ECE 398GG – ELECTRIC VEHICLES

17. EV DEPLOYMENT AND EVCI STATUS

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GLOBAL BEV AND PHEV SALES: 2013 – 2022

all numbers are in thousands

plug-in hybrids

battery electric vehicles

registration share in %

y-o-y growth in %

Source: EV volumes available at https://www.ev-volumes.com/
GLOBAL EV SALES 2022

- 2022 global BEV and PHEV sales saw the delivery of 10.5 million cars – a 55% increase over those in 2021 – and outnumbered the 8.4 million non-pluggable HEVs sold in 2022.

- The resilience of global EV sales in the weak 2022 auto markets is notable as the global ICEV sales declined by 7% from their 2021 level, with the light-duty vehicle (LDV) ICEV sales slipping from their 82.2% share in 2021 to 76.8% share in 2022.

GLOBAL EV SALES 2022

- EV sales constituted 13% of the 2022 global LDV sales, of which 9.5 (3.5)% were BEVs (PHEVs) – a marked increase from their 8.3% share in 2021.

- US and Canada EV sales grew 48% from 2021 despite a reduction of 8% in overall LDV sales.

- China’s BEV and PHEV sales increased 82% over 2021 sales to constitute 27% of China’s LDV sales.
GLOBAL EV SALES 2022

- BYD more than tripled its sales to 1.85 million cars, including 944,500 PHEVs, to catapult BYD to the first position in global EV sales
- TESLA sold 1.31 million BEVs in 2022 – by far the global leader in BEV sales
- Norway’s leading global status in EV sales with a 79% share of all LDVs sold in 2022 – 71 (8)% in BEV (PHEV) sales

GLOBAL EV SALES 2022

- Europe’s BEV and PHEV sales made up a 20.8% share of its total LDV sales
- The fastest growing EV sales markets in 2022 were in Indonesia – a jump from 1,000 in 2021 to 10,000 EVs in 2022 – and India – a growth of 223% over 2021 sales to 50,000 EVs, virtually all BEVs
GLOBAL EV SALES 2022

- Global PHEV sales were 27% of EV sales – a decline from 29% in 2021, even though the volume of sold units increased; the PHEV share is in global decline with an annual increase of 46% vis-à-vis the 59% growth in BEV sales.

- The global sales of fuel cell EVs in 2022 were 15,400 units – less than 0.02% of the global annual LDVs sold.

LIGHT-DUTY PEV MONTHLY MARKET SHARE DEC 2010 – DEC 2022

### 2022 Global BEV & PHEV Sales by Region

<table>
<thead>
<tr>
<th>Region</th>
<th>2022 Sales (thousands of vehicles)</th>
<th>2021 Sales (thousands of vehicles)</th>
<th>Year-to-Year Change % Sales</th>
</tr>
</thead>
<tbody>
<tr>
<td>Europe (W&amp;C)</td>
<td>2,683</td>
<td>2,332</td>
<td>15 – 6.2</td>
</tr>
<tr>
<td>China</td>
<td>3,396</td>
<td>6,181</td>
<td>82 – 5.3</td>
</tr>
<tr>
<td>Northern America</td>
<td>1,108</td>
<td>748</td>
<td>48 – 7.6</td>
</tr>
<tr>
<td>Others</td>
<td>551</td>
<td>291</td>
<td>89 11.3</td>
</tr>
</tbody>
</table>

Global total: 55,000 – 0.5

Source: EV volumes; available at https://www.ev-volumes.com/

### Top 5 Automaker Global EV Sales by Region: 2021

<table>
<thead>
<tr>
<th>Automaker</th>
<th>China</th>
<th>US</th>
<th>Europe</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tesla</td>
<td>936</td>
<td>170</td>
<td>352</td>
<td>321</td>
</tr>
<tr>
<td>VW Group</td>
<td>763</td>
<td>549</td>
<td>598</td>
<td>517</td>
</tr>
<tr>
<td>BYD</td>
<td>33</td>
<td>1</td>
<td>25</td>
<td>324</td>
</tr>
<tr>
<td>GM</td>
<td>595</td>
<td>486</td>
<td>6</td>
<td>385</td>
</tr>
<tr>
<td>Stellantis</td>
<td>93</td>
<td>154</td>
<td>14</td>
<td>11</td>
</tr>
</tbody>
</table>

Numbers are in thousands

**TOP 5 AUTOMAKER GLOBAL EV SALES: 2022**

<table>
<thead>
<tr>
<th>Automaker</th>
<th>Global Market Share (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BYD</td>
<td>18.4</td>
</tr>
<tr>
<td>Tesla</td>
<td>13.0</td>
</tr>
<tr>
<td>Volkswagen Group</td>
<td>8.2</td>
</tr>
<tr>
<td>SAIC</td>
<td>7.2</td>
</tr>
<tr>
<td>Geely-Volvo</td>
<td>6.0</td>
</tr>
</tbody>
</table>


**2022 TOP-SELLING GLOBAL PLUG-IN VEHICLE BRANDS**

<table>
<thead>
<tr>
<th>Brand</th>
<th>Million Sales</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tesla</td>
<td>1.38</td>
</tr>
<tr>
<td>BYD</td>
<td>1.22</td>
</tr>
<tr>
<td>SAIC</td>
<td>0.64</td>
</tr>
<tr>
<td>Volkswagen Group</td>
<td>0.63</td>
</tr>
<tr>
<td>Geely-Volvo</td>
<td>0.34</td>
</tr>
</tbody>
</table>

THE LEADING PLUG-IN VEHICLE SALES IN 2022

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Sales (thousands)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BYD</td>
<td>1,847,745</td>
</tr>
<tr>
<td>Tesla</td>
<td>1,314,330</td>
</tr>
<tr>
<td>SGMW</td>
<td>482,056</td>
</tr>
<tr>
<td>Volkswagen</td>
<td>433,636</td>
</tr>
<tr>
<td>BMW</td>
<td>372,694</td>
</tr>
<tr>
<td>Mercedes</td>
<td>293,597</td>
</tr>
<tr>
<td>GAC</td>
<td>271,557</td>
</tr>
<tr>
<td>SAIC</td>
<td>237,562</td>
</tr>
<tr>
<td>Changan</td>
<td>237,429</td>
</tr>
<tr>
<td>Chery</td>
<td>230,867</td>
</tr>
</tbody>
</table>


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TOP-SELLING EV MODELS IN CHINA: 2022


TOP-SELLING EV MODELS IN EUROPE: 2022

TOP 10 PHEV MODELS IN EUROPE DECEMBER 2022

<table>
<thead>
<tr>
<th>Model</th>
<th>Sales</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tesla Model Y</td>
<td>32,442</td>
</tr>
<tr>
<td>Tesla Model 3</td>
<td>20,335</td>
</tr>
<tr>
<td>VW ID.4</td>
<td>13,685</td>
</tr>
<tr>
<td>VW ID.3</td>
<td>11,561</td>
</tr>
<tr>
<td>Ford Kuga PHEV</td>
<td>10,726</td>
</tr>
<tr>
<td>Dacia Spring</td>
<td>9,694</td>
</tr>
<tr>
<td>Fiat 500 electric</td>
<td>8,333</td>
</tr>
<tr>
<td>Renault Megane E-Tech</td>
<td>8,084</td>
</tr>
<tr>
<td>Volvo XC40 Recharge</td>
<td>7,732</td>
</tr>
<tr>
<td>Cupra Born</td>
<td>7,489</td>
</tr>
</tbody>
</table>

TOTAL US PLUG-IN VEHICLES SOLD: DECEMBER 2010 – DECEMBER 2022

US plug-in vehicles sold in the current month

TOTAL US plug-in vehicles sold through preceding month

THE ANNUAL SHARE OF US PLUG-IN CARS OF ALL VEHICLES SOLD: 2011 – 2023

- **Plug-in vehicle share of total car sales**
- **Plug-in vehicle share of total light duty vehicle sales**
- **Plug-in light truck share of total light truck sales**


THE MONTHLY US ELECTRIC DRIVE VEHICLE SHARES AND GASOLINE PRICES

- **Monthly gasoline price**
- **Monthly HEV sales**
- **Monthly PHEV & BEV sales**

**Q1 2022 CA GASOLINE PRICES**


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**BEV AND PHEV SHARE OF TOTAL US EV SALES: 2020 – 2021**

TOTAL US BEV & PHEV SALES FROM 2011 TO 2021

<table>
<thead>
<tr>
<th></th>
<th>2011 – 2021</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHEV</td>
<td>810,291</td>
<td>34.7%</td>
</tr>
<tr>
<td>BEV</td>
<td>65.3%</td>
<td></td>
</tr>
<tr>
<td>Total Sales</td>
<td>1,523,442</td>
<td></td>
</tr>
</tbody>
</table>


THE MONTHLY US ELECTRIC DRIVE VEHICLE SHARES AND GASOLINE PRICES

- Monthly HEV sales
- Monthly PHEV & BEV sales
- Monthly gasoline price

3,578,374 PHEVs and BEVs have been sold since 2010

THE MONTHLY US ELECTRIC DRIVE VEHICLE SHARES AND GASOLINE PRICES

- March 2023 sales: 100,605 plug-in vehicles – 81,346 BEVs and 19,259 PHEVs – an increase of 25.2% from the sales in March 2022.
- EVs captured 7.37% of total light-duty vehicle sales in March 2023.


TESLA'S SHARE OF NEW 2022 US EV REGISTRATIONS DECLINES

- Tesla's share of EV market declined from 11% in January 2021 to 78% in January 2022.
- Other US OEMs
- Korean
- 3 German OEMs: BMW, MB & Audi

NOVEMBER 2022 US SALES OF NEW EV MODELS

<table>
<thead>
<tr>
<th>model</th>
<th>sales Nov-21</th>
<th>sales Nov-22</th>
<th>share of the Nov 22 EV market in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ford F series</td>
<td>0</td>
<td>2,217</td>
<td>3.2</td>
</tr>
<tr>
<td>BMW i4 Edrive 49</td>
<td>0</td>
<td>1,424</td>
<td>2.1</td>
</tr>
<tr>
<td>Hyundai Ioniq 5</td>
<td>0</td>
<td>1,190</td>
<td>1.7</td>
</tr>
<tr>
<td>Rivian EDV</td>
<td>0</td>
<td>1,187</td>
<td>1.7</td>
</tr>
<tr>
<td>BMW iX Xdrive 50</td>
<td>0</td>
<td>841</td>
<td>1.2</td>
</tr>
<tr>
<td>Ford Transit van</td>
<td>0</td>
<td>784</td>
<td>1.1</td>
</tr>
<tr>
<td>KIA EV6</td>
<td>0</td>
<td>688</td>
<td>1.0</td>
</tr>
<tr>
<td>BMW i4 M50</td>
<td>0</td>
<td>539</td>
<td>0.8</td>
</tr>
<tr>
<td>Volvo C40</td>
<td>0</td>
<td>477</td>
<td>0.7</td>
</tr>
<tr>
<td>Toyota BZ4X</td>
<td>0</td>
<td>257</td>
<td>0.4</td>
</tr>
<tr>
<td>Rivian R1S</td>
<td>0</td>
<td>217</td>
<td>0.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>model</th>
<th>sales Nov-21</th>
<th>sales Nov-22</th>
<th>share of the Nov 22 EV market in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercedes-Benz EQB</td>
<td>0</td>
<td>164</td>
<td>0.2</td>
</tr>
<tr>
<td>Genesis GV60</td>
<td>0</td>
<td>142</td>
<td>0.2</td>
</tr>
<tr>
<td>Audi E-tron sportback</td>
<td>0</td>
<td>70</td>
<td>0.1</td>
</tr>
<tr>
<td>Mercedes-Benz EQE</td>
<td>0</td>
<td>61</td>
<td>0.1</td>
</tr>
<tr>
<td>Cadillac Lyriq</td>
<td>0</td>
<td>43</td>
<td>0.1</td>
</tr>
<tr>
<td>Cruise AV</td>
<td>0</td>
<td>32</td>
<td>0.0</td>
</tr>
<tr>
<td>BMW i7</td>
<td>0</td>
<td>31</td>
<td>0.0</td>
</tr>
<tr>
<td>Genesis G80</td>
<td>0</td>
<td>26</td>
<td>0.0</td>
</tr>
</tbody>
</table>

**Total sales Nov-22:** 10,390

TESLA STOCK PRICES: 2020 – 2023

$1.24 trillion market value peak on Nov 4, 2021

$390 billion 68% decline since peak

$ 1.2
$ 0.8
$ 0.4
$ 0.0

2020 2021 2022 2023

**TESLA’s MANY CHALLENGES**

- *Tesla*, for the longest time, could do no wrong has capped off a rough 2022 with an awful December, with losses of about $219 billion of market value from December 1 – 23, 2022 – roughly, the market value of *Toyota*.

- Key contributors to this situation include:
  - drastic production and price cuts in *China*
  - heavy discounting in the *US*, where *Tesla’s* growth seemed unabated for a decade.

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**TESLA’s MANY CHALLENGES**

- lack of attention/focus due to Elon Musk’s purchase of *Twitter*
- Musk’s repeated sales of *Tesla* shares
- challenges posed by a tough economy with high inflation and rising interest rates
- inability to keep at bay the many legacy automakers pushing into the *EV* market
TESLA’s MANY CHALLENGES

- *Tesla* must deliver reinforcements for its product line in 2023 and reveal plans for
  - the systematic, scaled-up production of the multi-year delayed delivery of its Semi truck that ended on December 1, 2022
  - specifics on the start of the production of its first pickup – the *Cybertruck*

THE 2019 CYBERTRUCK PROTOTYPE

*Source: Photograph by Frederic J. Brown, AFP, in Bloomberg Hyperdrive, December 24, 2022*
**TESLA MODEL Y PRICES VARY BY POINT OF PURCHASE**

<table>
<thead>
<tr>
<th>Country</th>
<th>Price in US $ on 11/23/2022</th>
</tr>
</thead>
<tbody>
<tr>
<td>MO</td>
<td>49.5 k</td>
</tr>
<tr>
<td>NZ</td>
<td>48.4 k</td>
</tr>
<tr>
<td>JP</td>
<td>46.3 k</td>
</tr>
<tr>
<td>EE, LV, LT, SK</td>
<td>44.3 k</td>
</tr>
<tr>
<td>CN</td>
<td>40.4 k</td>
</tr>
</tbody>
</table>

Source: Tesla data as reported in Bloomberg Hyperdrive, 11/28/2022

**ANNUAL EV SHARE OF LIGHT DUTY VEHICLE SALES**

![Graph showing annual EV share of light duty vehicle sales over years 2016 to 2022 for California and US.]

Source: The Business Council for Sustainable Energy; https://bcse.org/factbook; p. 33
JURISDICTIONS THAT ADOPTED CA VEHICLE EMISSIONS STANDARDS


Source: IHS Markit / Auto Manufactures Alliance, Advanced Technology Sales; chart by Loren McDonald / EVAdoption, LLC; available at https://evadoption.com/us-

hybrid-and-phev-sales-growth-rate-outpaced-bevs-in-2021

FCEV  PHEV  BEV  HEV  alternative powertrains

increase in % from 2020 to 2021
SHARE OF TOTAL US ALTERNATIVE POWERTRAIN SALES: 2020 – 2021


NORWAY MONTHLY POWERTRAIN MARKET SHARE: DEC 2019 – FEB 2023

NORWAY NEW CAR SALES EV SHARE GROWTH: 2011 – 2022

diesel & petrol, including hybrids

electric

%  
100  80  60  40  20  0

2011  2013  2014  2017  2020

79%  21%

NORWAY ANNUAL CAR SALES:
2011 – 2022

US IMPORTS OF THE MINERALS USED IN EV BATTERIES

The imports’ share of the 2020 US mineral consumption

- Cobalt 76%
- Graphite 100%
- Lithium 50%
- Manganese 100%
- Nickel 50%


BIDEN INVOKES DPA ON MINERAL IMPORTS

- President Biden on March 31, 2022, invoked the Defense Production Act – DPA – to spur domestic mining and processing of minerals used to make batteries for EVs and energy storage resources
  - This effort aims to strengthen US energy independence and to develop more domestic production of storage technology
BIDEN INVOKES *DPA* ON MINERAL IMPORTS

- The directive supports *lithium, graphite, cobalt, manganese* and *nickel* production/processing

- Department of Defense is tasked to perform feasibility studies that adhere to "strong" environmental, labor, community and tribal consultation standards

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The directive, via the deployment of a Cold War relic, is timely since the minerals supply chain reliability is absolutely essential to the effective domestic manufacturing of batteries for *EVs*

- Notwithstanding the limited scope of the Biden administration’s *DPA* invokement, the action is significant since it sends a markets signal of its aim to bolster domestic battery production
THE STATUS OF GLOBAL PUBLIC CHARGING

- As EV sales increase at a pace much faster than the number of public charging ports, the criticality of the EVCI development is becoming a more pressing issue globally.

- The BNEF 2022 public charging report indicates that the global number of EVs on the road per public charging port rose to 9.2 at the end of 2021 from 7.4 at the end of 2020.

THE STATUS OF GLOBAL PUBLIC CHARGING

- The public charging facility developments in 2021 failed to keep pace with the 2021 global EV sales of 6.6 million cars, with the singular exception of China, whose ratio of the number of EVs to that of charging ports remained basically unchanged since 2018.

- China’s push to expand its EVCI has resulted in the fact that more than half the world’s public...
charging ports are in China

- The rapid increase in the deployment of EVs in the US was not accompanied by a larger number of public chargers and, therefore, there are fewer chargers per EV or there are more EVs per charging port than in earlier years

- The situation is even more acute in Europe, where,

EV sales surged since 2019, e.g., Germany’s ratio of the number of EVs per public charging point grew from 8 in 2019 to 20 in 2021 and in Norway – the most mature EV market in the world – the ratio is in the range of 30 to 40 EVs on the road per public charging port
THE STATUS OF GLOBAL PUBLIC CHARGING

- A very similar situation exists for DCFCs in the respective regions – China has 16 EVs for every ultra-fast charger and the US ratio is about 100.

- The number of 350-kW stations that are capable to add 100 km of range to an EV in just a few minutes is growing globally – a timely development as the trend to electrify trucks and pickups gets into a higher gear.

EV CHARGING AT ONE OF THE 4 MILLION CHINA CHARGING UNITS

Source: Getty images in the New York Times, September 26, 2022
ANNUAL GLOBAL RATIO OF EVs PER PUBLIC CHARGING POINT: 2014 – 2021

a public charging point is the number of individual charging connectors

RATIO OF EVs PER PUBLIC CHARGING POINT BY COUNTRIES: 2014 – 2021

Source: BNEF data in Bloomberg Hyperdrive issue of April 12, 2022
**RATIO OF EVs PER FAST/ULTRA-FAST PUBLIC CHARGING POINT: 2017 – 2021**

![Graph showing the ratio of EVs per fast/ultra-fast public charging point from 2017 to 2021. The graph compares different countries including the US, Norway, Germany, the UK, and China.]

Source: BNEF data in Bloomberg Hyperdrive issue of April 12, 2022

**MEAN NUMBER OF CHARGING CONNECTORS PER CHARGING STATION BY OPERATORS**

<table>
<thead>
<tr>
<th>Operator</th>
<th>Average Number of Ultra-Fast Charging Points Per Site, by Operator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tesla</td>
<td>10</td>
</tr>
<tr>
<td>BKK</td>
<td>3.8</td>
</tr>
<tr>
<td>Fastned</td>
<td>3.6</td>
</tr>
<tr>
<td>Ionity</td>
<td>3.5</td>
</tr>
<tr>
<td>Statkraft</td>
<td>2.9</td>
</tr>
<tr>
<td>BP</td>
<td>2.4</td>
</tr>
<tr>
<td>Shell</td>
<td>2.0</td>
</tr>
<tr>
<td>Allego</td>
<td>2.0</td>
</tr>
<tr>
<td>EnBW</td>
<td>2.0</td>
</tr>
</tbody>
</table>

Average number of ultra-fast charging points per site, by operator.
THE 10 LARGEST US CHARGING NETWORKS: 2021

LARGEST US DCFC NETWORKS: 2021

- Tesla: 12,580 ports, 58.0% share
- Electrify America: 3,112 ports, 14.4% share
- EVgo network: 1,711 ports, 7.9% share
- ChargePoint network: 1,675 ports, 7.7% share
- non-networked: 909 ports, 4.2% share
- Francis Energy: 545 ports, 2.5% share
- greenlots: 477 ports, 2.2% share
- others: 667 ports, 2.9% share

21,676 installed DCFC ports in the US

Source: evadoption.com; available at https://evadoption.com/ev-charging-stations-statistics/us-charging-network-rankings/
### LARGEST US LEVEL 2 NETWORKS: JANUARY 1, 2022

<table>
<thead>
<tr>
<th>Network</th>
<th>Ports</th>
<th>Share of Tesla Destination of the total level 2 ports</th>
</tr>
</thead>
<tbody>
<tr>
<td>ChargePoint network</td>
<td>47,114</td>
<td>51.5%</td>
</tr>
<tr>
<td>Tesla Destination</td>
<td>14,677</td>
<td>16.0%</td>
</tr>
<tr>
<td>non-networked</td>
<td>10,519</td>
<td>11.5%</td>
</tr>
<tr>
<td>SemaConnect network</td>
<td>5,802</td>
<td>6.3%</td>
</tr>
<tr>
<td>Blink network</td>
<td>3,158</td>
<td>3.4%</td>
</tr>
<tr>
<td>EV connect</td>
<td>2,774</td>
<td>3.0%</td>
</tr>
<tr>
<td>Greenlots</td>
<td>2,309</td>
<td>2.5%</td>
</tr>
<tr>
<td>Volta</td>
<td>2,199</td>
<td>2.4%</td>
</tr>
<tr>
<td>others</td>
<td>2,987</td>
<td>3.4%</td>
</tr>
</tbody>
</table>

**Source:** evadoption; available at https://evadoption.com/ev-charging-stations-statistics/us-charging-network-rankings/
The higher ratios of the number of EVs on the road to the number of charging stations is not necessarily a bad outcome since many charging stations are currently under-utilized; but, these high ratios signal the need for more private investment in EVCI and to achieve such an outcome, higher utilization per charger is required to improve the economics of charging station operations.

Given the slow pace of development in EVCI, one may conclude that a successful business model is yet to be established for EVCI stations; such a situation is not surprising given the wide array of issues, such as EVSE, siting costs, electricity tariffs, charging speeds, government regulation, fee/pricing structure, support and permitting, that need to be considered and effectively addressed.
THE HIGHER NUMBER OF *EV*s PER PUBLIC CHARGING STATION

- We illustrate the complexity and challenges in the *EVCI* business model: consider the determination of the appropriate number of station chargers—an issue that requires to keep in balance competing objectives: charging station operators desire more charging sessions per day, but too many sessions imply that there are times when drivers must wait because of queues at occupied ports, resulting in *undesirable customer experience*; while operators aim for high utilization, it cannot be so high as to cause *customer frustration*.

A BUMP–UP IN BATTERY PRICES IN 2022

*volume–weighted average in 2022 $/kWh*

Source: Bloomberg, January 13, 2023
THE INCREASED SHARE OF **LFP** BATTERIES IN **CHINESE EVs**

Source: Bloomberg Hyperdrive, 11/15/2022

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**THE EV FRUNK**

- Some *EVs* come with front trunks, which are typically referred to as *frunks*.

- *EV* carmakers remain split on the *frunk*:
  - some *EV* models for sale in the **US** have super-sized them to emphasize their *novelty* and *utility*.

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THE EV FRUNK

- A third of models, however, skip the frunk altogether to free up cabin space on the basis that customers accustomed to frunkless cars will not necessarily need one when they go electric.
- The remaining third uses the frunk to store the adapters for use in different EVCI station charging ports.

For example, Ford uses the frunk to attract new customers to their EVs: the almost 5-ft³ storage of the Ford Mustang Mach-E frunk has been a hit with EV shoppers and Ford is marketing the refrigerator-sized front trunk that comes standard on two of its electric vehicles, complete with drain, as a sushi bar on wheels.
THE FORD MUSTANG MACH-E FRUNK

FORD's MUSTANG MACH-E FRUNK FITS TAILGATING NEEDS
AN ULTRA LOW EMISSION ZONE SIGN AT TOWER HILL, CENTRAL LONDON

Source: Yui Mok/PA Wire, published in Bloomberg Hyperdrive, November 25, 2022

TOWARDS CLEANER AIR IN LONDON

- London charges drivers of ICEVs £12.50 ($15) a day to drive in the Ultra Low Emission Zone that spans London’s central and inner boroughs; failure to pay results in a fine of £160

- London expanded the ULEZ to the city’s outer reaches in August 2022 to combat air pollution to improve air quality and speed up the EV transition
THE ELECTRIFICATION OF SCHOOL BUSES

School buses constitute the largest form of U.S. public transportation, with nearly 25 million students riding on them to school and back. At present, fewer than 1% of the nation’s school buses are fueled by electricity. The application of EV advances to school bus technology and the effective use of the federal government funding under the Infrastructure Investment and Jobs Act (II&JA) of 2021 are key.
THE ELECTRIFICATION OF SCHOOL BUSES

drivers to make the adoption of ESBs – electric school buses – a viable option for school districts

- ESBs equipped with V2G technology can reduce GHG from both the transportation and power generation sectors – the two US economy sectors that contribute most of GHG emissions
- the replacement of the large number of school buses by ESBs, by itself, results in a sizeable reduction of GHG emissions;

- the effective deployment of ESBs’ batteries can further reduce utilization of polluting resources and wholesale electricity market prices to aid energy transition and encourage deeper renewable energy resource penetrations; and,

- in addition to these environmental benefits, the wider deployment of ESB fleets equipped
THE ELECTRIFICATION OF SCHOOL BUSES

with V2G technology improve the health of the population in their locations

- The wider deployment of ESB fleets equipped with V2G technology can benefit the grid and the electricity consumers with the services such fleets provide to the grid through the effective utilization of their aggregated batteries in terms of:
  - various demand response and demand management applications such as peak clipping, valley filling and load shaping;
  - emergency support to enhance the electricity reliability during peak demand periods; and
  - reduction of the investment made by utilities due to the provision of these support services and thereby bring in new revenue streams to the school districts
THE ELECTRIFICATION OF SCHOOL BUSES

- The realization of such benefits will require the formulation of supportive policies and their enactment into legislative initiatives at all levels of government – local, county, state and federal – together with the implementation of tariff modifications by regulatory agencies, and the cooperation of school districts.

- Specifically, the formulation of effective incentives will create a major push to the wider and more effective deployment of ESBs.

CON EDISON ESB DEMONSTRATION PROJECT

- Con Edison reported its findings of a demonstration project with the objective to determine the technical and economic viability of using V2G-equipped school buses to support the grid at times of high demand for electricity.

- Con Edison worked with bus manufacturer Lion Electric, White Plains school bus contractor National Express and project developer First Priority Group.
CON EDISON ESB DEMONSTRATION PROJECT

Electrified (FPGe) and energy technology company Nuvve Holding Corp to undertake the three-year study that was performed with 5 ESBs that took elementary school students in White Plains, NY, to their classes each day

- Three of the buses were retrofitted with power converters to allow them to perform V2G bi-directional charging

The study showed that electrification of school buses can provide benefits to school districts, transportation providers and utility customers without deleterious impacts on the batteries:

- the utilization of the batteries for both transportation and grid support causes the batteries to degrade just as much as for transportation only
CON EDISON ESB DEMONSTRATION PROJECT

- Bus availability and transportation performance of EBSs were almost the same as that of the diesel buses.
- Roughly 85% of the battery energy reached the grid – 15% losses were in line with the Con Edison criteria.

The project demonstrated the feasibility of the V2G-equipped EBSs to support the grid at times when demand for power is high, which is usually on hot summer NY afternoons.

Overall, the results indicate the huge potential to deploy ESBs on a large scale to discharge power into the grid at times of peak loads and the associated benefits for school districts, transportation providers and utility customers that the electrification of school buses can provide.
US POSTAL SERVICE PLANS TO ELECTRIFY

- On December 20, 2022, the USPS unveiled its plans to include the purchase of 66,000 electric delivery vehicles that will constitute one of the biggest electric fleets in the US.

- USPS estimated costs of $9.6 billion for the EVs and the EVCI construction benefit from $3 billion support provided by the Inflation Reduction Act.

The purchases from 2 suppliers consist of:

- 60,000 next generation delivery vehicles or NGDV s from defense contractor Oshkosh, of which 45,000 will be electric, i.e., ENGDV s

- 46,000 mainstream OEM vehicles, of which 21,000 will be EV s
THE FUTURE USPS FLEET

Oshkosh

other US car manufacturers

<table>
<thead>
<tr>
<th>Oshkosh</th>
<th>Other US car manufacturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>45,000  EVs</td>
<td>21,000 EVs</td>
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<tr>
<td>15,000</td>
<td>25,000</td>
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</tbody>
</table>

Source: Jacob Bogage, “Postal Service will electrify trucks by 2026 in climate win for Biden,” Washington Post, December 20, 2022; online at https://www.washingtonpost.com/business/2022/12/20/usps-ev-vehicles/

US POSTAL SERVICE PLANS FOR ELECTRIFICATION

- The USPS has over 217,000 ICEVs that make up the largest part of the civilian fleet owned by the federal government.
- The USPS must replace its 30-year-old fleet of vans/trucks which have no air conditioning, air bags and other standard safety features and has a very poor fuel efficiency – its current value is a mere 8.2 mpg for the boxy white vans.
USPS PLANS: IMPLICATIONS

- USPS plans represent a concrete and significant step towards a zero-emission fleet by the federal government.
- The Biden administration intends to use the USPS fleet as a role model for USPS competitors to adopt zero-emission vehicles (ZEVs) on a speedier basis.
- More generally, the deployment of electric models for the boxy, white mail vans can provide useful examples to US drivers to adopt ZEVs.

AFFORDABILITY OF US EVs

- The analysis by EV Adoption of US EV prices indicates that 67 of the 82 available EV and PHEV models in the US in 2022 have a base manufacturer’s suggested retail price (MSRP) above $39,999.
- The actual purchase prices exceed the base MSRP as they include non-standard features, additional options and upgrades, delivery charges, sales tax and fees.
In addition, dealers/showrooms may charge so-called dealer market adjustments – additional markups that are typical for luxury vehicles.

The average transaction price for an EV in the US in September 2022 was $65,291 according to the Kelley Blue Book.

The lack of EVs available at or below $30,000 is a huge barrier to the mass adoption of EVs.

### US EV 2022 MSRP DISTRIBUTION BUCKETS

<table>
<thead>
<tr>
<th>MSRP in k$</th>
<th>number of BEV/PHEV models</th>
</tr>
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<tbody>
<tr>
<td>20–29</td>
<td>5</td>
</tr>
<tr>
<td>30–39</td>
<td>10</td>
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<td>90–99</td>
<td>12</td>
</tr>
<tr>
<td>&gt;100</td>
<td>2</td>
</tr>
</tbody>
</table>

mean BEV/PHEV MSRP = $75,637  
BEV MSRP = $66,520  
PHEV MSRP = $87,879 ($64,479)  
median BEV/PHEV MSRP = $56,900

Source: Manufacturer website data as published in the EV adoption article at https://evadoption.com/
A MORE AGGREGATED MSRP DISTRIBUTION

- $70,000+:
  - 31 models – 37.8%
- Under $40,000:
  - 15 models – 18.3%
- $40,000 – $69,999:
  - 36 models – 43.9%

Source: Manufacturer website data as published in the EV adoption article at https://evadoption.com/

PG&E’s BI-DIRECTIONAL EV RESIDENTIAL CHARGING PROGRAM

- PG&E entered into a partnership with GM to create a bi-directional EV program able to supply homes and small businesses with the electricity stored in the EVs located on site; a pilot program in Summer 2022 tested V2G and V2H – vehicle-to-home – systems

- The key objective of the PG&E – GM pilot program was to determine the extent of the capability of the
EVs are entering rental companies’ fleets

- Tesla, GM and Polestar – the all-electric automaker controlled by Volvo and its Chinese owner Zhejiang Geely Holding Group – have signed fleet deals with rental companies that exploit the economies of scale of OEMs from the increased sales to fleets

- For example, GM has agreed to supply 175k EVs to Hertz over the next 5 years; Hertz also secured 100k EVs from Tesla and another 100k EVs from Polestar

These fleet deals benefit both the buyers/sellers:

- EVs command an extra $30 – 35 a day at the rental company counter, despite the lower fueling and maintenance costs
- the EV resale values are also stronger than those for many ICEVs
- marketing studies indicate that rental companies can prime the market for EV sales since car buyers are twice as likely to consider an EV once they have driven one
PG&E’S BI-DIRECTIONAL EV RESIDENTIAL CHARGING PROGRAM

V2G and V2H systems to improve the PG&E distribution grid reliability

- CA Senate Bill 676 required the CPUC to formulate strategies and metrics to integrate EVs into the grid by 2030; the PG&E – GM pilot program is an initiative under the CPUC-approved framework for the integration of EVs into the grid to comply with the Senate Bill 676 requirements

Testing tasks comprised the installation of EV chargers and bi-directional hardware & communication software used to coordinate among the home/business network, EVs and the PG&E distribution grid

- PG&E developed a mechanism to specify the price signals to use the EV batteries to serve home/business demand and grid load with the explicit consideration in the rates for electricity supplied to the customer of the worth of a charged EV to provide mobility


**PG&E'S BI-DIRECTIONAL EV RESIDENTIAL CHARGING PROGRAM**

- The creation of the tariff for the bi-directional EV charging program modified the two current time-of-use rate tariffs for EVs:
  - home-charging EV-2A, under which the electricity to charge the EV is combined with that to serve the customer electricity needs;
  - home-charging EV-2B, under which the electricity to charge the EV is separated from that for the customer needs and requires the installation of an additional meter.

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**PG&E AND FORD ASSESS THE F-150 EV FOR GRID SUPPORT**

On the heels of PG&E’s announcement of a collaborative effort with GM to assess the ability of GM EVs to act as on-demand electricity sources for homes, the utility started a joint effort with Ford to study the capability of F-150 Lightning EV trucks to provide reliability services in terms of backup energy for customers’ homes.

GM HUMMER EV

- 9,000 + lbs
- 329 mi range
- 100 mi charge in 12 m with an 800-V DCFC
- $112,595

Source: BNEF data in Bloomberg Hyperdrive issue of April, 12, 2022

THE NEW NISSAN ARYA EV


ECE 398GG © 2022–2023 George Gross, University of Illinois at Urbana-Champaign, All Rights Reserved.
HYUNDAI IONIQ5 2022 EV


WULING HONGGUANG WAS CHINA’S BEST-SELLING EV IN 2021

Source: Getty images in the New York Times, September 26, 2022
**BYD TANG PHEV MODEL**

Source: Bloomberg photo in Bloomberg Hyperdrive, 11/14/2022

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**BYD EVs AT THE WUHAN, CN, AUTO SHOW IN JULY 2022**

Source: Getty images in the New York Times, September 26, 2022
THE VOLVO EX 90

ROLLS-ROYCE's ELECTRIC SPECTRE COUPE
THE NEW *TESLA SEMI*

- *Tesla*’s all-electric semi truck has completed its first 500–mile journey on a single charge with an 81,000–lb load in December 2022.
- The successful test run is a major milestone for the future of trucking as none of the competitor manufacturers – *Mercedes*, *Volvo* or *Nikola* – has achieved long-range test runs on this scale.
- *Tesla* initially announced its plans to build a semi in 2017 with a target release date of 2019.

*Tesla* initially announced its plans to build a semi in 2017 with a target release date of 2019.
- The adoption of electric trucks will take considerable time but the buyers are interested in *all-electric semi trucks* to meet their emission target goals.
- The key challenges are to scale up production levels of the manufacturing sector to meet the eventual demand and to incorporate into the *EVCI* the charging needs of the demands of the semis.
THE NEW *TESLA SEMI*

Source: Tesla Photo, available online at https://electrek.co/2022/12/02/tesla-semi-96kwh-battery-pack-but-more-answers-needed/

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**SIGNIFICANT IMPACTS OF THE IRA**

- The nature and scope of the *IRA* tax credit and incentive provisions are such that the *IRA* is *primarily an industrial policy legislation* rather than a climate change mitigation instrument

- The *IRA* tax credit provisions are for *EVs* that are assembled in *North America*, with batteries produced/manufactured in *North America* and using raw materials sourced from *US, Canada or Mexico*
SIGNIFICANT IMPACTS OF THE IRA

- Beyond the tax subsidies to EV buyers at the point of purchase, IRA has provisions for tax credits to US-based battery cell and pack manufacturers: these tax credits provide 35 $/kWh for battery cell assembly plus 10 $/kWh for battery packs
- These incentives have led to a series of major investments by various foreign companies to establish US-based manufacturing of batteries

Over 13 billion $ of investment in raw battery material production and battery and EV manufacturing has been announced since August 16, 2022:

- Honda and Toyota earmarked almost 7 billion $ for EV battery plant investments
- An Australian development company started
SIGNIFICANT IMPACTS OF THE IRA

- up the first US Cobalt mine in 30 years
- Volkswagen and Mercedes-Benz contracted to secure Canadian mining/refining resources
- BMW announced a 1.7 billion $ expansion of its South Carolina SUV factory
- A detailed study by UBS indicates that the wave of investment unleashed by the IRA tax credits may make battery cell manufacturing highly profitable in the US and lead to a battery boom

Source: Bloomberg Hyperdrive, 11/08/2022