Global Autos & Industrial Tech

Can new AI technology help accelerate AV deployments? Updating our global ADAS and AV forecast

Some investors and market observers argue that the industry is on the cusp of a breakthrough in autonomous vehicle (AV) scaling driven by new AI and GPU technology, while others argue that broad-based AV deployments may never occur.

The bottom-line is that we believe improved AI technology will help the industry reach higher levels of performance, although we also believe that wide scale AV adoption is still at least a few years away as a base case. We believe that global level 3 (L3) ADAS penetration (e.g. vehicles that can situationally have eyes-off driving, such as on a highway) will reach 10% of the market for new vehicle sales in 2030, with level 4 or AVs (e.g. eyes-off in a given area, such as a robotaxi in a city) at 2.5% in 2030. This implies that level 4 (L4) volumes will continue growing, albeit generally for commercial use cases like robotaxis in the near to intermediate term.

We assume most of the ADAS (advanced driver assistance systems) and AV industry volume growth in the next few years will come from partially autonomous L2/L2+ vehicles that require driver supervision. We assume L2/L2+ mix will rise from about 20% of sales this year to about 30% in 2027.

Our AV forecast implies that a global fleet of a few million commercial AVs used for rideshare could be on the road in 2030. Although this would comprise less than 1% of the global car parc of over 1 bn vehicles, it could result in a >$25 bn market for personal mobility from robotaxis.

We believe that **stocks investors should own on this theme include Nvidia, Uber, Mobileye, Renesas, Baidu, Desay SV** and **Quanta.**

Given advances in AI technology, including the latest Nvidia processors as well as different training approaches (e.g. a fully "end-to-end" approach of camera/sensor inputs in and driving policy out that can potentially help solve difficult edge cases especially if there is enough data, or a "compound approach" that utilizes machine learning/AI but with subsystems that can allow for efficiency and verification of the solution), **we attempt to better understand if the rate of progress toward wider-scale adoption of autonomy will accelerate,** including L3 and L4. See our

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"AI 101" section of this report for more details on AI approaches like end-to-end.

With this report we update our global ADAS and AV forecasts based on inputs from our global auto, industrial, and TMT team members.

Key work in this report -

1) Examination of Tesla's technical progress, and progress of various AV company efforts

2) Illustrative cost per mile for an AV robotaxi business with a vertically integrated model, and a discussion on rideshare and AV business models

3) Updated global ADAS/AV forecast

4) Discussion of new electronic architectures and implications for semis

5) 2030 EPS scenario analysis for Tesla

PM Summary

We think it is notable that there are now autonomous vehicles on the road. There are a small number of AVs operating in parts of major cities such as San Francisco, Phoenix, Beijing and Wuhan.

However, the technology has yet to be broadly deployed. Key issues gating growth are related to understanding complex traffic/driving scenarios (or edge cases), along with business and regulatory factors. While AVs from companies such as Baidu (Apollo Go), Waymo and Pony.ai may already be safer in terms of accidents per mile than human drivers within geofenced areas (e.g. per data from leading companies such as Waymo, albeit with AVs on the road today typically able to query a human in a remote location for assistance if needed), there continue to be cases where AVs get confused or stuck in scenarios a human could likely navigate.

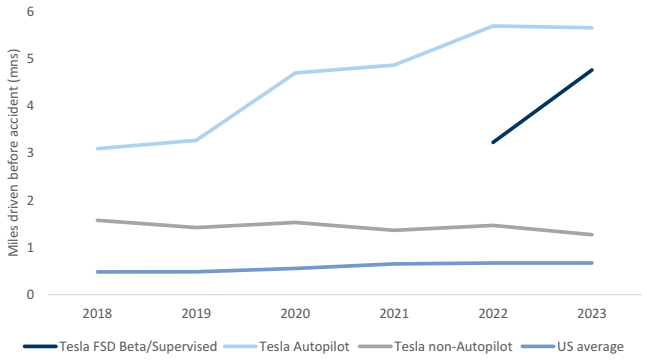
We seek to better understand where the technology and industry currently stands, and if new AI technology can help to accelerate progress toward wider-scale adoption of L3 (e.g. situationally eyes-off and hands-off driving, such as on a highway) or L4 (e.g. eyes-off in a given area, such as a robotaxi in a city) autonomy.

Research on AI scaling does suggest that added compute, larger training datasets, and improved model architectures should contribute to better AI model performance. Microsoft CEO Satya Nadella during a keynote at Microsoft Build 2024 noted that similar to how Moore's Law drove technology in the past, AI technology now allows compute performance for training deep neural networks to roughly double every 6 months (referencing research from Epoch).

We consider Tesla to be one of the leaders in autonomous technology. Tesla's supervised full self driving (FSD) technology, which is an L2/L2+ system as it requires the driver to pay attention and be prepared to take over at all times, is already safer than vehicles driven manually in terms of accidents per mile data from Tesla (Exhibit 1). Tesla's data shows that in 2023 accidents with supervised FSD

(which is Tesla's solution that will allow the car to do point to point navigation, and works on highways and city streets) occurred every 4 to 5 million miles, and accidents on Autopilot (which includes more basic features like traffic aware cruise control and lane keeping) occurred every 5 to 6 mn miles (although these are generally highway miles), compared to once every 600-700K miles for the US on average. In 1Q24, accidents with Autopilot happened once every 7-8 million miles.

Exhibit 1: Tesla ADAS system miles driven before an accident



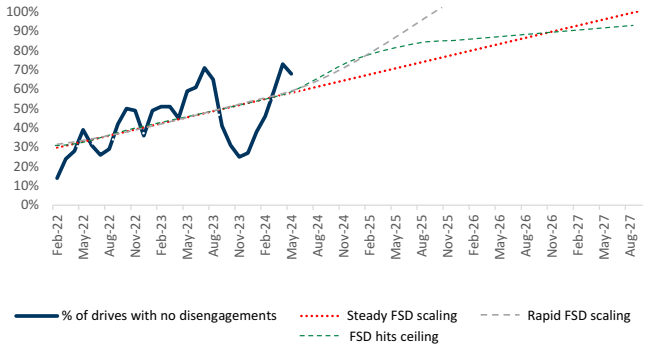
Source: Company data, FHWA, NHTSA, Goldman Sachs Global Investment Research

While we consider these safety statistics to be important, measuring if Tesla drivers get in fewer accidents while using the technology with active driver supervision (and taking over if there is an issue) is not the same as whether the vehicles would be better and/or safer when unsupervised (e.g. L3/L4 capability). We therefore believe it is also helpful to gauge the percentage of drives with no interventions and interventions per mile to assess when Tesla may reach unsupervised capability (e.g. L3 or L4). There are other performance metrics beyond just accidents to consider (e.g. proper lane selection, smooth driving behavior, and responding to emergency vehicles).

While Tesla doesn't disclose intervention data on FSD (and interventions are at the discretion of the driver which can complicate an analysis of this sort), some drivers submit intervention data to TeslaFSDtracker and this shows that the percentage of drives without an intervention has gone up, and **about 70% of drives with the latest version of FSD have been no-intervention per this crowd-sourced data** (Exhibit 2). Tesla's latest FSD version (V12) was developed with more reliance on AI, or an "end-to-end" approach of vision/camera inputs in and driving policy out that can potentially help solve difficult edge cases especially if there is enough data.

Moreover, **this same data suggests critical interventions occur every ~300 miles with FSD. While we think it would be wrong to assume that every disengagement would have resulted in a crash, it also suggests the technology could be some time off from being L3 or L4 given the 600-700K miles traveled between accidents for the typical vehicle in the US.** Our own recent rides in FSD enabled vehicles also suggest that FSD is impressive but not yet ready to be L3 or L4, in our opinion.

Exhibit 2: Percent of Tesla drives without an intervention per crowd sourced data



Source: TeslaFSDTracker, Goldman Sachs Global Investment Research

Extrapolating the rate of no intervention drives implies in our view that Tesla could reach L3 on highways at full speeds, at least in clear weather, in the next two to three years, especially if Tesla's significant investments in technology (Tesla is spending $3-$4 bn on Nvidia compute this year) and use of an end-to-end AI approach help. Given the added complexities of operating in dense urban environments and high bar for safety in unsupervised driving, we assume generalized L4 would take longer to reach. We believe that utilizing human assistance in a remote location (similar to current robotaxi efforts like Waymo and Baidu) could allow Tesla to reach L4 functionality sooner than it is otherwise tracking to albeit with added cost and scaling challenges.

Looking at AV efforts besides Tesla, while accident data has been promising (e.g. Waymo's analysis shows at least 57% fewer vehicle crashes per mile than a human driver with its L4 robotaxis), the current deployments (e.g. from Waymo, Pony.ai and Baidu Apollo Go) have **thus far been targeted in terms of deployments, and limited to certain sections of select cities (we have more details in the "Company ADAS and AV efforts" section of this report**). While this may be due in part to technology scalability issues (e.g. relying on detailed 3-D maps, needing human remote assistance at times, and difficulty in high traffic/complex scenarios like construction), we also believe economic considerations are a factor. As we show in Exhibit 3, the costs per mile are likely very high at low volumes due in part to the cost of the hardware/compute and human remote assistance (note that Tesla could have a cost advantage with its AV/ADAS technology given its vertical integration for inference chips, scale, and its limited sensor suite).

Assuming that depreciation and insurance costs normalize to levels on par with human driven commercial rideshare entities, we estimate that vehicle driving costs per mile for an AV at 50-75k miles driven per year per vehicle and roughly 10 cars per remote operator could reach ~$1.00 per mile (we show this for illustrative purposes occurring in the 2030 timeframe in Exhibit 3). Costs with corporate overhead/R&D would be higher. Longer-term these costs could decline.

Exhibit 3: Illustrative cost model for a vertically integrated AV rideshare company

	2023	2024E	2025E	2030E	2035E	2040E
AV cost per vehicle ($US)	125,000	100,000	85,000	50,000	50,000	50,000
Miles driven per car	22,500	25,000	27,500	75,000	100,000	125,000
Vehicles in service year end	177	259	478	2,570	18,597	72,967
Wages per remote operator	76,875	78,797	80,373	87,870	94,661	99,982
Cars per operator	3	3	3	10	30	35
Vehicle driving cost per mile	**$3.35**	**$3.13**	**$2.94**	**$0.98**	**$0.70**	**$0.58**
R&D ($US mn)	825	908	998	1,521	1,960	2,502
SG&A ($US mn)	230	265	304	612	1,127	1,479
Total cost per mile	**$268.71**	**$184.11**	**$102.03**	**$12.04**	**$2.36**	**$1.02**

Source: Goldman Sachs Global Investment Research

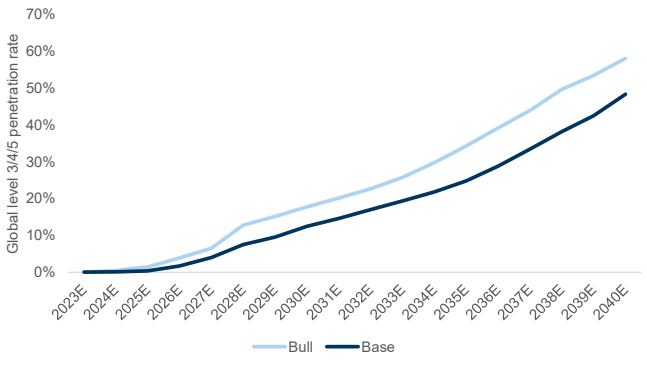
For context, Lyft committed to paying drivers at least 70% of rider payments per week after external fees like commercial insurance (we estimate ~$0.30 per mile) are subtracted, and Lyft estimates that there are ~$0.31/mile of expenses associated with operating the car for the driver (i.e. fuel costs, maintenance, cleaning, and depreciation). We note that the average cost to own a personal car in the US is ~$0.80 per mile per AAA, assuming 15K miles driven per year.

In addition, our recent discussions with AV operators in China suggest that AV companies so far need to charge a discount to conventional rideshare platforms such as DiDi of at least 30% in order to attract users to the network and to compensate for factors like limits to the locations that AVs can presently reach due to geofencing restrictions.

Finally, regulatory/liability and societal concerns may gate the rate of growth. For example, Cruise paused commercial operations after a severe accident involving one of its robotaxis, and communities may have a much higher safety bar for AVs than current human performance.

As a base case we now assume that globally L3 enabled vehicles could reach 10% of industry unit sales volumes in 2030, and that L4 will be 2.5% in 2030 driven by continued technological advancement (including from AI) and lower costs of relevant hardware (e.g. lidar and the introduction of purpose built AV platforms)**.** However, if the latest AI technology helps the industry to accelerate autonomous vehicle development faster than we expect, then we believe this could occur a few years earlier.

Exhibit 4: Global ADAS and AV L3-5 penetration rate as a percent of new light vehicle sales



Source: Company data, Goldman Sachs Global Investment Research

Our AV forecast implies that a global fleet of a few million commercial AVs used for rideshare could be on the road in 2030. Although this would comprise less than 1% of the global car parc of over 1 bn vehicles, it could result in a >$25 bn market for personal mobility from robotaxis (depending on factors such as ASPs, trips per day, and average miles traveled per trip).

Exhibit 5: We estimate the market in 2030 for robotaxis could be >$25 bn

2030 market scenarios for robotaxis ($ mn)								
Revenue per trip	Trips per robotaxi per day	Global AVs in operation (000s) 150	750	1,350	2,000	2,650	3,300	4,000
$5	2	$548	$2,738	$4,928	$7,300	$9,673	$12,045	$14,600
	4	$1,095	$5,475	$9,855	$14,600	$19,345	$24,090	$29,200
	6	$1,643	$8,213	$14,783	$21,900	$29,018	$36,135	$43,800
	8	$2,190	$10,950	$19,710	$29,200	$38,690	$48,180	$58,400
	10	$2,738	$13,688	$24,638	$36,500	$48,363	$60,225	$73,000
	12	$3,285	$16,425	$29,565	$43,800	$58,035	$72,270	$87,600
	14	$3,833	$19,163	$34,493	$51,100	$67,708	$84,315	$102,200
$7	2	$767	$3,833	$6,899	$10,220	$13,542	$16,863	$20,440
	4	$1,533	$7,665	$13,797	$20,440	$27,083	$33,726	$40,880
	6	$2,300	$11,498	$20,696	$30,660	$40,625	$50,589	$61,320
	8	$3,066	$15,330	$27,594	$40,880	$54,166	$67,452	$81,760
	10	$3,833	$19,163	$34,493	$51,100	$67,708	$84,315	$102,200
	12	$4,599	$22,995	$41,391	$61,320	$81,249	$101,178	$122,640
	14	$5,366	$26,828	$48,290	$71,540	$94,791	$118,041	$143,080
$9	2	$986	$4,928	$8,870	$13,140	$17,411	$21,681	$26,280
	4	$1,971	$9,855	$17,739	$26,280	$34,821	$43,362	$52,560
	6	$2,957	$14,783	$26,609	$39,420	$52,232	$65,043	$78,840
	8	$3,942	$19,710	$35,478	$52,560	$69,642	$86,724	$105,120
	10	$4,928	$24,638	$44,348	$65,700	$87,053	$108,405	$131,400
	12	$5,913	$29,565	$53,217	$78,840	$104,463	$130,086	$157,680
	14	$6,899	$34,493	$62,087	$91,980	$121,874	$151,767	$183,960

Source: Company data, Goldman Sachs Global Investment Research

There are also significant societal benefits from ADAS and AV technology, as about 40k people die in traffic fatalities in the US annually per NHTSA, and over 1 million people die each year globally in accidents per the World Health Organization.

AI 101 - What is AI, and what's the difference between "end-to-end" and a "compound approach"?

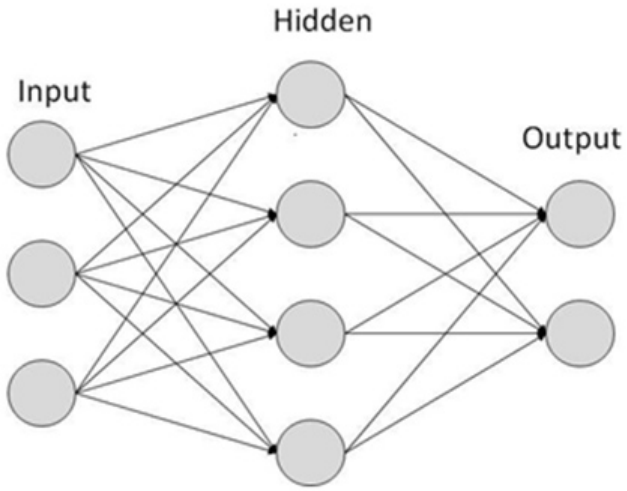
In this section of the report, we explain key concepts for artificial intelligence, as detailed in a prior report led by Toshiya Hari.

Artificial Intelligence: Artificial intelligence describes a science of simulating intelligent behavior in computers. It entails enabling computers to exhibit human-like behavioral traits including knowledge, reasoning, common sense, learning, and decision making.

Machine learning: Machine learning is a branch of artificial intelligence and entails enabling computers to learn from data without being explicitly programmed. For example, the computer learns how to identify an object such as a dog or a cat with data.

Neural networks: A neural network in the context of AI/machine learning describes a type of computer architecture that simulates the structure of a human brain onto which AI/machine learning programs can be built. It consists of connected nodes in aggregate that can solve more complex problems and learn, like the neurons in a human brain, such as in Exhibit 6. The process of back propagation is used in machine learning to adjust the weight of the neurons in the neural net and strengthen the paths to produce a correct answer (e.g. to identify an object).

Exhibit 6: Illustrative neural net framework



Source: Goldman Sachs Global Investment Research

Deep learning is a subset of machine learning with a hierarchy of layers in a neural net, with deep learning having more layers. For example in the dog or cat example, different layers could correspond to the key defining features of a given animal.

Compound AI system vs. end-to-end approach: There are different approaches to AI development in the context of autonomous driving, with one being an end-to-end design (as described more fully in this article), which is the approach Tesla has moved to and is a single model that takes the vision inputs in and directly outputs the drive policy like steering and braking. It reduces the need for human coding, and may help solve the

kind of edge cases that have limited AV progress thus far. An alternative approach is a compound solution that can utilize AI for different subsystems or inputs. The solution can then use this together with glue code and/or overlay other rules/factors (e.g. ensuring certain traffic laws are obeyed). While there is a debate if this will limit what AI can achieve in terms of hard to understand edge case scenarios, it can have efficiencies (e.g. ChatGPT doesn't need to use AI training to solve basic math, it can just query a calculator module, as described in this blog on the pros and cons of an end-to-end vs. a compound approach) and a compound system can be easier to understand/verify (which is especially important in driving as a mistake from AI could be fatal). Compound AI approaches still make use of advanced AI techniques like transformers. We also note that a blend of approaches can be used, such as an end-to-end model as a consideration for the driving decisions but with certain policy rules that are programmed.

Will more compute and an end-to-end approach help Tesla's FSD progress?

Tesla had expected to have fully autonomous vehicles ready in 2020 per comments at its 2019 Autonomy Investor Day, and the industry more broadly has struggled to meet its AV targets. In this section we discuss if newer AI technology can help Tesla to meet this objective.

Specifically, in May 2023, Tesla announced on X that it was would adopt an end-to-end AI approach with Version 12 of its supervised Full Self Driving (or FSD) product. Recall that an end-to-end approach is vision in (from the cameras) and driving policy (such as steering and braking) out. Moreover, on its 1Q24 earnings call, Tesla commented that it was no longer compute constrained.

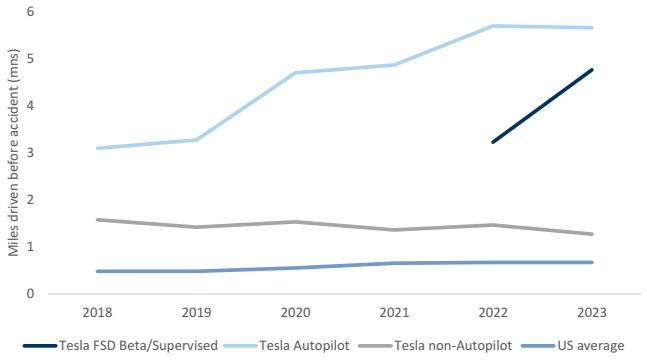
Research on AI scaling does suggest that added compute, larger training datasets, and improved model architectures should contribute to better AI model performance. Microsoft CEO Satya Nadella during a keynote at Microsoft Build 2024 noted that similar to how Moore's Law drove technology in the past, AI technology now allows compute performance for training deep neural networks to roughly double every 6 months (referencing research from Epoch).

On compute, Tesla is expecting to have commissioned and installed around 85K H100 GPUs from Nvidia by the end of 2024, up from 35K as of its 1Q24 earnings call. Tesla plans to invest about $3-$4 bn in Nvidia hardware in 2024. The H100 improves performance by up to 9X for AI training and up to 30X for AI inference over the prior A100 GPU for large language model (LLM) transformer development per Nvidia. Additionally, Nvidia noted that the upcoming GB200 with Blackwell could offer up to 30X better performance compared to the same number of Nvidia H100s for LLM inference workloads with up to 25X lower cost and energy consumption.

We consider Tesla to be one of the leaders in autonomous technology. Tesla's supervised FSD technology, which is an L2/L2+ system as it requires the driver to pay attention and be prepared to take over at all times, is already safer than a

human driver in terms of accidents per mile per data from Tesla (Exhibit 7). Tesla's data shows that in 2023 accidents with FSD (which is Tesla's solution that allows the car to do point to point navigation, and works on highways and city streets) occurred every 4 to 5 million miles, and accidents on Autopilot (which includes more basic features like traffic aware cruise control and lane keeping) occurred every 5 to 6 mn miles (although these are generally highway miles), compared to once every 600-700K miles for the US on average. In 1Q24, accidents with Autopilot happened once every 7-8 million miles.

Exhibit 7: Tesla ADAS system miles driven before an accident

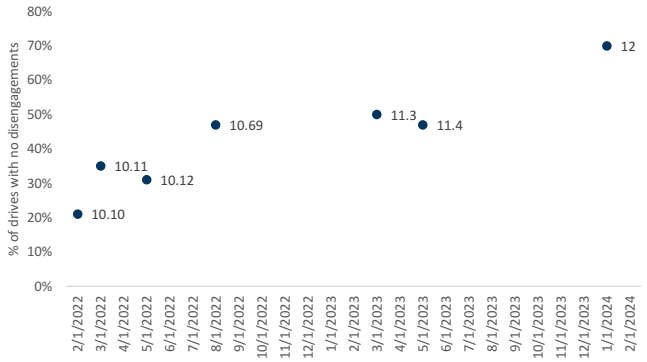


Source: Company data, FHWA, NHTSA, Goldman Sachs Global Investment Research

While we consider this an important metric (with real world implications), measuring if Tesla drivers get in fewer accidents while using the technology with active driver supervision (and taking over if there is an issue) is not the same as whether the vehicles would be better and/or safer when unsupervised (e.g. L3/L4 capability). We therefore believe it is also helpful to gauge the percentage of drives with no interventions, and interventions per mile, to assess when Tesla may reach unsupervised capability (e.g. L3 or L4).

While Tesla doesn't disclose intervention data on FSD (and interventions are at the discretion of the driver which can complicate an analysis of this sort), some drivers submit intervention data to TeslaFSDtracker which shows that the percentage of drives without an intervention has trended higher with FSD V12 (the version when Tesla moved to an end-to-end AI approach). **About 70% of drives on V12 have been no-intervention per this crowd-sourced data, which is an improvement from V10 and V11.**

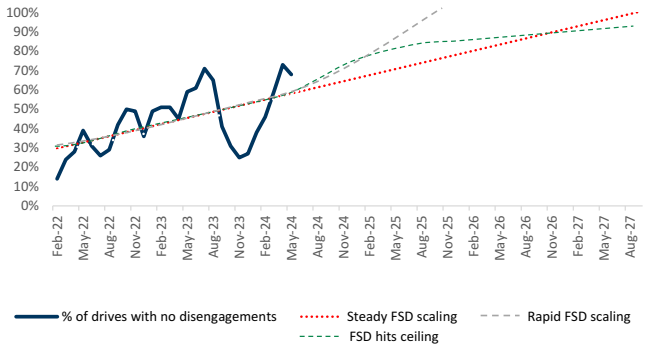
Exhibit 8: Tesla FSD performance by version per crowd-sourced data



Source: TeslaFSDTracker

More importantly, what does this data suggest for when Tesla could reach L3 or eyes-off capability? There are different potential extrapolations of the data, including rapid scaling, slower but steady progress, or an eventual ceiling on improvement. **While we recognize that this data is imperfect, it would imply in our opinion that Tesla is tracking to be at L3 in two to three years in a highway type scenario** (and unlike current L3 offerings that only work in very limited circumstances like a traffic jam on select highways, we mean L3 at full highway speeds).

Exhibit 9: Tesla FSD performance as % of drives with no disengagements

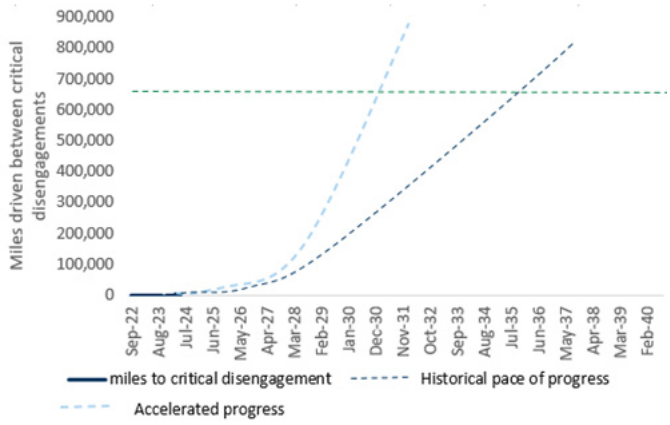


Source: TeslaFSDTracker, Goldman Sachs Global Investment Research

The data has also shown that critical disengagements, at least per this user data, have occurred roughly once every 300 miles (for context the average vehicle in the US has an accident every 600-700K miles). We think it would be wrong to assume that every disengagement would have resulted in a crash, but it also suggests the technology could be a longer time off from being L4 and working without the potential for a person to take over especially in urban environments. There are other performance metrics beyond just accidents to consider (e.g. proper lane selection, smooth driving behavior, operating in adverse weather, and responding to emergency vehicles). We also believe Tesla could benefit from an expanded number of cameras/camera placement and/or the use of different sensors like radar, to reach L4 in cities. We also believe it will take some time for Tesla to get the permits and regulatory

approvals needed for a robotaxi network. Using humans for remote assistance (similar to current AV operators like Waymo and Baidu) could allow it to reach this functionality sooner than we believe it is currently tracking to, albeit with added cost.

Exhibit 10: Tesla FSD miles between critical disengagements
The green line denotes the average miles driven by a US driver before an accident

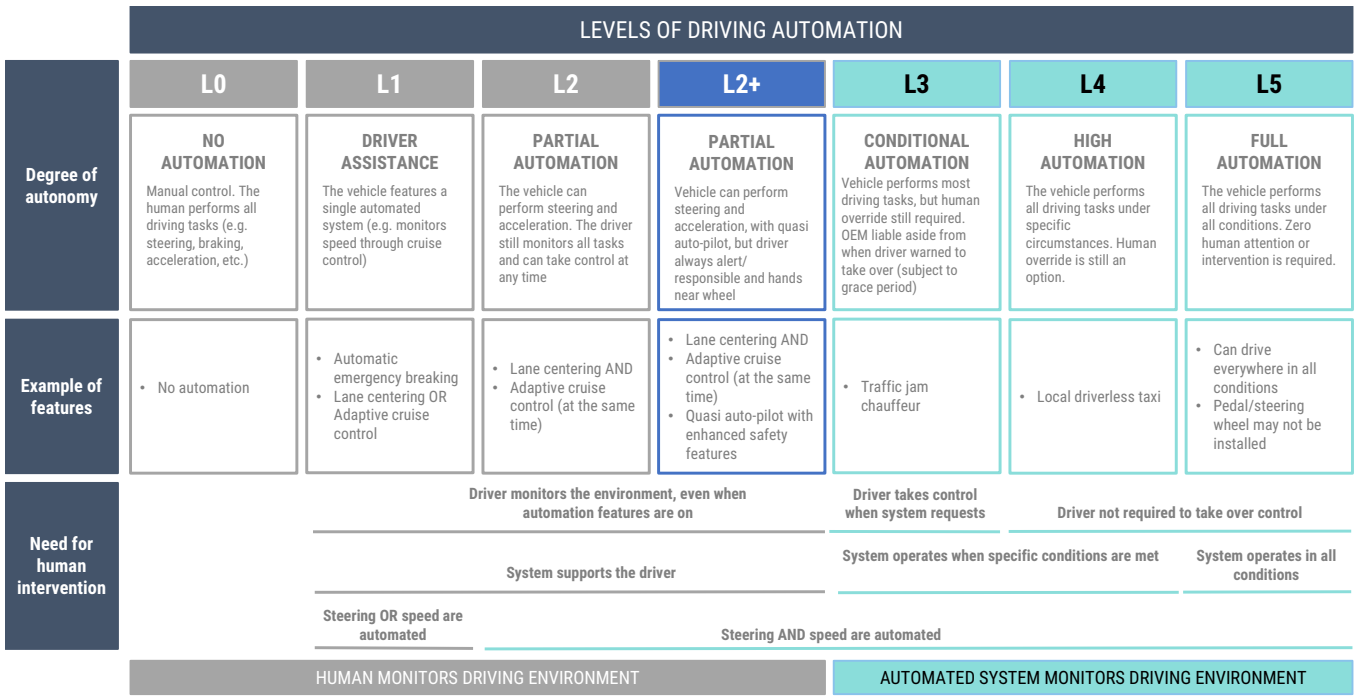


Source: FHWA, NHTSA, TeslaFSDTracker, Goldman Sachs Global Investment Research

Updating our ADAS-AV industry forecast

We define the different levels of autonomy, per the Society of Automotive Engineers (SAE) in Exhibit 11 below. L1 is basic driver assistance, and L2 is partial automation (e.g. lane centering and adaptive cruise control simultaneously). L3 is when a driver can take their eyes and hands off of the wheel in select situations such as while driving on a highway in clear weather, and in those scenarios the OEM would be liable for an accident if the vehicle is at fault. L4 is a fully autonomous vehicle in a given area like a city, such as a robotaxi. Industry participants also refer to additional levels such as L2+ (which is a vehicle that is able to perform more complex tasks and may be technically capable of L3, but the driver still needs to be alert, and the driver is responsible for an accident).

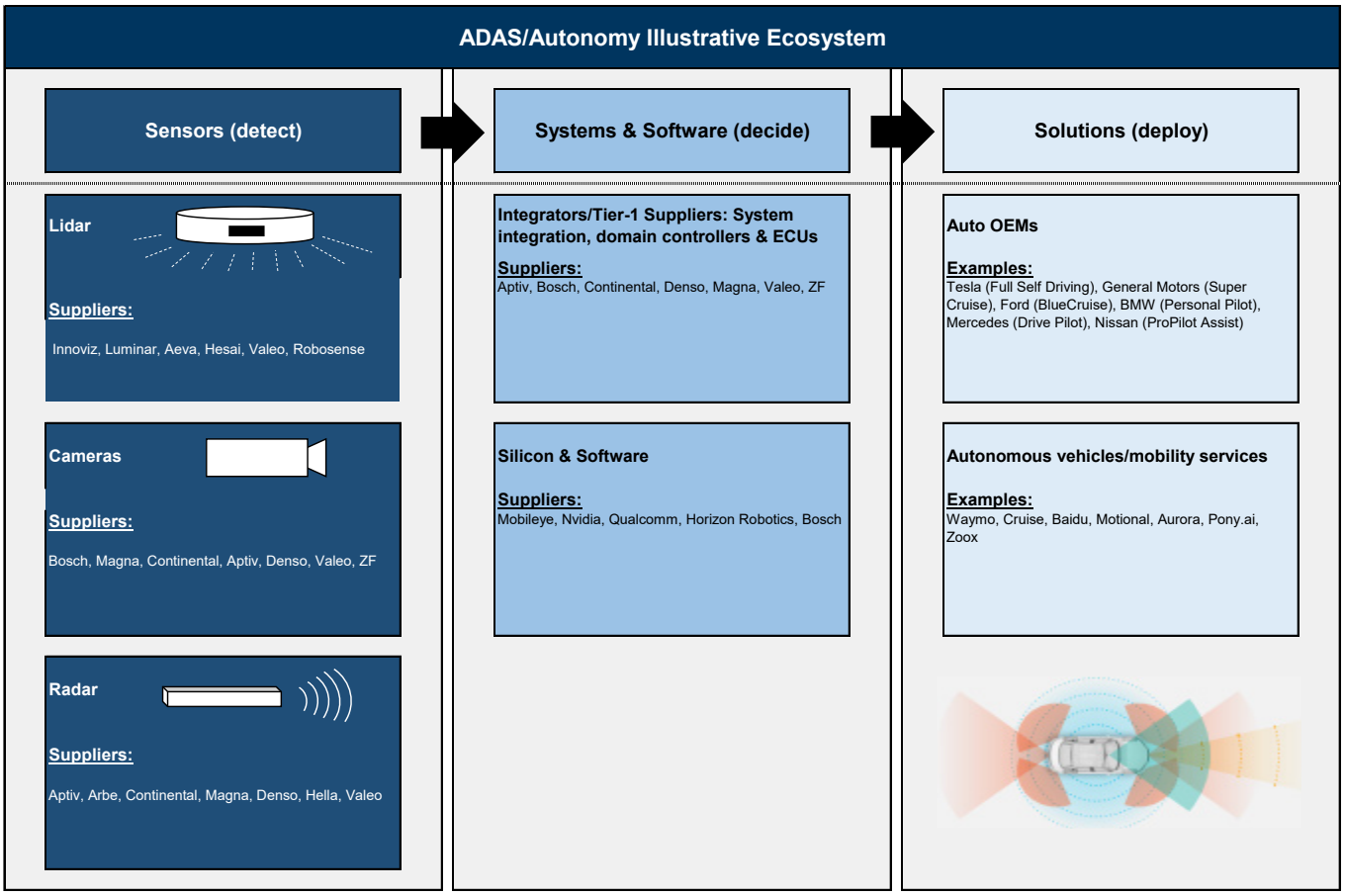
Exhibit 11: Level of autonomy in autonomous vehicles (Definition of SAE)



Source: SAE, NHTSA, Company data, Goldman Sachs Global Investment Research

Driver assistance and fully autonomous vehicles make use of dozens of sensors, including cameras, radar and in some cases lidar (Exhibit 12). Tesla currently makes use of 8 cameras in its consumer vehicles, while Waymo uses 29 cameras in the fifth gen design along with radar and lidar. From our industry discussions, most robotaxis efforts use at least 7-8 cameras, but some use 12 or more. There are typically at least 4 radar and lidars per robotaxi. For L3 cars, we believe most OEMs are seeking to use 1 lidar, although Tesla plans to use cameras only (although Tesla has been open to radar in the past). At L2+, we believe many OEMs are looking to use just cameras and/or radar to avoid the cost of lidar.

Exhibit 12: ADAS/Autonomy illustrative ecosystem
Representative but not exhaustive list

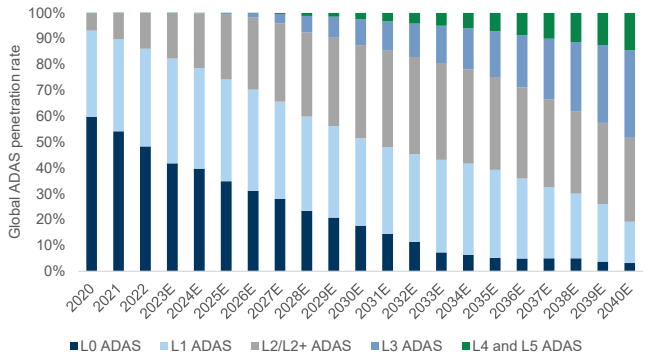


Source: Data compiled by Goldman Sachs Global Investment Research

We estimate that nearly 60% of vehicles currently have some level of driver assistance technology such as adaptive control or automatic emergency breaking. We estimate that about 20% of vehicles are L2/L2+ enabled in 2024. There are a small number of L3 vehicles on the road today, but the conditions are currently very limited (e.g. select highways at sub 35-40 MPH with a lead car, such as a traffic jam type scenario). There are also a small number of robotaxi deployments (e.g. NHTSA reports imply Waymo has a fleet of ~700 vehicles). We estimate that currently L3/L4 vehicles are well under 1% of global sales. The L4 vehicles on the road at present operate in geofenced areas and can query humans in a remote location for assistance if needed.

In 2026, we believe that 1-2% of global vehicles will ship as L3. By 2030 we estimate that L3 vehicles will account for 10% of sales volume and L4 will be a few percent of total volumes. We expect that L4 use cases could expand in the 2030-2040 timeframe and increasingly include consumer vehicles (perhaps with a subscription to access remote assistance).

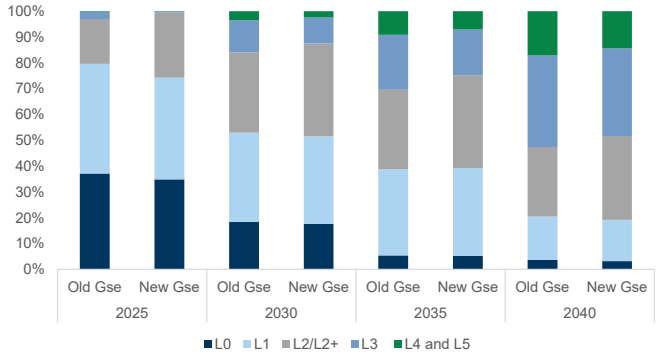
Exhibit 13: GS global ADAS/AV penetration forecast



Source: Company data, Goldman Sachs Global Investment Research

The shift to higher levels of autonomy is happening slower than our forecast from 2022, with a comparison of our old and new forecasts below in Exhibit 14. We believe that technology readiness (such as solving edge cases) has been the key constraint, but regulatory and business model considerations have all also contributed to the slower ramp in our opinion.

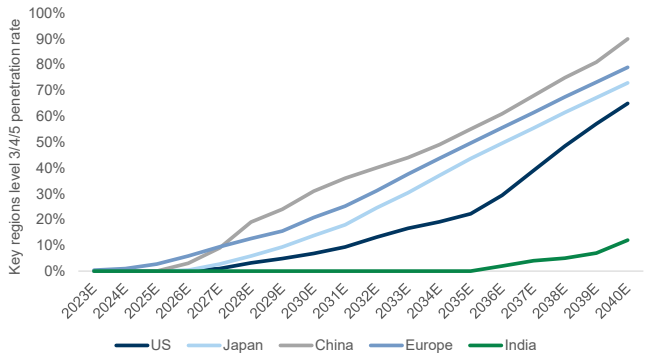
Exhibit 14: Old vs. new GS forecasts for autonomy penetration by level (2025/2030/2035/2040) globally



Source: Company data, Goldman Sachs Global Investment Research

Importantly, we highlight our expectation for L3-L5 penetration rates by region in Exhibit 15.

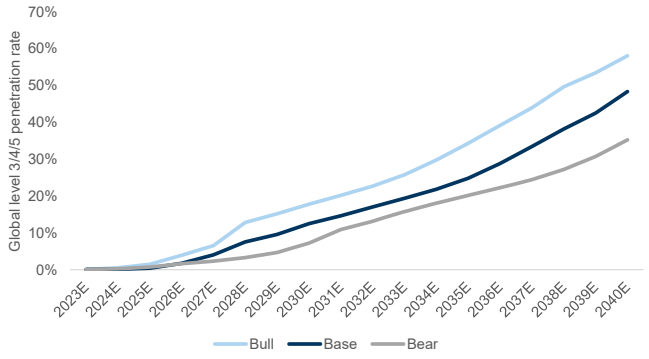
Exhibit 15: Key regions level 3/4/5 penetration rate



Source: Company data, Goldman Sachs Global Investment Research

We show our global bull, bear, and base case L3-L5 penetration rates in Exhibit 16.

Exhibit 16: GSe global level 3/4/5 bull, base, and bear case



Source: Company data, Goldman Sachs Global Investment Research

For Class 8 trucking, our industry discussions and company comments suggest that targeted point to point L4 routes will start at the end of 2024/in 2025 timeframe in the US. L4 trucking technology for Class 8 vehicles can benefit from going on more predictable routes than consumer robotaxis, but the larger vehicles take more time to stop and thus need longer-range sensors. L4 trucking adoption has also been late, with some of the AV companies citing delays in the necessary trucking hardware. We believe that L4 Class 8 trucking will take time to gain more material market share given the approach of using specific routes and initially higher costs (similar to how L4 robotaxi operations so far have been fleets of hundreds or a few thousand vehicles). We expect L4 Class 8 vehicles to reach a few percent of industry new truck sales volumes at the end of the decade.

We now estimate that the Lidar TAM for light vehicles will be $1-$2 bn USD in 2025, nearly $2 bn in 2026, and $2-3 bn in 2027. This is smaller than the implied ~$3-$3.5 bn estimate for 2025 we made when we initiated coverage of companies in the lidar market in 2021. We attribute this to a combination of factors including a slower L3/L4 ramp, lower lidar attach rates on L2+ vehicles, and ongoing price competition in the market. In China, lidar ASPs have fallen from about $700 in 2022 to about $370 in 2024

per a June 2024 report from our colleague Tina Hou. While we believe ASPs for lidar with European and US OEMs are tracking somewhat higher than in China currently, we'd note that this is still on small overall volumes, and we expect lidar ASPs from 2024-2027 to decline at a double digit CAGR.

Economics of AVs likely are a limiting factor to scaling currently, but over time the market could be very large

Current robotaxi efforts (e.g. from Waymo, Pony.ai and Baidu Apollo Go) have thus far been targeted in terms of deployments, and limited to certain sections of select cities. While this may be due in part to technology scalability issues (e.g. relying on detailed 3-D maps, and difficulty in high traffic/complex scenarios like construction), we also believe economic considerations are a factor.

As we wrote in our Initial framing of robotaxi opportunity, and updated FSD scenarios note, some of the key costs per mile to consider include insurance, repair/maintenance, cleaning, and fuel/electricity. Lyft has estimated that driver costs such as fuel, repair/maintenance, depreciation, and cleaning averaged $0.31 per mile and, specifically for EVs, noted a cost per mile of $0.23 (with lower fuel costs than ICE vehicles). In addition, commercial insurance that rideshare companies provide can average roughly $0.30 per mile as implied by 10-K reports. This suggests to us that insurance per mile for a robotaxi could be >$0.50 to start (with a likely higher cost of repairs for an AV than a typical consumer vehicle), but could decline to well under $0.30 per mile if AV accident rates are eventually significantly lower than human drivers (and the cost to buy/repair an AV declines as the industry grows).

When we examine the costs of AV start-ups (e.g. Motional, Cruise, Aurora) and also current established rideshare operators like Uber and Lyft, it suggests at least hundreds of millions if not billions of dollars of opex are often needed to stand-up an early AV and rideshare business.

Current AV companies (e.g. Waymo, Baidu and Pony.ai) also use human remote assistance that can help give a car instructions if it gets stuck or confused.

Assuming that depreciation and insurance costs normalize to levels on par with human driven commercial rideshare entities, we estimate that vehicle driving costs per mile for an AV at 50-75k miles driven per year per vehicle and roughly 10 cars per remote operator could reach ~$1.00 per mile (we show this occurring in the later part of this decade/the 2030 timeframe in Exhibit 17). When considering the sizable operating expenses AV and rideshare businesses have historically needed, assuming 100-125K miles per year per vehicle, more favorable insurance (closer to $0.20 per mile) costs, lower vehicle depreciation costs per mile as AV hardware matures, lower cost of the vehicle (driven by lower sensor costs and the introduction of purpose-built robotaxi platforms, and consistent with our industry discussions) and 30-35 cars per remote operator, then AVs could take more material market share (shown in the 2035-2040 timeframe in the below exhibit).

Exhibit 17: Illustrative AV rideshare cost model

	2023	2024E	2025E	2030E	2035E	2040E
AV cost per vehicle ($US)	125,000	100,000	85,000	50,000	50,000	50,000
Miles driven per car	22,500	25,000	27,500	75,000	100,000	125,000
Vehicles in service year end	177	259	478	2,570	18,597	72,967
Wages per remote operator	76,875	78,797	80,373	87,870	94,661	99,982
Cars per operator	3	3	3	10	30	35
Vehicle driving cost per mile	**$3.35**	**$3.13**	**$2.94**	**$0.98**	**$0.70**	**$0.58**
R&D ($US mn)	825	908	998	1,521	1,960	2,502
SG&A ($US mn)	230	265	304	612	1,127	1,479
Total cost per mile	**$268.71**	**$184.11**	**$102.03**	**$12.04**	**$2.36**	**$1.02**

Source: Goldman Sachs Global Investment Research

To put this in context, AAA estimates the cost of personal car ownership in the US was ~$0.80 per mile last year for a typical driver (assuming 15K miles traveled per year). When considering the margin an AV company would need to charge on top of the cost per mile, it suggests to us that personal car ownership will remain more economical for drivers for at least the next 5-10 years. However, a meaningful improvement in miles an AV operates per year beyond the 125K per year assumption we used, or more favorable vehicle cost/insurance assumptions, could alter this.

Importantly, our discussions with AV operators in China suggest that currently AV companies need to charge a discount to conventional rideshare platforms such as DiDi of at least 30% in order to attract users to the network and to compensate for factors like limits to the locations that AVs can currently reach due to geofencing restrictions.

As we initially wrote in our Initial framing of robotaxi opportunity, and updated FSD scenarios note, we show the early stage revenue opportunity from robotaxis based on trips per day, total robotaxis deployed, and an assumed revenue per mile of ~$2-$2.25 (in line with current market pricing in the US on average for ride sharing) in Exhibit 18. We assumed an average of 9 miles driven per trip (similar to the current rideshare market), and 50-1,000 vehicles deployed (similar to the scale of early AV deployments from Waymo and Baidu).

Exhibit 18: Annual revenue opportunity ($ mn) from initial deployment of robotaxis

Annual revenue in mns from robotaxis					
	Robotaxis in operation				
Trips per robotaxi per day	50	100	250	500	1,000
5	$2	$3	$9	$17	$35
8	$3	$6	$14	$28	$56
10	$3	$7	$17	$35	$70
12	$4	$8	$21	$42	$84
15	$5	$10	$26	$52	$105
18	$6	$13	$31	$63	$126
20	$7	$14	$35	$70	$140

Source: Company data, Goldman Sachs Global Investment Research

Longer-term the revenue opportunity from robotaxis could be more significant with a range of scenarios around trips per day, revenue per trip, and robotaxis in operation as we show in Exhibit 19.

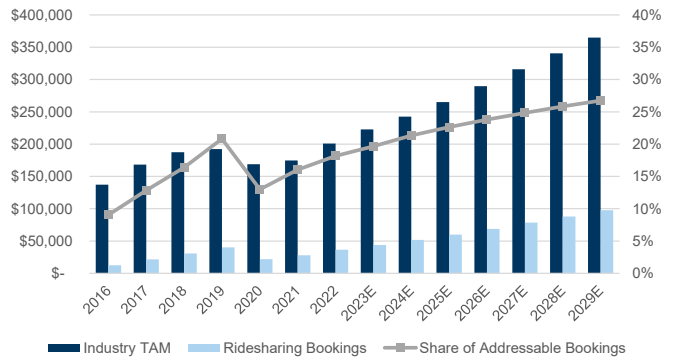
Exhibit 19: Analysis of the annual revenue opportunity ($mn) from a larger fleet of robotaxis deployed globally in a range of scenarios

Annual revenue in mns from robotaxis									
		Robotaxis in operation							
Revenue per trip	Trips per robotaxi per day	5,000	10,000	25,000	50,000	100,000	250,000	500,000	1,000,000
$5	2	$18	$37	$91	$183	$365	$913	$1,825	$3,650
	4	$37	$73	$183	$365	$730	$1,825	$3,650	$7,300
	6	$55	$110	$274	$548	$1,095	$2,738	$5,475	$10,950
	8	$73	$146	$365	$730	$1,460	$3,650	$7,300	$14,600
	10	$91	$183	$456	$913	$1,825	$4,563	$9,125	$18,250
	12	$110	$219	$548	$1,095	$2,190	$5,475	$10,950	$21,900
	14	$128	$256	$639	$1,278	$2,555	$6,388	$12,775	$25,550
$10	2	$37	$73	$183	$365	$730	$1,825	$3,650	$7,300
	4	$73	$146	$365	$730	$1,460	$3,650	$7,300	$14,600
	6	$110	$219	$548	$1,095	$2,190	$5,475	$10,950	$21,900
	8	$146	$292	$730	$1,460	$2,920	$7,300	$14,600	$29,200
	10	$183	$365	$913	$1,825	$3,650	$9,125	$18,250	$36,500
	12	$219	$438	$1,095	$2,190	$4,380	$10,950	$21,900	$43,800
	14	$256	$511	$1,278	$2,555	$5,110	$12,775	$25,550	$51,100
$15	5	$137	$274	$684	$1,369	$2,738	$6,844	$13,688	$27,375
	8	$219	$438	$1,095	$2,190	$4,380	$10,950	$21,900	$43,800
	10	$274	$548	$1,369	$2,738	$5,475	$13,688	$27,375	$54,750
	12	$329	$657	$1,643	$3,285	$6,570	$16,425	$32,850	$65,700
	15	$411	$821	$2,053	$4,106	$8,213	$20,531	$41,063	$82,125
	18	$493	$986	$2,464	$4,928	$9,855	$24,638	$49,275	$98,550
	20	$548	$1,095	$2,738	$5,475	$10,950	$27,375	$54,750	$109,500
$25	5	$228	$456	$1,141	$2,281	$4,563	$11,406	$22,813	$45,625
	8	$365	$730	$1,825	$3,650	$7,300	$18,250	$36,500	$73,000
	10	$456	$913	$2,281	$4,563	$9,125	$22,813	$45,625	$91,250
	12	$548	$1,095	$2,738	$5,475	$10,950	$27,375	$54,750	$109,500
	15	$684	$1,369	$3,422	$6,844	$13,688	$34,219	$68,438	$136,875
	18	$821	$1,643	$4,106	$8,213	$16,425	$41,063	$82,125	$164,250
	20	$913	$1,825	$4,563	$9,125	$18,250	$45,625	$91,250	$182,500
$35	5	$319	$639	$1,597	$3,194	$6,388	$15,969	$31,938	$63,875
	8	$511	$1,022	$2,555	$5,110	$10,220	$25,550	$51,100	$102,200
	10	$639	$1,278	$3,194	$6,388	$12,775	$31,938	$63,875	$127,750
	12	$767	$1,533	$3,833	$7,665	$15,330	$38,325	$76,650	$153,300
	15	$958	$1,916	$4,791	$9,581	$19,163	$47,906	$95,813	$191,625
	18	$1,150	$2,300	$5,749	$11,498	$22,995	$57,488	$114,975	$229,950
	20	$1,278	$2,555	$6,388	$12,775	$25,550	$63,875	$127,750	$255,500

Source: Company data, Goldman Sachs Global Investment Research

Our colleagues Eric Sheridan, Ben Miller, and team estimate that the US/Canada ridesharing industry TAM will grow at a 9% CAGR (2023-2029E) and reach over $350 bn, and that ridesharing bookings of about $44 bn in 2023 (implying roughly 20% penetration) will grow at a 14% CAGR through 2029 Exhibit 20.

Exhibit 20: US & Canada estimated rideshare booking & TAM



Source: Company data, Federal Reserve Bank of St. Louis, Census Bureau, World Bank, Second Measure, McKinsey, Statistics Canada, Goldman Sachs Global Investment Research

Our AV forecast implies that a global fleet of a few million commercial AVs used for rideshare could be on the road in 2030. Although this would comprise less than 1% of the global car parc of over 1 bn vehicles, it could result in a >$25 bn market for personal mobility from robotaxis (depending on factors such as ASPs, trips per day, and average miles traveled per trip). We assume the international mix of the business affects the revenue per trip in this 2030 scenario. More optimistic scenarios on utilization and ASPs would imply a $100 bn+ market in 2030.

Exhibit 21: We show a market scenario analysis for the robotaxi market in 2030

2030 market scenarios for robotaxis ($ mn)								
		Global AVs in operation (000s)						
Revenue per trip	Trips per robotaxi per day	150	750	1,350	2,000	2,650	3,300	4,000
$5	2	$548	$2,738	$4,928	$7,300	$9,673	$12,045	$14,600
	4	$1,095	$5,475	$9,855	$14,600	$19,345	$24,090	$29,200
	6	$1,643	$8,213	$14,783	$21,900	$29,018	$36,135	$43,800
	8	$2,190	$10,950	$19,710	$29,200	$38,690	$48,180	$58,400
	10	$2,738	$13,688	$24,638	$36,500	$48,363	$60,225	$73,000
	12	$3,285	$16,425	$29,565	$43,800	$58,035	$72,270	$87,600
	14	$3,833	$19,163	$34,493	$51,100	$67,708	$84,315	$102,200
$7	2	$767	$3,833	$6,899	$10,220	$13,542	$16,863	$20,440
	4	$1,533	$7,665	$13,797	$20,440	$27,083	$33,726	$40,880
	6	$2,300	$11,498	$20,696	$30,660	$40,625	$50,589	$61,320
	8	$3,066	$15,330	$27,594	$40,880	$54,166	$67,452	$81,760
	10	$3,833	$19,163	$34,493	$51,100	$67,708	$84,315	$102,200
	12	$4,599	$22,995	$41,391	$61,320	$81,249	$101,178	$122,640
	14	$5,366	$26,828	$48,290	$71,540	$94,791	$118,041	$143,080
$9	2	$986	$4,928	$8,870	$13,140	$17,411	$21,681	$26,280
	4	$1,971	$9,855	$17,739	$26,280	$34,821	$43,362	$52,560
	6	$2,957	$14,783	$26,609	$39,420	$52,232	$65,043	$78,840
	8	$3,942	$19,710	$35,478	$52,560	$69,642	$86,724	$105,120
	10	$4,928	$24,638	$44,348	$65,700	$87,053	$108,405	$131,400
	12	$5,913	$29,565	$53,217	$78,840	$104,463	$130,086	$157,680
	14	$6,899	$34,493	$62,087	$91,980	$121,874	$151,767	$183,960

Source: Company data, Goldman Sachs Global Investment Research

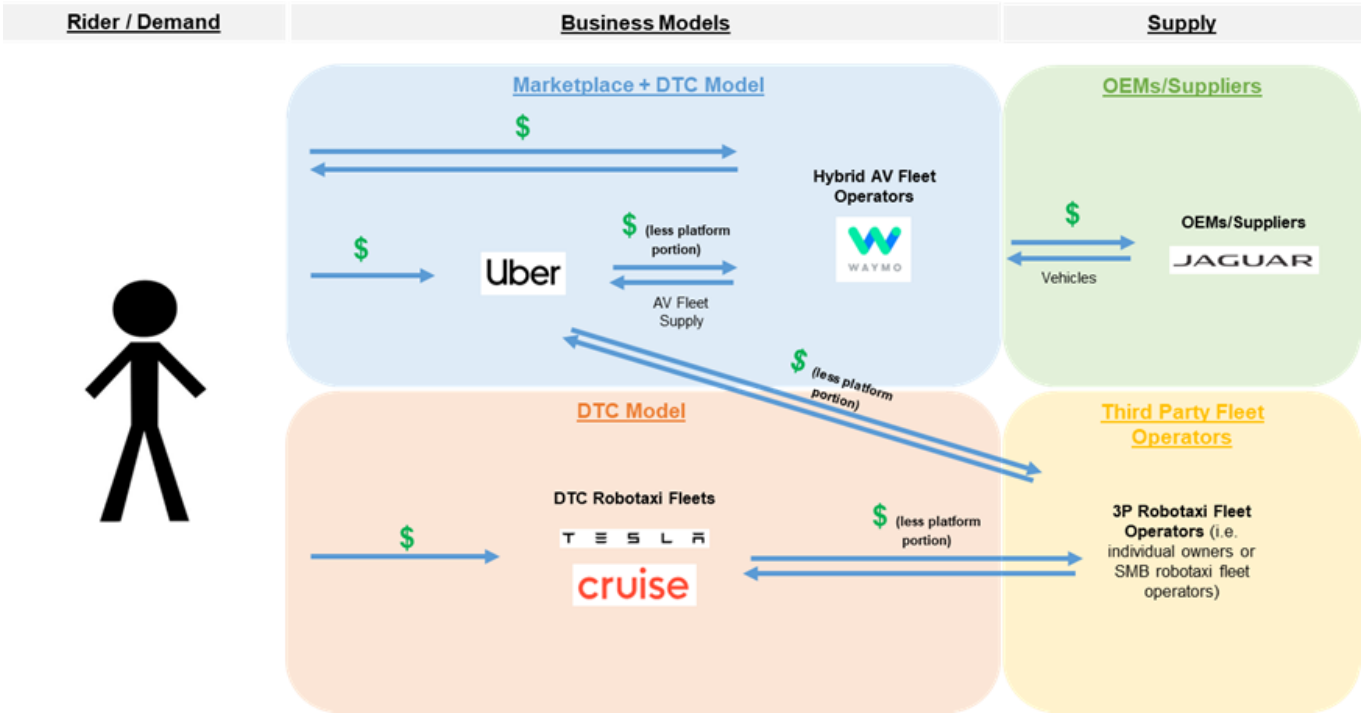
There could be substantial long-term upside from AVs if they were to displace personal car ownership. Uber has framed the long-term global personal mobility TAM at 11.9 tn miles per year, which represents a $6 tn market opportunity per the company (across

175 countries).

How could an eventual shift to L4 autonomous vehicles change the ridesharing industry ecosystem?

We see one of the key debates for UBER & LYFT as what the long-term picture of how the AV industry and rideshare networks interact over the medium-to-long term looks like. We believe Uber & Lyft will primarily operate as an asset-light third-party (3P) marketplace for AV fleet operators to plug their supply into as a way to generate demand. That said, we acknowledge other businesses could emerge as well within the broader rideshare/robotaxi industry. For example, in addition to Waymo being available on Uber in Phoenix, consumers can also book direct via Waymo's app. Similarly, it appears Tesla would look to approach the industry through its own direct to consumer app. We also see a potential scenario where entirely new businesses could be formed around this technology. For example, professional fleet operators who buy up 10-20 robotaxis and plug-in to marketplaces for demand generation (similar to how vacation rental owners list on Airbnb/Vrbo or individuals who own fleets of vehicles list them to rent on Turo).

Exhibit 22: US Rideshare Industry - Illustrative Ecosystem with Autonomous Vehicles

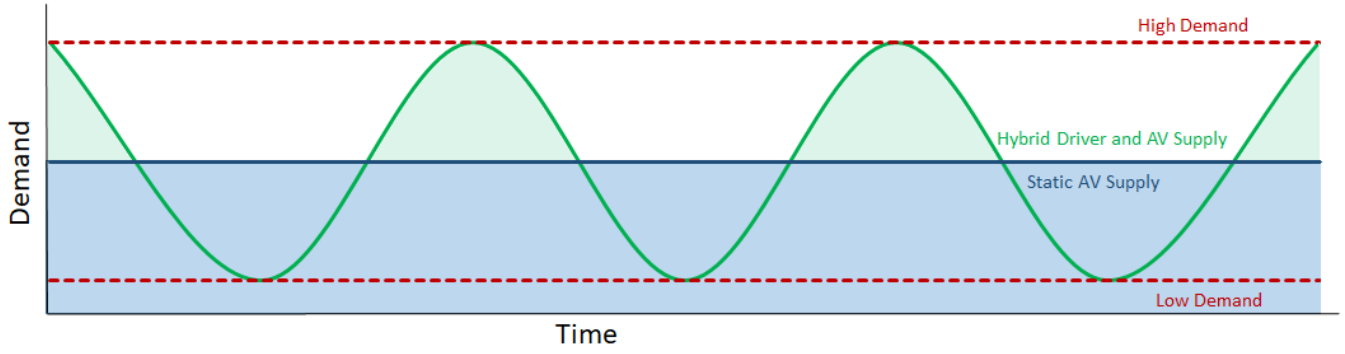


Source: Company reports, Goldman Sachs Global Investment Research

An area we will be paying close attention to as AVs begin to get deployed on ridesharing networks is how these deals are structured & what the unit economics look like. As AV fleet operators scale, and we transition from Ridesharing 1.0 to Ridesharing 2.0, we could see a gradual shift in the supply-side industry structure from highly fragmented (i.e. millions of individual drivers) to more consolidated (i.e. a handful of AV fleet operators). This could have implications for take rates & unit economics for marketplaces, similar to how chain & independent/boutique hotels have different negotiated deal structures with online travel agencies like Booking Holdings (BKNG) &

Expedia (EXPE). The relative negotiating leverage will likely depend on a number of factors including: the route coverage AVs will be capable of handling, how consolidated AV fleet operators become, AV unit economics, how successful AV fleet operators will be in launching a DTC product, etc. That said, even if AVs were to gradually be deployed in certain geographies over the next 3-5 years, it is likely they will operate as supplemental supply for specific routes as opposed to being the only option. Over the near-to-medium term, a hybrid offering combining AVs and human drivers unlocks the highest utilization, ensures availability and a better user experience for riders, in our view. Further, we'd note the most profitable routes are often the most complex to solve from an AV technology perspective (i.e. airport pick-up/drop-offs, late night pick-up/drop-offs to nightlife in crowded city streets, etc.).

Exhibit 23: Hybrid AV Networks Allow for Balance of Utilization & Customer Experience



Source: Lyft, Goldman Sachs Global Investment Research

New electric and electronic architectures underpin advanced ADAS and AV vehicles

We believe an important supporting technology of more advanced vehicles that have L3/L4 autonomy will be electronic architectures that use ethernet connectivity and more centralized compute. These types of architectures allow for less cabling/wires in the vehicle, removing weight and complexity, while allowing for high-speed data transmission and they can more easily be updated over the air (OTA). For example in Rivian's next gen R1 platform, the company highlighted that its new compute platform will use 7 in-house ECUs (electronic control units), down from 17 in the first gen R1 (and compared to the 30-40 or more ECUs that has been traditional in the industry) and allowing for the removal of 1.6 miles (2.6 km) of wiring in the second generation R1. Similarly, Tesla highlighted at its March 2023 investor day that it continues to move toward in-house controllers to better support a centralized compute approach and reduce weight/complexity. For Cybertruck, Tesla designed 85% of the controllers in house, up from 20% in the original Model S.

Company ADAS and AV efforts

OEMs continue to focus on autonomy technology, and there are already several

commercially available solutions available on the market. We highlight many but not all in this section of the report.

We detail key strategies and recent commentary below:

Tesla: Tesla highlighted progress it has made with ADAS/autonomy on its 1Q24 EPS call. On FSD, Tesla commented that it has rolled out V12 to all vehicles with cameras and Hardware 3 (and is on ~1.8 mn vehicles). Moreover, over 300 mn miles had been driven with FSD V12 with about half of the ~1.8 mn vehicles using it so far. Tesla said it is in discussion with one major auto OEM on potentially licensing FSD, and believes it could potentially sign one or more deals by the end of the year (but noted that it would still take multiple years for another OEM to deploy the FSD technology). Tesla also suggested that progress on licensing could track with FSD technology.

Tesla is also currently working on unsupervised FSD and ride-hailing functionality that will be available in the future. Tesla commented that it expects to own and operate a portion of a robotaxi fleet with some vehicles also owned by end users. Tesla's CEO posted on 4/5/2024 on X that the company will unveil its robotaxi on 8/8/24.

On AI compute, Tesla commented that the company has been actively working on expanding Tesla's core AI infrastructure. The company commented that it is no longer training-constrained and has installed and commissioned ~35K H100s and expects that to grow to roughly 85K by the end of 2024.

GM: On its 1Q24 earnings call, GM commented that it's making progress at Cruise (its self-driving subsidiary) and is mapping/gathering road information in Phoenix. GM noted that Cruise is frequently engaging with regulators and stakeholders and building trust as it regains momentum. Since Cruise paused operations last fall, it has continued to work on improving its core tech stack and strengthening the safety of the system by evaluating low probability but higher severity type issues. Cruise plans to demonstrate that the model works in one city before expanding from there. GM also said it is exploring a few options for funding Cruise, including potentially taking outside investments. As of June 11, Cruise is now performing manual driving/mapping in Phoenix, Houston, and Dallas, and supervised AV testing in Phoenix and Dallas per a blog post on the company website.

Recall Cruise paused operations after the California DMV suspended Cruise's permit for autonomous driving in October 2023, and Cruise paused operations of its fleet to redesign its approach to safety following two pedestrian injuries that involved Cruise vehicles, per press reports. Cruise had been testing/operating in 15 cities, and GM stated that Cruise had eclipsed > 5mn driverless miles as of its 3Q23 earnings call.

On Super Cruise (GM's hands-free driver assistance technology for compatible roads), GM continues to roll out the technology to more vehicles.

Ford: BlueCruise, Ford's advanced driver assistance system, is available in Great Britain, Germany and Spain, in addition to the US and Canada. Management commented at a conference at the end of May that BlueCruise has reached about 26 mn hours. The company commented that as of 4Q23, more than 290K BlueCruise-equipped Ford and

Lincoln vehicles were on the road, with customer use exceeding 2.3 mn hours and 156 mn hands-free miles. On its 3Q23 EPS call, Ford commented that it launched version 1.3 of BlueCruise, which helps customers stay engaged longer in hands-free mode by improving performance, with greater ability to navigate narrow lanes and curves, per the company.

On its broader ADAS strategy, Ford commented at its 2023 capital markets day that ADAS is one of its most important horizontals that extends across the whole portfolio. L3 autonomy (i.e. hands-off and eyes-off), is expected to launch on Ford's Gen 2 EVs (not right at the point of the platform launch, but as soon as Ford can get the technology working). Recall Ford believes that the opportunity in L2+ and L3 autonomy is nearer-term, higher growth, and more profitable than L4.

Mercedes: Mercedes DRIVE PILOT is certified as an L3 system in the US on major freeways in California and parts of Nevada (e.g., hands and eyes off, and with the OEM liable for accidents the system could cause), but with restrictions (e.g., select highways, clear weather, at certain speeds). As of February 2024, Mercedes highlighted that automatic lane change functionality was introduced in the US and it expects China and Europe to follow. Additionally, Mercedes aims to extend DRIVE PILOT speeds to ~90 km/h in Germany by the end of 2024. Mercedes is cooperating with NVIDIA on the joint development of future driving systems.

VW: In March 2024, VW and Mobileye announced an expanded collaboration in automated driving for L2/L3/L4 capabilities (i.e. hands-free, eyes-on driving/hands-free, eyes-off systems/fully autonomous vehicles) across multiple VW brands. In the long term, Volkswagen aims to rely on its own in-house system (Cariad), and the company continues to focus on partnerships with Bosch and Qualcomm.

BMW: BMW vehicles in Europe and the US offer L2 ADAS systems such as Highway Assist. In Germany, BMW has the Personal Pilot L3, which started deployment in March 2024 on select vehicle models, and allows eyes off driving at up to 60 kph on select highways, and can even work in the dark per the company. When the function is being used, the customer still has to be ready to reassume the task of driving at any time (i.e. as soon as the situation on the road requires them to or the stretch of road suitable for using the BMW Personal Pilot L3 comes to an end).

Honda: Honda has several autonomous offerings, with solutions ranging from its SENSING offering (L1) through Honda SENSING Elite (L2+/L3). The SENSING Elite can perform L3 driving in traffic jam situations (Traffic Jam Pilot) per the company but was only included on a limited run of vehicles in Japan. The majority of Honda vehicles still use L1/L2 functionality.

Waymo: Waymo currently operates in several areas, including San Francisco, Los Angeles, and Phoenix and plans to expand to Austin later this year. Per a post on the company's X page, Waymo is now providing more than 50k paid rides per week across three major cities as of 5/10/24. Waymo also has a partnership with Uber, and has started providing driverless delivery for select Uber Eats restaurants in the Phoenix area per the company. Per a post on the company's X page, Waymo had completed over 14.8

mn rider-only miles as of the end of March 2024 over which it had 30 fewer injury crashes and 32 fewer police-reported crashes, which the company stated is 3.5x and 2x better than a human driver.

Apollo Go: Currently, Apollo Go, Baidu's autonomous ride-hailing service, operates a fleet of 1,000+ in cities such as Beijing and Wuhan and has now expanded to fully driverless commercial operations since late 2023. Apollo Go provided about 826K rides in the first quarter of 2024, up 25% year over year. As of April 19, 2024, the cumulative rides provided to the public by Apollo Go surpassed 6 million. In 2023, Apollo Go provided more than 3 million rides.

Trucking

Waabi: Waabi is a Toronto-based autonomous trucking startup that launched in 2021. Waabi was founded by Raquel Urtasun, who was the chief scientist at Uber ATG. The Waabi Driver is powered by generative AI and blends an end to end trained AI stack with an interpretable architecture. In November 2022, Waabi unveiled its first generation of trucks that are purpose-built for OEM integration that are powered by the Waabi Driver (a combination of Waabi's software, sensors and compute). The company revealed Waabi World, which is its closed-loop simulator that virtually tests Waabi's self-driving software and teaches it in real time. The company believes this training and testing strategy can help it to scale autonomous trucking faster in part because Waabi doesn't have to spend as much time collecting real-world data to train its models or testing its trucks in the real world.

In 2023, Waabi announced a 10 year strategic partnership with Uber Freight and committed billions of miles of driverless capacity to the Uber Freight network as part of the partnership. Waabi began commercial pilots with shippers on the Uber Freight network to haul goods between Dallas and Houston. Ultimately, Waabi plans to move to a Driver-as-a-Service business model where carriers buy trucks built with Waabi's Driver and can opt into the Uber Freight marketplace.

Gatik: Gatik is an autonomous middle mile logistics company that was founded in Silicon Valley in 2017. The company focuses on short-haul, B2B logistics for Fortune 500 retailers. Gatik's Class 3-7 autonomous box trucks are commercially deployed in multiple markets including Texas, Arkansas, and Ontario. Gatik's partnerships include Ryder, Goodyear and Isuzu. In 2021, the company removed the safety driver from autonomous trucks operating for Walmart. Other customers include Kroger, Tyson, Georgia-Pacific, and Loblaws. Gatik also announced in May 2024 that it is expanding its partnership with Isuzu for mass production of L4 autonomous trucks. Per the press release, these vehicles will be equipped with safety-critical redundant systems to accelerate the deployment of Freight-Only operations without a human driver at scale. As part of the agreement, Isuzu has invested $30 mn into Gatik. Gatik expects the truck platform will be manufactured at a dedicated manufacturing facility that will be established by Isuzu and begin operations in 2027. First deliveries of L4-capable autonomous trucks from the new manufacturing facility are expected to be delivered to Gatik's fleet customers.

Since Gatik began autonomous deliveries, it has completed over 600k commercial

orders for customers in the US and Canada. The current fleet is now over 60 trucks.

Aurora: Aurora is focused on developing autonomous driving technology, with an initial focus on the Class 8 trucking market. The company plans to initially launch in Texas at the end of 2024 on its Dallas to Houston route, and expand over time. Aurora commented during its 1Q24 earnings that it is scheduling about 120 loads per week for its customers. Cumulative to-date through 4/30/24, Aurora has autonomously delivered (under the supervision of vehicle operators) 5,450 loads, driving ~1.5 mn commercial miles, with nearly 100% on-time performance for its pilot customers, including FedEx, Werner, Schneider, and Uber Freight, per the company. Additionally, Aurora reiterated its target for a commercial launch at the end of 2024 and noted it is readying its technology to close its launch lane Safety Case. Importantly, while Aurora plans to own and operate its early trucking fleet, its long term plan is to operate a driver as a service business (DaaS) where Aurora will supply self-driving technology and earn revenue on a fee per mile basis. Aurora is partnering with Continental to jointly develop, manufacture, and service future generations of the Aurora Driver hardware. This would begin in 2027, and Aurora would pay Continental on a per mile basis.

Kodiak: Kodiak Robotics is a private company that has developed Kodiak Drive, which is an autonomous driving solution, and the company is currently focused on the Class 8 market. Kodiak's technology is less dependent on mapping, and is platform agnostic. An important feature of its hardware kit (SensorPods) is that the company can quickly change them out for replacement. Kodiak's network incorporates more than 18,000 miles of freight-dense lanes. Kodiak highlights partners including Werner, Pilot Flying J, and Maersk.

Daimler Truck: Daimler takes a dual track strategy in its autonomous trucking business: 1) captive solution provided by its independent subsidiary Torc which has a fully integrated pure-play product with a virtual driver on board and optimised for hub-to-hub trucking. Torc has been testing autonomous-ready Freightliner Cascadia trucks in real-world applications with selected logistics companies such as Schneider and C.R. England, successfully moving customer freight autonomously on its test route between Phoenix and Oklahoma City, over the past year. 2) non-captive solution through its cooperation with Waymo which focuses on more complex problems and Waymo will retrofit its virtual driver technology onto redundant autonomous-ready chassis manufactured by Daimler. Daimler believes this dual track offers customers maximum flexibility and estimates the US autonomous freight market to be $450bn in 2030. During CMD 2023, Daimler announced targets to start to deliver autonomous trucks in the US by 2027 and to reach revenues of over €3 billion and an EBIT of over €1 billion by 2030.

Tesla earnings implications and 2030 EPS scenarios

We believe that Tesla's FSD revenue is currently $1-3 bn per year, mostly from up-front license sales (currently priced at $8K/vehicle in the US market) that is generally a license attached to that vehicle for the life of the car. Tesla also offers a subscription of $99 per

month.

We show revenue potential from purchases of FSD on a subscription or up-front basis in Exhibit 24 and Exhibit 25, and we assume that by 2030 Tesla's software related revenue could be tens of billions of dollars per year in total (we expect this to come primarily or fully from sales to its own fleet of vehicles as a base case).

We recognize there are scenarios beyond the range we show (e.g., upside cases given that Tesla aspires to sell 20 mn vehicles a year and could license FSD to other OEMs, and downside cases that are less positive from factors including regulatory constraints and/or software development challenges).

Exhibit 24: Tesla revenue opportunity from FSD subscription

Annual revenue in mns from monthly FSD subscrptions							
		Installed Base (mn)					
Monthly ASP	Attach Rate	25	30	35	40	45	50
$25.0	10%	750	900	1,050	1,200	1,350	1,500
	25%	1,875	2,250	2,625	3,000	3,375	3,750
	40%	3,000	3,600	4,200	4,800	5,400	6,000
	50%	3,750	4,500	5,250	6,000	6,750	7,500
	75%	5,625	6,750	7,875	9,000	10,125	11,250
$50.0	10%	1,500	1,800	2,100	2,400	2,700	3,000
	25%	3,750	4,500	5,250	6,000	6,750	7,500
	40%	6,000	7,200	8,400	9,600	10,800	12,000
	50%	7,500	9,000	10,500	12,000	13,500	15,000
	75%	11,250	13,500	15,750	18,000	20,250	22,500
$100.0	10%	3,000	3,600	4,200	4,800	5,400	6,000
	25%	7,500	9,000	10,500	12,000	13,500	15,000
	40%	12,000	14,400	16,800	19,200	21,600	24,000
	50%	15,000	18,000	21,000	24,000	27,000	30,000
	75%	22,500	27,000	31,500	36,000	40,500	45,000
$150.0	10%	4,500	5,400	6,300	7,200	8,100	9,000
	25%	11,250	13,500	15,750	18,000	20,250	22,500
	40%	18,000	21,600	25,200	28,800	32,400	36,000
	50%	22,500	27,000	31,500	36,000	40,500	45,000
	75%	33,750	40,500	47,250	54,000	60,750	67,500
$200.0	10%	6,000	7,200	8,400	9,600	10,800	12,000
	25%	15,000	18,000	21,000	24,000	27,000	30,000
	40%	24,000	28,800	33,600	38,400	43,200	48,000
	50%	30,000	36,000	42,000	48,000	54,000	60,000
	75%	45,000	54,000	63,000	72,000	81,000	90,000
$300.0	10%	9,000	10,800	12,600	14,400	16,200	18,000
	25%	22,500	27,000	31,500	36,000	40,500	45,000
	40%	36,000	43,200	50,400	57,600	64,800	72,000
	50%	45,000	54,000	63,000	72,000	81,000	90,000
	75%	67,500	81,000	94,500	108,000	121,500	135,000

Source: Goldman Sachs Global Investment Research

Exhibit 25: Tesla revenue opportunity from upfront FSD purchase

Revenue in mns from upfront FSD purchase							
		2030 Unit Sales (mn)					
ASP	Attach Rate	4	5	6	7	8	9
$2,500.0	10%	1,000	1,250	1,500	1,750	2,000	2,250
	25%	2,500	3,125	3,750	4,375	5,000	5,625
	40%	4,000	5,000	6,000	7,000	8,000	9,000
	50%	5,000	6,250	7,500	8,750	10,000	11,250
	75%	7,500	9,375	11,250	13,125	15,000	16,875
$5,000.0	10%	2,000	2,500	3,000	3,500	4,000	4,500
	25%	5,000	6,250	7,500	8,750	10,000	11,250
	40%	8,000	10,000	12,000	14,000	16,000	18,000
	50%	10,000	12,500	15,000	17,500	20,000	22,500
	75%	15,000	18,750	22,500	26,250	30,000	33,750
$8,000.0	10%	3,200	4,000	4,800	5,600	6,400	7,200
	25%	8,000	10,000	12,000	14,000	16,000	18,000
	40%	12,800	16,000	19,200	22,400	25,600	28,800
	50%	16,000	20,000	24,000	28,000	32,000	36,000
	75%	24,000	30,000	36,000	42,000	48,000	54,000
$12,000.0	10%	4,800	6,000	7,200	8,400	9,600	10,800
	25%	12,000	15,000	18,000	21,000	24,000	27,000
	40%	19,200	24,000	28,800	33,600	38,400	43,200
	50%	24,000	30,000	36,000	42,000	48,000	54,000
	75%	36,000	45,000	54,000	63,000	72,000	81,000
$15,000.0	10%	6,000	7,500	9,000	10,500	12,000	13,500
	25%	15,000	18,750	22,500	26,250	30,000	33,750
	40%	24,000	30,000	36,000	42,000	48,000	54,000
	50%	30,000	37,500	45,000	52,500	60,000	67,500
	75%	45,000	56,250	67,500	78,750	90,000	101,250

Source: Goldman Sachs Global Investment Research

As we have previously written, given that PEG ratios for tech and industrial stocks often range from ~1.25-2X, Tesla would need to grow at a ~20-40% EPS CAGR to warrant a roughly 25-75X P/E target multiple. We show scenarios of what Tesla's EPS could look like in 2030, assuming automotive vehicle revenue of $175-$350 bn, software (with FSD the largest component) at $10-$75 bn, as well as Services & Other ($75-125 bn; note the humanoid robot market could be ~$10-15 bn in 2030 per a report from our colleagues) and Energy ($30-50 bn). Taken together, we believe that these scenarios suggest that a 20-40% EPS CAGR is achievable for 2025-2030 for Tesla.

Relative to the 2030 EPS scenario analysis we published in our November 2023 report, "Contextualizing Tesla's AI and FSD opportunities", we have raised our revenue range for the base and upside scenarios for the Services & Other line to better reflect opportunities in robotics and a robotaxi business, while lowering our automotive revenue assumptions given our reduced BEV market outlook. We have also lowered the EBIT margin assumptions to better account for pricing challenges in the auto business.

Exhibit 26: 2030 Tesla EPS Scenarios

2030 EPS scenarios	Low	Mid	High
Revenue			
Vehicles	175	225	350
Software	10	25	75
Energy	30	40	50
Services & Other	75	100	125
Total	290	390	600
EBIT Margin	9.0%	12.5%	19.0%
EPS	$6.58	$11.93	$26.91
CAGR from 2025	*16%*	*30%*	*53%*

Revenue in $bn

Source: Goldman Sachs Global Investment Research

The bottom line is that we believe Tesla is among the leaders in AI technology, and we expect that this will help it to expand businesses like FSD in particular for Tesla's own fleet of vehicles in the intermediate to longer-term term. We also believe a robotaxi specific business could take time to grow given both technology as well as regulatory considerations.

We are Neutral rated on the stock, and our 12-month price target is $248 (based on 65X Q5-Q8E EPS). Key downside risks to our view relate to potentially larger vehicle price reductions than we expect, increased competition in EVs, slower EV demand, delays with products/capabilities like FSD/4680, key person risk, the internal control environment, margins, and operational risks associated with Tesla's high degree of vertical integration. Upside risks include faster EV adoption and/or share gain by Tesla, a stronger macroeconomic environment for new vehicle sales more generally, earlier new product launches than we expect, and an earlier/larger impact from AI enabled products (e.g., FSD, Optimus and robotaxis) than we currently anticipate.

Stock implications, price targets, and key risks

Nvidia (NVDA, Buy (CL); covered by Toshiya Hari): Although the sharp increase in Data Center revenue has led to a decline in the Automotive business' contribution to the overall company (i.e. >1% of total revenue), we believe Nvidia is well-positioned to benefit from growth in the ADAS/AV market given its a) leadership position in accelerated computing (i.e. offering of hardware and software), b) deep partnerships with nearly every Automotive company, per Nvidia, and c) a strong revenue pipeline of $14bn over six years as of May of last year. Automotive companies have been leveraging Nvidia's DRIVE AGX platform (includes hardware and software necessary to develop automated driving functions and immersive in-cabin experiences) for their next-gen fleet development. Mercedes, for instance, is ramping its AI-enabled fleet in CY2025 by using NVIDIA DRIVE Orin (i.e. SoC that delivers 254 TOPS of Compute performance) to support a comprehensive sensor suite to safely enable assisted driving and ultimately,

level 3 conditionally automated driving. JLR, as another example, is using Nvidia's full-stack solution based on NVIDIA DRIVE Hyperion, which features DRIVE Orin centralized AV computers; DRIVE AV and DRIVE IX software, and is expected to ramp in CY2026. Nvidia has also announced the next-gen successor to Orin, named Thor (based on the Blackwell architecture, and delivers 1,000 INT8 TOPS) and has announced design wins with several leading EV makers including BYD, XPENG and Nuro. Automotive companies have also been using Nvidia's Data Center products for Training and Inferencing their LLMs designed for autonomous driving, with the company calling out Automotive as the largest Enterprise vertical in terms of revenue contribution within its Data Center segment, driving a multi-billion revenue opportunity in the current year. Bottom line, we believe that Nvidia is playing a pivotal role in the growth of ADAS/AV market through its Data Center products for Training and Inference, and Automotive specific hardware and software enabling autonomous driving and intelligent cockpits at the edge.

Our 12-month price target of $135 is based on 50x our normalized EPS estimate of $2.70. Key downside risks to our estimates and price target include: 1) a sudden decline in Gen AI infrastructure spend by the major CSPs and/or enterprises; 2) further restrictions on GPU exports; 3) delays in new product introductions; 4) weaker-than-expected demand for Gaming GPUs; and 5) supply chain issues.

Uber (UBER, Buy; covered by Eric Sheridan): We believe Uber is well positioned as an asset light aggregator of supply and a demand generation engine for that supply in a world where autonomous vehicles become more widespread. This is based on our view that as AVs are gradually deployed in certain geographies over the next 3-5+ years, it is likely they will operate as supplemental supply for specific routes as opposed to being the only option. Over the near-to-medium term, a hybrid offering combining AVs and human drivers unlocks the highest utilization, ensures availability and a better user experience for riders. We'd also note the most profitable routes are often the most complex to solve from an AV technology perspective (i.e. airport pick-up/drop-offs, late night pick-up/drop-offs to nightlife in crowded city streets, etc.). Finally, should AVs allow for a lower cost per trip for the consumer, this could help unlock additional pools of demand over time for rideshare networks.

Looking long term, we continue to believe that UBER's equity story is centered on the key themes of scaling end-markets, rising profitability levels (even while remaining committed to investing for the long-term) and increased evidence of the platform cross-sell/flywheel effects which should result in investors revisiting the mix of growth, margins & FCF that Uber can generate in the years ahead. We see Uber as a company growing topline at a mid-teens% CAGR, that is compounding Adj. EBITDA at ~40% over the same period with high FCF conversion (~90%) and capability to return capital to shareholders.

Our $85, 12-month price target is based on an equal blend of (1) 22.5x EV/GAAP EBITDA applied to our NTM + 1 year estimates and (2) a modified DCF using a 22.5x EV/FCF-SBC multiple applied to our NTM + 4 years estimates discounted back 3 years.

Risks to our Buy rating include: a) Slower recovery in Mobility in a post-COVID

environment (airport rides, business travel, use case in major cities, slower disruption in car owning communities); b) Regulatory environment around driver classification (incl. compensation, benefits, etc.), merchant commission caps, ESG, etc.; c) Competitive forces in both Mobility and Delivery (incl. local commerce/logistics); d) Tougher comps for Delivery in a post-COVID environment (indoor dining, meals cooked at home); and e) volatility caused by the global macroeconomic environment and investor risk appetite for growth stocks.

Mobileye (MBLY, Buy; covered by Mark Delaney): We believe that Mobileye is a leading auto tech enabler for ADAS and AV applications, and we view the company as well positioned for growth given its vision/AI capabilities that are applicable for both ADAS and AVs, its ability to provide full solutions, and its strong market share. As we highlighted in this report, as more OEMs focus on reaching higher levels of autonomy we believe Mobileye is well-positioned for additional wins with its more advanced solutions (e.g. its hands-free but eyes-on product SuperVision, and eyes-off product Chauffeur), given Mobileye's strong perception capability, data access, and ability to provide low power solutions that are scalable (e.g. the technology for its L2+ SuperVision product is a key building block for Chauffeur). Importantly, these advanced solutions offer significantly higher ASPs and EBIT potential for Mobileye than its traditional products, and we therefore expect this to drive attractive long-term growth.

Our 12-month price target of $32 is based on a 30X multiple applied to our Q5-Q8 EBITDA estimate (ex. SBC). Key downside risks to our Buy thesis include: 1) Market share as the industry is extremely competitive with key players including Qualcomm, Nvidia, and in house tech; 2) China/geopolitical risks given significant business restrictions and geopolitical tensions between the US and China, there is the risk that new policies could limit the amount of business that Mobileye could do in China; 3) Mobileye's driving policy depends in part on the upkeep of its HD maps and these maps are crowdsourced from participating OEMs' vehicles. If OEMs were to no longer share this data with Mobileye, or if there were other new challenges around data privacy and/or storage, it could be a risk; 4) AV launch timing and performance; 5) Supply constraints and supplier/partner readiness; 6) Macroeconomic risk on auto demand.

Renesas Electronics (6723.T. Buy (CL); covered by Daiki Takayama): Renesas Electronics has a wide lineup of products for ADAS/AD (AV) applications, including MCUs and SoC. Autonomous driving is one of the areas where it applies its successful strategy of not only delivering individual products in response to specific requests from customers, but also meeting customer needs with solutions that combine several products. Renesas is one of the largest global suppliers of MCUs, which we think will remain a core part of its business. We expect demand for its MCUs to increase, driven by the evolution of autonomous driving technology.

Customers in the ADAS/AV space look for products that are efficient in terms of power consumption, as well as being able to meet their software calculation and safety requirements. Renesas has established a track record of reliability with its R-Car SoC and MCU lineup. It caters to a wide range of customer sizes and needs, from those looking for entry-level to premium models, as well as starter kits.

The company also makes its open development platform Renesas autonomy available to customers. By using the ecosystem provided by Renesas and its partners, customers can develop unique applications while substantially reducing the time needed between developing and launching a product.

According to Gartner data, Renesas lost market share in MCUs (especially automotive applications) in 2023. Auto-related MCUs are a core business for the company, which has maintained its global market share for many years, and this is fueling concerns among some investors. Renesas cited two factors behind the decline in market share: (1) a weaker yen and inventory adjustments starting earlier than at peers (one-off factors), and (2) a misread of future customer demand. On the second point, it said that auto-related computing design generally takes around five years, and the recent decline in market share reflects strategic decisions made around 2018-2019. While Renesas led the market shift to 40 nm/28 nm, it conservatively assumed that the move to EVs would be slower, and its focus at the time was on product specifications for internal combustion engine (ICE) powered vehicles. It also developed crossover MCUs with high performance on the assumption that these would be utilized along with advances in zone control units. However, the shift to EVs was faster than the company had expected, and demand has remained focused on functions for individual applications rather than zone control computing. We also assume the company was unable to meet customer demand due to delays in the development of ARM core-based products. Renesas has been developing proprietary core-based products (for example, the RX family) since its founding, and began marketing ARM core-based products (including RA family) later than its peers in 2019. We believe the recent decline in market share can be attributed in part to its falling behind technological trends. In response, Renesas has already begun developing specialized MCU products for individual functions. The company said that this has resulted in strong inquiries in recent sales negotiations, and it expects this move to bear fruit over the next few years.

Our 12-month target price of ¥3,800 is based on FY12/25E-12/26E EV/GCI vs. CROCI/WACC, applying an EV/DACF multiple of 10X (25% premium to the sector average, implying a target P/E of 12X. Key risks include a slowdown or delayed recovery in consumer electronics-related demand, stagnant automobile production, protracted reduction in semiconductor inventories, delayed recovery for industrial equipment applications, and yen appreciation.

Fuji Electric (6504.T, Buy; covered by Ryo Harada): We expect Fuji Electric to continue to benefit from the EV theme. Fuji Electric is a beneficiary of the current situation of its major customer Toyota delivering strong production for HEVs. In addition to preparing to add capacity in anticipation of the full-scale takeoff of the SiC module market in 2025-26, Fuji Electric is also planning a broad response to vehicle electrification that includes the rollout of RC-IGBTs – an area of strength for the company in Si-IGBT modules – for minivehicles and compact cars. RC-IGBTs are formed by combining IGBTs and FWDs (freewheeling diodes) in a single chip. This greatly reduces the chip area and the number of power elements to be mounted, thereby reducing costs. Fuji Electric's co-developed the RC-IGBTs with Denso, and competitors such as Mitsubishi Electric and Infineon are yet to mass produce them.

In its MTP, Fuji Electric is expecting auto IGBT sales to be flat from FY24/3 to FY27/3, but we think there is upside given the company is conservatively only pricing in the negative factor of expected vehicle model transitional period in FY26/3-27/3 by EU/US OEMs, and not the positive factor of expected continued strong sales of HEVs.

Our 12-month price target of ¥11,800 is based on an EV/EBITDA of 8X (FY3/26E).

Key risks for the semiconductor business include further increases in investment and depreciation, deterioration in market conditions due to excessive investment by other companies, higher-than-expected development costs and lower-than-expected sales prices for automotive IGBT modules, weak sales of auto models that adopt or plan to adopt Fuji Electric's IGBT modules.

Baidu (BIDU/9888.HK, Buy; covered by Lincoln Kong): We view Baidu as one of the pioneers in the China Robotaxi industry, with a current fleet of 1,000+ and having expanded to fully driverless commercial operations since late 2023. Apollo Go, Baidu's autonomous ride-hailing service, provided about 826K rides in the first quarter of 2024, up 25% year over year. As of April 19, 2024, the cumulative rides provided to the public by Apollo Go surpassed 6 million. In a city like Wuhan, currently 70% of commercial operation is in fully driverless mode with a target to reach 100% by the end of the year. On Unit economics, with the new generation of Robotaxi RT6 set for massive production before year end, cost per fleet will likely fall to RMB250K according to the company. As such, by 2025 in the Wuhan region it's likely to reach operational breakeven for Baidu's Robotaxi services, and total Apollo Go losses should shrink significantly from current levels. In the medium term, Baidu is also open to outsourcing technology to 3rd party auto OEMs as the industry TAM expands and profitability improves.

We are Buy-rated on Baidu with 12-month SOTP-based target prices for BIDU/9888.HK of US$153/HK$150. We use target 9X P/E for core search, 3X P/S for cloud business and discounted back valuation for Apollo Go. Key risks include 1) slower recovery in macro and advertising spending, 2) higher-than-expected competition in the advertising/search industry, 3) delay of AI monetization progress.

Honda (7267.T, Buy; covered by Kota Yuzawa): On January 10, Honda announced the basic outline of its new electrified vehicle (EV) strategy at CES 2024. The company said it plans to adopt a new logo for EVs scheduled for launch from 2025. Honda also unveiled its Saloon and Space-Hub concept cars that use a dedicated 0-series architecture platform. The 0-series will be equipped with Level 2 ADAS initially, but Honda said it plans to adopt systems equivalent to Level 3 ADAS in the latter half of the 2020s. It also aims to make some hands-free functions that can only be used on highways available for partial use on general roads. With regard to level 4, Honda, GM, and Cruise plan to establish a joint venture and launch a driverless ridehail service in Tokyo in early 2026. The plans call for the service to start with dozens of vehicles and subsequently expand to a fleet of 500. The service will then be expanded to areas outside of Tokyo. The venture will be the first to offer this service in central Tokyo. Honda has three suites of autonomous driving technologies for Levels 1 to 3, namely Honda Sensing, Sensing 360, and Sensing Elite, as a part of its strategy to address needs among various regions and customers. In 2021, Honda released the world's first Level 3

autonomous vehicle as a part of its Legend series, and it has been a global leader in development of the technology (operational design domain (ODD) for Level 3 at 30-50 km/h on highways). We think the latest announcement shows a clear move toward commercializing Level 4, and we view it as a positive development as Honda looks to maintain its position as one of the companies leading advances in the field of autonomous vehicles

Our 12-month target price of ¥2,400 is based on P/B-ROE correlation and our FY3/25 estimates. Risks include yen appreciation, a sharp rise in raw material prices, weaker-than-expected sales of new vehicles, inefficiency in multiple EV projects, and margin deterioration in the China business.

XPeng Inc. (XPEV/9868.HK, Buy; covered by Tina Hou) - XPeng is a fast-growing pure EV maker in China with a focus on intelligent vehicle features. We believe XPeng's leading position in NOA (navigation on autopilot) with strong R&D focus could provide further upside to its revenue growth and margin profile. With the start of recognition of R&D services revenue from VW, XPeng's gross margin improved to 12.9% in 1Q24 from 1.7%/6.2% in 1Q23/4Q23. XPeng achieved services and other revenue of Rmb1bn in 1Q24 (+93% yoy / +22% qoq). According to management, XPeng recorded multiple hundred million Rmb of revenue from VW in 1Q24 under service and other revenue. XPeng will start to record revenue from its EEA collaboration with VW starting from 2H24 and expects higher revenue from VW in the subsequent quarters after 1Q24. With recurring software services revenue recognition, the company believes its gross margin should be sustainable at low-to-mid teens levels throughout 2024. XPeng released XOS 5.1.0 - "AI Tianji" to users of major models on May 20, featuring non-HD map and end-to-end large model. The company targets to achieve city XNGP on all the roads nationwide by 3Q24. Powered by end-to-end AI model, XPeng would be able to iterate software and AI technology on a monthly basis. Management expects to achieve one manual takeover per hundred of kilometers for city XNGP in 2025.

We are Buy rated with 12m DCF-based (WACC 11.8%, TGR 3.0%) TPs of US$12.1/HK$47 for ADR/H share. Risks: intensified competition, component cost fluctuation, software monetization, liquidity, lower-than-expected G6 sales growth.

Hesai Group (HSAI, Neutral; covered by Tina Hou) – Hesai is one of the world's leading light detection and ranging (LiDAR) solution providers. Its LiDAR products cater to applications across advanced driver assistance systems (ADAS), autonomous mobility, and robotics. Our China ADAS LiDAR industry model uses a bottom-up approach based on individual vehicle models, where we expect the industry TAM to grow at 40% CAGR from US$300mn in 2023 to US$819mn in 2026E, driven by a 74% volume CAGR and partially offset by a -20% ASP CAGR. We estimate Hesai accounts for c.30% volume market share, and believe the company will maintain this through the ongoing customer diversification (Li Auto remains the largest customer contributing to >50% of revenue in 2024E-26E, while Xiaomi and Leapmotor are the two key OEMs on incremental revenue). In addition, customers' sensitivity to unit costs due to intensifying price competition and declining ASP of LiDAR products could impede Hesai's revenue growth. In the longer term, there is also debate over whether LiDAR is a must-have for ADAS and autonomous driving.

We are Neutral rated with a 12m target price of US$6.0 (based on 1-year forward P/S valuation methodology of 2x 2025E revenue). Risks include LiDAR adoption pace, pricing trend, competition dynamics, emerging technologies, and policy risks.

Desay SV (002920.SZ, Buy; covered by Verena Jeng): Desay SV is a local leading tier 1 player riding on specification upgrade across smart cockpit and smart driving. The company is an early mover with the NVIDIA chipset platform, riding on L2 / L4's growing trend in China. Despite the automotive market slowdown in China, Desay SV could continue to outperform thanks to its product mix upgrade driving revenues growth. Desay SV also enjoys: (1) a larger scale to share the R&D burden: Desay SV serves multiple car OEMs across various models, which enables it to better share the R&D burden, such as domain controllers for smart driving, (2) total solution across smart cockpit, smart driving, and IoV, with upside in software (e.g. smart driving algorithm, OS customization, Middleware, OTA services, etc.).

We are Buy rated on Desay SV with a 12-month target price of Rmb175. Our TP is derived from a discounted P/E. We use a 27.5x target P/E multiple, which is derived from sector correlation of forward year earnings growth vs. P/E. Key risks to our Buy thesis include 1) slower-than-expected smart driving revenue growth; 2) slower-than-expected new IoV business expansion; and 3) worse-than-expected gross margin in the smart driving segment.

Quanta (2382.TW, Buy; covered by Allen Chang): Quanta is an early entrant of smart driving domain controllers, starting mass production for global OEM clients in US and Europe from 2019-20. We see the company continuing to penetrate key OEM clients and diversify its production base, and expect automotive revenues contribution at 7%/ 8% of Quanta's total revenues in 2024/ 25E. As a leading ODM supplier expanding to automotive electronics, Quanta has strong know-how of DCU and partners with supply chain player AIMotive (private) to develop new products.

We are Buy-rated on Quanta with a 12-month target price of NT$405. Our TP is based on a 22x 2025E P/E, which is based on PC/server peers' EPS growth vs. P/E multiple correlation. We see EPS growth as a major factor for the stock's performance. Key downside risks include: 1) weaker-than-expected PC market recovery, 2) slower-than-expected AI server ramp-up, and 3) weaker-than-expected demand on general server.

Infineon (IFX, Buy; covered by Alexander Duval): Infineon provides microcontrollers, radar processing chips and power semis for L1-L5 ADAS technologies. The company is primarily exposed to the ADAS market through its portfolio of MCUs, which are used for pre-processing of sensor data (camera/radar/lidar) before central processing in the sensor fusion box, but also as ISO 26262-certified safety domain controllers that send signals for the final actuation of the vehicle physical parts (e.g. steering wheel, brakes). We estimate that IFX has c.30% global market share in auto MCU, with its ISO 26262-certified AURIX MCU gaining traction, suggesting that it could achieve 30%+ market share in the ADAS segment in our view. Further, in power management, Infineon offers a range of power management ICs tailored for ADAS. These semis play an important role in managing voltages in an ADAS system of very high computational

power. Infineon's presence in power semis provides it with exposure to the trend of increasing levels of redundancy in mechanical systems (e.g. braking, steering) as the levels of autonomy rise (towards L4/L5), and hence we expect a substantial increase in the power semis BoM over the next 5 years.

We are Buy rated on Infineon with a 12-month price target of €43.5 (unchanged) based on a 10x CY25E EV/EBITDA multiple. Key risks to our view and price target include weaker end markets (such as lower-than-expected EV adoption rates), a worsening semi cycle and negative macro dynamics that could prolong the weakness in consumer demand and lead to demand being pushed out.

STMicro (STM, Neutral; covered by Alexander Duval): STMicro supplies vision-based processing chips, short-range radar processing chips, MCUs and power semis to the ADAS market. STM has been a co-developer of vision-based camera EyeQ chips with Mobileye for the past 15+ years. We believe that STM's processing chips (co-developed with Mobileye) currently garner a leading market share, especially viz-a-vis vision based processing. STM also offers a comprehensive portfolio of ADAS ICs for power management, as well as radar chips. Furthermore, STM offers optical sensing solutions for driver and occupant monitoring systems, which are required in L2+ vehicles that monitor to ensure drivers remain alert in the event that ADAS systems prompt require human control. Finally, STM also has market share in MCUs, with the company present in both the microcontroller used for radar processing in high volume production and in the housekeeping MCUs that sit beside Mobileye processing chips.

We are Neutral-rated on STM, with 12-month price targets of €42.5 / ADR $45.8 based on an 8x CY25E EV/EBITDA multiple. Key risks to our view and price targets include a quicker/slower-than-expected inventory correction trough in consumer semis, accelerating/slowing Silicon Carbide momentum at competitors and evidence that currently favourable pricing can be sustainable.

Greater China EV Technology

SiC / IGBT: We see China power semiconductors suppliers expanding to EVs and the industrial market, with a rising SiC adoption rate in EVs to realize fast charging (5mins charge for 200km drive); for example: Xiaomi SU7 Max, Stelato S9 etc. on 800V SiC platform. SICC (688234.SS, Buy) is the local leader in SiC substrate, the most valuable part in SiC MOSFET. We are positive on SICC on its customers expansion and margins recovery on larger scale and improving yield rate. Starpower (603290.SS, Neutral) is the local leader in IGBT, CR Micro (688396.SS, Sell) is expanding from MOSFET to IGBT and SiC MOSFET; however, we see fiercer competition in IGBT vs. SiC and in devices vs. substrate.

ADAS / AD chips and domain controllers: ADAS and AD drive specification upgrade of chips and domain controllers across cockpit, driving, and integration of cockpit/driving domains. Car OEMs increasingly view smart driving/ autonomous driving as key technology functions to differentiate new models, and also have started providing low-cost configurations (Orin N, local chipset platforms) to cover car models priced

under Rmb250k (US$34k). The domain integration is still in the early stages, which could lower the overall vehicle cost. Desay SV (002920.SZ, Buy) is a local leader in smart cockpit and domain controllers for smart driving. Quanta (2382.TW, Buy), Pegatron (4938.TW, Neutral), Compal (2324.TW, Neutral), Inventec (2356.TW, Neutral) and Gigabyte (2376.TW, Buy) have exposure, and mainly serve global-tier car OEMs in US and Europe, with DCU shipment ramp up starting from 2025E.

Cameras: With growing adoption of L2/ L2+ driving functions, we see increasing number of cameras used per car, and specification upgrades of cameras on vehicles towards 8MPx cameras. For example, SAIC IM LS7 adopts 11 cameras, Li Auto L9 uses 11 cameras including 6 8MPx cameras. Will Semi (603501.SS, Buy) recently announced new 8MPx CIS with leading performance, supporting the company's mix upgrades and penetration of key car OEM clients. Sunny Optical (2382.HK, Neutral) is the global leader in vehicle lens and is expanding to vehicle camera modules. The company continues to improve its lens design and manufacturing efficiency. AAC (2018.HK, Buy) offers automotive acoustics solution for leading OEM clients, and is also expanding to the vehicle lens business: WLG (wafer-level glass) for ADAS cameras. O-Film (002456.SZ, Buy) vehicle camera business continues to see solid growth, penetrating 20+ local car OEMs.

Software: Generative AI functions are used in smart cockpit to enhance drivers' and passengers' interaction with the car; for example: AI assistant, or personalized interactions. NOA (navigate on autopilot) is also seeing rising adoption, and car OEMs tend to rely more on sensors + algorithm solutions rather than HD map, to save costs. Thundersoft (300496.SZ, Neutral) provides OS customization, middleware, and user interface for smart cockpit, and is expanding to smart driving domain controllers. In 1Q24, the company announced AquaDrive OS (Link) for cockpit / driving domain integration to reduce vehicle costs, targeting POC (Proof of Concept) to start from 2025/ 26E. Arcsoft (688088.SS, Buy) offers AI automotive algorithm, expanding from DMS (Driver Monitoring System) to ADAS/ AD solution. iFlytek (002230.SZ, Neutral) offers smart cockpit solution across automotive LLM and voice interaction for local car OEMs.

Exhibit 27: GC Tech Automotive revenues exposure table

Company name	Ticker	2024 Automotive rev exposure	Automotive-related products
Semiconductors			
SICC	688234.SS	46%	SiC substrate for EV SiC devices
StarPower	603290.SS	41%	IGBT / SiC module
Will Semi	603501.SS	34%	Automotive CIS
Novosense	688052.SS	31%	Signal sensing IC / Digital isolation IC / Driver IC / Power management IC
CR Micro	688396.SS	22%	MOSFET, IGBT, SiC
ASMPT	0522.HK	20%	SMT equipment for automotive electronics
Vanguard	5347.TWO	15-20%	Foundry for MCU, PMIC, auto DDIC chip, etc
UMC	2303.TW	15%	Foundry for MCU, PMIC, DDIC, connectivity, etc
KYEC	2449.TW	11%	IC testing
VeriSilicon	688521.SS	10%	Chip design service and chip production management service
TSMC	2330.TW	<10%	Foundry for ADAS, CMOS, MCU, WiFi, PMIC, etc
Silergy	6415.TW	8-10%	PMIC
ASE	3711.TW	5-10%	OSAT
Hua Hong	1347.HK	5%	IGBT, MCU, Memory
Sanan	600703.SS	5%	SiC, LED for car lighting
SG Micro	300661.SZ	5%	PMIC, Signal chain IC
Primarius	688206.SS	<5%	EDA for automotive applications
Empyrean	301269.SZ	<5%	EDA for automotive applications
Novatek Microelectronics	3034.TW	<5%	Auto DDIC
MediaTek	2454.TW	<3%	5G SoC, telematics, etc
Realtek	2379.TW	1-2%	Auto ethernet, switch IC, etc
uPI	6719.TW	<2%	On-board charger, PMIC
Win Semi	3105.TWO	<1%	ADAS / LiDAR sensing chips
Components, brands / EMS			
Yageo	2327.TW	20-25%	MLCC, R Chip, tantalum capacitor, sensor etc.
ITEQ	6213.TW	19%	Car computing board CCL
Sunny Optical	2382.HK	17%	Vehicle camera lens/module
AAC	2018.HK	17%	Automotive acoustics, haptics
EMC	2383.TW	11%	Car computing board CCL
USI	601231.SS	10%	Power modules, Powertrain
Pegatron	4938.TW	<10%	Car computer, ECU
Lotes	3533.TW	9%	Connectors/cables for auto
O-film	002456.SZ	6%	Automotive camera lens/module
BOE	000725.SZ	6%	Automotive panels
NYPCB	8046.TW	5-10%	Automotive PCB / BT & ABF substrates
Quanta	2382.TW	6%	ECU, ADAS controller
Luxshare	002475.SZ	6%	Cable connector
Kinsus	3189.TW	5%	Automotive BT & ABF substrates
Dahua	002236.SZ	<5%	smart cockpit, camera, radar, L2+ ADAS etc.
Largan	3008.TW	<5%	Vehicle camera lens/module
Hon Hai	2317.TW	3%	Automotive components, EV assembly
Wistron	3231.TW	<3%	ECU, ADAS controller
Gigabyte	2376.TW	<3%	ADAS controller
GCE	2368.TW	<3%	Automotive PCB
TUC	6274.TWO	<3%	Car connectivity CCL
Compal	2324.TW	1-2%	ADAS Component
Unimicron	3037.TW	<1%	Automotive PCB / BT & ABF substrates
Inventec	2356.TW	<1%	Ultra-Wideband access system, Connected gateway
Asus	2357.TW	0%	Smart cockpit component
Software			
Desay SV	002920.SZ	100%	Smartcockpit OS & ECU / ADAS DCU / T-BOX / Dashboard
Thundersoft	300496.SZ	54%	Smartcockpit OS / ADAS software design
Arcsoft	688088.SS	25%	Automotive AI algorithm
Yonyou	600588.SS	<10%	ERP for automotive customers
Kingdee	0268.HK	<5%	ERP for automotive customers
ZWSOFT	688083.SS	<5%	CAD for automotive customers
Venustech	002439.SZ	<2%	Automotive security software
Chinasoft Intl.	0354.HK	<2%	IT services for automotive platform
Kingsoft Office	688111.SS	<1%	Office software for automotive customers

Source: Company data, Goldman Sachs Global Investment Research

Disclosure Appendix

Reg AC

We, Mark Delaney, CFA, Kota Yuzawa, Allen Chang, George Galliers, Tina Hou, Eric Sheridan, Toshiya Hari, Daiki Takayama, Ben Miller, Lincoln Kong, CFA, Jerry Revich, CFA, Daniela Costa, Verena Jeng, Ryo Harada, Alexander Duval, Chandramouli Muthiah, Kee Ryung Kim, Will Bryant, Morgan Leung, Aman Gupta and Sian Keegan, hereby certify that all of the views expressed in this report accurately reflect our personal views about the subject company or companies and its or their securities. We also certify that no part of our compensation was, is or will be, directly or indirectly, related to the specific recommendations or views expressed in this report.

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GS Factor Profile

The Goldman Sachs Factor Profile provides investment context for a stock by comparing key attributes to the market (i.e. our coverage universe) and its sector peers. The four key attributes depicted are: Growth, Financial Returns, Multiple (e.g. valuation) and Integrated (a composite of Growth, Financial Returns and Multiple). Growth, Financial Returns and Multiple are calculated by using normalized ranks for specific metrics for each stock. The normalized ranks for the metrics are then averaged and converted into percentiles for the relevant attribute. The precise calculation of each metric may vary depending on the fiscal year, industry and region, but the standard approach is as follows:

Growth is based on a stock's forward-looking sales growth, EBITDA growth and EPS growth (for financial stocks, only EPS and sales growth), with a higher percentile indicating a higher growth company. **Financial Returns** is based on a stock's forward-looking ROE, ROCE and CROCI (for financial stocks, only ROE), with a higher percentile indicating a company with higher financial returns. **Multiple** is based on a stock's forward-looking P/E, P/B, price/dividend (P/D), EV/EBITDA, EV/FCF and EV/Debt Adjusted Cash Flow (DACF) (for financial stocks, only P/E, P/B and P/D), with a higher percentile indicating a stock trading at a higher multiple. The **Integrated** percentile is calculated as the average of the Growth percentile, Financial Returns percentile and (100% - Multiple percentile).

Financial Returns and Multiple use the Goldman Sachs analyst forecasts at the fiscal year-end at least three quarters in the future. Growth uses inputs for the fiscal year at least seven quarters in the future compared with the year at least three quarters in the future (on a per-share basis for all metrics).

For a more detailed description of how we calculate the GS Factor Profile, please contact your GS representative.

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Across our global coverage, we examine stocks using an M&A framework, considering both qualitative factors and quantitative factors (which may vary across sectors and regions) to incorporate the potential that certain companies could be acquired. We then assign a M&A rank as a means of scoring companies under our rated coverage from 1 to 3, with 1 representing high (30%-50%) probability of the company becoming an acquisition target, 2 representing medium (15%-30%) probability and 3 representing low (0%-15%) probability. For companies ranked 1 or 2, in line with our standard departmental guidelines we incorporate an M&A component into our target price. M&A rank of 3 is considered immaterial and therefore does not factor into our price target, and may or may not be discussed in research.

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Disclosures

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Pricing information

AAC (HK$31.80), Arcsoft (Rmb27.21), Baidu.com Inc. (ADR) ($95.40), Baidu.com Inc. (H) (HK$86.30), CR Micro (Rmb38.29), Compal (NT$34.10), Desay SV (Rmb92.10), Fuji Electric Co. (¥9,431), Gigabyte (NT$315.00), Hesai Group ($4.58), Honda Motor (¥1,703), Infineon (€34.98), Inventec (NT$56.00), Mobileye Global Inc. ($26.68), Nvidia Corp. ($131.38), O-film (Rmb8.24), Pegatron (NT$104.50), Quanta (NT$336.00), Renesas Electronics (¥3,293), SICC (Rmb47.25), STMicroelectronics ($41.51), STMicroelectronics (€38.22), StarPower (Rmb79.32), Sunny Optical (HK$46.50), Tesla Inc. ($262.33), Thundersoft (Rmb43.47), Uber Technologies Inc. ($71.32), Will Semi (Rmb103.65), XPeng Inc. (ADR) ($7.51), XPeng Inc. (H) (HK$29.00) and iFlytek (Rmb39.00)

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Entertainment Group (ADR), Tencent Music Entertainment Group (H), XD Inc., Zhihu Inc. (ADR), Zhihu Inc. (H), iQIYI Inc.

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The rating(s) for Hesai Group, XPeng Inc. (ADR) and XPeng Inc. (H) is/are relative to the other companies in its/their coverage universe: BYD Co. (A), BYD Co. (H), Fuyao Glass Industry Group (A), Fuyao Glass Industry Group (H), Guangzhou Automobile Group (A), Guangzhou Automobile Group (H), Hesai Group, Huayu Automotive Systems, Li Auto Inc. (ADR), Li Auto Inc. (H), MeiDong Auto, Minth Group, NIO Inc. (ADR), NIO Inc. (H), Ningbo Tuopu Group, SAIC Motor, XPeng Inc. (ADR), XPeng Inc. (H), Yongda Auto, ZEEKR Intelligent Technology Holding, Zhongsheng Group

Company-specific regulatory disclosures

Compendium report: please see disclosures at https://www.gs.com/research/hedge.html. Disclosures applicable to the companies included in this compendium can be found in the latest relevant published research

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Goldman Sachs Investment Research global Equity coverage universe

	Rating Distribution			Investment Banking Relationships		
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Global	48%	35%	17%	64%	57%	41%

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Price target and rating history chart(s)

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