

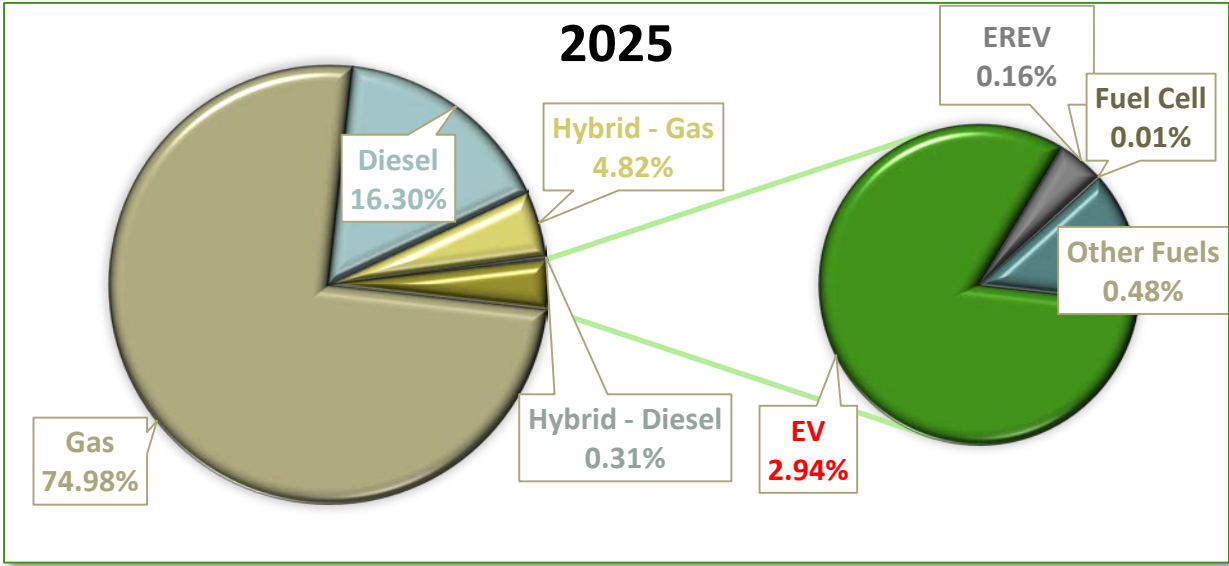
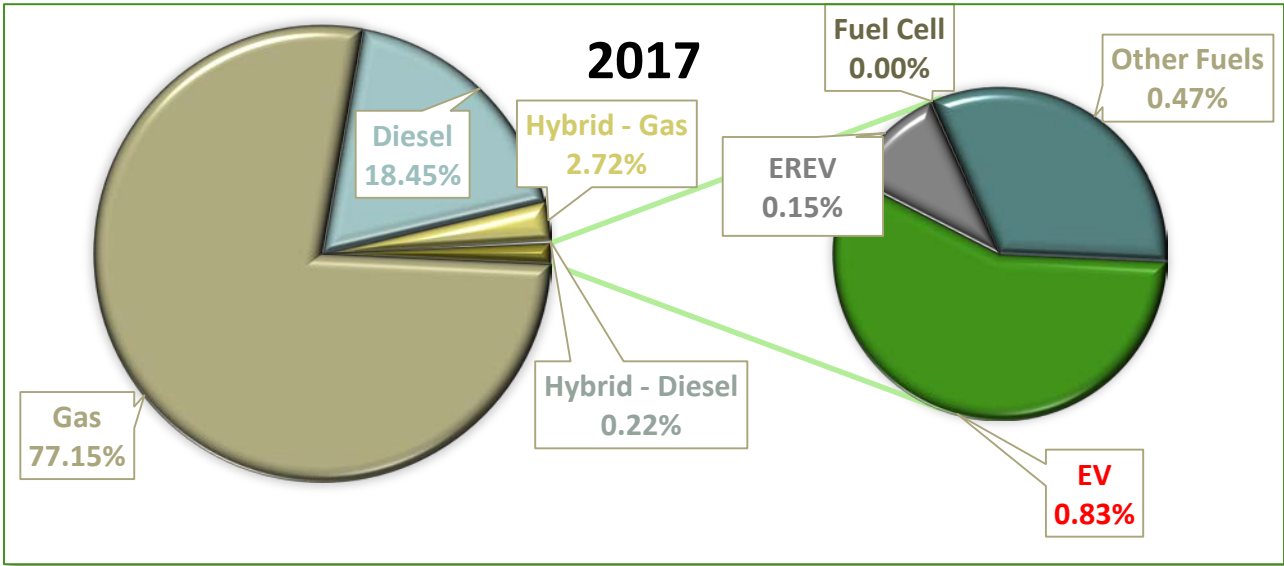
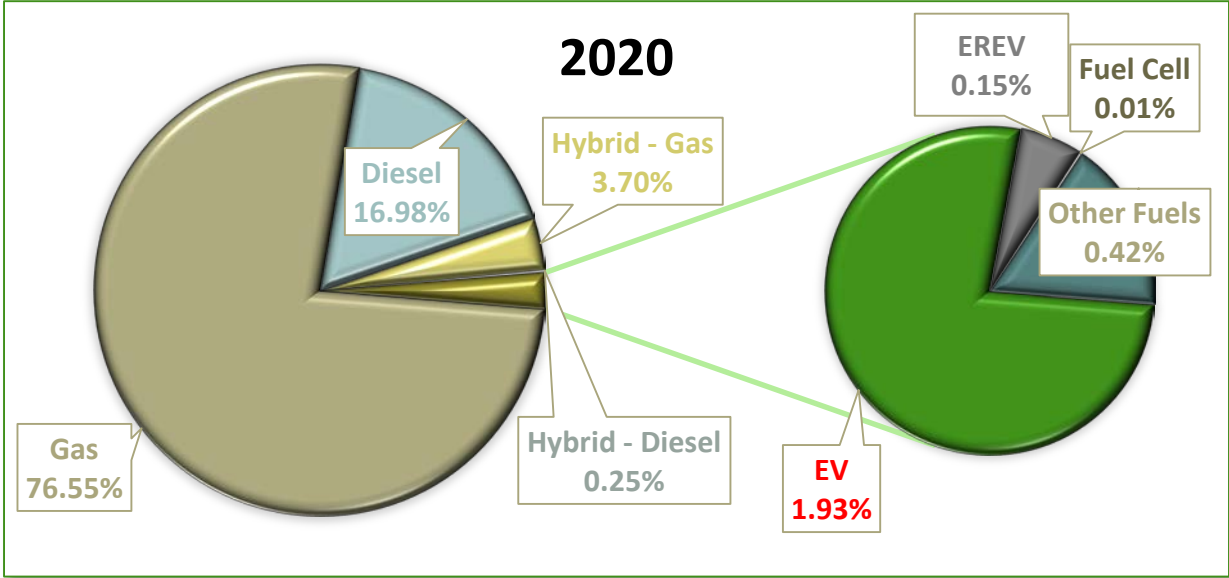
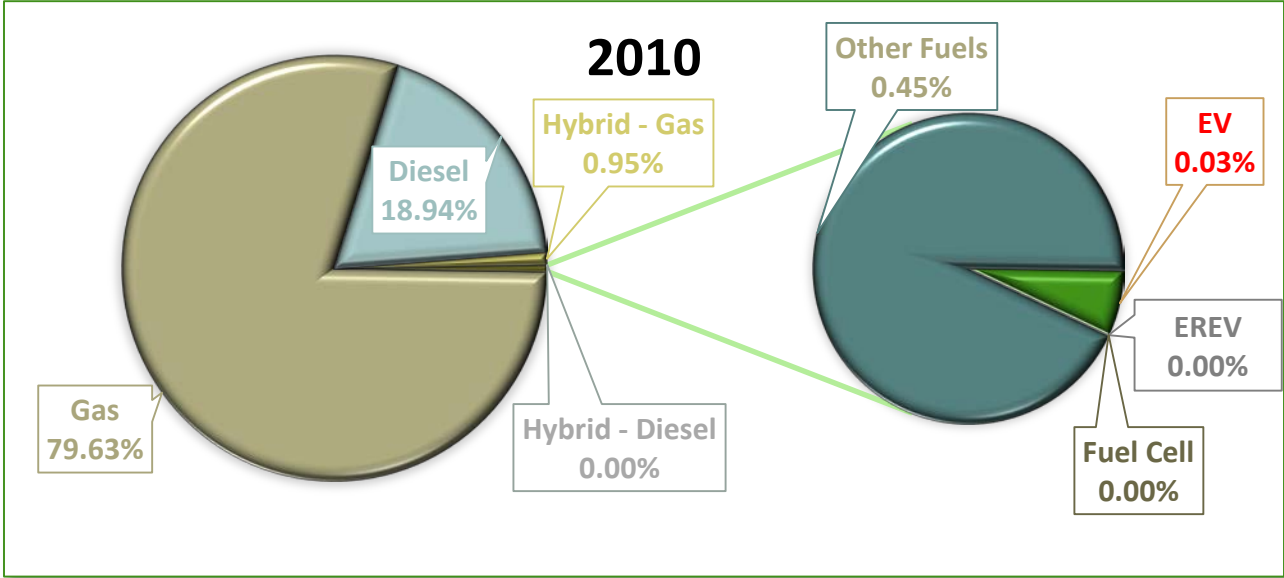


Global Alternative Propulsion Outlook & Analysis

Brian Maxim, Vice President, Global Powertrain Forecasting
855.734.4590 ext. 1004

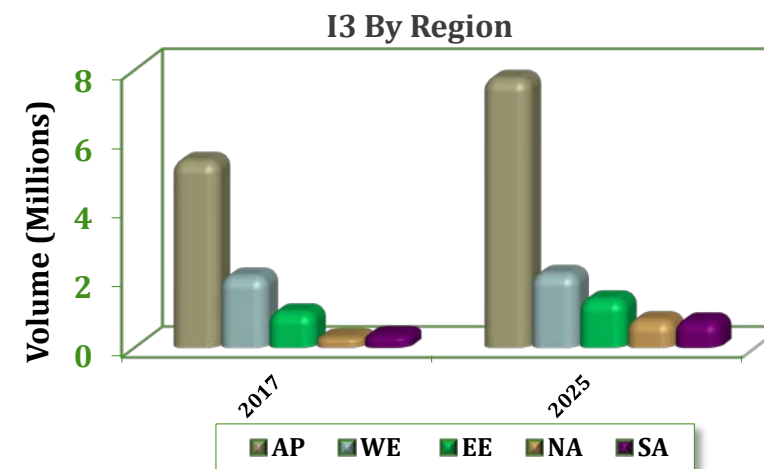
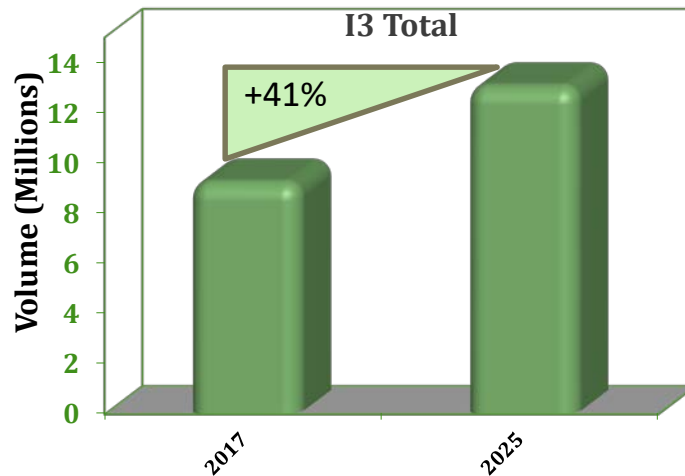
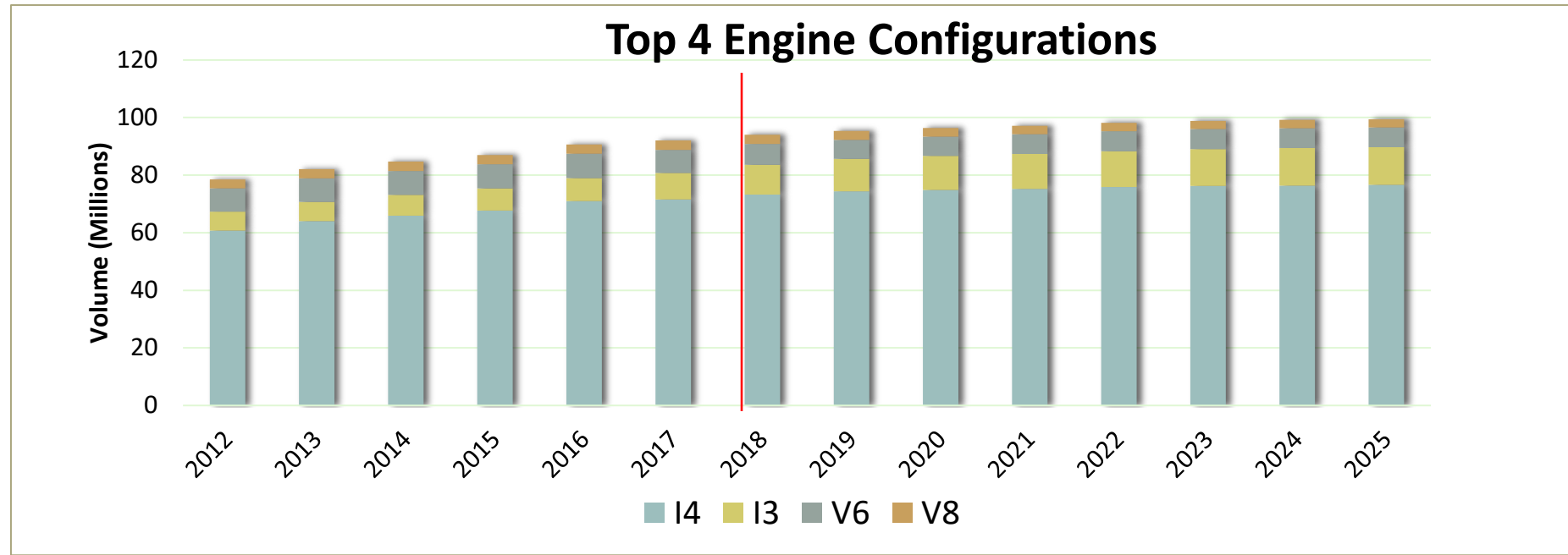
GLOBAL ENGINE ANALYSIS

Global Light Vehicle Production by Fuel Type



Source: AutoForecast Solutions – May 2018

Global Engine Volumes -By Major Configuration



Source: AutoForecast Solutions – May 2018

Global Engine Trends

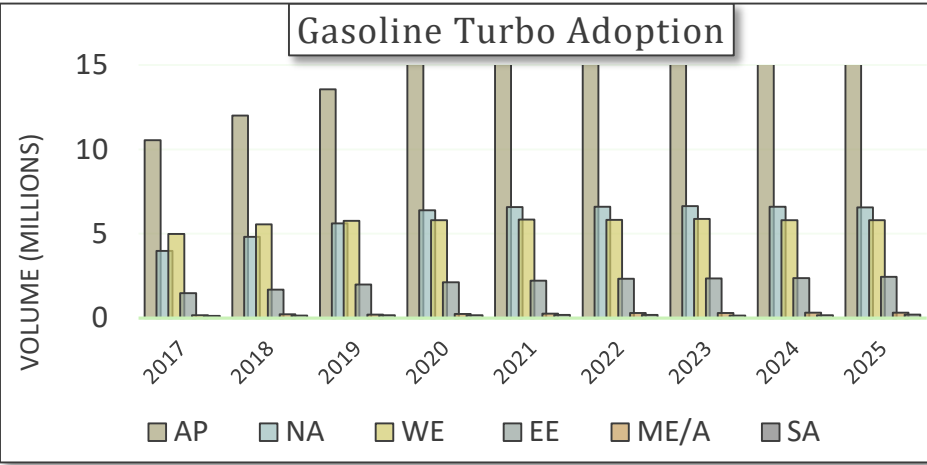
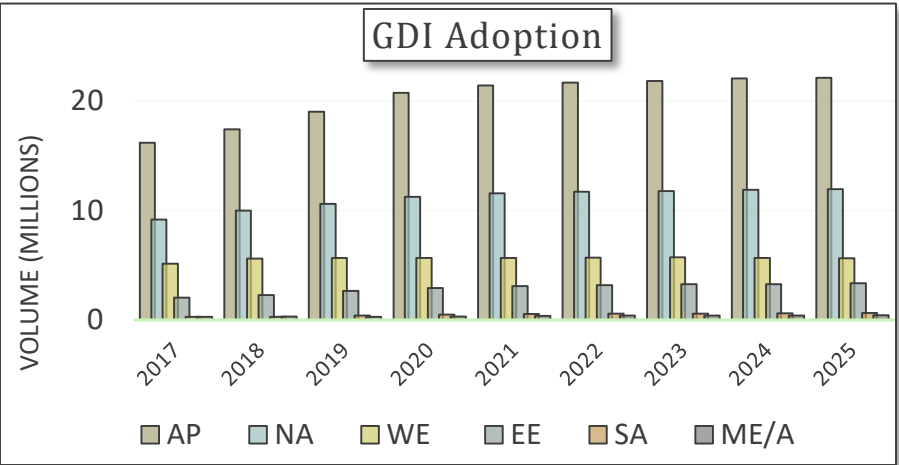
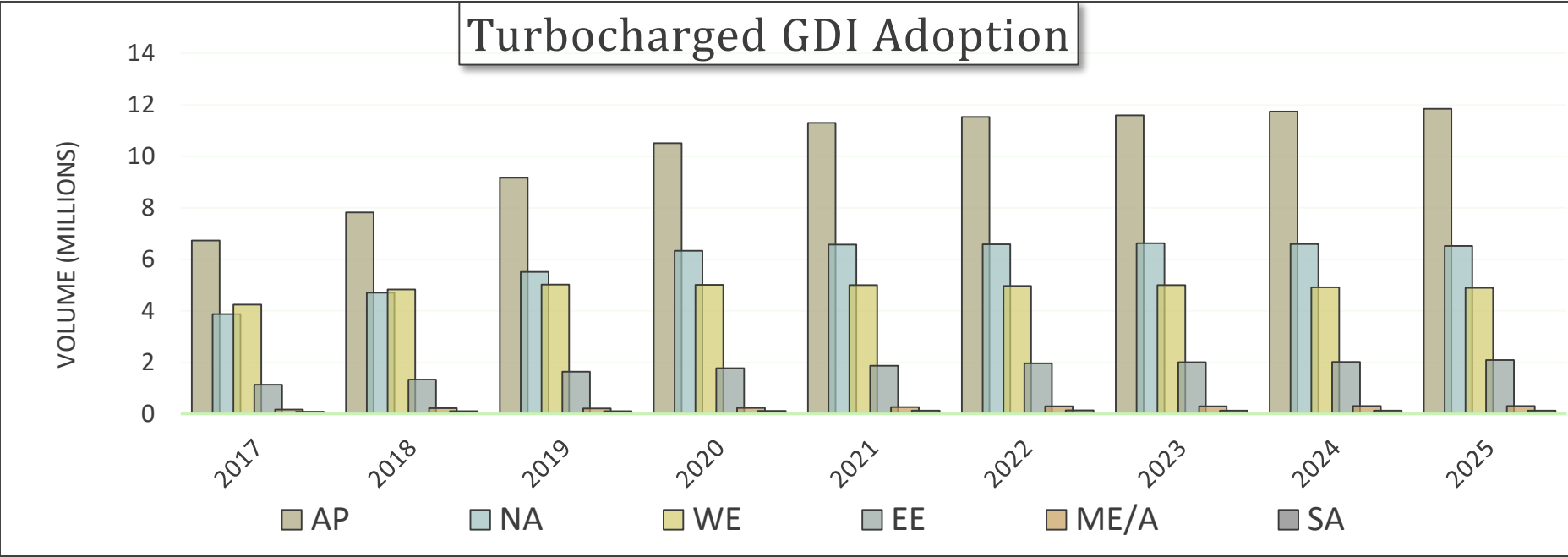
- Programs gravitating down similar paths
 - Smaller engine programs looking fairly similar
 - 2.0L I4 GDI Turbo
 - Still replacing smaller V6s
 - Offered as upgrade to non-turbo 2.0L
 - 1.5L GDI Turbo
 - Some are 1.4L or 1.6L
 - Replacing larger I4s
 - 1.0L GDI Turbo
 - Replacing medium and small I3/I4s
 - 3.0L 6-cylinder with GDI
 - 3.0L is a global approach
 - Fiat Chrysler (FCA), GM and Ford differ slightly
 - V8s diverge
 - Reserved more for sports cars and truck based vehicles
 - Non-NA assemblers were first to choose GDI
 - NA assemblers going different paths, embracing different technologies



Cadillac ATS

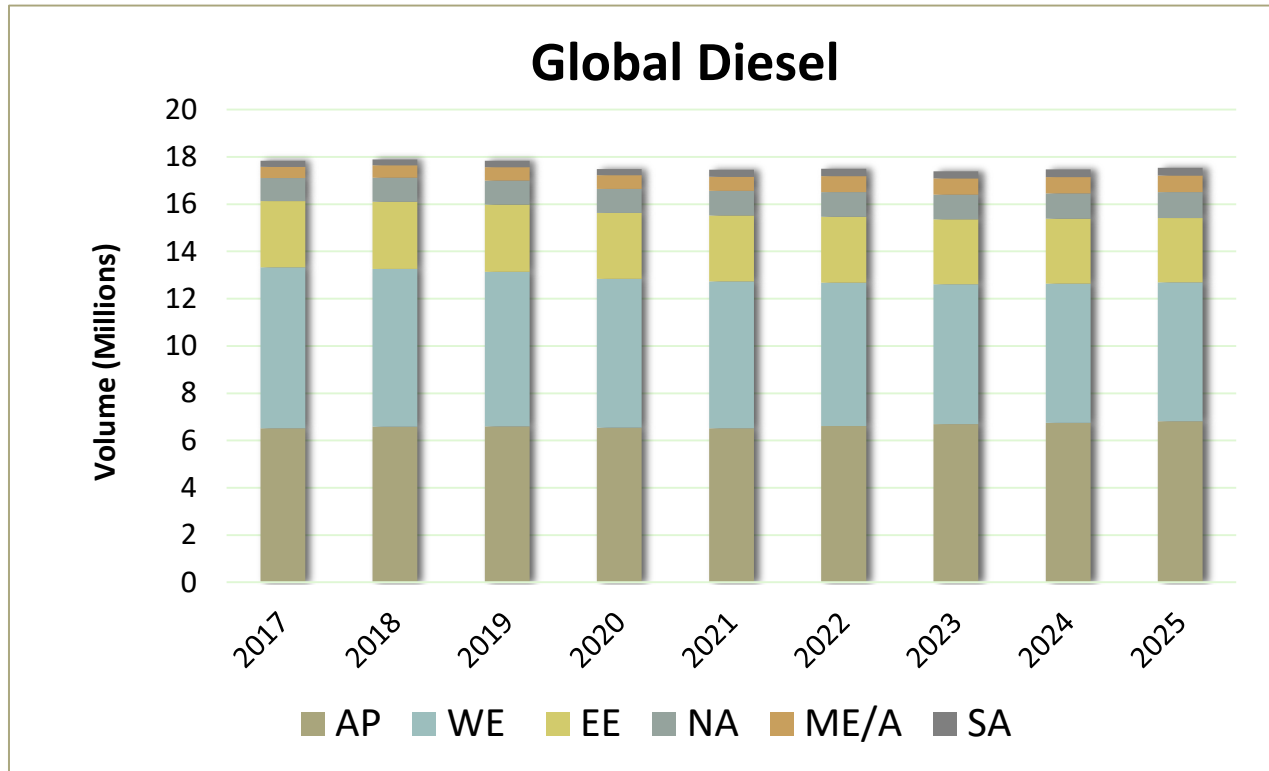
2013 Lexus 2.0L I4 VNT 18 Turbo (LPG)

Accelerated Global GDI Adoption



Source: AutoForecast Solutions – May 2018

Light Vehicle Diesel Volume Analysis



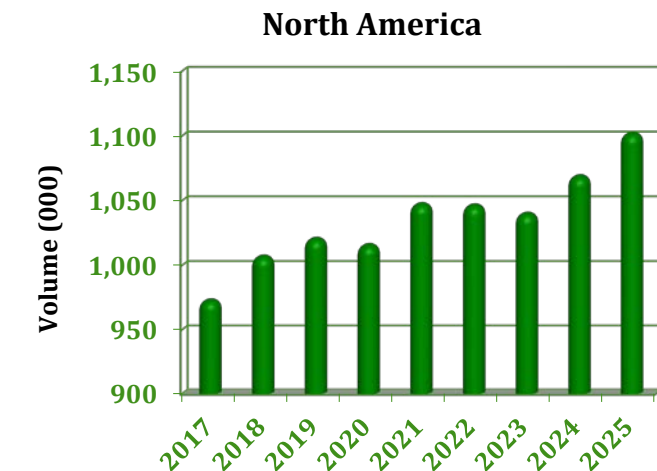
North America adding applications

- Small diesels on full-sized pickups
- Car applications now shrinking

Fuel and purchase price cost pressures still a factor

Growth in Asia and North America

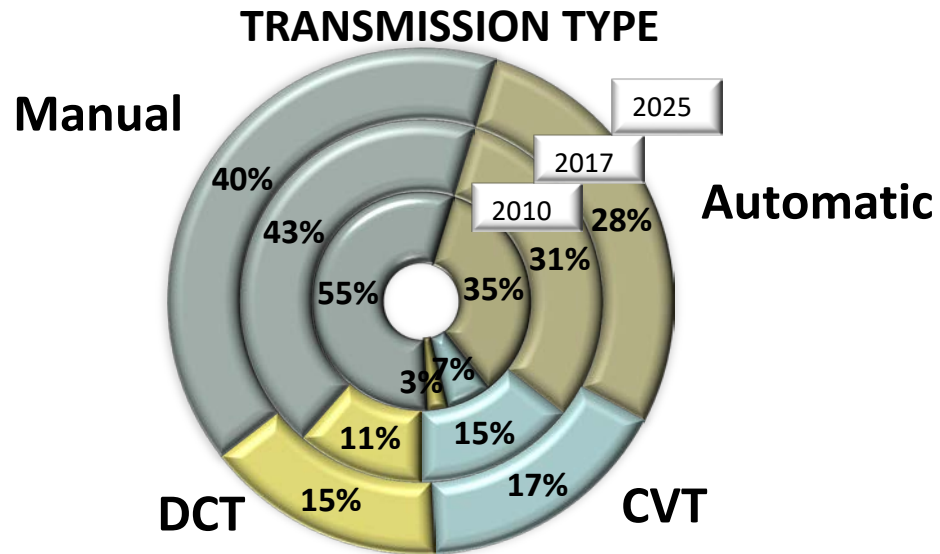
- India and China lead the way
- Europe now shrinking
- Growth in North America



Source: AutoForecast Solutions – May 2018

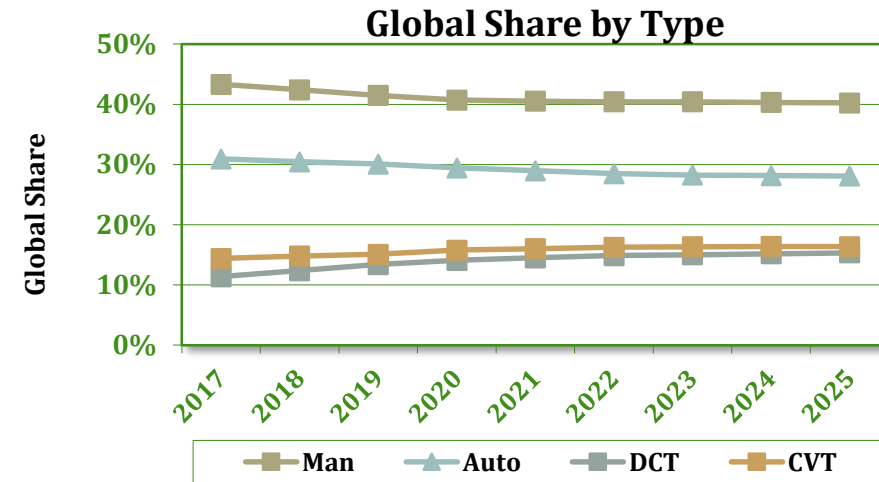
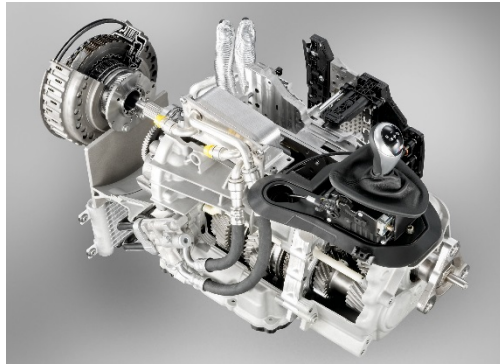
GLOBAL TRANSMISSION ANALYSIS

Global Transmission Trends - By Type



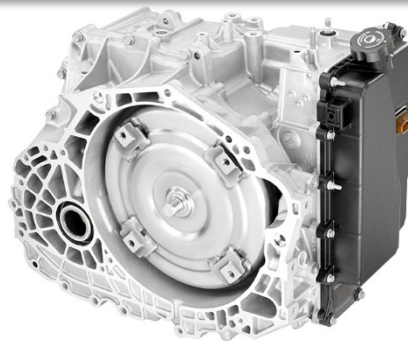
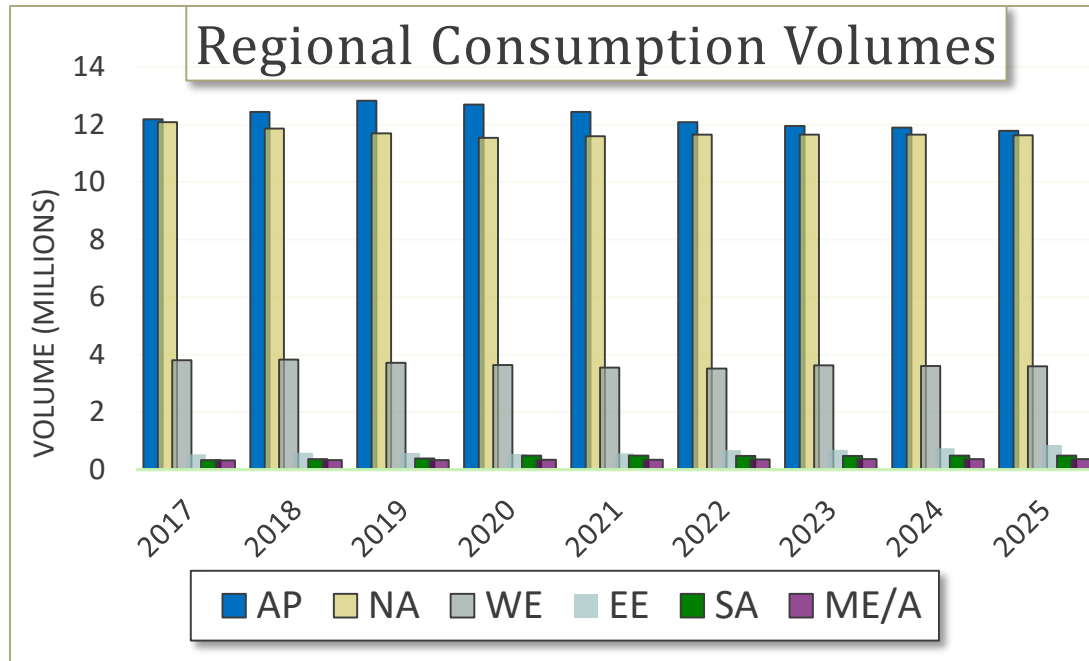
Manuels still dominate, but shrinking

- Europe and developing markets now shifting to non-manual options
- DCTs and CVTs gaining ground
- Traditional automatics hang on by using newer technologies



Source: AutoForecast Solutions – May 2018

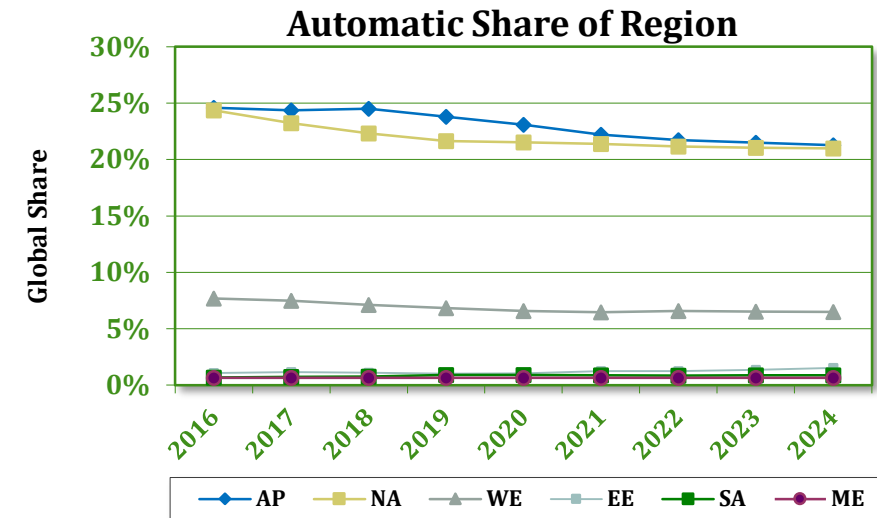
Global Automatic Adoption - Traditional Automatics



2014 Honda Civic 6-Speed AWD Automatic Transmission

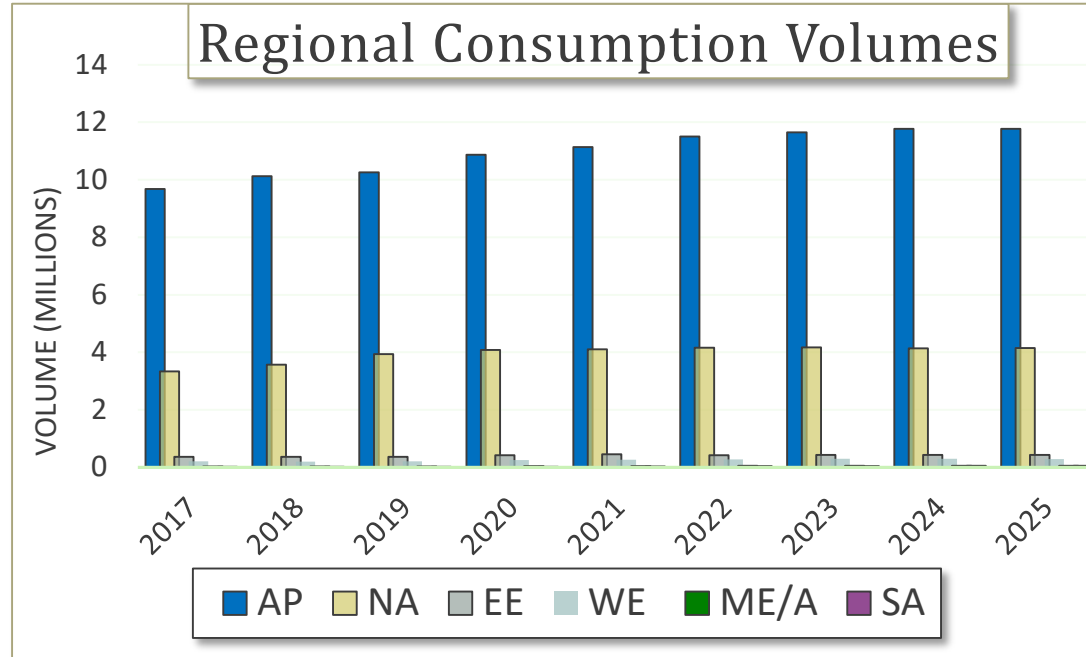
Influenced by North America and Europe

- Asia Volumes mostly from China
- North America prefers the traditional automatic
- Europe prefers manuals and DCTs, keeping volumes low



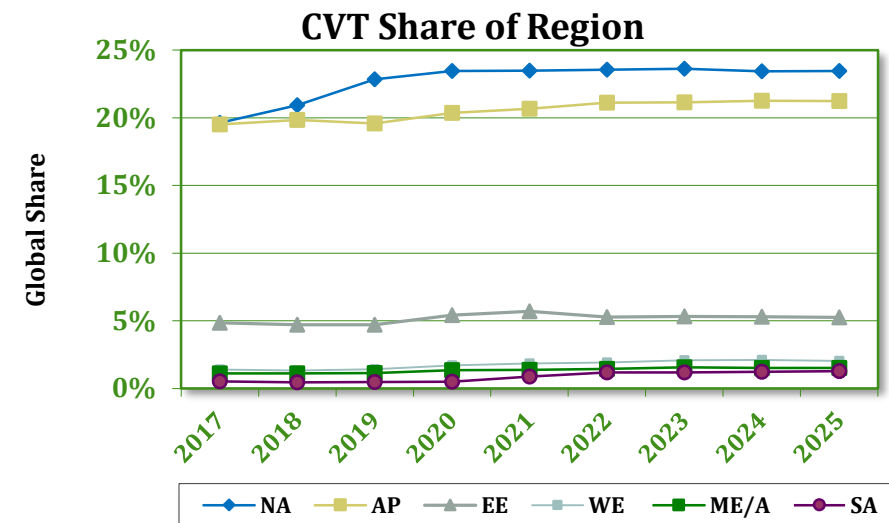
Source: AutoForecast Solutions – May 2018

Global CVT Adoption



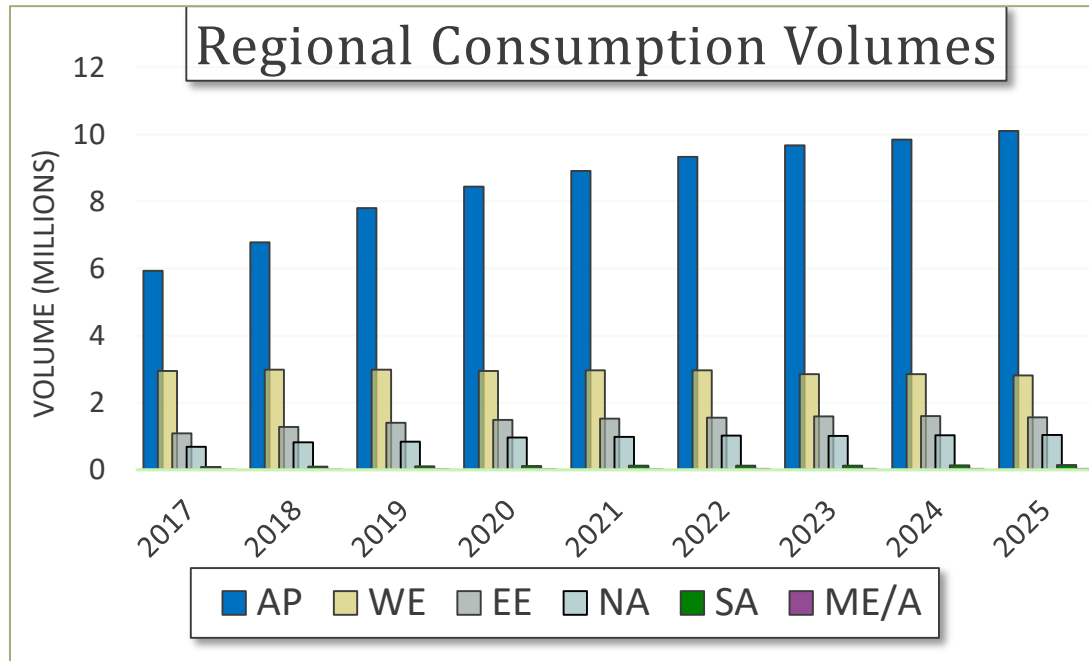
Strong Japanese Influence

- Asia volumes initiated with Japan but now significantly growing due to China
- North America is a result of Japan
- Europe prefer DCTs and automatics



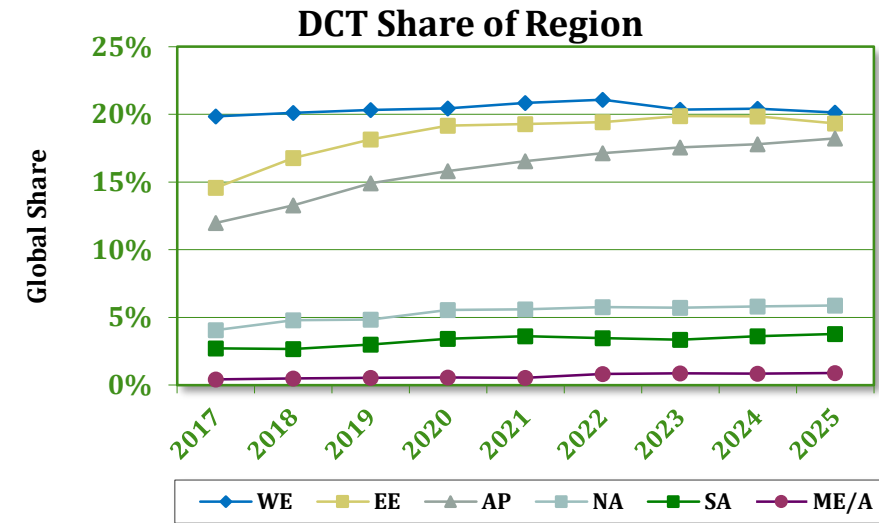
Source: AutoForecast Solutions – May 2018

Global DCT Adoption



Strong European Influence

- Asia Volumes mostly from China
- Europe volumes fairly low due to preferring manuals
- North America influenced some by Europe



Source: AutoForecast Solutions – May 2018

Future of Traditional Powertrains

Engines Become More Efficient

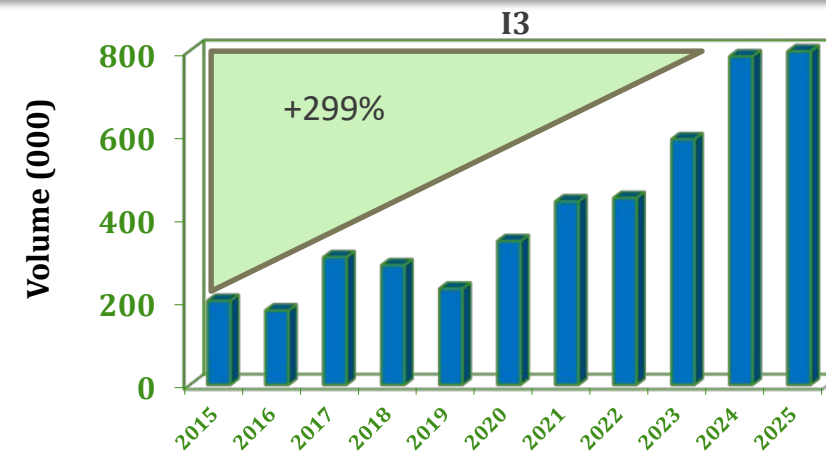
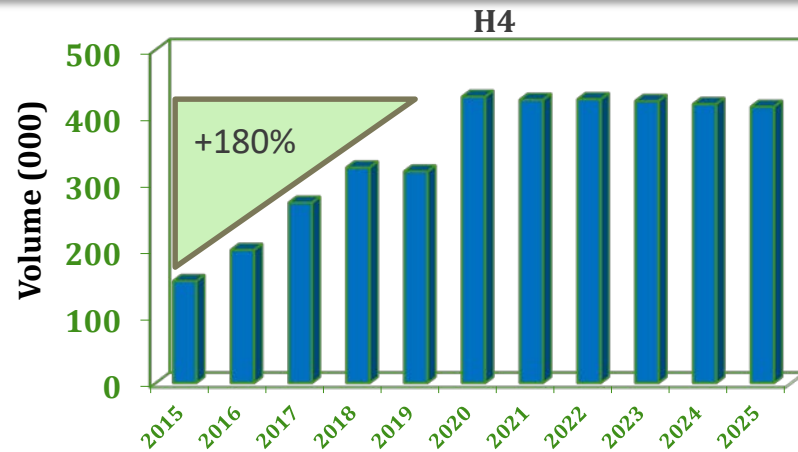
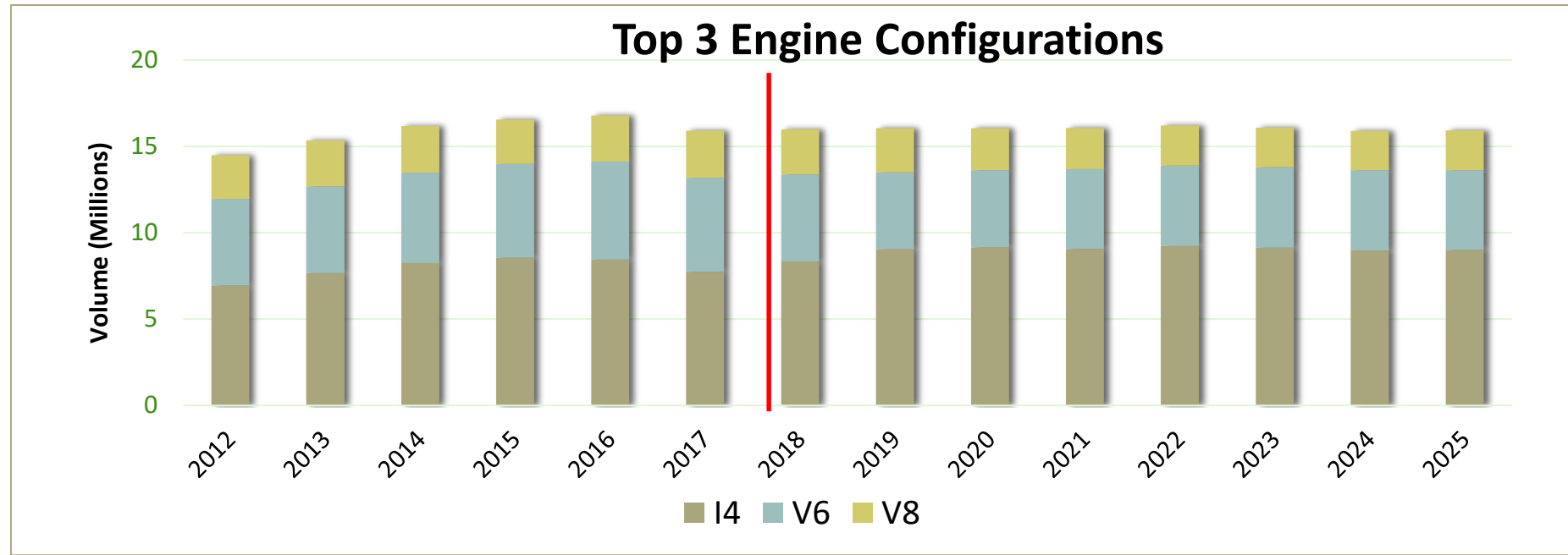
- Gasoline Direct Injection (GDI) Growing
 - Growing from less than 5% (2002) to more than 43% (2025) of global market
- Significant Expansion of Turbocharging
 - Especially combined with GDI
- Increasing Electrification
 - Stop/Start and BAS Systems Solidify IC engines
- Electrified turbochargers
 - Starting to show up in limited applications
- Electric Superchargers on the Horizon
 - Replacing mechanical turbochargers
- Compressed Ignition, Direct Injection Gasoline Engines
 - Around 2019 – Mazda leading the way
- Electronic Valvetrain
 - Expected after 2023CY

Revolution in Transmissions

- Traditional Automatics With Up to 10 Gears
 - 7-, 8- and 9- speed FWD units
 - 8-, 9- and 10-speed RWD units
- Increase in Continuously Variable Transmissions (CVTs)
 - More Japanese influenced vehicles and many hybrids
 - Growth in China by specific vehicle assemblers
- Growth in Dual-Clutch Transmissions (DCTs)
 - More for Europe, South America and China
- Special Versions Being Developed for Hybrid Applications
 - Electric motor integration into automatics
- Transmissions Beginning to Grow on EVs
 - Allowing for better performance on both highways and city streets

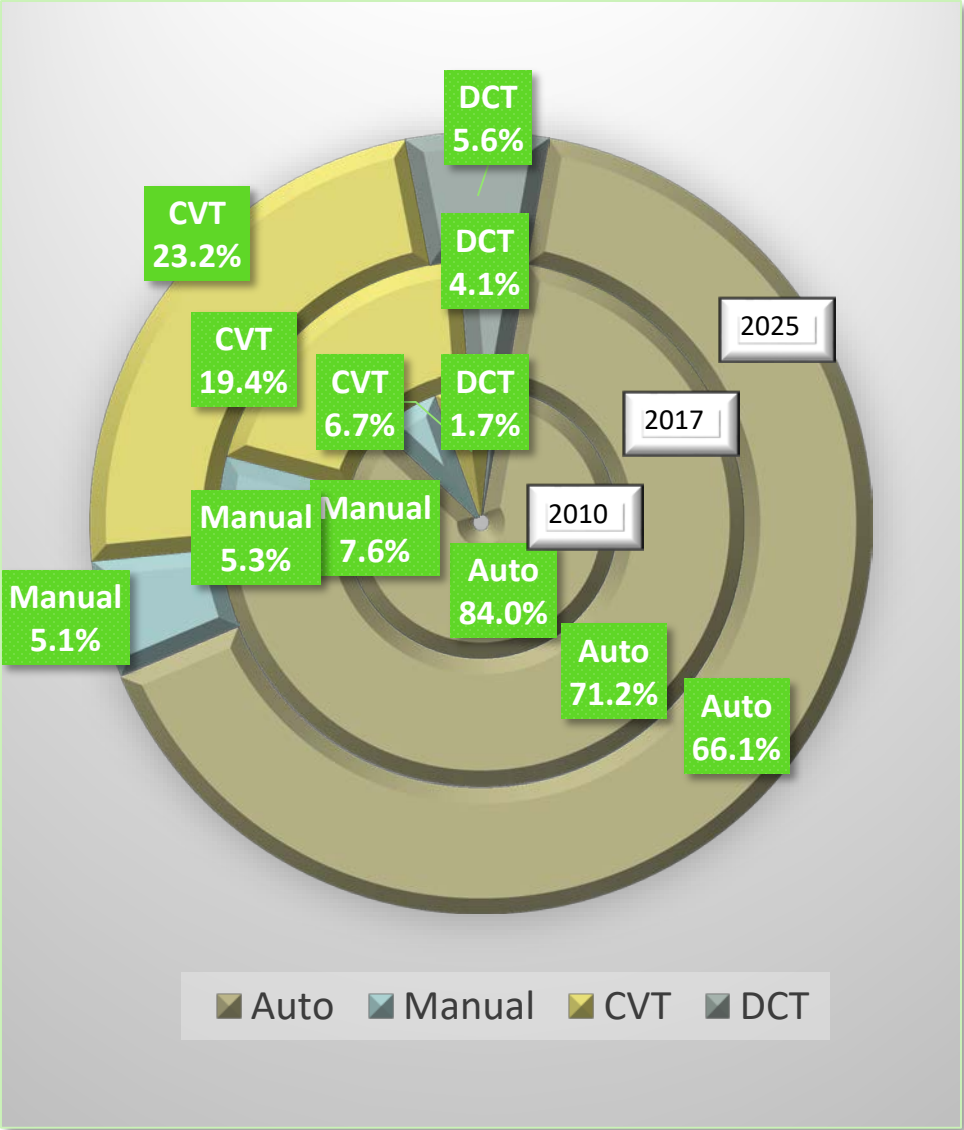
NORTH AMERICAN ENGINE & TRANSMISSION ANALYSIS

North America Engine Volumes -By Major Configuration

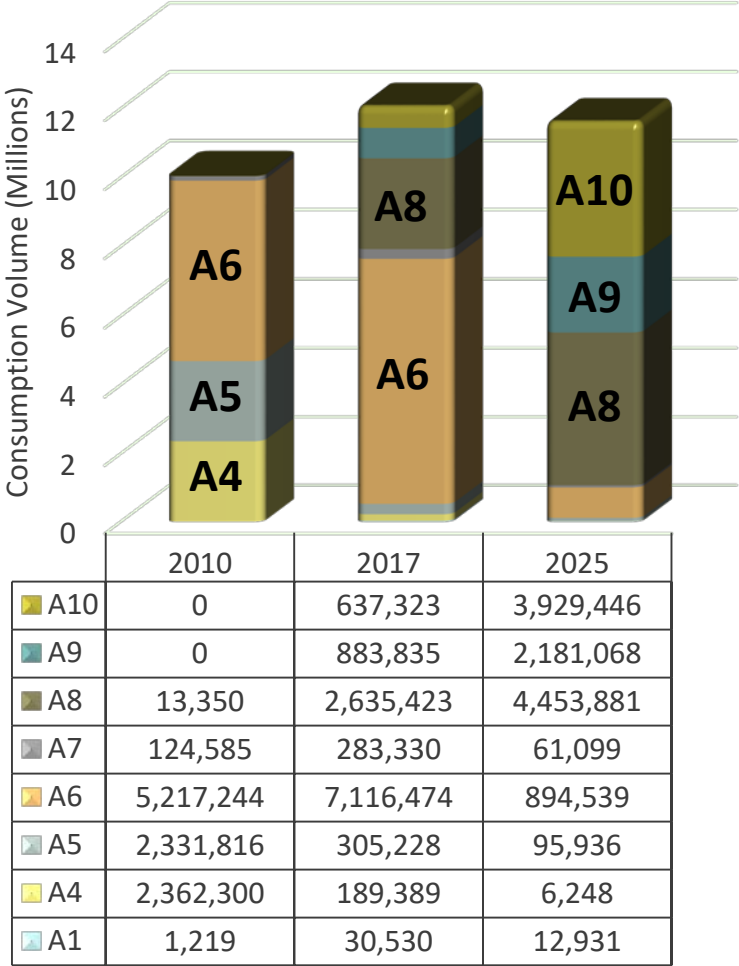


Source: AutoForecast Solutions – May 2018

North America Transmission Trends



Automatic Transmission Trends

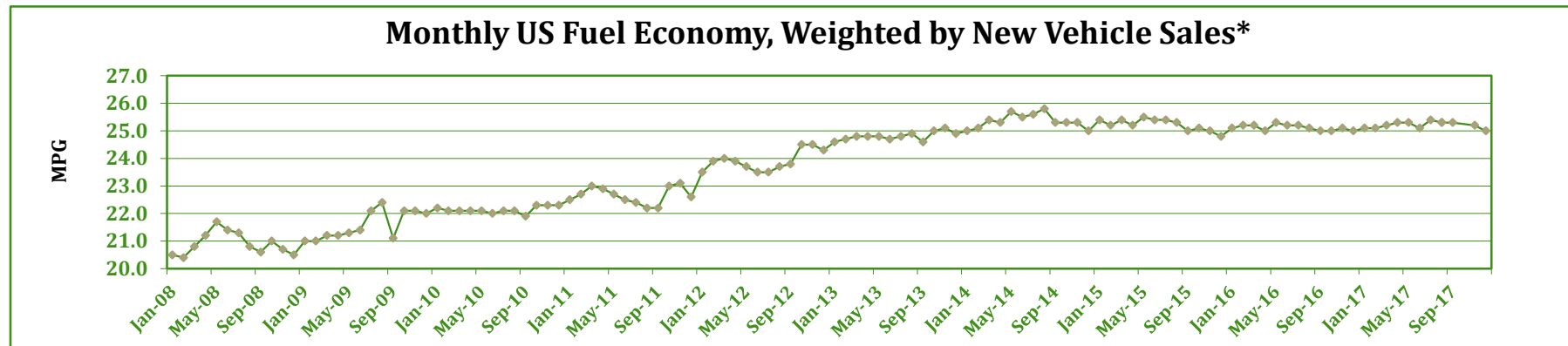


Source: AutoForecast Solutions – May 2018

Fuel Price Effect on Powertrain

- **Falling fuel prices – fuel economy less important**
 - Consumers choosing larger engines again
 - Choosing different vehicles with larger engines
 - Hybrid and EV growth limited
 - More difficult to justify added costs and/or compromises
 - China is bucking the trend and growing
 - Higher fuel prices in Europe and possible city bans of IC engines generating more interest

Small diesel programs
being revived for pickups



Sales of fuel efficient vehicles in North America are driven more by government incentives and mandates than by consumer preferences

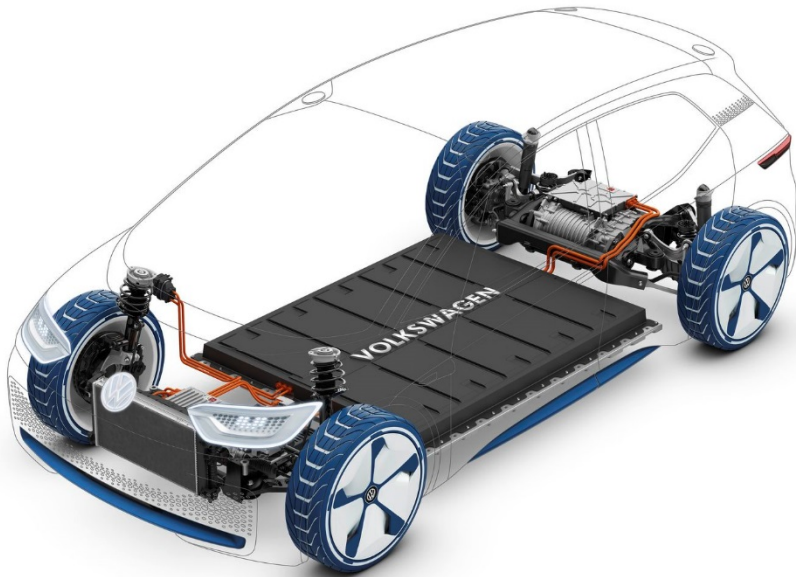
* From the Transportation Research Institute, University of Michigan

ELECTRIFICATION

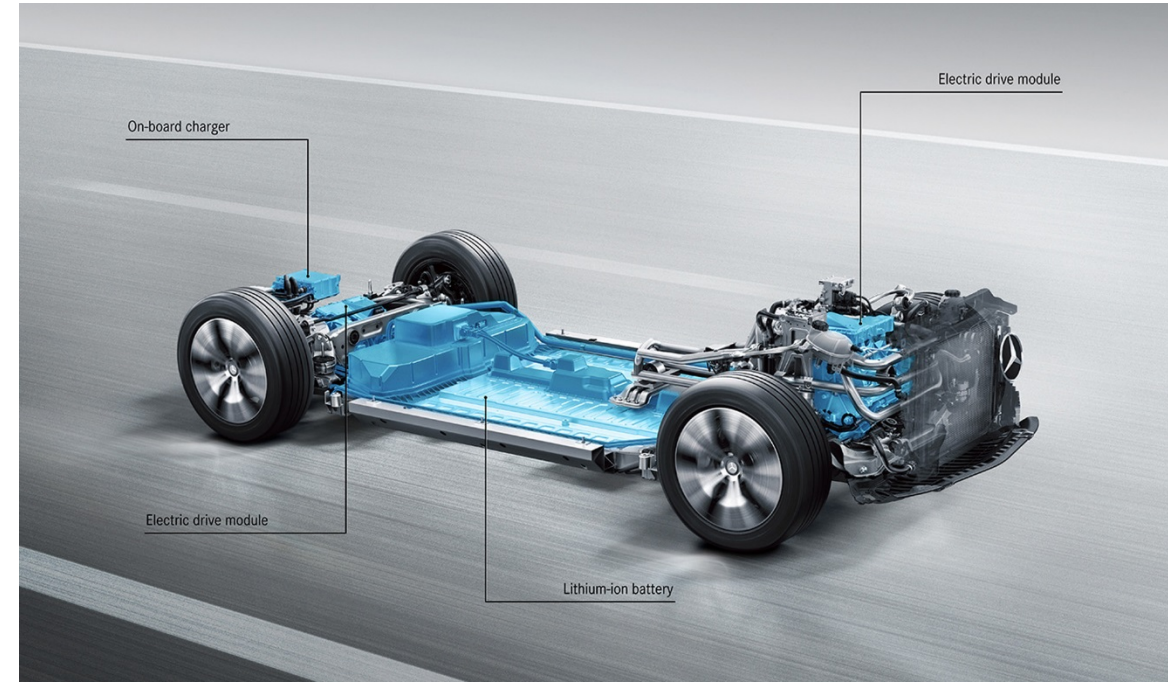
New Electrified Vehicles



New Electric Platforms

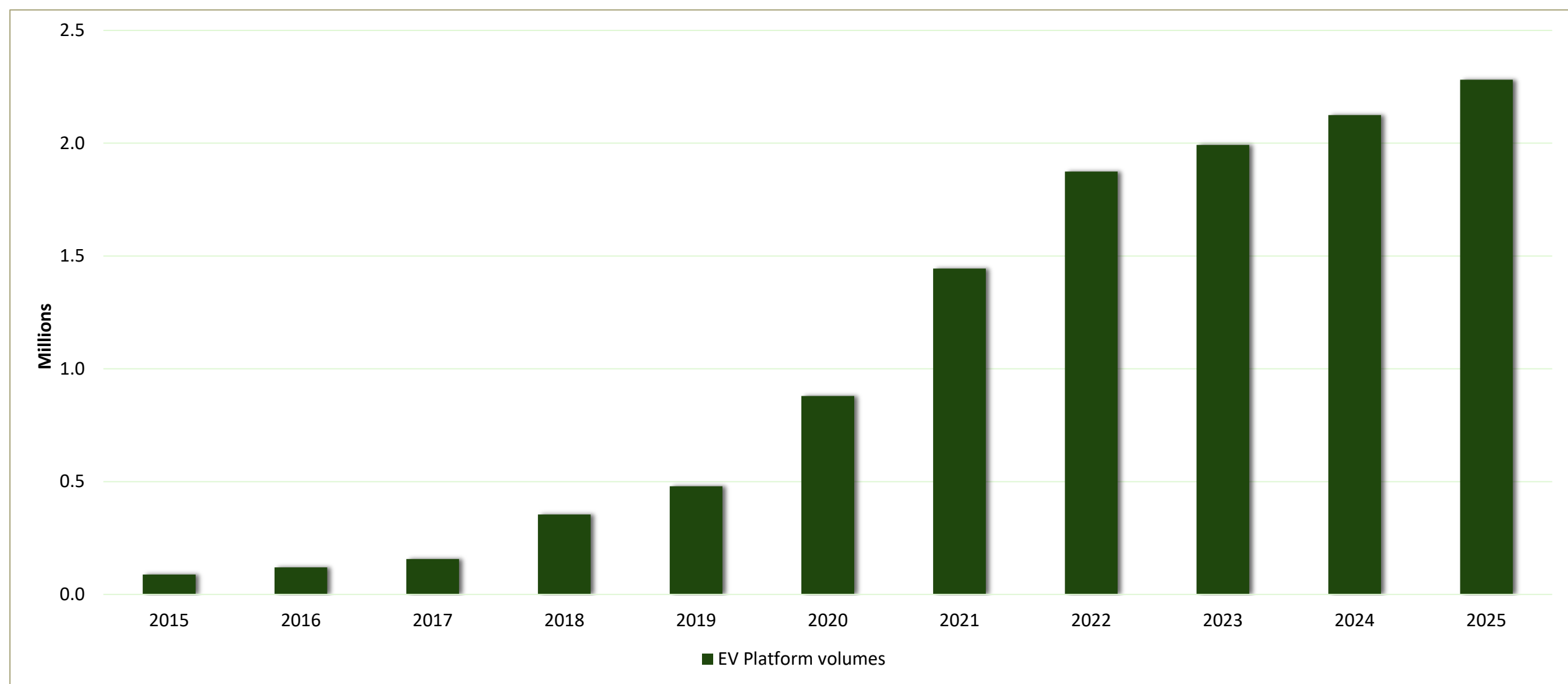


Volkswagen's MEB Platform



Daimler's EVA Platform

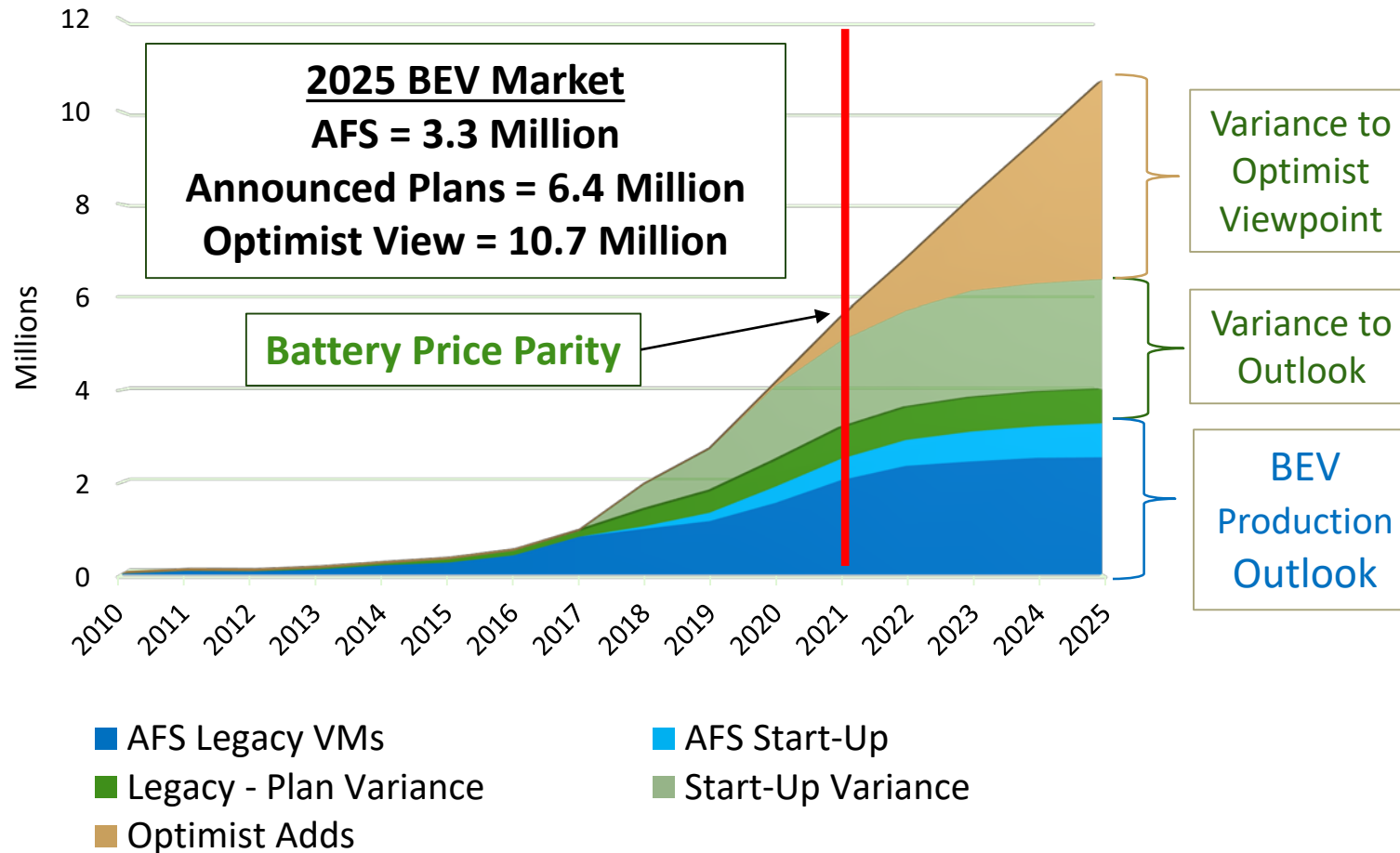
Dedicated Electric Platform Production Volume



Source: AutoForecast Solutions – May 2018

EV Market Sizing

EV Market Outlook
AFS Forecast vs. VM Announced Plans



Conservative Forecast

- Who wants to build what
 - Each individual program is scrutinized
 - What is the likelihood the program will be built and then survive
- What other factors come into play
 - Consumer preferences
 - Government mandates
 - Fuel prices and availability
 - Materials scarcity

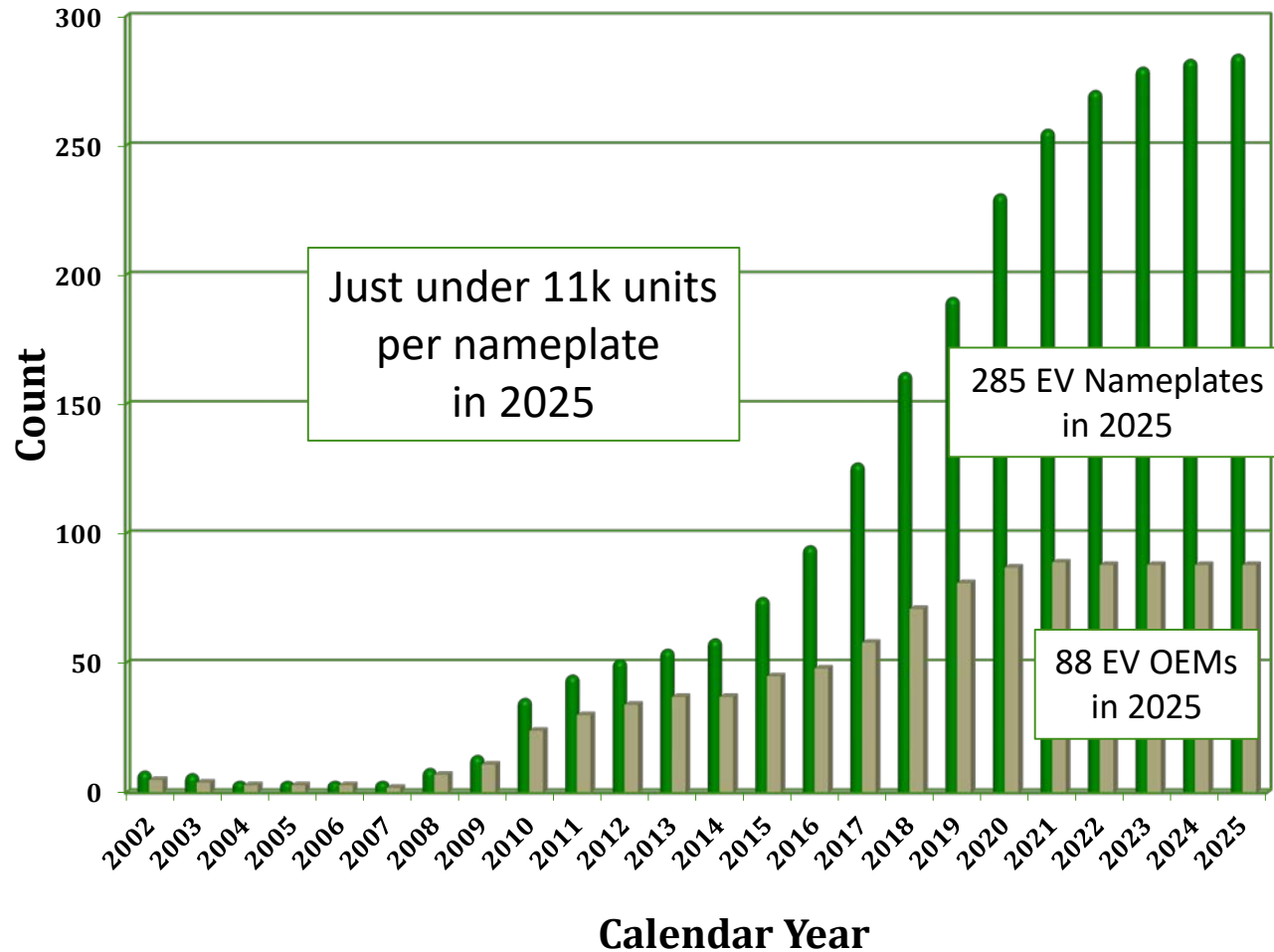
What If the Optimists Are Right?

- Maintain the “Hockey Stick” growth
 - EVs represent 10% of global market
- Battery price parity will change everything!
- This time it is different!

Source: AutoForecast Solutions – May 2018

Global EV Analysis

Available EV Nameplates



- **Global EV market will remain highly fragmented in 2025**
 - Several OEMs command bulk of the volume
 - Top 5 OEMs account for 48%
 - Top 10 OEMs account for 64%
 - Top OEMs still have significant proliferation of EVs
 - Top 5 OEMs account for 82 nameplates, averaging 18k units per nameplate
 - Top 10 OEMs account for 114 nameplates, averaging 17k units per nameplate
- **Top 3 OEMs**
 - Volkswagen expected to produce the most
 - 372k units in 2025, with 31 nameplates
 - Tesla expected to be a close second
 - 340k units in 2025, with 5 nameplates
 - Geely expected to be third
 - 296k units in 2025, with 22 nameplates

Source: AutoForecast Solutions – May 2018

Great Deal of Confusion About Electrification

• Not All “Hybrids” Are Created Equal

- Full Hybrids
 - Electric motor can move the car alone, without IC engine
- Plug-In Hybrids
 - Consumer can plug vehicle in like a BEV
- Mild Hybrids
 - Electric motor helps move the car but can not power the car alone
- Micro Hybrids
 - Generally, a stop-start system which does not help move the vehicle, thus, not a real hybrid
- 48 Volt Hybrids
 - Many are not actual hybrids
 - True versions are usually mild hybrids
 - Battery Alternator Starters (BAS)

• Differences Among Mild Hybrids

- Audi A8 and A7
 - Very sophisticated stop-start systems
 - Does not help move the vehicle
- All Volvo vehicles 2019+
 - Helps move the vehicle a little bit
 - New future strategy after fading safety path
- 48 Volt Hybrids
 - Most will be non-hybrids, being stop-start systems
 - Most real hybrid versions will most likely be mild
 - Some hybrid versions will offer some minimal physical power, making them a full hybrid

Electrification Is Usually Pushed By Mandates

- **Strategies Driven More by Mandates**

- Renault/Nissan
 - Leaf
- General Motors
 - Volt and Bolt
- Ford
 - Focus EV
- Fiat/Chrysler
 - Fiat 500
- Volkswagen
 - VW brand, adding ID sub-brand
- Most Chinese Manufacturers
 - Adding EVs
 - Adding PHEVs

- **Proper Strategies**

- Tesla
 - Exclusive and expensive performance vehicles
 - First new auto manufacturer in NA in decades
- Volvo
 - Trying to raise already upmarket vehicles
- Maserati
 - Improving performance on exclusive vehicles
- BMW
 - i3, i8
- Volkswagen
 - Bentley, Porsche, Audi

New technologies are almost always rolled out on luxury vehicles and then migrate down to less expensive vehicles. (Air conditioning, electric windows and locks, heated seats, blind spot detection, automatic headlights, etc.)

Differing OEM Viewpoints

- **Electrification Adopters**

- Renault/Nissan
 - Nissan Leaf and NV200 EVs
 - Renault Kangoo, Zoe and Twizy EVs
- Volkswagen
 - New direction to avoid past diesel issues
 - Creating ID sub-brand to Volkswagen
 - “Electrifying” Audi, Porsche and Bentley
- Most Chinese Manufacturers
 - Adding EVs
 - BAIC, BYD, Changan, Chery, Dongfeng, Geely, Jianghuai, Jiangling, SAIC, Zotye
 - Adding PHEVs
 - BYD, Chery, Dongfeng, FAW, GAC, Geely, SAIC

- **The Resistance**

- Mazda
 - No EVs or hybrids
 - Rather refine current technologies
 - CIDI gasoline engines
 - Growing diesel volumes
- Fiat/Chrysler
 - Losing money on each hybrid and EV
 - Marchionne has come out said not to buy Fiat 500 EVs
- Toyota – Sort of
 - Fully embracing hybrids
 - Avoiding EVs as much as possible
 - China forcing production

Future Hybrid Trends

- **Most future programs will follow two separate paths**

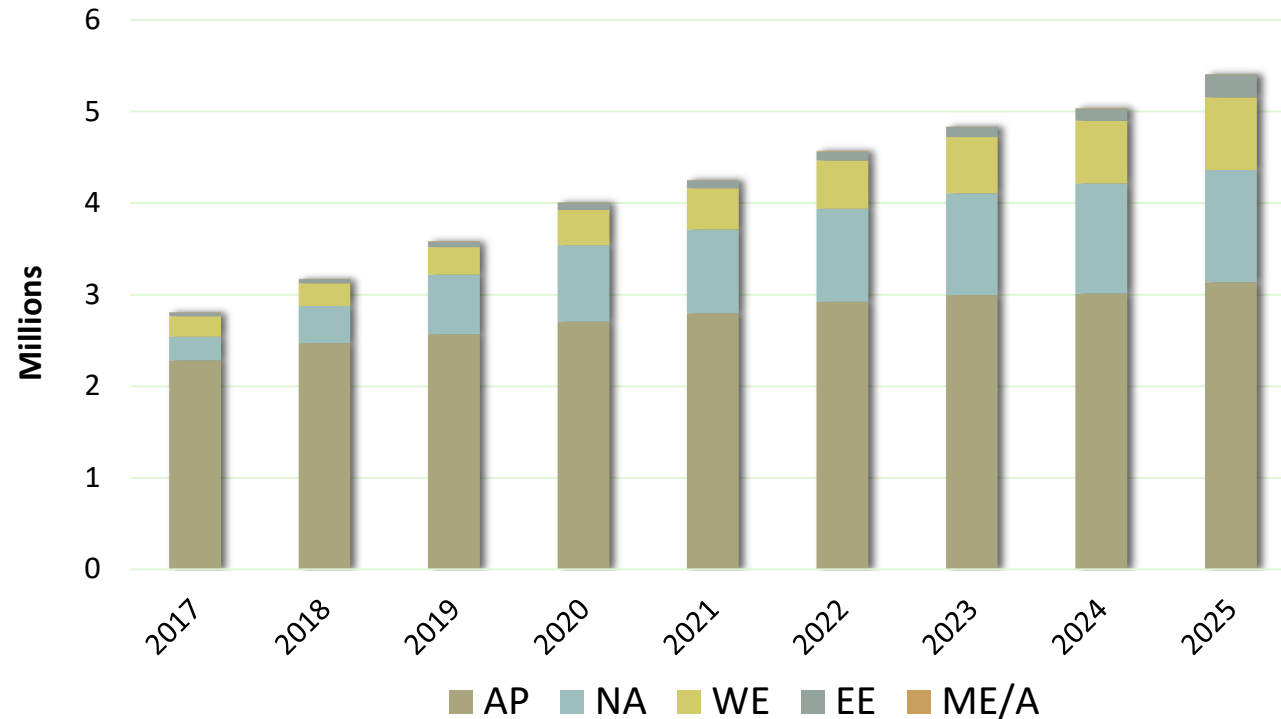
- 48 Volt Hybrids
 - Most cost effective way to provide a hybrid
 - Usually a Belt Alternator System (BAS)
 - Significant increase in 48 volt vehicles expected
 - Makes it a lot easier to add a mild hybrid later
- Plug-In Hybrids (PHEVs)
 - Government mandates forcing traditional HEVs to be replaced by PHEVs
 - Over 90% of consumers rather have an HEV over a PHEV
 - PHEV costs more than a traditional HEV
 - Most consumers who will buy PHEVs will use them as HEVs
 - PHEVs usually have a greater battery capacity, allowing for more government incentives

- **Hybrid strategies are advancing, morphing with some becoming much more refined**

- Instead of many different engine combinations, BMW is settling on a couple for PHEV systems
 - Mainly a 2.0L gasoline turbo
- Many more systems will be brought to market under the “hybrid” title
 - Some will not be genuine hybrids
 - Much like the Audi system
 - Many will try to green-wash a brand
- Some brands see mild hybrids as a way to differentiate themselves
 - Audi, Volvo, Lincoln, Maserati
- Proliferation of mild hybrids can ease consumers into accepting more sophisticated electrified vehicles
 - Stepping stone to PHEVs and EVs

Light Vehicle Hybrid Volume Analysis

Global Hybrid Production



North America is planning to add applications and volume

- Attempting to meet future fuel economy related mandates
- Adding hybrids to full-sized pickups

Significant pressure from low fuel prices and fickle consumers

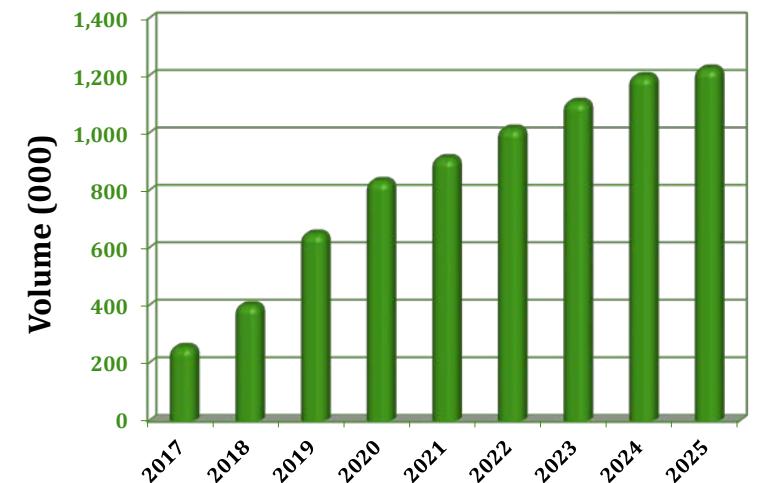
Global growth expected

- China is driving most of the growth
- Many new hybrids planned
 - Many near luxury models
- Toyota is currently the clear leader

Regional volumes are based on vehicle production

- Many hybrids are exported from OEM's home market

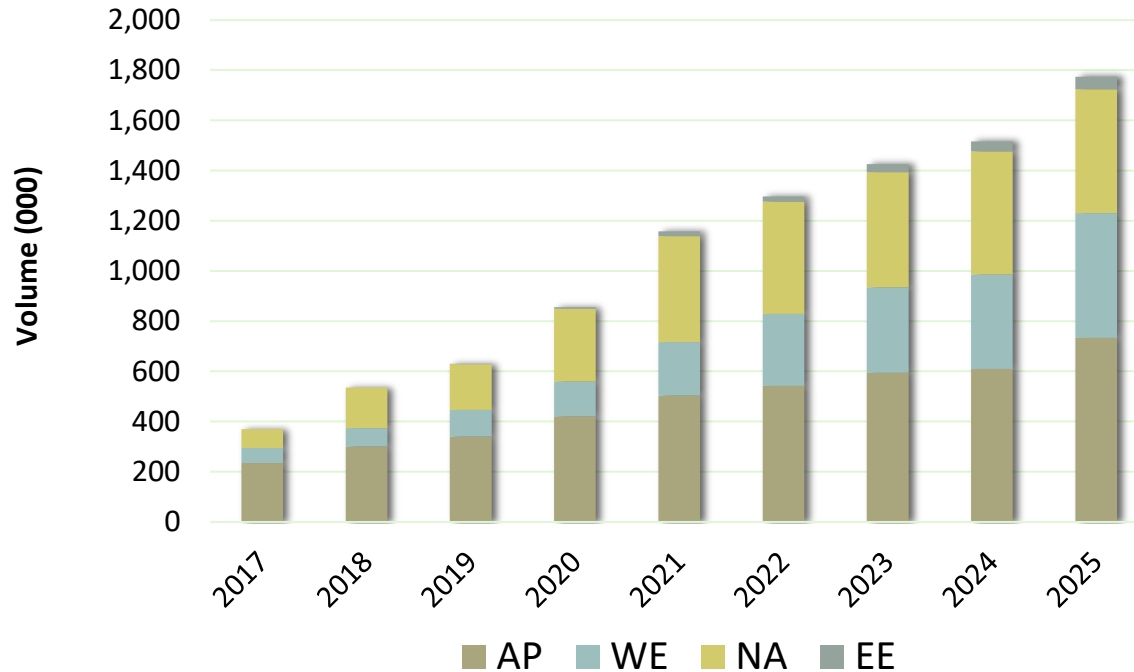
North America



Source: AutoForecast Solutions – May 2018

Light Vehicle AWDe Volume Analysis

Global AWDe Vehicles



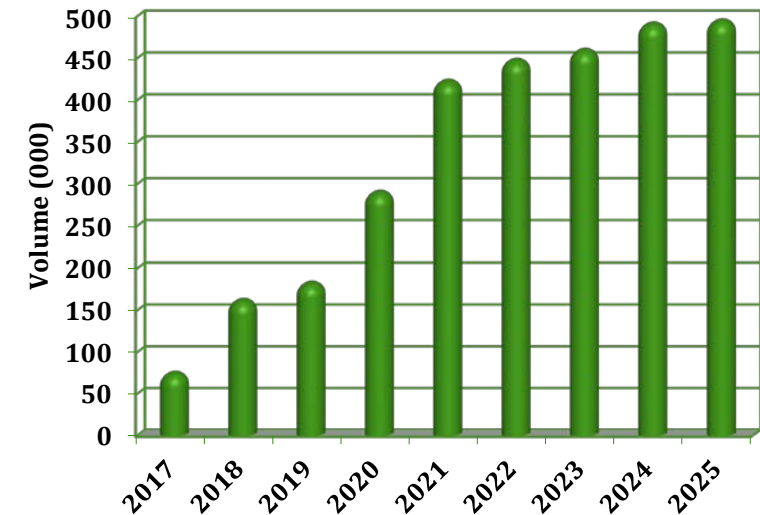
Significant Growth in Asia, Western Europe and North America

- Greatly helps justifying added costs
 - Vehicle receives AWD and a hybrid system for the same price
 - Additional applications and volumes expected toward end of the forecast window

Global growth expected

- Current volumes are conservative
 - More programs expected to be announced
- All major OEMs adding applications and volume
 - Some are dabbling
 - Others, like Geely, plan to fully embrace AWDe

North America AWDe



Source: AutoForecast Solutions – May 2018

eAxle Hybrid Systems

- Huge growth area expanding now
 - Modular design
 - Flexible enough for multiple vehicles and platforms
 - Greater ROI
 - Provides Electronic All Wheel Drive (AWDe)
 - The cost of the systems come with two benefits, not just one
 - Better consumer pricing
 - Many suppliers will offer systems
 - GKN
 - American Axle
 - Dana
 - ZF
 - Bosch
 - Magna



China – The Wild Card

- **North America has moderate growth**

- Strong steady growth
 - Greatly dependent on fuel prices
 - Greatly dependent on government mandates
 - Trump effect may reduce overall volumes

- **Europe will have more vigorous growth**

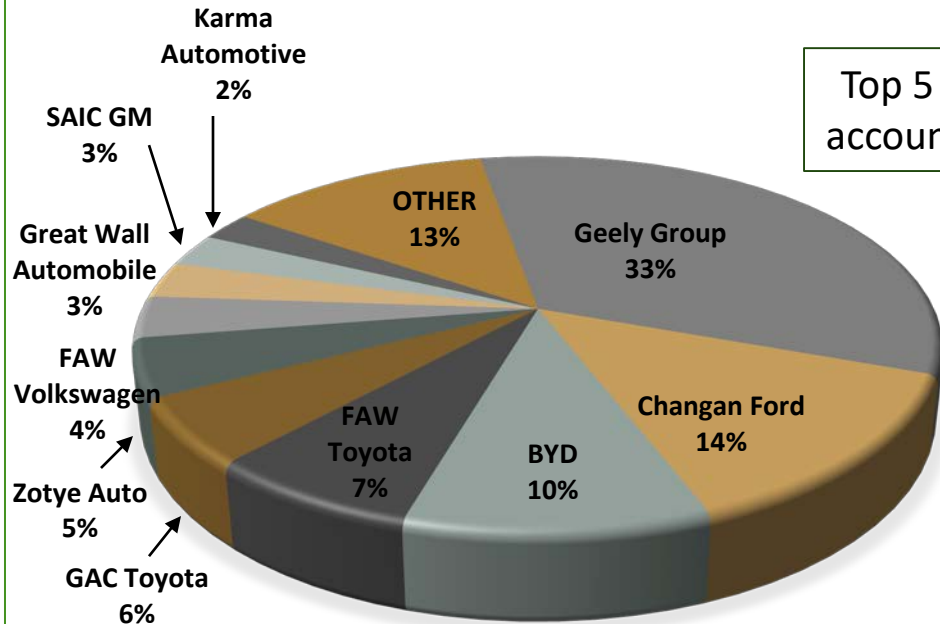
- Strong push from regional governments
 - Push to invoke quotas and ICE bans
- Much higher fuel prices than the Americas
 - Payback on HEVs and EVs is much faster
 - Recent bad publicity for diesel making consumers reconsider electrified options

- **China**

- Strong push by government to increase sales of EVs and PHEVs
 - Incentives for consumers to purchase electrified vehicles
 - Mandates for local assemblers to offer EVs and PHEVs
 - Easy to acquire license plates for EVs and PHEVs
- Government has the ability to use “stick” methods
 - Other countries and regions must rely on just using “carrots”
 - Can’t strong-arm any regulations into place
- Huge market and population
 - A small percentage of the market can add up to significant volumes
 - Population broken up into either strongly rural or completely urban groupings
 - Little to no electricity in rural areas
 - Number of cities much larger than other countries

China HEV Market Sizing

TOP 10 HEV ASSEMBLERS - 2025



Top 5 HEV assemblers account for 70% in 2025

China accounts for over 1M HEV vehicles in 2025

- **Government push for PHEV started after an earlier, stronger push for EVs**
 - Chinese government didn't want local manufacturers to play catch-up to foreign HEV programs
 - Wanted to leap-frog technologies and go right to EVs, in hopes to command dominance
 - After poor sales and strong push back from manufacturers, the Chinese governments allowed provisions for PHEVs
 - Regular HEVs are considered the same as other ICE vehicles
 - As a result of the late allowances for PHEVs, many more EV programs are currently planned than PHEVs
 - More PHEV programs expected, as time goes on
 - PHEVs tend to have an easier fit than EVs
 - Rural areas lack electricity, in general
 - Having a charging station near your apartment or condo may be difficult at times

Source: AutoForecast Solutions – May 2018

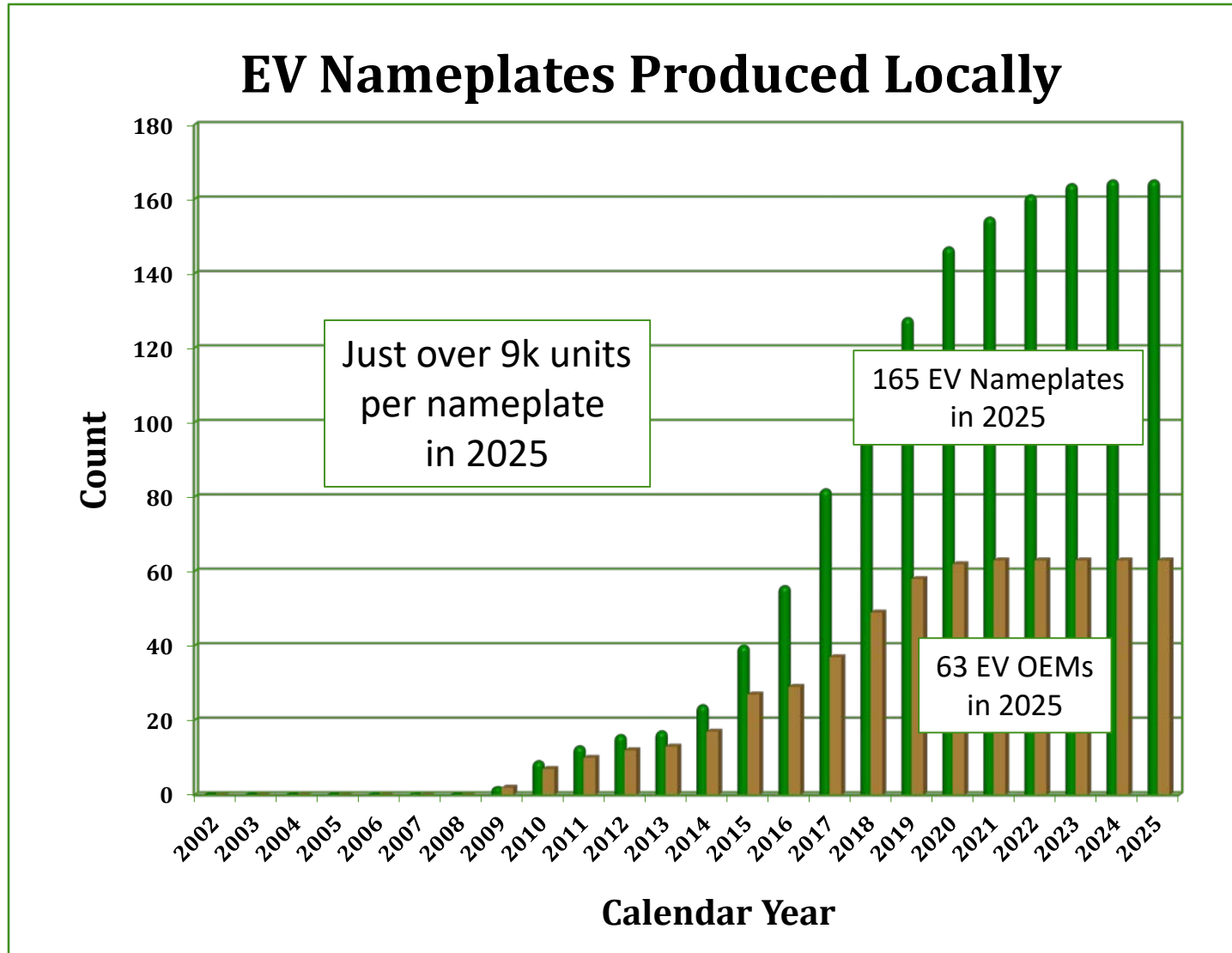
China HEV Market Sizing (cont'd)

2025CY HEV Manufacturers

- Beijing Hyundai (1)
- Beiqi Foton (5)
- BMW Brilliance (5)
- Brilliance Jinbei (1)
- BYD (7)
- Changan Auto (1)
- Changan Ford (8)
- Changan PSA (3)
- Chery (3)
- Dongfeng Honda (2)
- Dongfeng Nissan (1)
- FAW Car (3)
- FAW Toyota (3)
- FAW Volkswagen (7)
- GAC Hino (1)
- GAC Honda (1)
- GAC Motor (2)
- GAC Toyota (4)
- Geely Group (16)
- Great Wall (1)
- Jiangxi Hanteng (2)
- Karma Automotive (1)
- Nanjing Iveco (1)
- Renault-Brilliance (1)
- SAIC GM (7)
- SAIC GM Dongyue (1)
- SAIC GM Norsom (3)
- SAIC Motor (2)
- SAIC VW (3)
- SAIC-GM-Wuling (2)
- Zotye Auto (2)

**Total HEV models in
2025 =
100**

China EV Analysis

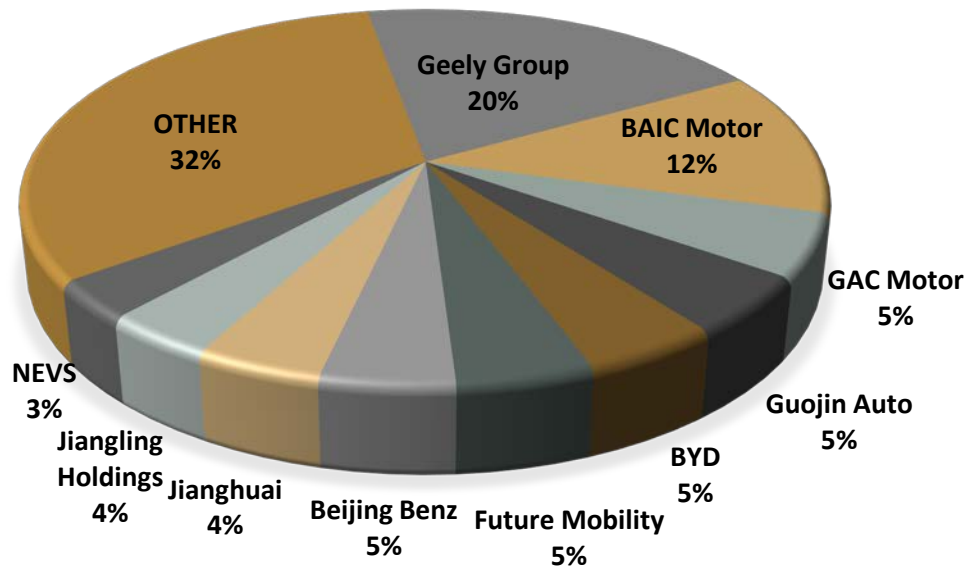


- **Chinese EV market will remain highly fragmented in 2025**
 - Several OEMs command bulk of the volume
 - Top 5 OEMs account for 47%
 - Top 10 OEMs account for 67%
 - Top OEMs still have significant proliferation of EVs
 - Top 5 OEMs account for 47 nameplates, averaging 15k units per nameplate
 - Top 10 OEMs account for 71 nameplates, averaging 14k units per nameplate
- **Top 3 OEMs in China**
 - Geely expected to produce the most
 - 292k units in 2025, with 22 nameplates
 - BAIC expected to be a close second
 - 187k units in 2025, with 10 nameplates
 - GAC Motors expected to be third
 - 81k units in 2025, with 5 nameplates

Source: AutoForecast Solutions – May 2018

China EV Market Sizing

TOP 10 EV ASSEMBLERS - 2025



China accounts for roughly 1.5M EV vehicles in 2025

- **Substantial Growth Expected For EVs in China**

- Plans were being formulated before PHEV concepts
 - Due to government mandates
- Many new manufacturers have received approval
 - Chinese government may issue more for EVs
 - Has led to a very fragmented landscape
 - Not all programs will come to fruition or survive
- Most programs greatly aided by non-domestic partners
 - Chinese government wants an injection of EV technology to help domestic manufacturers
- Bulk of growth from license plate strategy
 - Cheap and easy to get license plates for EVs and PHEVs, where as traditional IC engine vehicles and regular HEVs must go to an expensive and limited auction process
 - Previous incentives had fallen flat, even when they brought EV purchase prices below that of a comparable ICE vehicle
- China will account for over half of the EV volumes in 2025

Source: AutoForecast Solutions – May 2018

China EV Market Sizing (Cont'd)

Manufacturers Adding EVs

(# of EVs in 2025CY)

- BAIC Motor (10)
- BAIC-Yinxiang (2)
- Beijing Benz (4)
- Beijing Hyundai (1)
- Beiqi Foton (2)
- BMW Brilliance (5)
- Brilliance Jinbei (1)
- BYD (7)
- **BYD Daimler (1)**
- **CH Auto (1)**
- Changan Auto (5)
- Changan PSA (1)
- Changhe Suzuki (1)
- **Chehejia (1)**
- Chery (4)
- Chongqing Lifan (2)
- Dongfeng Honda (1)
- Dongfeng Liuzhou (1)
- Dongfeng Motors (3)
- Dongfeng Nanchong (1)
- Dongfeng PV (2)
- Dongfeng Renault (1)
- Dongfeng Yu'an (1)
- Dongfeng Yueda Kia (1)
- Dongfeng –Luxgen (1)
- Faw Haima (1)
- FAW Toyota (1)
- FAW Volkswagen (3)
- **FDG Electric Vehicles (1)**
- Fujian New Longma (1)
- **Future Mobility (3)**
- GAC Changfeng (2)
- GAC Honda (1)
- GAC Motor (5)
- Geely Group (22)
- **Guojin Auto (3)**
- Haima Zhengzhou (2)
- **Harmony Futeng (1)**
- Hawtai (2)
- HK Motors (1)
- Hozon Auto (3)
- Jianghuai (8)
- Jiangjui-VW (1)
- Jiangling Holdings (7)
- **Kandi Electric Vehicles (1)**
- **LeapMotors (1)**
- **LeEco (2)**
- Nanjing Iveco (1)
- **NEVS (2)**
- Qoros (2)
- SAIC Commercial (1)
- SAIC GM (1)
- SAIC Motor (2)
- SAIC VW (4)
- SAIC-GM-Wuling (1)
- Shanghai Maple (2)
- Sichuan Auto (3)
- South-east Automobile (2)
- **WM Motor (1)**
- **Youxia (1)**
- **Yudo Auto (2)**
- Zhengzhou Nissan (2)
- Zotye Auto (6)

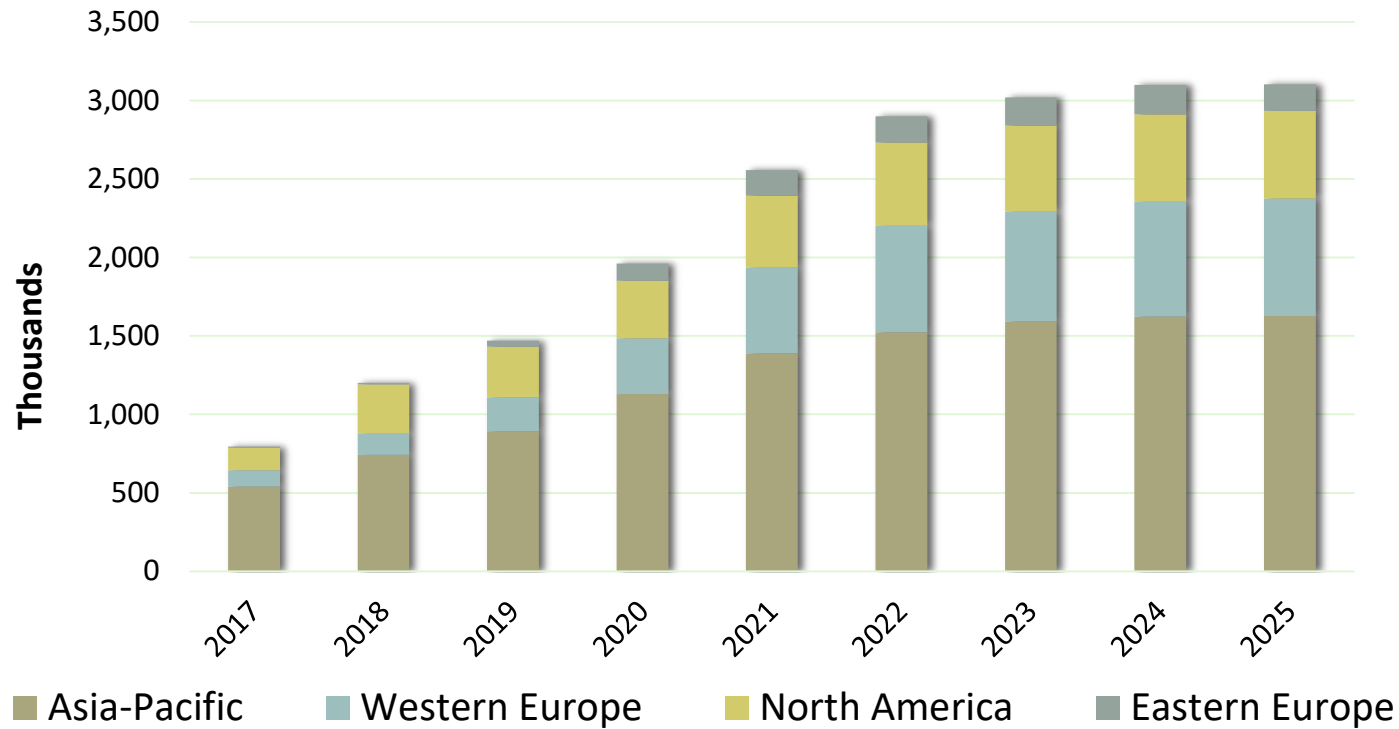
**Total EV models
in 2025 =**

165

**Red Entries are OEMs that
will only produce EVs**

Light Vehicle EV Volume Analysis

Global EV Production



Strong North American growth, but following Asia and Europe

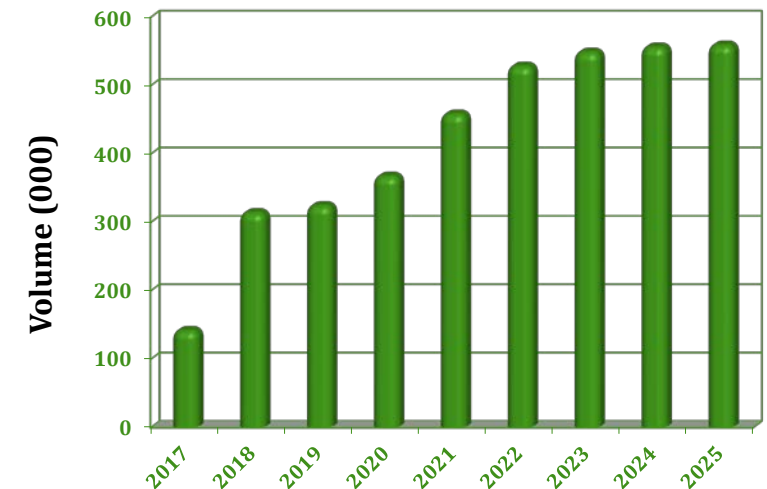
- Tesla and Renault/Nissan lead the way
- Smaller volumes from traditional manufacturers

Low fuel prices hurt budget market vehicles

Global growth expected

- China is starting to drive AP and global growth
- Many high-end sporty car models being added
- All major OEMs adding applications and volume

North America



Source: AutoForecast Solutions – May 2018

Growth of EVs depends on:

- If gas prices continue to rise
- If battery prices continue to fall
- If precious metal prices don't increase
- If charging infrastructures greatly expand
- If vehicle distances increase
- If electricity rates remain low
- If consumers can come up with a daily driving plan
- If consumers can accept new concepts and technology

if

- If government EV mandates increase
- If government EV incentives continue/increase
- If cities exclude combustion powered vehicles
- If taxes on EVs don't exist or remain lower than ICE vehicles
- If government actions use “sticks” rather than “carrots”
- If Trump doesn't have his way

We are currently in the age of convenience. EVs require thinking ahead and planning your daily route to make sure you have enough fuel to easily make it back home. How does this fit into a society that gives up quality for convenience? (MP3s vs CDs, phone cameras, fast food restaurants)

The EV Double Standard

• Optimist's Arguments

- Fuel prices will always rise
 - Scarcity and taxes
- Battery prices will continue to fall leading to vehicle price parity
 - Technology and material improvements
- Governments are banning internal combustion engines
 - Paris, various cities in China and India, the UK
- Charging infrastructures continue to grow
 - Easing fears of range anxiety
- No emissions vs ICE vehicle

• In Reality

- Fuel prices fluctuate greatly
 - If EVs take off and eat into IC engine vehicles, fuel prices will actually drop, evening things out a bit
- Battery prices will drop and may become less expensive than IC engine vehicles
 - Material scarcity may drive up battery prices during significant EV growth
- Governments will have an extremely hard time actually banning the internal combustion engine
 - China can be a wild card and actually successfully mandate this
 - Most other cities and countries will meet strong opposition
- Charging infrastructures will continue to improve
 - A sufficient infrastructure already exists – you just have to find it
 - Range anxiety is not a rational fear
- Emissions shifted from tailpipe to smokestack
 - In general, still cleaner, but not eliminated

“If you build it, they will come,” doesn’t always work

Severe Socio-Economic Disruption

- **Huge Shift In Jobs**

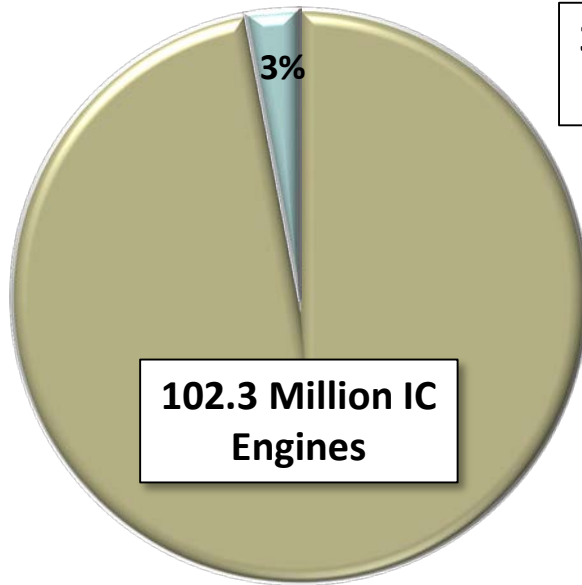
- Much fewer parts
 - Most assembly jobs will simply be eliminated
 - Eliminating 7 out of every 8 jobs, roughly, in a plant
- Remaining jobs will be very different than ICE based ones
 - Different type of engineers and developers
 - Different type of line workers
 - Replacing about half the engineers
- Employment locations will also shift
 - Battery and electric motor factories will most likely open in states south of Michigan
 - Many electric motors may be imported
 - Battery pack assembly expected to stay in North America due to size, weight and percentage of vehicle origin rules

- **Significant Geographic Impact**

- Reliance on Middle East Oil will diminish some
- Reliance on South American countries and China will greatly increase
 - Due to importance of lithium and other rare substances
 - Will South America be the new OPEC of lithium?
 - Some of these countries have a history of governments raiding foreign businesses and then nationalizing them to grab control
- With significant Chinese push for EVs and PHEVs, they may become the global leaders in the technology
 - Europe, namely Germany, also making a strong push for EV and PHEV production
 - Could US engineering and manufacturing slide even further behind the rest of the world?

Global Light Vehicle Production by Power Type

2025 **AFS** Forecast
By Power Type



■ IC Engine ■ EV

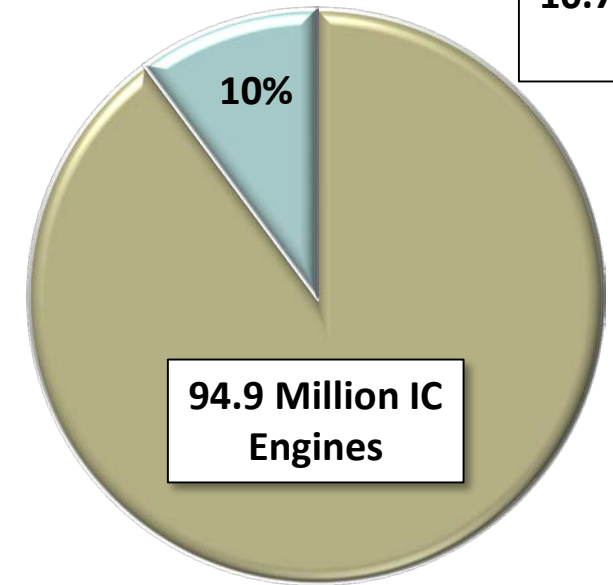
3.3 Million
EVs

102.3 Million IC
Engines

- **Substantial Investment into EVs**

- Billions of dollars going into many programs at many manufacturers
 - Volkswagen – 31 EVs
 - Geely – 22 EVs
 - Renault/Nissan – 14 EVs
 - BAIC & Daimler – 10 EVs, each
 - BMW – 9 EVs
- Some OEMs say that they will stop investing into IC engines
- Other OEMs are resisting EVs
 - Mazda
 - FCA
 - Toyota

2025 **Optimistic** Forecast
By Power Type



■ IC Engine ■ EV

10.7 Million
EVs

94.9 Million IC
Engines

**Significant amount of
Rhetoric and Puffery**

Source: AutoForecast Solutions – May 2018

What Should the OEMs Build?

Unprofitable Vehicles



500e
Volt
Mirai
RAV EV
Leaf
Model S
Focus EV

Profitable Vehicles



F-150
Silverado
Tacoma
Ram Pickup
Wrangler
Pilot
Anything with the Hellcat engine



Global Alternative Propulsion Outlook & Analysis

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