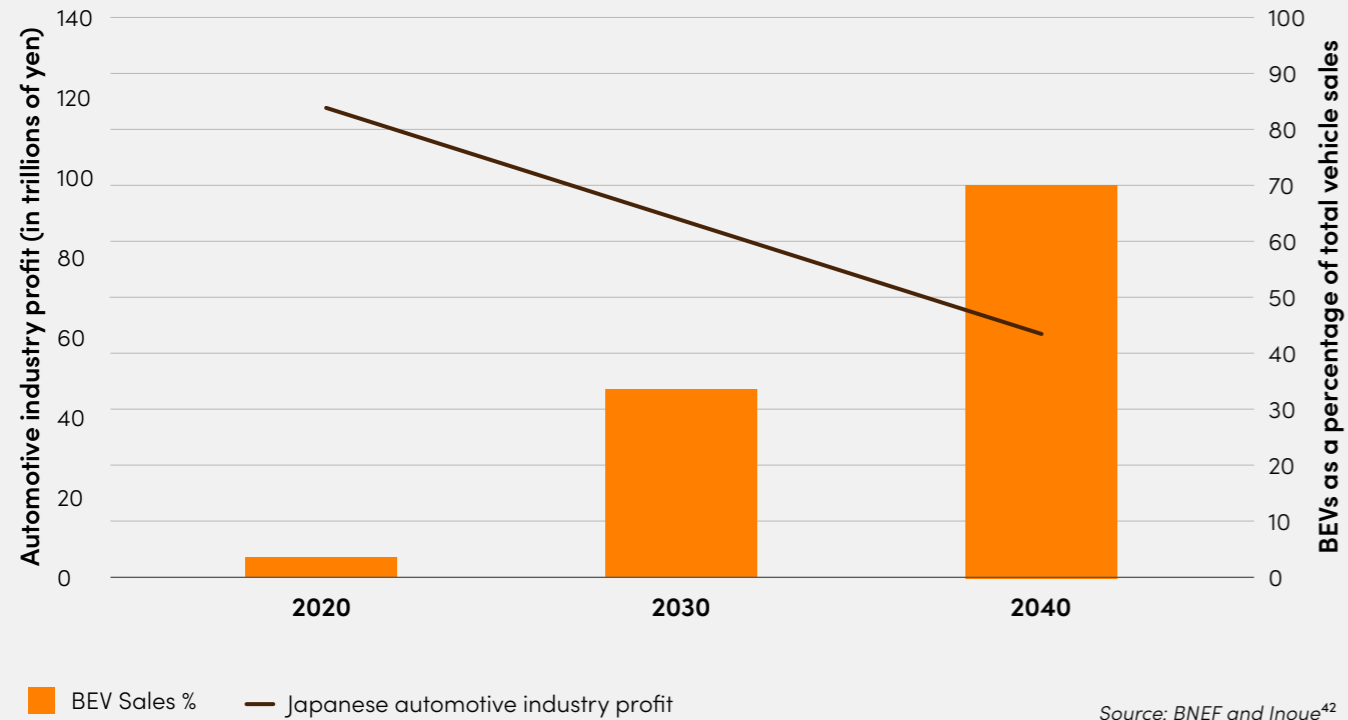
	2030	2040
<b>Economic Transition Scenario</b>	34%	70%
<b>Net Zero Scenario</b>	58%	100%

Source: BNEF<sup>41</sup>

40 [web-assets.bcg.com/82/0a/17e745504e46b5981b74fadba825/is-e-mobility-a-green-boost.pdf](https://web-assets.bcg.com/82/0a/17e745504e46b5981b74fadba825/is-e-mobility-a-green-boost.pdf)

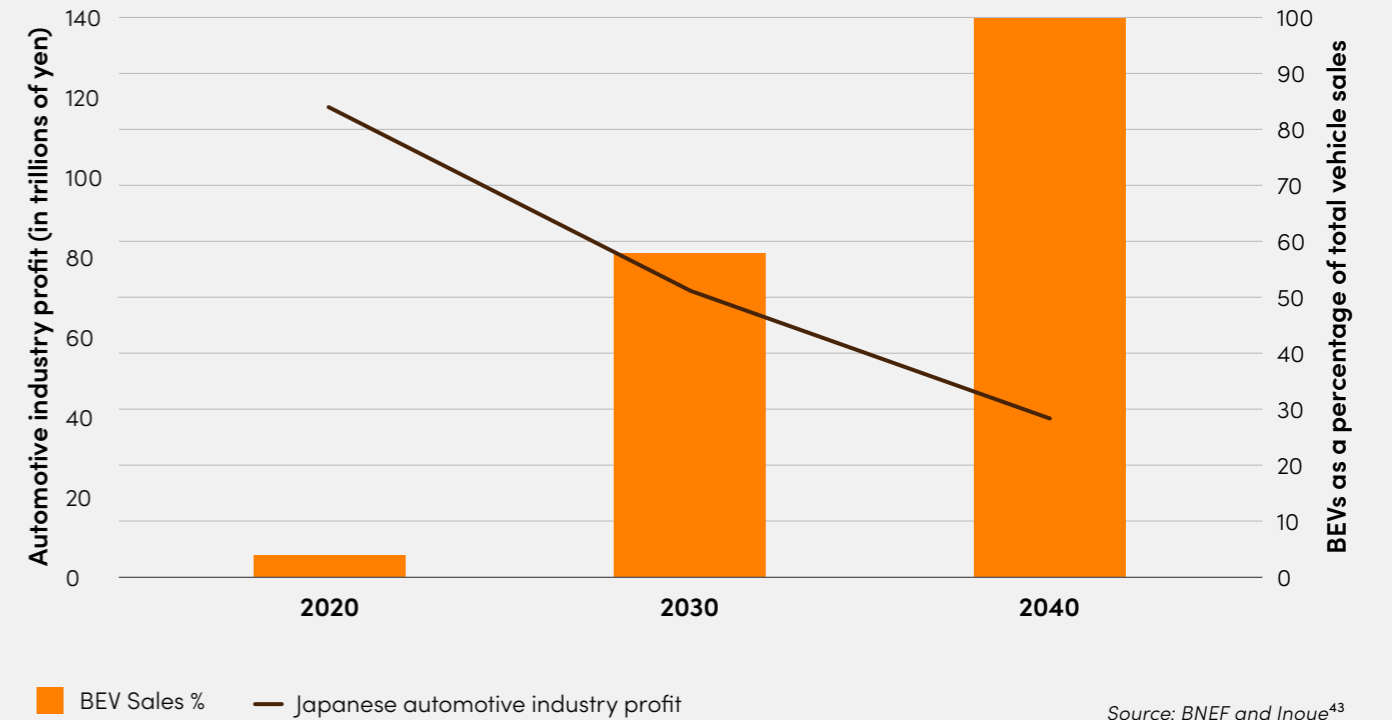
41 [about.bnef.com/electric-vehicle-outlook/](https://about.bnef.com/electric-vehicle-outlook/)

**Graph 17:** Global BEV sales and impact on Japanese car industry – Economic Transition Scenario



Source: BNEF and Inoue<sup>42</sup>

**Graph 18:** Global BEV sales and impact on Japanese car industry – Net Zero Scenario



Source: BNEF and Inoue<sup>43</sup>

**Table 8:** Potential loss of profit from delay in Japanese automotive industry transition to ZEVs

	2030		2040	
	Economic Transition Scenario	Net Zero Scenario	Economic Transition Scenario	Net Zero Scenario
<b>Potential loss of profit in Japanese automotive industry</b>	26.8 trillion yen (232.7 billion USD)	45.6 trillion yen (399.3 billion USD)	55.1 trillion yen (482.5 billion USD)	78.7 trillion yen (689.2 billion USD)
<b>Potential % loss of GDP</b>	4.8%	8.2%	9.8%	14.1%

Source: Inoue

42 [about.bnef.com/electric-vehicle-outlook/](https://about.bnef.com/electric-vehicle-outlook/)

The second scenario is called the “Net Zero Scenario”, where significant global government intervention leads to decarbonisation of the road transport sector being completed by 2050.

Under the latter scenario, all sales of new internal combustion engine vehicles, including HEVs, will be banned by 2035. Table 7 sets out BNEF’s predictions on the portion of global new vehicle sales that will be ZEVs in 2030 and 2040 under these two scenarios. BNEF also predict that the overall automotive market will grow by 8% during this time period.

Based on data looking at the importance of the automotive industry to Japan’s GDP,

alongside the importance of exports and overseas markets, Inoue estimates the impact of an 80% loss of competitiveness – comparable to what was seen for Japan’s semiconductor industry. He calculates the risk to the Japanese automotive industry and the resultant potential loss of GDP under these two scenarios in 2030 and 2040 (Table 8).<sup>44</sup>

Graph 17 then plots the global rise in BEV sales and the potential impact on the Japanese automotive industry under the Economic Transition Scenario. Graph 18 does the same under the Net Zero Scenario. In both these scenarios, the impact is a sharp decline in the Japanese automotive industry.

43 Ibid.

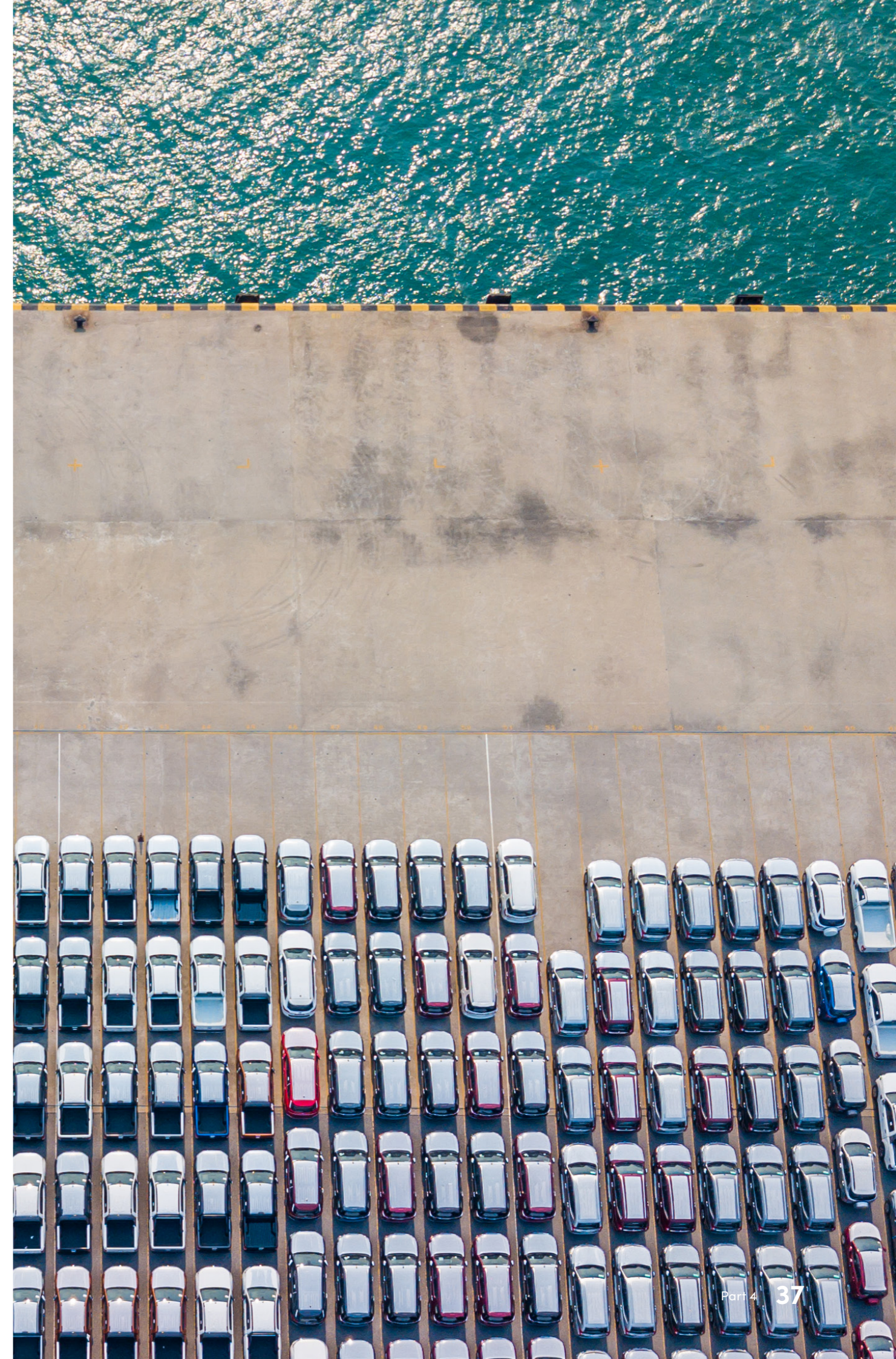
44 Inoue’s calculation takes into account the following parameters: Japan’s GDP; profit share from the automotive industry; export share; predicted overall growth in global automotive market; global market share of ZEVs under each BNEF scenario; predicted loss of ZEV market share for Japan.

# Policy suggestions

Both Inoue and Wada offered a list of recommended policy proposals to counter the risk of Japan developing into a “Galapagos” vehicle market and losing out in the global transition to ZEVs. These are set out below and represent the independent views of each of the researchers.

## Inoue policy suggestions

- 1. Investment in the development of factories and facilities for battery production:** The Japanese government should support Japanese automotive and battery makers looking to make strategic investments in the development of battery producing facilities. These domestic factories would provide new employment opportunities for the Japanese labour force. In order to mitigate risk and provide investment incentives for makers, Inoue proposes the Japanese government allocate 2 trillion yen (US\$17.6 billion) each year from 2021 to 2030.
- 2. Review of next-generation vehicle subsidy composition to exclude passenger FCEVs:** The viability of FCEVs is limited compared to BEV. However, green hydrogen generated using electrolysis from clean electricity could be considered for heavy duty trucking applications.
- 3. Preferential treatment for low-priced BEVs and a subsidy policy for promoting the scrapping of internal combustion engine vehicles:** Japan should consider implementing subsidies – such as those in Europe – in order to offset the higher cost of BEVs and encourage consumers to purchase BEVs at higher rates.
- 4. Enact legislation to support charging for condominiums and apartments:** In some parts of the world with more supportive BEV policies, tenants are by law able to submit a request to their landlord to install charging infrastructure at their accommodation, with the government covering as much as 75% of the cost. Japan could institute a similar system, which would incentivise the development of charging infrastructure beyond designated charging stations.
- 5. Install high-capacity rapid charging stations at highway service areas:** Installing four to eight 100–150kW rapid charging units at service areas across Japan would help alleviate concerns surrounding the use of BEVs over long distances.



“ **Develop new technology and win ahead of the rest of the world on the premise of zero emissions!** ”

**Wada policy suggestions**

- 1. Carrot-and-stick government policy:** The Japanese government should provide clear outlines and roadmaps for automotive manufacturers working to transition to a BEV-focused production base. At the same time, the government should also consider stricter restrictions or tighter regulations on the manufacturing of vehicles that fail to meet ZEV criteria.
- 2. Beyond lithium-ion:** Japan should invest in next-generation battery technologies, such as lithium-sulphur, fluoride-ion, and lithium-air batteries.
- 3. Development of advanced power devices for BEVs:** Japanese manufacturers should focus production efforts on developing components for BEVs like Insulated Gate Bipolar Transistors (IGBTs) and silicon-carbide and gallium-nitride semiconductors.



- 4. Strengthening development of distributed power:** As Japan is particularly prone to the effects of natural disasters, it should consider a wider distribution of its power sources to ensure stability in its power supply.
- 5. Exploring the mass production of hydrogen engine vehicles and e-fuel vehicles:** Wada believes the Japanese automotive industry should consider incorporating hydrogen engine vehicles and e-fuel vehicles<sup>45</sup> into their production. Some projections show hydrogen becoming a viable technology option for some vehicle applications, and this offers the potential for synergetic development of a green hydrogen industry alongside the burgeoning renewable energy industry in Japan.
- 6. Strengthening development of V2X (vehicle-to-everything) communication:** As BEVs and PHEVs gain prominence among consumers, demand for more efficient energy management and interconnectivity with other devices and appliances is expected to rise in response. While V2X is still in the early stages of development, the development of such technology could address such demands and give rise to new industries.
- 7. Strengthening development of wireless charging while driving:** Although wireless power supply development is still in its infancy, investment in such infrastructure will be vital. The government should consider investing in current academic efforts in this field.

<sup>45</sup> There has been some debate over whether ICEVs powered by synthetic fuels created using clean electricity can be considered alongside true ZEVs (BEVs and FCEVs) as a viable option to decarbonise transport. Due to the fact that this does not offer co-benefits from reducing air pollution and the significant efficiency losses in e-fuel production, an increasing number of experts expect only a very limited future role for this technology in road transport.

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Design: [Alchemy Mill](#)

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**#RouteZero**