U.S. EV Battery Disposition and Recycling Process Opportunities

TCEQ EV Reuse and Recycling Advisory Group

August 31, 2022

ALLIANCE FOR AUTOMOTIVE INNOVATION

Our Members


AISIN GROUP


APTIV

ARGO AI

Autoliv

BMW GROUP

BOSCH

cruise

DENSO

Ferrari

Ford

GHOST

gm

HARMAN
A SAMSUNG COMPANY

HONDA

HYUNDAI

Infineon

intel

ISUZU

JAGUAR
LAND ROVER

KIA

LUMINAR

MAGNA

mazda

Mercedes-Benz

MITSUBISHI
MOTORS

NISSAN

nuro

NXP

Panasonic

PORSCHE

Qualcomm

RV
INDUSTRY
ASSOCIATION

SiriusXM
CONNECTED VEHICLE SERVICES

STELLANTIS

SUBARU

SUZUKI

Texas
Instruments

TOYOTA

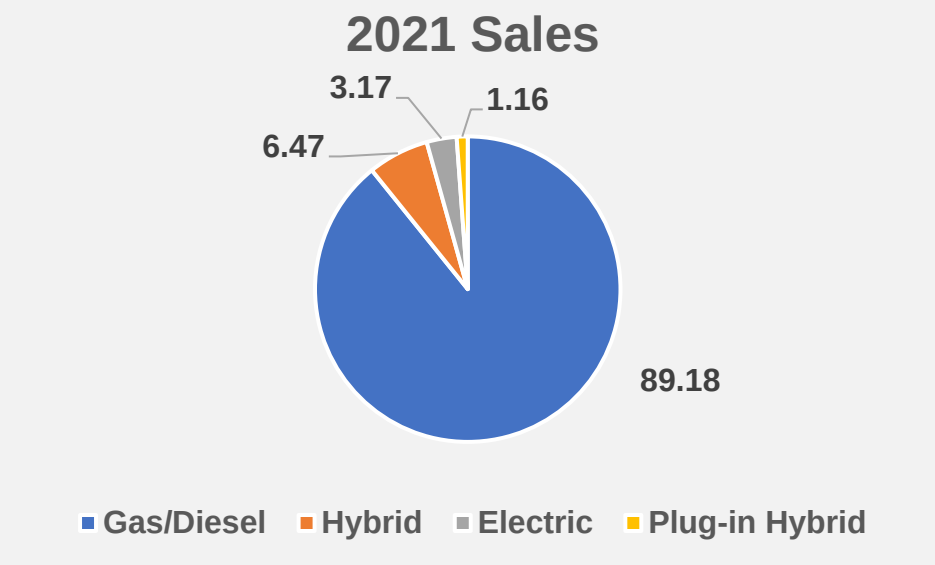
VOLKSWAGEN
GROUP OF AMERICA

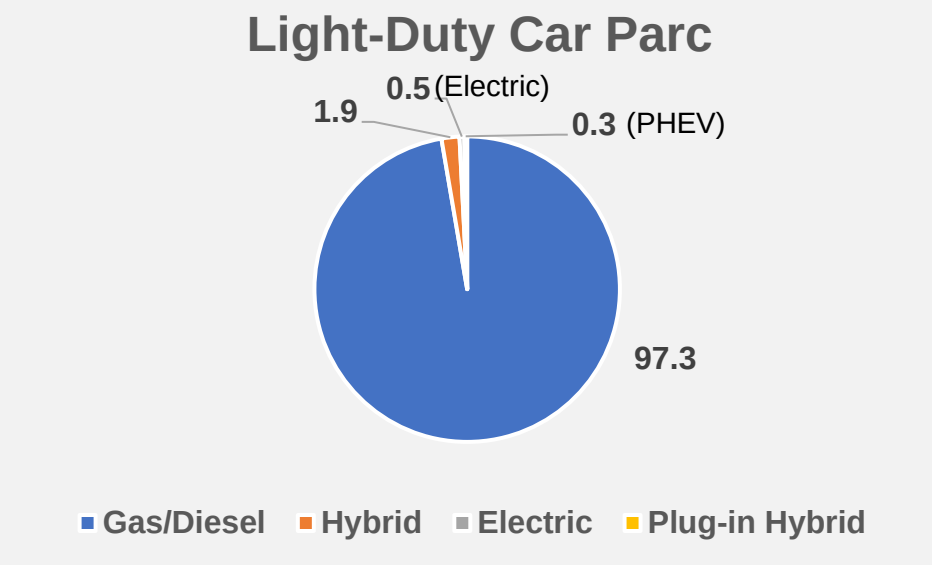
VOLVO

State of the Light-Duty Vehicle Industry

U.S. Light-Duty Vehicles

- 283 million registered vehicles (2.2 million electrified)
- 14.9 million new vehicles sold in 2021
  - 12 percent drop vs 2019, but 3 percent gain vs 2020
- Average purchase price – ~$46,000
- Average age – 12 years old+

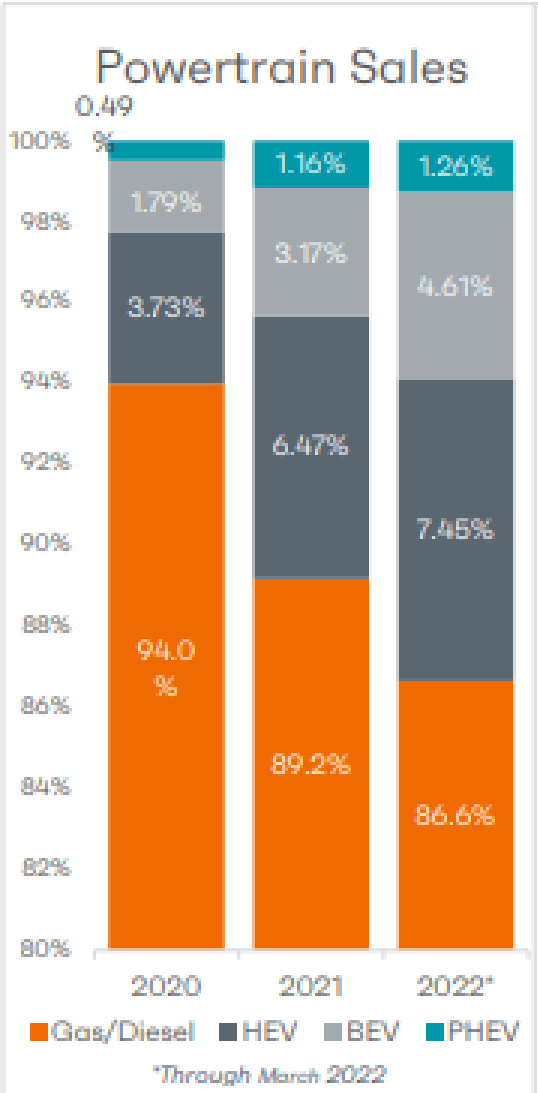


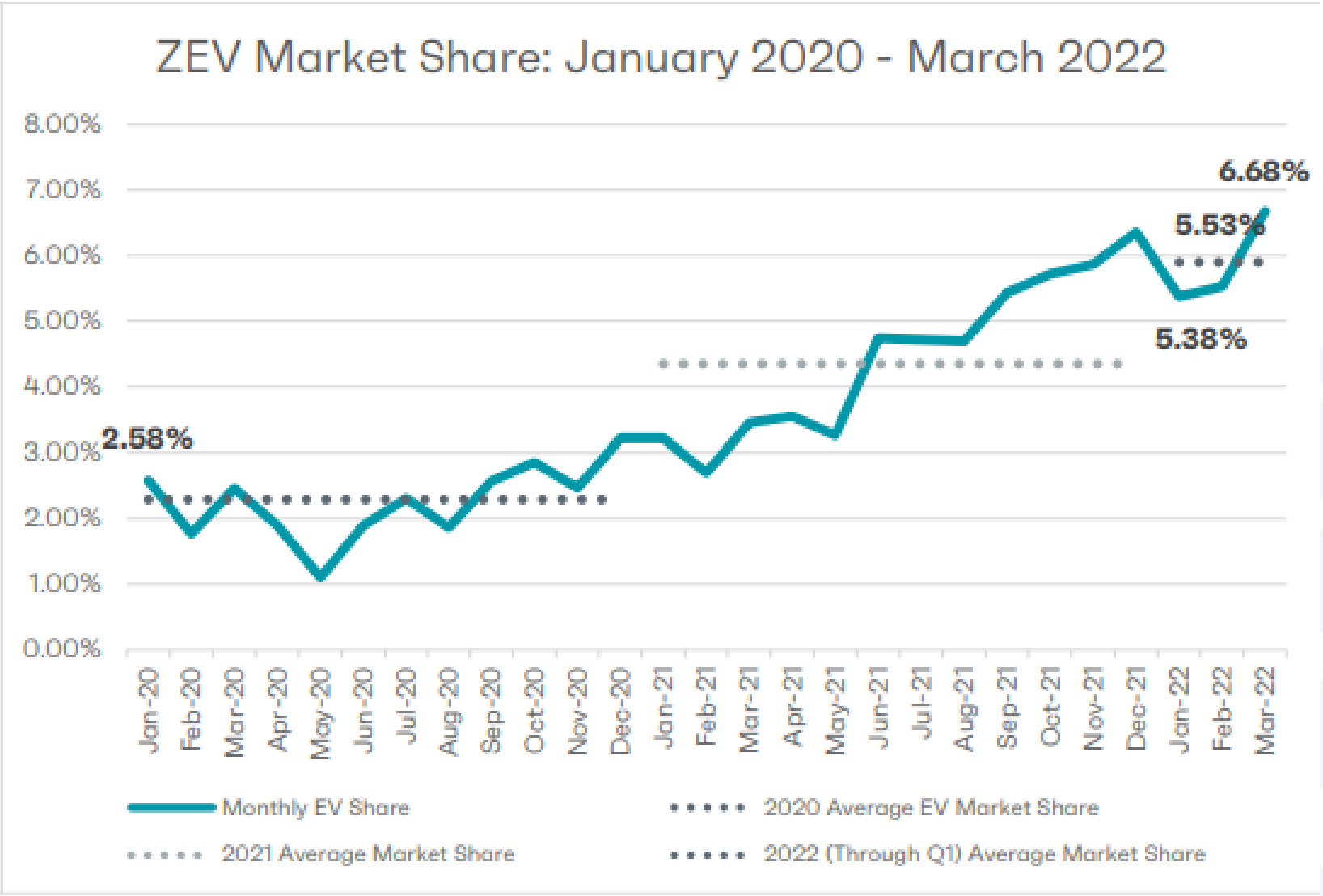


Source: IHS Markit 2021 Sales data

Also see, "Reading the Meter: State of the Industry Report"

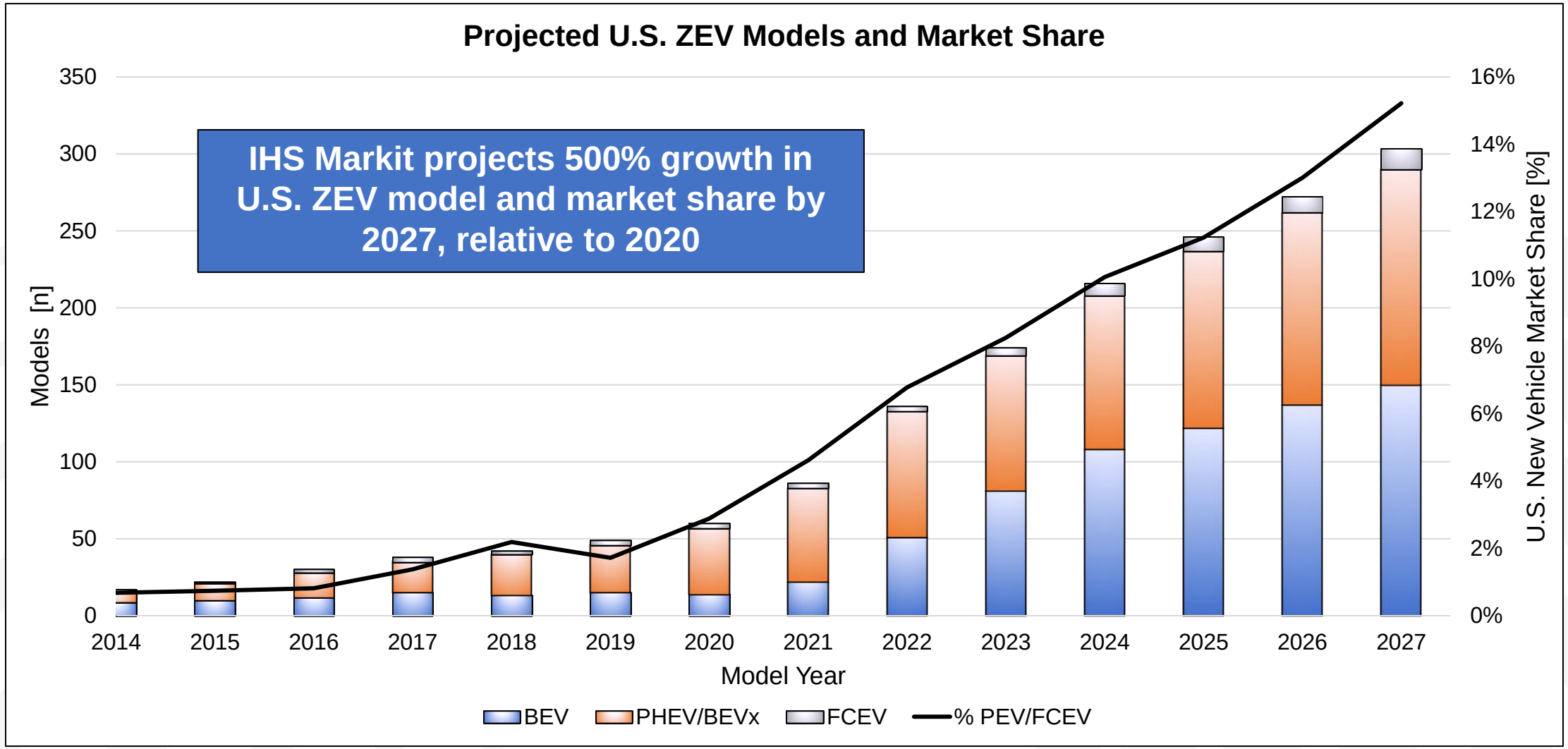
U.S. Light-Duty Vehicles





ALLIANCE FOR AUTOMOTIVE INNOVATION

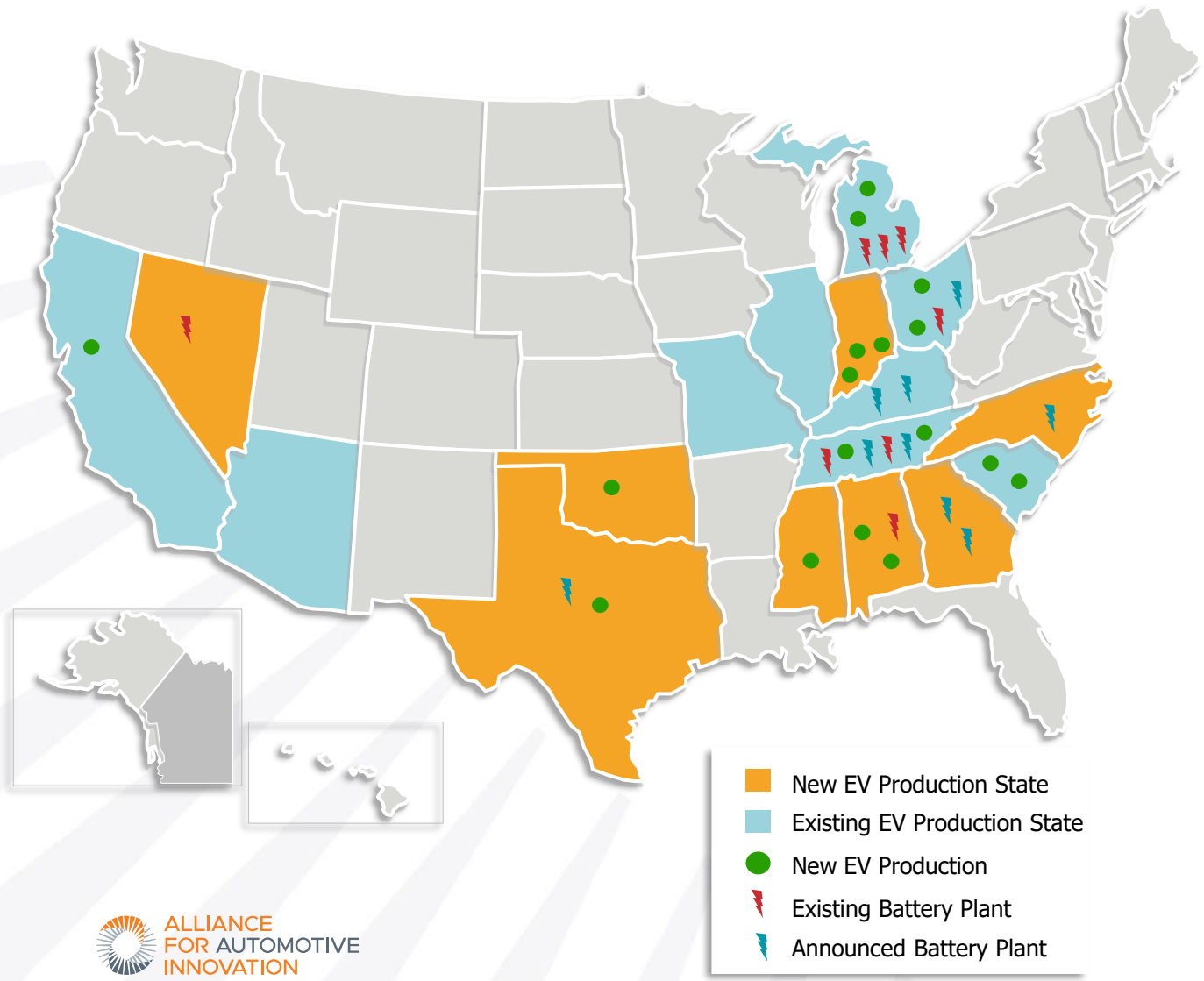
Anticipated Growth in U.S. ZEV Models and Market



ALLIANCE FOR AUTOMOTIVE INNOVATION

Analysis by the Alliance for Automotive Innovation based on content supplied by IHS Markit VPaC - Vehicle Performance and Compliance Monitor (October 2020) and Baseline Studies for Auto Innovators. See disclaimer.

The Future is Electric



- $91.8 Billion U.S. EV Investment
- $515 Billion Global EV Investment
- 78 Electrified Models in the U.S.
- Battery plant manufacturing capacity set to grow 383% by 2025
- More than 4 Million electric vehicles produced by 2023
- Increased EV penetration and domestic battery production provide a source for battery recycling and reuse

ALLIANCE FOR AUTOMOTIVE INNOVATION

EV Battery Recycling

Lithium-Ion Batteries Are Different & Will Continue to Evolve

	Lead Acid Starter	NiMH HVB	Li-Ion HVB
Key Materials	Lead	Nickel, Cobalt	Cobalt, lithium, manganese, nickel
Voltage	Low	High	High
EOL Infrastructure	Developed (>95% recycled)	Growing	Emerging
Weight	Low (~32 lbs)	Medium (~150-200 lbs)	High (~500-2600 lbs)

Practical and viable processes, with consultation from all stakeholders, need to be in place to achieve positive value recycling.

Due to weight, size, and voltage, Li-ion batteries will require professional removal, similar to internal combustion engines and transmissions

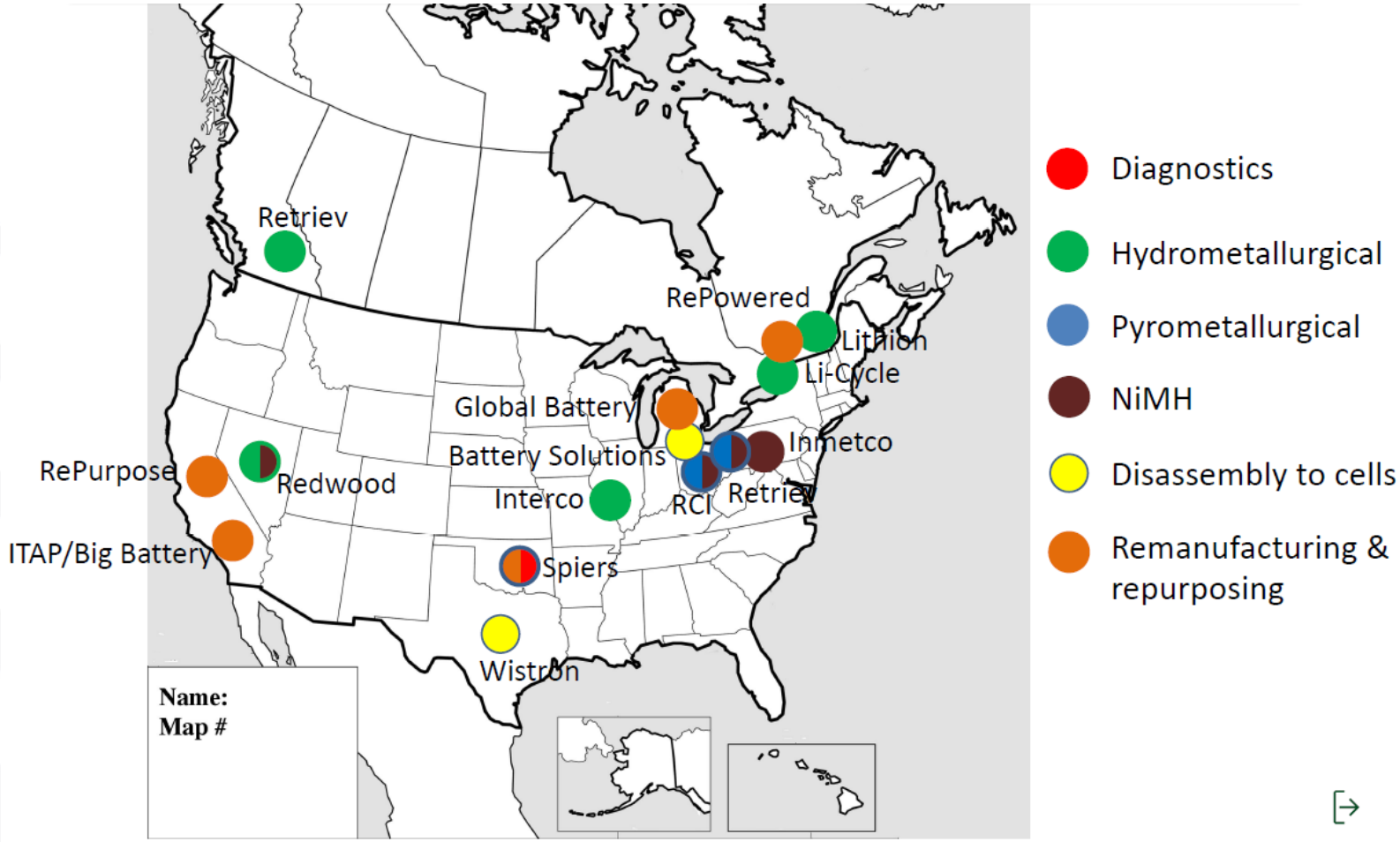
Goals of an EV Battery Recycling Process

Key Needs For A Battery Reuse / Recycle Process

- Enables capturing ~100% of EoL vehicle batteries
- Allows the reclamation of the critical minerals, supporting a circular battery economy
- Creates a clear path for batteries/battery materials to be recycled/reused

Policies evaluated in CA Li-Ion EV Battery Recycling Advisory Committee	
Producer Take-Back (aka extended producer responsibility)	Manufacturer responsible to ensure proper repurposing, reuse, or recycling at end-of-life
Core exchange with complete vehicle backstop	Vehicles in-service: Core exchange program Vehicles out of service: Dismantler who removes EV battery is responsible. If EOL EV is not purchased by a dismantler, vehicle manufacturer acts as a backstop for the complete vehicle.
Environmental handling fee to finance an EOL management program	A fee is used to finance an EOL collection and recycling program

Existing North American Battery Recycling Network



call2recycle
Leading the charge for recycling

Emerging technologies such as hydrometallurgical recycling can:

- Reduce waste from the recycling process
- Lower energy consumption and CO_2 generation
- Increase recovered material over traditional pyro technology

EV Batteries - Circular Economy Growth – North America

Time Frame	Near Term (~2020-2025)	Medium Term (~2026-2030)	Long Term (beyond 2030)
EV Battery Manufacturing in US	• First cell plants (beyond Gigafactory) open • Scrap from cell plants will promote more recycling facilities	• >10 EV battery cell plants • Direct positive-value recycling facilities increasing	• >20 EV battery cell plants • Potential for direct recycling/cathode and anode recovery
EV Battery Supply Chain Development	• First domestic CAM & precursor plants • Input material supply chain tied only to mining operations • Recycled material validation	• Refining/processing comes on-line • First mines/extractions • Supply chain hooking up with recyclers • Recycled material use begins	• Mature domestic supply chain, including recycling with appropriate standards like plastics industry • Recycled material is a significant portion of battery material
EV Battery Re-use Technology/Market	• "R&D" phase	• "Start-up" phase	• "Mature" phase
Large Format Li-Ion Recycling Volume	• Most batteries refurbished (few entire batteries are scrapped) • Low quantities of batteries processed through pyro processes	• Some batteries/vehicles reach EOL • Positive-value recycling scaling up	• Closer to "steady state" of used EV battery flow
kWh of vehicle Li-ion batteries recycled / year	• LOW	• LOW and growing	• MEDIUM and growing
Battery Recycling	• Positive-value recycling emerging	• Positive-value recycling technology and logistics growth	Cathode manufacturing uses a high percentage of recycled material like copper industry

ALLIANCE FOR AUTOMOTIVE INNOVATION

Positive Value Recycling

- The preponderance of automotive batteries in North America are value positive NMC chemistry when recycled
  - Quickly expanding value positive recycling capability in North America
- Market-based automotive recycling systems in the United States have worked well for other positive-value recycling streams:
  - Catalytic converters, NiMH batteries, alternators/starter motors
- European Battery Directive was put in place when lithium-ion EV battery recycling was negative value
  - Existing European negative value recycling infrastructure was shaped by this legislation resulting in slow technology improvements
  - Manufacturers have been sending batteries to Asia where recycling is positive value
    - Legislation has been adjusted to stop the flow of these strategic materials from leaving Europe
- Positive value recycling provides a domestic supply of raw materials for the nascent EV battery cell manufacturing industry

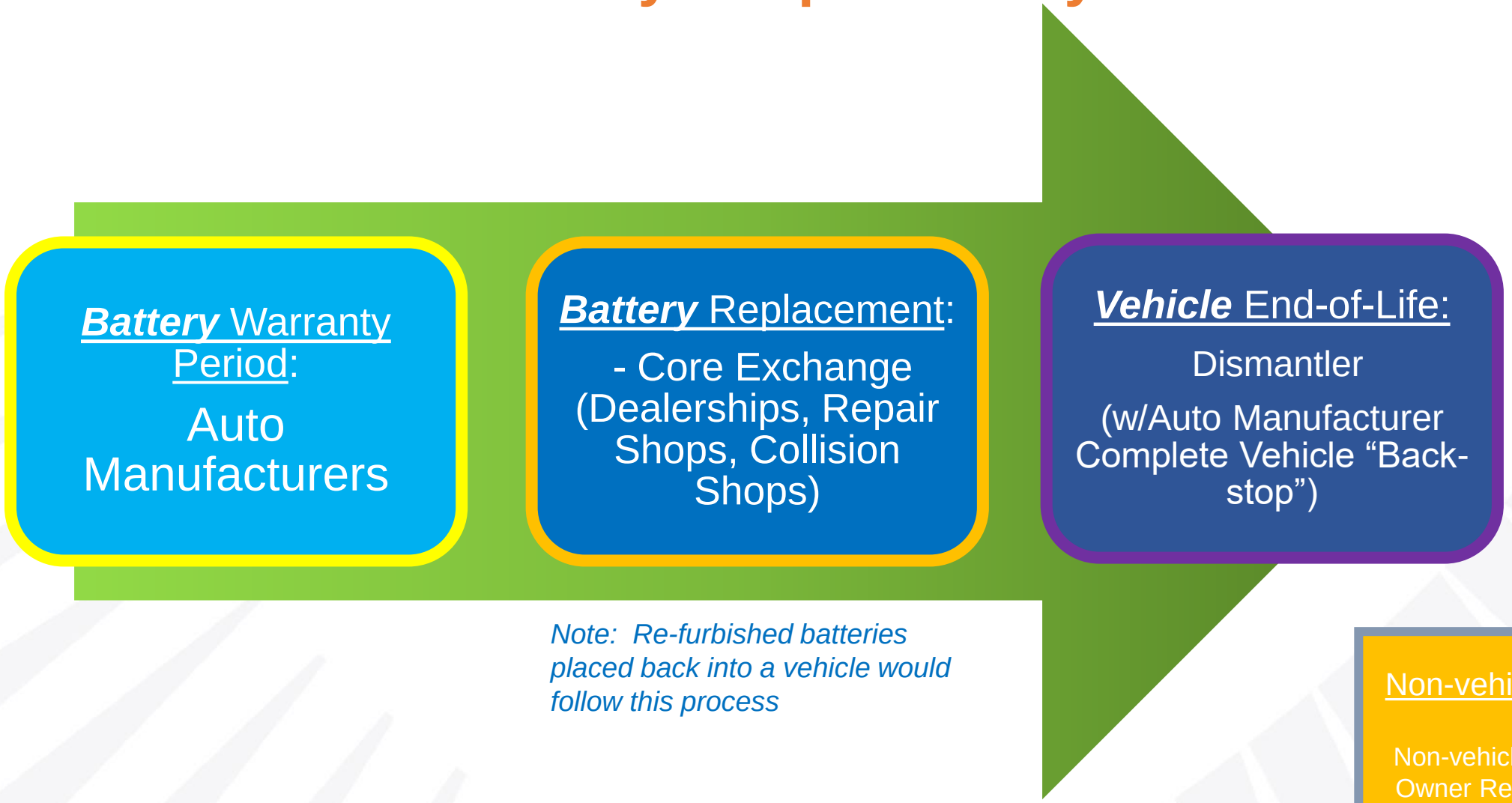
Core Exchange with Complete Vehicle Backstop

Core Exchange with a Complete Vehicle Backstop

For EVs still in service, if a battery (or any module or cell) is replaced before the vehicle reaches end-of-life, a core exchange program as detailed by the EV battery supplier or vehicle manufacturer shall be used for the replacement battery (or any module or cell). The entity removing the battery shall be responsible for ensuring that the battery (or module or cell) is transferred to a qualified facility to be properly refurbished, repurposed, or recycled.

For EVs reaching end-of-life, a dismantler who removes the lithium-ion battery from the vehicle is responsible for ensuring the battery is properly reused, refurbished, or recycled. In circumstances where an end-of-life EV is unwanted, and no parts are removed (i.e., a "complete vehicle") by a licensed dismantler, the vehicle manufacturer shall be responsible to accept the vehicle and ensure that it is properly dismantled and the lithium-ion battery is properly reused, refurbished, or recycled.

Lithium-Ion Car Battery Responsibility Timeline



Note: Re-furbished batteries placed back into a vehicle would follow this process

Non-vehicle Secondary Use:
Non-vehicle secondary use Owner Responsible unless stated otherwise in a contract

ALLIANCE FOR AUTOMOTIVE INNOVATION

EV Battery End-of-Life Responsibility for a Core Exchange w/ Complete Vehicle Backstop

State of Vehicle	State of Battery	Warranty Status	Responsible Party
In-Service	Damaged or otherwise needs to be replaced	In warranty	Vehicle manufacturer is responsible for ensuring EV battery is properly reused, refurbished, or recycled
In-Service	Damaged or otherwise needs to be replaced	Outside of warranty	• Dealerships, independent repair shops, collision shops, entity removing the battery, etc. are responsible for ensuring the battery is transferred to a qualified facility to be properly reused, refurbished, or recycled. • Record-keeping for a core exchange shall be required for each battery pack, module, or cell replaced. A clear, identifiable, and traceable serial number is required on the replacement part.
End-of-Life	N/A (dismantler or vehicle manufacturer will determine state of battery)	Outside of warranty	• A dismantler who removes the lithium-ion battery from the vehicle is responsible for ensuring the battery is transferred to a qualified facility to be properly reused, refurbished, or recycled. • In circumstances where an EOL EV is unwanted, and no parts are removed (i.e. a “complete vehicle”) by a licensed dismantler, the vehicle manufacturer shall be responsible for ensuring that the vehicle is properly dismantled and the lithium-Ion battery is properly reused, refurbished, or recycled.
EV Battery Secondary Use			Non-vehicle secondary use owner is responsible to ensure the battery is properly recycled, unless stated otherwise in a contract.

Why a Complete Vehicle Backstop is an Appropriate Policy?

Traditional EPR schemes are appropriate for negative recycling value products, limited secondary life opportunities, and/or natural resource-intensive recycling technologies.

We are already witnessing the domestic battery supply chain's quick adaption to market dynamics due to the positive value of recovered materials, secondary life market opportunities, and awareness and demand for a domestic supply chain.

Complete Vehicle "Back-stop":

- Ensures EV batteries are properly reused, refurbished, or recycled throughout their life-cycle in the vehicle
- Likely would not increase the cost of electric vehicles for consumers
- Ensures licensed dismantlers are not "cut-out" of the market at end-of-life
  - If the complete vehicle is a positive business case, licensed dismantlers will continue to acquire end-of-life EVs
  - If the battery becomes positive value at end-of-life, it does not take away this opportunity for dismantlers (like EPR might)
- Encourages auto manufacturers to continue to design for recycling and reuse
- Does not discourage innovation amongst recyclers
- Encourages dismantlers to become "licensed"
- Complete vehicle is easier to transport than an EV lithium-ion battery

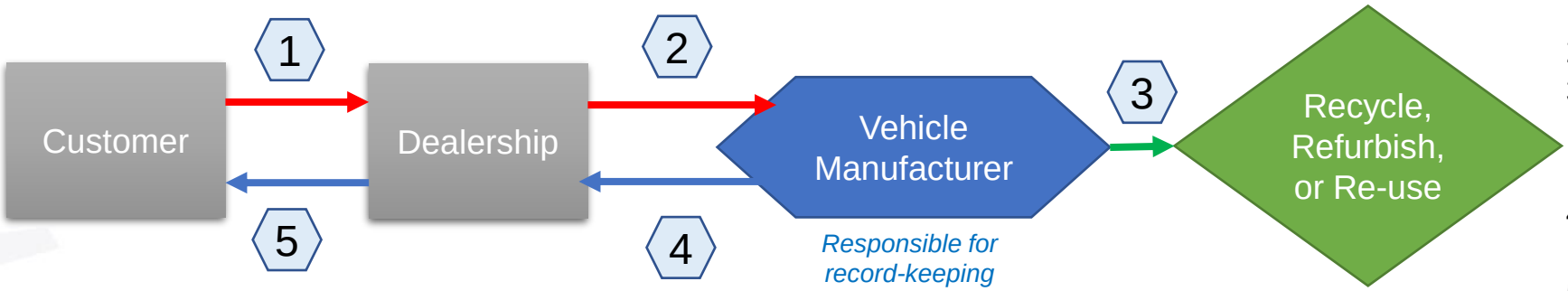
This policy provides a safety net to capture outlier EV batteries (orphaned batteries) that have fallen outside of use cases and, importantly, during unforeseen market fluctuations.

ALLIANCE FOR AUTOMOTIVE INNOVATION

Transforming Personal Mobility

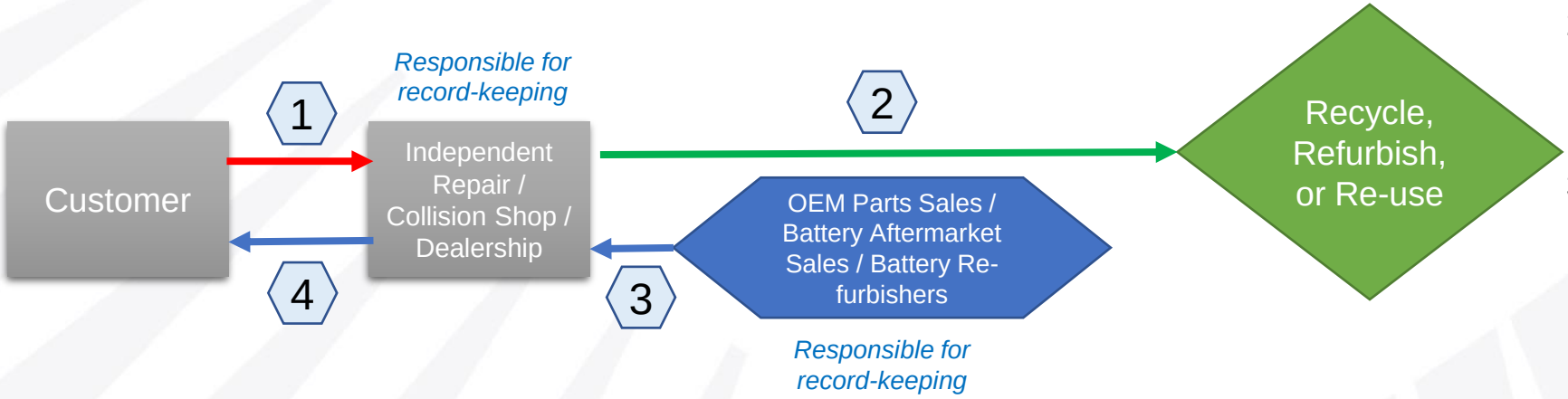
Dan Bowerson
Senior Director, Energy & Environment
dbowerson@autosinnovate.org

Example Use Case: In-Service, Under Warranty



1. Customer Drops off vehicle at dealership for repair
2. Dealership removes battery
3. Vehicle manufacturer ensures that EV battery is properly recycled, refurbished, or put into a non-vehicle secondary-use
4. Vehicle Manufacturer provides a replacement battery to the dealership
5. Dealership provides repaired vehicle to customer

Example Use Case: In-Service, Outside Warranty

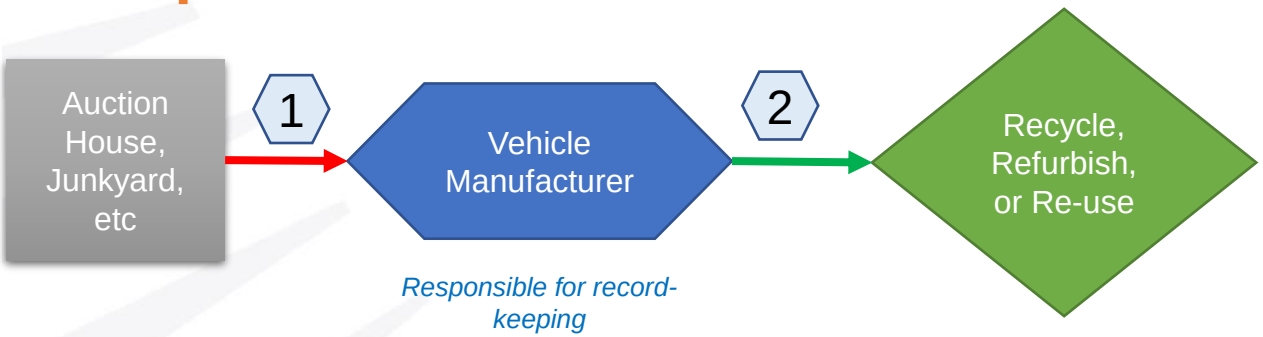


1. Customer Drops off vehicle at independent repair / collision shop / dealership for repair
2. Independent repair / collision shop / dealership removes battery and ensures that is properly recycled, refurbished, or put into a non-vehicle secondary use
3. OEM parts sales / battery aftermarket sales / battery re-furbishers provides new or refurbished battery to independent repair / collision shop / dealership through a core exchange program
4. Repaired vehicle is delivered to customer

Example Use Case: EV End-of-Life

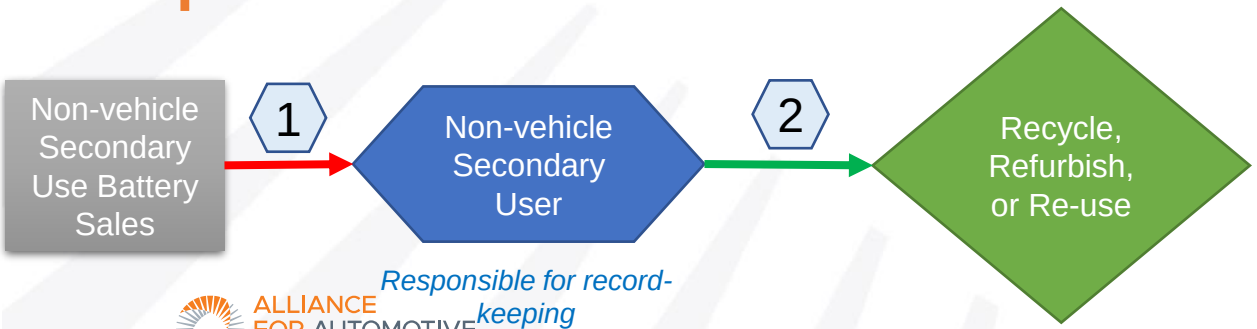
1. Auction house sells end-of-life EV to a licensed dismantler
2. Licensed dismantler is responsible for ensuring that the used EV battery is properly recycled, refurbished, or put into a non-vehicle secondary use

Example Use Case: Unwanted EV at End-of-Life



1. Licensed dismantler **does not** purchase end-of-life EV from an auction house
2. Vehicle manufacturer takes possession of complete EV and is responsible for ensuring that the used EV battery is properly recycled, refurbished, or put into a non-vehicle secondary use

Example Use Case: Non-vehicle Secondary Use



1. Entity selling EV battery for non-vehicle secondary use ships battery to non-vehicle secondary user
2. Non-vehicle secondary user is responsible for ensuring that the used EV battery is properly recycled, refurbished, or put into a non-vehicle secondary use