The Macroeconomic Benefits of the EV Transition

Elaine Buckberg, Chief Economist, General Motors
September 15, 2022
GM aspires to eliminate tailpipe emissions from new light-duty vehicles.

GM commits to 100% renewable energy for electricity to power global facilities.

GM aspires to be carbon neutral in global products and operations.
Everybody In: consumers want a no compromises EV

**COST**
COMPETITIVE WITH ICE ENGINE

Lower operating costs expected to offset any premium in ~3 years.

**COMPARABLE RANGE**
WITH ICE ENGINE

350+ miles of range.

**UBIQUITOUS, CONVENIENT, AND FAST CHARGING**

Fast charging required to spur adoption, but current owners prefer home charging.

**BROAD BODY STYLE CHOICE**

With strong interior and exterior styling.
U.S. consumer interest in EVs has grown 110% since 2017, with strong EV consideration across all segments.

Across All Segments, Consumers Indicate Strong EV Consideration

<table>
<thead>
<tr>
<th>Segment</th>
<th>U.S. EV Consideration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Market</td>
<td>50%</td>
</tr>
<tr>
<td>Luxury</td>
<td>64%</td>
</tr>
<tr>
<td>Pickups (Mid + Large)</td>
<td>44%</td>
</tr>
<tr>
<td>Mainstream Car</td>
<td>52%</td>
</tr>
<tr>
<td>Mainstream SUV</td>
<td>46%</td>
</tr>
</tbody>
</table>

% of U.S. Consumers Who Rate Electric Propulsion As Appealing

- 20% (2017)
- 31% (2021)
- 42% (2022)

110% increase
Third-party forecasts of U.S. EV adoption range widely but center around ~40% in 2030

<table>
<thead>
<tr>
<th></th>
<th>2025</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goldman Sachs (3/22)</td>
<td>20%</td>
<td>50%</td>
</tr>
<tr>
<td>UBS (4/22)</td>
<td>17%</td>
<td>48%</td>
</tr>
<tr>
<td>BCG (6/22)</td>
<td>19%</td>
<td>47%</td>
</tr>
<tr>
<td>EV-Volumes (8/22)</td>
<td>16%</td>
<td>43%</td>
</tr>
<tr>
<td>BNEF (6/22)</td>
<td>14%</td>
<td>39%</td>
</tr>
<tr>
<td>LMC (3/22)</td>
<td>13%</td>
<td>36%</td>
</tr>
<tr>
<td>IHS (5/22)</td>
<td>15%</td>
<td>35%</td>
</tr>
<tr>
<td>Guidehouse (12/21)</td>
<td>9%</td>
<td>26%</td>
</tr>
<tr>
<td>Morgan Stanley (10/20)</td>
<td>10%</td>
<td>25%</td>
</tr>
<tr>
<td>Median Forecast</td>
<td>15%</td>
<td>39%</td>
</tr>
</tbody>
</table>
EV industry penetrations are 4.7% for CYTD 2022, more than doubling 2020 levels

Sources: IHS Polk Registrations
Battery costs have declined ~20% per year, while EV range is increasing

Source: Bloomberg New Energy Finance

Volume-Weighted Average Battery Pack Cost
Real 2021 $/kWh

U.S. Electric Range, Miles

Source: Fuel economy.gov
Most of the EV growth so far has been in luxury cars and SUVs, but a tremendous opportunity exists in the mainstream market.
Number of U.S. EV entries increasing exponentially

Total U.S. EV Entries

- 2021: 29
- 2023: 89
- 2025: 170

Sources: General Motors, IHS VPaC May 2022 (minimum 100 sales)

ev.png

Top EV Segments in U.S.

- SUV/Crossover: 2021: 9, 2023: 9, 2025: 25
- Pickup: 2021: 1, 2023: 6, 2025: 11

Sources: General Motors, IHS VPaC May 2022 (minimum 100 sales)
At current gas prices, a BEV saves ~$1.4K in fuel costs per year based on national average electricity rates and gas prices.

<table>
<thead>
<tr>
<th></th>
<th>Battery Electric Vehicle (BEV)</th>
<th>Internal Combustion Engine (ICE)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Current</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$5.00/gal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$4.00/gal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$3.00/gal</td>
</tr>
<tr>
<td>Miles/yr$^1$</td>
<td></td>
<td>12,416</td>
</tr>
<tr>
<td>Electricity ($/kWh)$^2$ or Gasoline ($/gal)</td>
<td>$0.15</td>
<td>$3.75$^3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$5.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$4.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$3.00</td>
</tr>
<tr>
<td>Miles/kWh$^4$ or Miles/gal$^5$</td>
<td>3.1</td>
<td>23.6</td>
</tr>
<tr>
<td>Fuel cost/yr</td>
<td>$601</td>
<td>$1,973</td>
</tr>
<tr>
<td></td>
<td>$2,631</td>
<td>$2,104</td>
</tr>
<tr>
<td></td>
<td>$1,578</td>
<td></td>
</tr>
<tr>
<td>BEV savings</td>
<td>$1,372</td>
<td>$2,030</td>
</tr>
<tr>
<td></td>
<td>$1,503</td>
<td>$977</td>
</tr>
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</table>

1. Annual miles per vehicle according to Highway Statistics 2000; fhwa.dot.gov
2. US average residential cost of electricity per kWh, Apr 2022; eia.gov
3. US average retail gasoline price (regular grade), September 8, 2022; gasprices.aaa.com
4. Median efficiency of 2021 MY electric vehicles is 104 mpge (or 3.1 mi/kWh); fueleconomy.gov
5. Median fuel economy of 2021 MY gasoline vehicles; fueleconomy.gov
Early adopters will do majority of charging at home or work

U.S. Energy Demand, Home-Centered Scenario

% of kilowatt-hours

Source: McKinsey, Charging ahead: electric vehicle infrastructure demand
Policy matters: Recent federal policies that will drive EV investment and adoption

1. $7.5B of public investment in charging stations

2. Consumer EV purchase incentives for new, used, and commercial EVs

3. Production tax credits to support domestic critical mineral processing and EV battery production

4. Grants to support transition of auto manufacturing facilities to EV production

5. More stringent GHG and fuel economy standards
<table>
<thead>
<tr>
<th>Phase-Out Year</th>
<th>Market</th>
<th>Market (Cities and States)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2025</td>
<td>Norway</td>
<td>London</td>
</tr>
<tr>
<td>2030</td>
<td>Iceland, Sweden,</td>
<td>Los Angeles, Seattle,</td>
</tr>
<tr>
<td></td>
<td>Ireland, Israel,</td>
<td>Paris, Barcelona</td>
</tr>
<tr>
<td></td>
<td>Netherlands,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Singapore</td>
<td></td>
</tr>
<tr>
<td>2035</td>
<td>Denmark, United</td>
<td>California, Massachusetts,</td>
</tr>
<tr>
<td></td>
<td>Kingdom</td>
<td>New York</td>
</tr>
<tr>
<td>2040</td>
<td>Canada, China,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>France, Portugal,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spain, Taiwan</td>
<td></td>
</tr>
</tbody>
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The EV Supply Chain
Establishing a sustainable EV raw material value chain

GM is actively pursuing opportunities to localize as much of the supply chain as possible.

Partnerships created for lithium, cobalt, rare earths, alloy flakes, permanent magnets, and CAM.

Recycling should be the primary source of battery raw materials in the long term.

*Recycling today:* cobalt, nickel

*Future recycling:* cobalt, nickel, lithium, graphite, copper, manganese, and aluminum
GM sustainable EV supply chain partnerships

Lithium:
- **Controlled Thermal Resources** to secure lithium produced by the 1st stage of its California Hell’s Kitchen Project.
- **Livent** will supply battery-grade lithium hydroxide under a multi-year agreement, with the goal of transitioning 100% of Livent’s downstream lithium hydroxide processing for GM to North America.

Cobalt with Glencore, which will supply Australian cobalt under a multi-year agreement.

Rare earth materials with GE, to develop a rare earth value chain.

Alloy flakes with MP Materials, which will establish the first North American processing site for alloy flakes. The company will expand into magnet manufacturing ~2025 at its new production facility in Fort Worth, TX.

Permanent magnets with VAC, which will establish a North America footprint to support GM’s magnet requirements starting in 2024, including locally sourced raw materials and finished magnet production.

CAM:
- **POSCO**: The Quebec site will process CAM, a key battery material consisting of components like processed nickel, lithium and other materials representing about 40% of the cost of a battery cell.
- **LG Chem** will supply CAM under a multi-year agreement, with enough CAM for ~5 million units of EV production. GM and LG Chem will also explore the localization of a CAM production facility in North America.
Our Ultium Cells LLC joint venture with LG Energy has an agreement with Li-Cycle to recycle up to 100% of material scrap from our battery cell manufacturing process.

Modular design of Ultium batteries also makes them easy to reuse or recycle.

*Recycling today:* cobalt, nickel

*Future recycling:* cobalt, nickel, lithium, graphite, copper, manganese, and aluminum using a new process that emits 30% fewer emissions than traditional recycling processes.

Recycling should be primary source of battery raw materials in the long term
Macroeconomic Stability Benefits of the EV Transition
What does the EV transition imply for the U.S. economy?

The EV transition can improve macroeconomic stability by reducing vulnerability to oil price shocks.

Shifting transportation energy demand from oil products to electricity will reduce U.S. energy price volatility. The energy sources that power the electricity grid are more diversified, have more stable prices, and are less affected by geopolitical risk.

Reduced vulnerability to oil supply shocks and less dependence on gasoline will insulate consumers from high and volatile gasoline prices, which have been found to negatively impact consumer sentiment, consumption, and GDP.

EVs can be powered by cleaner energy sources over time. Combined with optimizing charging times, emissions can fall substantially further.
Global oil market volatility drives volatile gas prices
U.S. gasoline prices are closely tied to international oil prices

Monthly Crude Oil ($/Barrel, left axis) vs. U.S. Regular Gasoline ($/Gallon, right axis)

Sources: EIA, Haver Analytics
Large run ups in oil price preceded several U.S. recessions

Inflation-Adjusted WTI Prices ($/Barrel) vs. Real GDP Growth (y/y % Chg.), with Recession Shading


general motors
U.S. EV owners are insulated from oil price volatility
Based on historical data, BEV fueling costs are lower and less volatile

Hypothetical Monthly U.S. Average Fueling Costs ($)

Fueling costs calculated assuming:

- 1,035 miles/month based on annual miles per vehicle of 12,416 according to Highway Statistics 2000; fhwa.dot.gov
- U.S. monthly average residential price of electricity per kWh. Residential electricity prices vary by state. Source: EIA, Haver Analytics
- U.S. monthly average regular gasoline price. Source: EIA, Haver Analytics
- Median efficiency of 2021 MY electric models is 104 mpg (or 3.1 mi/kWh). Source: fueleconomy.gov.
- Median fuel economy for 2021 MY is 23.6 miles per gallon. Source: epa.gov.
U.S. electricity grid is ~60% powered by coal and natural gas whose prices are less volatile than oil and in which the U.S. is self-sufficient.

Brent Prices vs. U.S. Cost of Fossil Fuels for Electricity Generation ($/M Btu)

Annual U.S. Natural Gas and Coal Net Imports (Quadrillion Btu)

Sources: EIA, Haver Analytics. Assume 1 barrel of crude oil = 5,691,000 Btu; EIA.

Since 2017, U.S. has been a net exporter of natural gas and coal.

Sources: EIA, Haver Analytics
U.S. coal and natural gas prices are lower than and less closely tied to international prices than oil.

**Annual Coal Prices ($/Metric Ton)**
- Northwest Europe Marker
- Japan Steam Spot CIF
- China Qinhuangdao Spot
- Japan Coking Coal Import CIF
- US Central Appalachian Coal Spot Index

**Annual Natural Gas Prices ($/M Btu)**
- Avg German Import
- Japan CIF
- Netherlands TTF DA Heren Index
- UK Heren NBP Index
- Canada Alberta
- Japan Korea Marker [JKM]
- OECD Countries CIF
- US Henry Hub

Sources: British Petroleum, Haver Analytics
U.S. vulnerability to oil price shocks has fallen greatly due to increased U.S. production and greater energy efficiency.

**U.S. Net Imports of:**
- << Crude Oil and Petroleum Products (M Brls/Day)
- Natural Gas (B Cubic Ft) >>

**U.S. Energy Intensity**
- 1970 = 100, Ratio of total primary energy consumption to real GDP

Sources: EIA, Haver Analytics

General Motors
Gasoline and diesel are 22-23% of current U.S. energy consumption and two-thirds of petroleum use.

**U.S. Share of Energy Consumption by Source**

<table>
<thead>
<tr>
<th></th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Petroleum</strong></td>
<td>37</td>
<td>35</td>
<td>36</td>
</tr>
<tr>
<td><strong>Motor Gasoline and Diesel</strong>¹</td>
<td>23</td>
<td>22</td>
<td>23</td>
</tr>
<tr>
<td><strong>Other Petroleum Products</strong>²</td>
<td>14</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td><strong>Natural Gas</strong></td>
<td>32</td>
<td>34</td>
<td>32</td>
</tr>
<tr>
<td><strong>Coal</strong></td>
<td>11</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td><strong>Nuclear</strong></td>
<td>8</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td><strong>Renewables</strong></td>
<td>11</td>
<td>12</td>
<td>13</td>
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¹Motor gasoline and diesel consumption for the transportation sector.

²Other petroleum products include liquefied petroleum gases and other; jet fuel; kerosene; distillate fuel oil use outside the transportation sector; residual fuel oil; petrochemical feedstocks; and other petroleum (e.g., aviation gasoline, road oil, misc. petroleum products).

Sources: EIA, Haver Analytics

General Motors
But sentiment remains closely tied to gas prices
Lower, stable EV fueling costs could positively impact sentiment

“Consumer sentiment becomes more pessimistic with rising gas prices. This effect is strongest for consumers who lived through the recessionary oil crises in the 1970s...”
- Binder and Makridis (2022)

“[W]e also find that aggregate demand and other oil demand shocks have significant influence on household satisfaction with economic policy measures ‘to fight inflation and unemployment.’”
- Güntner and Linsbauer (2018)

“[H]istorically energy price shocks have been an important factor in explaining U.S. real consumption growth, but by no means the dominant factor.”
- Edelstein and Kilian (2009)
Mass EV adoption would transform U.S. energy consumption even with the 2020 mix of electricity sources

**Calculations reflect different ICE parc share scenarios under an immediate EV transition, with the electricity grid mix as in 2020.**

- 2020 U.S. electricity generation sourced from coal ~19% and from natural gas is ~40%.  *Source: EIA*

- Assumes that EVs will use as much energy (in Btus) as ICE. Calculations based on 2021 MY EV efficiency and ICE fuel economy suggest EVs may potentially use less energy than ICE.

Sources: EIA, Haver Analytics
Increasingly renewable U.S. electricity generation will further increase climate benefits as the U.S. vehicle fleet transitions to EVs.

~60% electricity generation from fossil fuels in 2020 down to ~45% in 2040.

**U.S. Electricity Generation from Selected Fuels (billion kWh)**

- Coal
- Natural Gas
- Nuclear
- Hydroelectric
- Wind
- Solar

**Projections**

- Fossil Fuels ~60% in 2020
- Fossil Fuels ~45% in 2040

**Actuals**

Sources: EIA, Annual Energy Outlook 2022, Reference case; Haver Analytics
“Electrifying 100% of car miles traveled (thereby eliminating gasoline vehicle carbon emissions) increases electricity-sector carbon emissions by 23-27% if vehicles are charged at night but could decrease electricity-sector carbon emissions if vehicles are charged during the day.”

If you further net out avoided gas/diesel emissions from ICE vehicles, annual welfare gains of 100% EV adoption relative to zero EV adoption can increase by as much as 9%-28% with optimized charging (i.e., charging primarily in the afternoon).

The EV transition reduces U.S. vulnerability to macroeconomic shocks from oil price volatility and geopolitical risk. In doing so, it should reduce economic volatility.

The EV transition shifts U.S. energy consumption away from crude oil to self-sufficient sources that power the U.S. electricity grid.

EV owners can expect lower and more stable fueling costs on average recognizing that there may be local variation in electricity pricing. Avoiding gas price shocks should reduce downside to consumer sentiment.

The climate benefits of the EV transition will increase over time as the electricity grid becomes cleaner.