Impact of Transportation-Related Environmental Initiatives

Final Report
22nd May, 2020
Project C021273
Contents

- Executive summary
- Project report
- Appendix – I (Project report addendum)
- Appendix – II (Movement 101)
- Appendix – III (Summary of research)
37 U.S. and global Movements were assessed prior to shortlisting 14 U.S. specific Movements for long term impact assessment.

**Global Movements assessed**
- China Corporate Average Fuel Consumption (CAFC) standard Tolls
- EU Emission Standards
- Japan Energy Conservation Law
- South Korea Average Fuel Economy (AFE) program
- China NEV Mandate
- Norway Norsk Elbilforening
- EU Renewable Fuels Directive II (RED II)
- EU Fuels Quality Directive (FQD)
- London Congestion Charge
- Milan Area C
- Trängselskatt I Stockholm
- Canada Telework Policy
- EU Energy Taxation Directive (ETD)
- Autonomous Vehicle Bill
- EU Standard 2018/0143 (COD)
- France Mobility Law

**Movements excluded**
- Vehicle retirement program
- Tolls
- Parking benefits
- Passenger drones
- Multi-modal transit
- Delivery platforms
Each Movement’s influence on emissions, fuel economy, vehicle demand, cost and scale of impact were considered for assessment.

Movement Category:  
- Emissions, fuel economy and carbon pricing
- Alternative fuels
- Tolls, congestion pricing and telecommuting
- Mobility initiatives

Legend

**Effectiveness**: influence of a Movement on emissions reduction, fuel economy improvement and plug-in electric vehicle demand weighted equally.

**Cost**: cost to comply with a Movement.

**Impact**: scale of impact of a Movement:
- Localized impact from movements, limited to urban areas / few cities
- Movement adopted by few states
- National level movements / can be adopted federally

Source: Ricardo analysis
Telecommuting along with PEV subsidies and ZEV mandate are most effective in reducing emissions

**Movement Category:**
- **Emissions, fuel economy and carbon pricing**
- **Alternative fuels**
- **Tolls, congestion pricing and telecommuting**
- **Mobility initiatives**

**Impact:** considers scale of impact of a Movement
- Localized impact from movements, limited to urban areas / few cities
- Movement adopted by few states
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**Acronyms**
- Corporate Average Fuel Economy (CAFE)
- Transportation Climate Initiative (TCI)
- Low Carbon Fuel Standard (LCFS)
- Cleaner Trucks Initiative (CTI)
- Zero-Emission Vehicle (ZEV)
- Connected and Autonomous Vehicles (CAV)

*Source: Ricardo analysis*
Technological advancements in batteries will likely aid several Movements in the mid to long term

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Telecommuting</td>
<td>Telecommuting would reduce emissions by ~5% - 15% – equivalent to several other “Movements” – but at negligible cost</td>
</tr>
<tr>
<td>Emissions, fuel economy and carbon pricing</td>
<td>PEV “Movements” have the highest emissions reduction effectiveness though with relatively high cost. Subsidies most effective in near term</td>
</tr>
<tr>
<td>CAFE standard</td>
<td>Scaling back of CAFE standards will affect emissions reduction drawing higher reliance on PEVs to achieve desired impact</td>
</tr>
<tr>
<td>Biofuels</td>
<td>LCFS has had moderate success but will rely on PEV uptake in future. EPA continues to roll back RFS targets for 3 out of 4 alternative fuels; effectiveness of mandate under question</td>
</tr>
<tr>
<td>Carbon pricing</td>
<td>TCI and carbon pricing – though effective tools – may have marginal impact given the limited nationwide momentum they may generate</td>
</tr>
</tbody>
</table>
## Impact of Transportation - Related Environmental Initiatives

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**Movements range from federal to local mandates, and ones in proposal phase**

| Emissions, fuel economy and carbon pricing |  
|-----------------------------------------|---|
| **Subsidies**: Federal and state incentives offered to incentivize PEV adoption. Federal tax credit of up to $7,500 available for PEVs. Various state level rebates, HOV access etc. offered |  
| **ZEV mandate**: adopted in 1990 by California to control emissions from passenger vehicles decrees increasing ZEV floor requirements through 2025+. Adopted by 11 other states (CT, ME, MA, VT, RI, OR, NY, NJ, MD, CO, WA) |  
| **CAFE standard**: fleet wide average fuel economy targets to be achieved by passenger vehicle OEMs. SAFE rule implemented in March 2020 mandates ~1.5% CAGR growth in fleet fuel economy for MY 2021 – 2026. Scaled back CAFE standards mandated ~5% CAGR fuel economy improvement between 2020 – 2025 |  
| **Cleaner Trucks Initiative (CTI)**: is still in proposal phase and aims to address diesel commercial trucks NOX emissions in low load conditions. Estimated to impact model years 2025+ |  
| **Transportation Climate Initiative (TCI)**: is a still-in-work “cap & invest” initiative estimated to start in 2022. TCI seeks to reduce transportation emissions and develop a clean energy economy in 12 Northeastern regions |  
| Numerous **carbon pricing** initiatives have been proposed; however none has been enacted into legislation. Distribution of revenue from most proposed carbon pricing initiatives are not targeted towards transportation |  

| Alternative fuels |  
|-------------------|---|
| **LCFS**: adopted by California and Oregon mandates reduced “Carbon Intensity (CI)” of fuels over time. 20% CI reduction targeted by 2030 compared to 2010 level |  
| **RFS**: is a federal biofuel standard passed in 2005 with aim of blending ~36B gallons of biofuels by 2022 in U.S. fuel mix |  

| Tolls, congestion pricing and telecommuting |  
|---------------------------------------------|---|
| **Telecommuting**: Telework Enhancement Act of 2010 (applicable only for federal employees) mandates each federal agency to establish a telecommuting policy and maximize where applicable |  
| **Zone based congestion pricing** legislation adopted only by New York City in U.S. (implementation in 2021) |  

| Mobility initiatives |  
|----------------------|---|
| **No legislation currently in place** |  

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**Movement Category:**

- **Emissions, fuel economy & carbon pricing**
- **Alternative fuels**
- **Tolls, congestion pricing & telecommuting**
- **Mobility initiatives**
### Acronyms and abbreviations

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANPR</td>
<td>Advance Notice of Proposed Rule</td>
</tr>
<tr>
<td>BEV</td>
<td>Battery Electric Vehicle</td>
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<tr>
<td>CAFE</td>
<td>Corporate Average Fuel Economy</td>
</tr>
<tr>
<td>CAGR</td>
<td>Compound Annual Growth Rate</td>
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<tr>
<td>CARB</td>
<td>California Air Resources Board</td>
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<tr>
<td>CAV</td>
<td>Connected and autonomous vehicles</td>
</tr>
<tr>
<td>CI</td>
<td>Carbon Intensity</td>
</tr>
<tr>
<td>CNG</td>
<td>Compresses natural gas</td>
</tr>
<tr>
<td>CSE</td>
<td>Center for Sustainable Energy</td>
</tr>
<tr>
<td>CTI</td>
<td>Cleaner Trucks Initiative</td>
</tr>
<tr>
<td>CVRP</td>
<td>Clean Vehicle Rebate Program</td>
</tr>
<tr>
<td>DCFC</td>
<td>Direct-current fast charger</td>
</tr>
<tr>
<td>EPA</td>
<td>Environmental Protection Agency</td>
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<tr>
<td>EU</td>
<td>European Union</td>
</tr>
<tr>
<td>EV</td>
<td>Electric vehicles</td>
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<tr>
<td>GHG emissions</td>
<td>Greenhouse gas emissions</td>
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<tr>
<td>HEV</td>
<td>Hybrid Electric Vehicle</td>
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<tr>
<td>ICE</td>
<td>Internal Combustion Engine</td>
</tr>
<tr>
<td>kWhr</td>
<td>kilowatt-hour</td>
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<tr>
<td>LCFS</td>
<td>Low Carbon Fuel Standard</td>
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<tr>
<td>LDV</td>
<td>Light Duty Vehicles (pass cars and light trucks)</td>
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<tr>
<td>LEZ</td>
<td>Low Emission Zone</td>
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<tr>
<td>LNG</td>
<td>Liquified natural gas</td>
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<tr>
<td>MMT</td>
<td>Million Metric Tonnes</td>
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<td>NEV</td>
<td>New energy vehicles</td>
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<tr>
<td>OEM</td>
<td>Original Equipment Manufacturer</td>
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<tr>
<td>parc / VIO</td>
<td>Vehicles in operation</td>
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<tr>
<td>PEV</td>
<td>Plug-in Electric Vehicles (includes Battery Electric Vehicles and Plug-in Hybrids)</td>
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<tr>
<td>PM emissions</td>
<td>Particulate matter emissions</td>
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<tr>
<td>RFS</td>
<td>Renewable Fuel Standard</td>
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<tr>
<td>SAFE</td>
<td>Safer Affordable Fuel-Efficient</td>
</tr>
<tr>
<td>TCI</td>
<td>Transportation Climate Initiative</td>
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<tr>
<td>VAT</td>
<td>Value-added tax</td>
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<tr>
<td>VMT</td>
<td>Vehicle Miles Traveled</td>
</tr>
<tr>
<td>xEV</td>
<td>include mild-hybrid, hybrid electric, plug-in hybrids and battery electric vehicles (BEV)</td>
</tr>
<tr>
<td>YOY</td>
<td>Year-on-year</td>
</tr>
<tr>
<td>ZEV</td>
<td>Zero-Emission Vehicle</td>
</tr>
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Impact of Transportation - Related Environmental Initiatives

Project # Co21273, 22 May 2020

Telecommuting would reduce emissions by ~5% - 15% – equivalent to several other “Movements” – but at negligible cost

Movements: Telecommuting

<table>
<thead>
<tr>
<th>Movement Category:</th>
<th>Emissions, fuel economy and carbon pricing</th>
<th>Alternative fuels</th>
<th>Tolls, congestion pricing and telecommuting</th>
<th>Mobility initiatives</th>
</tr>
</thead>
</table>

Source: Ricardo analysis; (1) University of Chicago study - [https://www.nber.org/papers/w26948.pdf](https://www.nber.org/papers/w26948.pdf); (2) [https://john-joseph-horton.com/papers/remote_work.pdf](https://john-joseph-horton.com/papers/remote_work.pdf); (3) Price of gasoline at $3 / gallon

Key takeaways

- ~37% of U.S. workforce can feasibly complete their work from home(1)
  - Current U.S workforce is ~165M(2)
  - Beginning of April 2020, ~50% of U.S. workforce telecommuted due to COVID-19
- Average annual per person fuel savings from telecommuting ranges from ~$150 - $800 based on number of days telecommuted(3)
- Few global regions registered ~40% - 70% reduction in criteria emissions from telecommuting / stay-home orders due to COVID-19
Telecommuting reduces pass car emissions (CO\textsubscript{2}, NO\textsubscript{X}, PM\textsubscript{2.5}) by ~10% nationally if 25% of workforce telecommutes 5 days / week

Telecommuting – GHG emissions

Emissions reduction based on % of U.S. workforce telecommuting (% emissions reduction compared to 2020 baseline)

- Telecommuting 1 day / week
- Telecommuting 3 days / week
- Telecommuting 5 days / week

% emissions reduction from telecommuting for GHG (CO\textsubscript{2}) and criteria emissions (NO\textsubscript{X}, PM\textsubscript{2.5}) are similar

Emissions from light duty vehicles:
- ~1,000 MMT in CO\textsubscript{2} emissions
- ~0.5 MMT in NO\textsubscript{X} emissions
- ~0.1 MMT in PM\textsubscript{2.5} emissions

- In 2020 U.S workforce is ~165M with ~3% of U.S. workforce telecommuting 1 day/week
- A University of Chicago study estimated ~37% of U.S. workforce can feasibly complete their work at home
- Telecommuting 1 day/week with ~37% of U.S workforce yields reduction in tailpipe emissions with ~5% for each CO\textsubscript{2}, NO\textsubscript{X} and PM\textsubscript{2.5}
- Average annual per person fuel savings from telecommuting 1 day / week to 5 days /week ranges from ~$150 - $800 (considering price of gasoline at $3 / gallon)

Work related vehicle miles travelled (VMT) per person is ~50% of annual VMT

Telecommuting / stay-home orders due to COVID-19 registered significantly reduced criteria & GHG emissions across global regions

Telecommuting – Impact from Covid-19

- China’s carbon emissions fell by around 25% over a four-week period, equivalent to around 200M tonnes of CO2 (MtCO2)
- Beginning in March 2020, EPA air quality data shows Los Angeles experienced its longest stretch of "good" air quality since 1995
- Major cities in India registered ~70% drop in NO\textsubscript{X} emissions
- >40% decline in NO\textsubscript{X} emissions in Northern Italy
- Bay Area air quality shows marked improvement during shelter in place with AQI in single digits

Post COVID-19, telecommuting impact on emissions can be assessed by government and organizations for telecommuting strategy roll-out
PEV “Movements” have the highest emissions reduction effectiveness though with relatively high cost. Subsidies most effective in near term

Movements: Subsidies / Incentives, Charging infrastructure, ZEV mandate

Key takeaways

- PEVs offer slightly lower lifecycle emissions compared to ICEs; renewable energy use will further reduce lifecycle emissions for PEVs
- Avg cost of a BEV is ~$8k - $12k higher w.r.t a comparable ICE vehicle. BEVs expected to achieve parity circa 2025+
- Subsidies and charging network are critical PEV uptake drivers in short-med term; ZEV mandate and charging network in long term
- Subsidies are vital for PEV sales – PEV buyers survey indicates, both federal and state level subsidies as critical drivers in their purchase decisions

Source: Ricardo analysis
Average cost of a BEV in 2020 is ~$8k - $12k higher with respect to a comparable ICE vehicle. BEVs expected to achieve parity circa 2025+

Emission, Fuel Economy and Carbon Pricing – Cost

- Average cost of a battery electric vehicle (BEV) is ~$8,000 - $12,000 higher compared to a similarly sized average ICE vehicle
  - Cost of battery pack ranges from ~$160 - $200 per kWhr based on volume

- Average cost of a BEV expected to attain parity with a comparable ICE vehicle in 2025+ timeframe based on expected reduce cost of battery
  - Cost of battery pack expected to range ~ $80 - $120 per kWhr

- Also, average cost of an ICE is expected to increase compared to today's vehicle by ~$2000 - $2500 based on SAFE rule or additional stringent CAFE standards

Technological advancements in batteries leading to lower cost will allow EV uptake and aid corresponding Movements; not vice-versa

Note: Average baseline cost of an ICE vehicle in 2020 is considered as $0 on the Y-axis

Source: [https://about.bnef.com/electric-vehicle-outlook/](https://about.bnef.com/electric-vehicle-outlook/) ; [https://www.eia.gov/outlooks/aeo/](https://www.eia.gov/outlooks/aeo/) ; [https://www.bts.gov/content/average-fuel-efficiency-us-light-duty-vehicles](https://www.bts.gov/content/average-fuel-efficiency-us-light-duty-vehicles); Ricardo analysis
Subsidies and charging network are critical PEV uptake drivers in short-med term; ZEV mandate and charging network in long term

Emission, Fuel Economy and Carbon Pricing – Vehicle Demand

- Network effect of subsidies and charging infrastructure have been linked to EV uptake in multiple studies
  - Ricardo estimates impact of subsidies will be reduced in 2030+ timeframe if pack costs reach ~$60 / kWhr
  - Charging infrastructure especially DCFC charging infrastructure will have a higher impact on PEV demand in 2030+ timeframe
    - Home charging still remains the primary use case for PEV charging with DCFC for intra city travel / travel corridors
    - New green deal etc. type legislation supporting charging infra have failed but will gain more traction as PEVs increase
- ZEV mandate states account for ~30% of annual U.S. vehicle sales, which drives higher model eligibility and mandates sales of vehicles to meet requirements
- CAFE standard has limited impact on PEV uptake with OEMs selling vehicles only to meet fleet mpg requirement
- Another key factor impacting current PEV adoption is states such as California is public visibility of PEV leading to ‘network effect’ and ‘neighbor effect’

Subsidies, ZEV mandate and charging infrastructure create a network effect to directly drive PEV uptake

Emission, Fuel Economy and Carbon Pricing – Vehicle Demand

Single “Movement” alone may not create the effect to drive PEV sales, but combination of all Movements drives the impact
PEVs offer slightly lower lifecycle emissions compared to ICEs; renewable energy use will further reduce lifecycle emissions for PEVs.

**Lifecycle GHG emissions from passenger cars**

**Life-cycle GHG emissions for passenger cars by powertrain, 2018**

- **ICE**
- **HEV**
- **PH EV**
- **BEV**
- **FCEV**

Variability relative to vehicle size:
- Impact of larger battery (+200km)
- Tank-to-wheel fuel cycle
- Well-to-tank fuel cycle
- Vehicle cycle batteries (200km)
- Vehicle cycle assembly, disposal and recycling
- Vehicle cycle - components and fluids

Source: IEA The Global EV Outlook 2019 – life-cycle analysis
If PEVs account for 60% new vehicle sales by 2040, results in ~50% reduction in avoided lifecycle GHG CO$_2$ emissions w.r.t 2020 sales

**Emission, Fuel Economy and Carbon Pricing – GHG Emissions**

Impact on GHG emissions of ‘New Vehicle Sales’ from Subsidies, CAFE standard, ZEV mandate and Charging infrastructure

(Lifecycle avoided emissions, MMT CO$_2$ equivalent)

- ZEV mandate, subsidies, and charging infrastructure enable higher PEV uptake resulting in higher avoided lifecycle CO$_2$ emissions
- ZEV mandate potentially results in ~40% - 60% higher avoided GHG emissions compared to baseline scenario
- Movements ‘Subsidies’ and ‘Charging infrastructure’ are indirect drivers on GHG emissions. Subsidies and charging infrastructure influences vehicle demand which indirectly impacts GHG emissions
- CAFE standard (modified) could potentially result in improvement of ~15% - 20% avoided GHG emissions compared to baseline scenario. Considers 5% CAGR in fleet wide fuel economy until 2025 and 1.5% CAGR from 2025-2040
- U.S. light duty new vehicle sales lifecycle emissions in 2019 is ~800 MMT CO$_2$

**Note:** Only new vehicle sales (not U.S. parc) avoided lifecycle GHG CO$_2$ emissions are considered. Light duty vehicles include passenger cars and light duty trucks

Source: [https://about.bnef.com/electric-vehicle-outlook/](https://about.bnef.com/electric-vehicle-outlook/); [https://www.eia.gov/outlooks/aeo/](https://www.eia.gov/outlooks/aeo/); [https://www.bts.gov/content/average-fuel-efficiency-us-light-duty-vehicles](https://www.bts.gov/content/average-fuel-efficiency-us-light-duty-vehicles); Ricardo analysis
60% PEV uptake (new vehicle sales) scenario in 2040 results in ~85M PEV parc, potentially displacing gasoline consumption by ~30B gal’s

Emission, Fuel Economy and Carbon Pricing – Fuel Economy

Low PEV uptake scenario

- 10% PEV penetration
- ~18M vehicles
- ~7B gallons

High PEV uptake scenario

- 60% PEV penetration
- ~85M vehicles
- ~30B gallons

PEV sales as % of light duty vehicle sales in 2040

PEV parc in 2040

Displaced gasoline consumption in 2040 (annual)

Note: 2019 U.S gasoline demand was ~142 Billion gallons

Subsidies are vital for PEV sales – in California PEV buyers survey, ~70% ranked subsidies a key factor in their purchase decision

Subsidies / Incentives – Vehicle Demand

- California under its Clean Vehicle Rebate Program (CVRP) offers max rebate of $2,500 for BEVs. Program was initiated in 2010 with ~$840M rebate funding approved till end of 2019
- The Center for Sustainable Energy (CSE), the administrator of the CVRP, surveyed and collected data between 2012 – 2015 regarding importance of the California state rebate ($2,500) and federal tax credit ($7,500)
  - >70% ranked both federal tax credit and state rebate as important factors in their decision to purchase a PEV
- Additionally, CSE also surveyed respondents regarding importance of only CVRP between 2015 - 2017 and >70% of respondents replied state rebate program was extremely important or very important factor in their purchase decision
- ~50% of respondents would not purchase or lease a PEV without the CVRP rebate – based on the same survey by CSE between 2013 – 2017

Georgia’s PEV demand dropped by ~60% after $5k state rebate was rescinded; similar trends observed in other countries, notably China

Subsidies / Incentives – Vehicle Demand

Georgia EV and PHEV sales YOY (unit volume in 000’s)

China EV and PHEV sales YOY (unit volume in 000’s)

Georgia EV and PHEV sales monthly (unit volume)

China plug-in sales monthly (unit volume)

Scaling back of CAFE standards will affect emissions reduction for ICE vehicles drawing higher reliance on PEVs for emissions reduction

Movements: CAFE standard

Movements:

- Emissions, fuel economy and carbon pricing
- Alternative fuels
- Tolls, congestion pricing and telecommuting
- Mobility initiatives

Key takeaways

- SAFE rule reduces fleet fuel economy targets and emissions reduction impact
  - SAFE rule fuel economy improvement extrapolated till 2040 results in ~180 MMT of avoided lifecycle CO2 emissions from new vehicle sales
- Continuation of CAFE standards fleet fuel economy requirements growth rate of 5% CAGR till 2040 requires >50% of new vehicle sales to PEVs by 2040

Source: Ricardo analysis
SAFE rule finalized in 2020 drastically reduces fleet fuel economy targets and emissions reduction impact compared to earlier targets

Emission, Fuel Economy and Carbon Pricing – GHG Emissions

- SAFE rule fuel economy improvement extrapolated till 2040 results in ~180 MMT of avoided lifecycle CO$_2$ emissions from new vehicle sales
- Modified CAFE standard results in improvement of ~15% - 20% avoided GHG emissions compared to baseline scenario
- Continuation of CAFE standard i.e. 5% CAGR growth in fleet wide fuel economy till 2040 requires fleet fuel economy greater >90 mpg by 2040. Feasible through electrification and would require ~60% PEV uptake by 2040 to meet this scenario
- Following assumptions were considered for the analysis:
  - SAFE rule: considers ~1.5% CAGR improvement in fleet wide fuel economy till 2040
  - Modified CAFE standard: 5% CAGR growth in fleet fuel economy, which is feasible through electrification and high PEV uptake
  - CAFE standard continued: 5% CAGR growth till 2040
- U.S. light duty new vehicle sales lifecycle emissions in 2019 is ~800 MMT CO$_2$ equivalent

Note: Only new vehicle sales (not U.S. parc) avoided lifecycle GHG CO$_2$ emissions are considered. Includes both passenger cars and light duty trucks

Source: [https://about.bnef.com/electric-vehicle-outlook/](https://about.bnef.com/electric-vehicle-outlook/) ; [https://www.eia.gov/outlooks/aeo/](https://www.eia.gov/outlooks/aeo/) ; [https://www.bts.gov/content/average-fuel-efficiency-us-light-duty-vehicles](https://www.bts.gov/content/average-fuel-efficiency-us-light-duty-vehicles); Ricardo analysis
LCFS (California and Washington) and RFS (federal) mandates have had varying success

Movements: Low Carbon Fuel Standard (LCFS), Renewable Fuel Standard (RFS)

Key takeaways
- LCFS is more effective than RFS however is aided by California’s head start with the Clean Air Act and buyer allegiance for EVs; if EVs plateau, some other alt fuel disruption needs to occur to meet LCFS
- EPA waivers for RFS show significant lag in meeting original targets
- A drawback of biofuel use is its lower fuel economy compared to baseline gasoline and diesel fuel which indirectly leads to higher fuel consumption compared to baseline fuels

Source: Ricardo analysis
LCFS is more effective than RFS however is aided by EV uptake; if EVs plateau, some other alt fuel disruption needs to occur to meet LCFS

### Key Takeaways from Biofuels: Low Carbon Fuel Standard (LCFS) and Renewable Fuel Standard (RFS)

<table>
<thead>
<tr>
<th>LCFS’ CI target approach is more effective than RFS’ volume-based</th>
</tr>
</thead>
<tbody>
<tr>
<td>• LCFS pursues a carbon intensity (CI) target approach while RFS has a volume target mandate</td>
</tr>
<tr>
<td>• RFS has needed to revise down its volume targets significantly whereas industry appears to only slightly lag behind LCFS targets</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Four main alt fuels contribute to LCFS</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Starch ethanol, biodiesel, renewable diesel and biomethane are the main fuels contributing to LCFS</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LCFS is not causing EV popularity but will benefit from it</th>
</tr>
</thead>
<tbody>
<tr>
<td>• EVs are popular due to industry’s technological advancements; not because of LCFS targets</td>
</tr>
<tr>
<td>• However, LCFS will continue to benefit from EV uptake as the mandate offers credits to electricity use in transportation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>If EVs plateau, some other alt fuel will need to incentivize consumers</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Outside of EVs, other alternative fuels (based on current projections), do not appear to cause a significant market shift in adoption, mainly because they do not offer consumers appreciable operational cost benefit or driving feature enhancements as EVs do</td>
</tr>
<tr>
<td>• If EVs plateau, some other alternative fuel disruption needs to occur to meet LCFS</td>
</tr>
</tbody>
</table>

*Source: Ricardo analysis*
EPA waivers for Renewable Fuel Standard (RFS) show significant lag in meeting original targets

NOTE: RFS Statute enacted under EISA (Energy Independence and Security Act of 2007) extends the yearly volume requirements out to 2022
TBD*: EPA sets final volumes each year for the following year. Hence, data is available for 2020 (finalized on 19th December, 2019) but not for 2021 and beyond

CARB projections estimate ethanol, biodiesel, renewable diesel and biomethane to be key drivers alongside electrification to meet targets.

**Main Alternative Fuels Contributing to LCFS**

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>2018</th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
<th>2040 (Ricardo estimate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cellulosic Ethanol</td>
<td></td>
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<tr>
<td>Sugar Ethanol</td>
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<tr>
<td>Alternative Jet Fuel</td>
<td></td>
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<tr>
<td>Biomethane</td>
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<td>Electricity</td>
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<td>Starch Ethanol</td>
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<td>Biomethane</td>
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</tr>
<tr>
<td>Renewable Diesel</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infrastructure and petroleum projects</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrogen</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**CI reduction target (compared to 2010)**

- 2018: 7.5%
- 2020: 13.75%
- 2025: 20%
- 2030: ~30%

Ricardo assumption

**LCFS estimated alternative fuels mix YOY (in million GGE)**

**LCFS estimated credit mix YOY (in MMT)**

Outside of three main alt. fuels, biomethane use may increase, however proportional credits for electricity are much more than those for biomethane.

Source: CARB illustrative compliance scenario, Aug 2018; Ricardo analysis.
Increased EV penetration is the key driver to comply with LCFS targets. Alternative fuels only enablers based on current technology.

### Carbon Intensity (grams of CO₂ per mega Joule of energy produced) for various alternative fuels

<table>
<thead>
<tr>
<th>Alternative Fuel</th>
<th>Average CI 2020 est.</th>
<th>Average CI 2040 est.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calif Gasoline</td>
<td>99</td>
<td>99</td>
</tr>
<tr>
<td>CNG</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>Starch Ethanol</td>
<td>71</td>
<td>45</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>CNG / LNG from landfill</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Renewable diesel</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Cellulosic Ethanol</td>
<td>30</td>
<td>4</td>
</tr>
<tr>
<td>Electricity</td>
<td>20</td>
<td>10</td>
</tr>
</tbody>
</table>

- **0.25% CI reduction - 2011 LCFS target**
- **7.5% CI reduction - 2020 LCFS target**
- **20% CI reduction - 2030 LCFS target**

### Through 2018 Q1, total emissions reduction requirements under the regulation were 28.9 million tons (MMT) CO₂e. Actual reported emissions reductions were 38.3 MMT CO₂e, representing overcompliance of 9.3 MMT CO₂e (33%), creating a system-wide credit “bank” that can be used to meet future targets.

- However, to meet stringent future carbon intensity (CI) targets, significant EV uptake along with alternative fuels required:
  - Electricity with its lower CI plays a significant role in meeting credit compliance compared to fuels such as biomethane and CNG.
  - Renewable diesel though comparable in CI with electricity, impact is limited mostly to heavy duty applications.

Fuel economy is lower for alternative fuels and blends compared to baseline gasoline and diesel fuel

Biofuels: Low Carbon Fuel Standard (LCFS) and Renewable Fuel Standard (RFS) – Fuel Economy

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>E10</th>
<th>E15</th>
<th>E85</th>
<th>B20</th>
<th>B100</th>
<th>Renewable Diesel</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fuel Economy Impact</strong></td>
<td>~3%-4% lower</td>
<td>~4%-5% lower</td>
<td>~15%-20% lower</td>
<td>~2% lower</td>
<td>~8%-10% lower</td>
<td>~3%-7% lower</td>
</tr>
<tr>
<td><strong>Annual Cost Impact</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For C/D segment vehicle for 20,000 miles per year:
- Incremental cost of fuel compared to baseline gasoline:
  - $50
  - $200

For Class 4 vehicle for 20,000 miles per year:
- Incremental cost of fuel (includes biofuel cost impact only) compared to baseline diesel:
  - $100
  - $700

- **Alternative fuels and fuel blends deliver marginally lower fuel economy in comparison to baseline gasoline and diesel fuels**

- **Renewable diesel (not provided above) is ~3% - 7% lower in fuel efficiency compared to baseline diesel**

Cleaner Trucks Initiative (CTI) still in proposal phase with expected impact in 2025+ timeframe

Movements: Cleaner Trucks Initiative (CTI)

**Key takeaways**

- CTI aims lower NO\(_X\) emissions with focus on lower-load conditions; CTI still in proposal phase with expected impact in 2025+ timeframe

- EPA’s existing rule of 0.6 g/mile (0.2 g/bhp-hr) for NO\(_X\) is being met only under highway operation

- Trucks meeting 0.6 g/mile target across all load conditions reduces NO\(_X\) emissions of Medium and Heavy duty diesel trucks parc by >65% in low electrification scenario and >75% in high electrification scenario

Source: Ricardo analysis
CTI aims to lower NO\textsubscript{X} emissions with focus on lower-load conditions; CTI still in proposal phase with expected impact in 2025+ timeframe

Cleaner Trucks Initiative (CTI)

- EPA’s current emissions standards have lowered overall NO\textsubscript{X} emissions, but have not resulted in effective emission control under low-load conditions. EPA’s existing rule of 0.6 g/mile (0.2 g/bhp-hr) for NO\textsubscript{X} is being met only under highway operation

- Objective of CTI is to achieve lower NO\textsubscript{X} emissions, with focus on lower-load conditions i.e. idle, slowing moving or stop-and-go traffic

- EPA last revised NO\textsubscript{X} standards for heavy-duty trucks in 2001, impacting MY 2007 – MY 2010. Standards set were:
  - NO\textsubscript{x} emissions of 0.20 g/bhp-hr
  - PM emissions of 0.01 g/bhp-hr
  - Non-methane hydrocarbons (NMHC) of 0.14 g/bhp-hr

- ICCT’s analysis of EPA’s Heavy Duty In-Use Testing (HDIUT) program found that >50% of HD vehicles average time is under low-load conditions

- On Jan 6, EPA signed Advance Notice of Proposed Rule (ANPR), requesting comments on Cleaner Trucks Initiative (CTI) from various industry bodies. Finalized rule is not expected until 2021, with expected rollout in a phased manner impacting MY2024 – MY2027

Diesel trucks meeting 0.6 g/mile target across all load conditions reduces NO$_X$ emissions of commercial vehicle parc by >65%

Cleaner Trucks Initiative (CTI) – Emissions

- CTI to impact only model years 2025+ and assuming CTI will target of 0.6 g/mile NO$_X$ emissions across all load profiles of diesel truck operation
- Meeting 0.6 g/mile target across all load conditions reduces Medium and Heavy duty diesel trucks parc NO$_X$ emissions by >65% in low electrification scenario and >75% in high electrification scenario

Source: [https://ww3.arb.ca.gov/research/veh-emissions/low-nox/low-nox.htm](https://ww3.arb.ca.gov/research/veh-emissions/low-nox/low-nox.htm) ; Ricardo analysis

**Impact on tailpipe NO$_X$ emissions of ‘U.S. Diesel Commercial Vehicle Parc’ from Cleaner Trucks Initiative (CTI)**

(Annual NO$_X$ emissions, MT)

**Powertrain**

<table>
<thead>
<tr>
<th></th>
<th>Current</th>
<th>2040 - Low PEV Scenario</th>
<th>2040 - High PEV Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel</td>
<td>61%</td>
<td>61%</td>
<td>48%</td>
</tr>
<tr>
<td>Gasoline</td>
<td>38%</td>
<td>35%</td>
<td>27%</td>
</tr>
<tr>
<td>PEV</td>
<td>&lt;1%</td>
<td>~2%</td>
<td>~22%</td>
</tr>
<tr>
<td>Others</td>
<td>&lt;1%</td>
<td>~2%</td>
<td>~3%</td>
</tr>
<tr>
<td>Total Vehicles</td>
<td>~3.5M</td>
<td>~5M</td>
<td>~5M</td>
</tr>
</tbody>
</table>

**Medium Duty Trucks (Class 4-6)**

- Diesel: 61%
- Gasoline: 38%
- PEV: <1%
- Others: <1%
- Total Vehicles: ~3.5M

**Heavy Duty Trucks (Class 7-8)**

- Diesel: 98%
- Gasoline: N/A
- PEV: <1%
- Others: <1%
- Total Vehicles: ~5M

**Note:** Analysis considers that PEVs replace highest emitting vehicles in the parc. Average annual VMT considered: Medium duty diesel trucks – 25k miles

Heavy duty diesel trucks – 45k miles
TCI and carbon pricing may have direct limited impact on emissions reduction given the limited nationwide momentum these may have.

Movements: Transportation Climate Initiative (TCI), Carbon pricing

**Key takeaways**

- TCI is estimated to contribute ~1% - 6% of the overall target of 20% - 25%, with the rest achieved through electrification and fuel efficiency improvement.
- Revenue from allowance sales to be invested by TCI signatory regions to support low-carbon transportation initiatives.
- Numerous carbon pricing legislation has been proposed however distribution of revenues are not targeted towards transportation.

Source: Ricardo analysis
TCI is estimated to contribute ~1% - 6% of the overall target, with rest achieved through electrification and fuel efficiency improvement.

Transportation Climate Initiative (TCI) – GHG Emissions

TCI states GHG emissions impact (MMT CO₂ equivalent)

![Graph showing GHG emissions reduction targets by 2032 for TCI states.](image)

- **TCI’s Estimated CO₂ Emissions Reduction Target by 2032**
  - 20%
  - 22%
  - 25%

- **Cap reduction target is set against 2022 estimated emissions of 254 MMT CO₂ equivalent**

- **Net impact**
  - ~1% – 6% GHG reduction if reference case projection till 2032 holds true

- Transportation Climate Initiative (TCI) is a still-in-work “cap & invest” initiative that is estimated to start in 2022
- Average yearly incremental cost for fuel in TCI states is estimated to range from ~$30 - $90 in 2022 to max of $100 - $150 in 2032

Note: Only new vehicle sales (not U.S. parc) avoided lifecycle GHG CO₂ emissions are considered. Light duty vehicles include passenger cars and light duty trucks.

Source: [https://www.transportationandclimate.org/sites/default/files/TCI%20Public%20Webinar%20Slides_20191217.pdf](https://www.transportationandclimate.org/sites/default/files/TCI%20Public%20Webinar%20Slides_20191217.pdf); [https://vtdigger.org/2020/01/01/john-mcclaughry-a-qa-on-tci/](https://vtdigger.org/2020/01/01/john-mcclaughry-a-qa-on-tci/); Ricardo analysis
Revenue from allowance sales to be invested by TCI signatory regions to support low-carbon transportation initiatives

Transportation Climate Initiative (TCI)

Illustrative Portfolios of Clean Transportation Investments – Outlined in TCI Working Groups’ analysis

<table>
<thead>
<tr>
<th>Scenario A</th>
<th>Scenario B</th>
<th>Scenario C</th>
</tr>
</thead>
<tbody>
<tr>
<td>5%</td>
<td>30%</td>
<td>54%</td>
</tr>
<tr>
<td>21%</td>
<td>23%</td>
<td>27%</td>
</tr>
<tr>
<td>35%</td>
<td>18%</td>
<td>-</td>
</tr>
<tr>
<td>16%</td>
<td>14%</td>
<td>10%</td>
</tr>
<tr>
<td>7%</td>
<td>8%</td>
<td>8%</td>
</tr>
<tr>
<td>17%</td>
<td>8%</td>
<td>-</td>
</tr>
</tbody>
</table>

- Electric cars, light trucks and vans
- Low and zero-emission buses and trucks
- Transit expansion and upkeep
- Pedestrian and bike safety, ride sharing
- System efficiency
- Indirect / Other

Source: [https://www.transportationandclimate.org/sites/default/files/TCI%20Public%20Webinar%20Slides_20191217.pdf](https://www.transportationandclimate.org/sites/default/files/TCI%20Public%20Webinar%20Slides_20191217.pdf)
Numerous carbon pricing legislation has been proposed however distribution of revenues are not targeted towards transportation.

Carbon pricing

- 50% of tax proposals support a higher initial tax rate that gradually increases to 2030.
- A third of the proposals support starting at a relatively lower initial tax rate with a steeper increase to 2030, eclipsing the tax rate of the initially higher rate proposals during the early 2020s.

Movements such as LEZ/ICE bans, congestion pricing and mobility initiatives are localized and limited to urban regions.

Movements: Low Emission Zone (LEZ) / ICE bans, Congestion pricing, Mobility / CAV

Movement Category: Emissions, fuel economy and carbon pricing, Alternative fuels, Tolls, congestion pricing and telecommuting, Mobility initiatives

Key takeaways:
- LEZ deployment in LA county potentially reduces NO\textsubscript{X} by >10% and CO\textsubscript{2} by ~4%-8% based on implementation scenario.
- Congestion pricing offers localized emissions reduction benefit with high cost of compliance. Investment in clean public transport required to sustain and improve emissions reduction.
- Increase in shared & autonomous mobility impacts U.S. parc with vehicle ownership per thousand reducing ~10% compared to 2019 value. CAV has an ambiguous future effect on emissions based on VMT.

Source: Ricardo analysis
LEZ deployment in LA county based on EU model potentially reduces NO\textsubscript{X} by >10% and CO\textsubscript{2} by ~4%-8% based on implementation scenario

Vehicle use type restrictions / ICE bans – Low Emission Zone (LEZ) in Los Angeles County

Impact if passenger vehicles older than 20 years are banned from driving in Los Angeles County Area

LA county has ~7.6M registered passenger vehicles in 2019. ~8% of vehicle population (~0.6M vehicles) are >=20 years in age

**Option - 1**

- Replaced with public transport / ZEVs
- 0.6M vehicles replaced with ZEVs / public transport
- ~16% reduction compared to baseline – no action is taken

**Option - 2**

- Replaced with EPA Tier 3 ICEs
- 0.6M vehicles replaced with EPA Tier 3 ICEs
- ~14% reduction

**Baseline:**
- 7.6M parc in LA county leads to ~31,000 tons of NO\textsubscript{X} emissions in 2019
- 7.6M parc in LA county generates ~38 MMT of CO\textsubscript{2} emissions in 2019

~14% reduction in NO\textsubscript{X} and ~8% reduction in CO\textsubscript{2} compared to baseline – no action is taken

Note: Impact on emissions from shift to public or alternative transport not considered

Emission reduction benefits of congestion pricing are **localized and sustained through clean public transport. Limited impact nationally**

**Congestion pricing – New York, Seattle, Los Angeles Impact on GHG emissions**

**Impact if congestion pricing is implemented in New York, Seattle and Los Angeles**

Transportation CO\(_2\) emissions (in MMT) are as following for each city: NY – 15 MMT, Seattle – 3 MMT, LA – 25 MMT

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Low Impact</th>
<th>High Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impact</td>
<td>Low per vehicle charge and significant exemptions granted</td>
<td>High per vehicle charge and shift to clean public transport</td>
</tr>
<tr>
<td>CO(_2) reduction - localized</td>
<td>~7% reduction</td>
<td>~20% reduction</td>
</tr>
<tr>
<td>compared to local transportation emissions</td>
<td>U.S. transportation sector resulted in ~1,500 MMT of CO(_2) emissions in 2019</td>
<td></td>
</tr>
<tr>
<td>CO(_2) reduction – U.S. wide</td>
<td>~0.2% reduction</td>
<td>~0.6% reduction</td>
</tr>
<tr>
<td>compared to U.S. wide transportation emissions</td>
<td>Transportation sector (3 cities) resulted in ~45 MMT of CO(_2) emissions in 2019</td>
<td></td>
</tr>
</tbody>
</table>

Note: Impact on emissions from shift to public or alternative transport not considered

Source: [https://www.seattle.gov/Documents/Departments/OSE/ClimateDocs/2016_SEA_GHG_Inventory_FINAL.pdf](https://www.seattle.gov/Documents/Departments/OSE/ClimateDocs/2016_SEA_GHG_Inventory_FINAL.pdf) ; [https://www1.nyc.gov/site/dep/environment/transportation-emissions.page](https://www1.nyc.gov/site/dep/environment/transportation-emissions.page) ; Ricardo analysis
Congestion pricing has a high cost of access and also yields high gains in localized emissions reduction

### Congestion pricing – Cost of Compliance

- Average yearly incremental cost for accessing a cordon congestion pricing zone is estimated to range from ~$1,000 - $3,000 in 2021 to max of $5,000 - $12,000 in 2040 based on stringency of implementation and revenue expected to be generated
  - Cost increase considered above is similar to cost increase for access to London congestion pricing zone over the past decade
- Congestion pricing costs spread across U.S. parc results in cost of ~$3 per person and increases as more cities adopt the scheme
  - Assessment assumes New York congestion pricing starts in 2021 and Seattle and Los Angeles follow suit later and congestion pricing access costs continue to increase

**Operational cost from Congestion pricing per person – where impacted**

(Average yearly cordon congestion pricing costs, $)

- **High stringency**
- **Low stringency**

**Yearly per person congestion pricing cost ($)**

- ~$3 /per person in 2021 (based on timeframe for roll-out in New York) to ~$10 - $20 per person in 2040

**Note:** Other operational cost such as fuel costs, parking etc. are not considered in the analysis

Source: [https://about.bnef.com/electric-vehicle-outlook/](https://about.bnef.com/electric-vehicle-outlook/); [https://www.eia.gov/outlooks/aeo/](https://www.eia.gov/outlooks/aeo/); [https://www.bts.gov/content/average-fuel-efficiency-us-light-duty-vehicles](https://www.bts.gov/content/average-fuel-efficiency-us-light-duty-vehicles); Ricardo analysis
Shared & autonomous mobility impacts U.S. parc with vehicle ownership per thousand reducing ~10% compared to 2019 value

Mobility and Connected and Autonomous Vehicles

Impact of shared mobility and autonomous mobility in 2030+

- CAVs have an ambiguous future effect on emissions based on VMT as there could be fundamental shift in usage. Potential uptick in use due to ease of travel and increased access to previously underserved communities.
- By 2050 LD vehicles could potentially increase fuel consumption by 42% or decrease it by -44.4%.

**Impact of shared mobility and autonomous mobility in 2030+**

**X** Vehicles per thousand people in 2040

- U.S. vehicles per thousand people in 2019 is 850

**Connected and Autonomous Vehicles - Fuel Consumption Impact - 2050**

- Low Technology Impact Max Δ
- Low Technology Impact Min Δ
- High Technology Impact Min Δ
- High Technology Impact Max Δ

*VMT: Vehicle Miles Traveled

- Level 1-3 CAV
- Level 4-5 CAV

https://tedb.ornl.gov/data/
https://www.dmv.ca.gov/portal/dmv/detail/pubs/media_center/statistics
Ricardo analysis
• Executive summary
• Project report
• Appendix – I (Project report addendum)
  – Light duty vehicles powertrain mix and parc scenarios and criteria emissions impact
  – Medium and heavy duty commercial vehicles powertrain mix and parc scenarios
  – Cost assessment methodology & assumptions used to project Movement impact until 2040
  – Biofuels
  – Cleaner Trucks Initiative (CTI)
  – Transportation Climate Initiative (TCI) and Carbon pricing
• Appendix – II (Movement 101)
• Appendix – III (Summary of research)
Ricardo reviewed multiple studies to generate PEV penetration outlook scenarios

U.S. Light Duty EV Penetration Scenarios

Low PEV uptake scenario
(10% PEV penetration by 2040)

High PEV uptake scenario
(60% PEV penetration by 2040)

~10% PEV penetration by 2040

~60% PEV penetration by 2040

Note: ~16M vehicle sales per year considered from 2020 through 2040

Impact of Transportation - Related Environmental Initiatives

U.S. Vehicle Parc low-to-high scenarios based on impact of vehicle private ownership vs shared mobility and autonomous vehicles

U.S. Light Duty Vehicle Parc Scenarios

Impact of shared mobility and autonomous mobility in 2030+

Example scenario: U.S. Parc – Low and High PEV uptake

~85M PEV Parc in 2040

Vehicles per thousand people in 2040

U.S. vehicles per thousand people in 2019 is 850

Current EPA emission standards (Tier -3) impact model years 2017-2025, with fleetwide adoption mandated by 2025

### EPA Emission Standards – Light Duty Vehicles

<table>
<thead>
<tr>
<th>U.S. Emissions Standards</th>
<th>Average vehicle registration age that meet the standards</th>
<th>NO$_X$ (g/mile)</th>
<th>PM (g/mile)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tier 1</td>
<td>Fleetwide phase-in from 1997</td>
<td>0.6</td>
<td>0.1</td>
</tr>
<tr>
<td>Tier 2</td>
<td>Fleetwide phase-in from 2007</td>
<td>0.07</td>
<td>0.01</td>
</tr>
<tr>
<td>Tier 3</td>
<td>Fleetwide phase-in to be completed in 2025</td>
<td>0.03</td>
<td>0.003</td>
</tr>
<tr>
<td>Tier 4 (Ricardo est.)</td>
<td>Fleetwide phase-in to be completed in 2031</td>
<td>0.015</td>
<td>0.0015</td>
</tr>
</tbody>
</table>

Source: Ricardo EMLEG, EPA, Dieselnet
Ricardo used following assumptions for estimating U.S. light duty vehicles 2040 parc NO$_X$ and PM$_{2.5}$ emissions

U.S. Light Duty Vehicle Parc Criteria Emissions

Assumptions:

- EPA defined NO$_X$ and PM$_{2.5}$ emissions until model year 2025. Ricardo estimated 2030 – 2040 emissions based on extrapolating historical emissions reduction.

- NO$_X$ and PM$_{2.5}$ impact from power generation facilities is forecasted till 2040 based on 1990 – 2018 data. Impact of renewable and clean energy is not clearly captured in the forecast, and exponential growth of renewable energy will result in higher emissions reduction than estimated.

- Fuel refiners emissions impact projections are based on gasoline consumption from vehicle fuel economy improvement.
~67% reduction in parc NO\textsubscript{X} emissions by 2040 from vehicle retirement. Additional ~23% reduction from high EV uptake

U.S. Light Duty Vehicle Parc Emissions - NO\textsubscript{X}

Emissions stated in Metric Tons (MT)

Current U.S. parc NO\textsubscript{X} emissions

<table>
<thead>
<tr>
<th></th>
<th>ICE</th>
<th>PEV</th>
<th>Total emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current</td>
<td>720,000</td>
<td>2,100</td>
<td>722,100</td>
</tr>
<tr>
<td></td>
<td>500,000</td>
<td>1,500</td>
<td></td>
</tr>
<tr>
<td></td>
<td>220,000</td>
<td>600</td>
<td></td>
</tr>
</tbody>
</table>

2040 U.S. parc NO\textsubscript{X} emissions – Low EV uptake

PEVs account for ~6% of Parc

<table>
<thead>
<tr>
<th></th>
<th>ICE</th>
<th>PEV</th>
<th>Total emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>2040</td>
<td>232,000</td>
<td>5,000</td>
<td>237,000</td>
</tr>
<tr>
<td>Low EV uptake</td>
<td>145,000</td>
<td>4,600</td>
<td>20,000</td>
</tr>
<tr>
<td></td>
<td>87,000</td>
<td>400</td>
<td>65,500</td>
</tr>
</tbody>
</table>

2040 U.S. parc NO\textsubscript{X} emissions – High EV uptake

PEVs account for ~29% of Parc

<table>
<thead>
<tr>
<th></th>
<th>ICE</th>
<th>PEV</th>
<th>Total emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>2040</td>
<td>160,500</td>
<td>20,000</td>
<td>182,500</td>
</tr>
<tr>
<td>High EV uptake</td>
<td>95,000</td>
<td>65,500</td>
<td>237,000</td>
</tr>
<tr>
<td></td>
<td>22,000</td>
<td>2,000</td>
<td>22,000</td>
</tr>
</tbody>
</table>

% NO\textsubscript{X} reduction:
- Low EV uptake: ~67%
- High EV uptake: ~23%

Source:
- https://www3.epa.gov/ttn/chief/conference/02/session8/hcai.pdf
- Ricardo analysis: https://www.epa.gov/ghgreporting/ghgrp-refineries
- https://www.epa.gov/criteria-air-pollutants/2017-national-emissions-inventory-nee-data

500,000

67%

23%
~70% reduction in parc PM$_{2.5}$ emissions by 2040 from vehicle retirement. Additional ~26% reduction from high EV uptake

U.S. Light Duty Vehicle Parc Emissions – PM$_{2.5}$

Emissions stated in Metric Tons (MT)

<table>
<thead>
<tr>
<th>Current U.S. parc PM$_{2.5}$ emissions</th>
<th>2040 U.S. parc PM$_{2.5}$ emissions – Low EV uptake</th>
<th>2040 U.S. parc PM$_{2.5}$ emissions – High EV uptake</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel producer to tank</td>
<td>Tank to wheels</td>
<td>PEVs account for ~6% of Parc</td>
</tr>
<tr>
<td>Current U.S. parc PM$_{2.5}$ emissions</td>
<td>2040 U.S. parc PM$_{2.5}$ emissions – Low EV uptake</td>
<td>2040 U.S. parc PM$_{2.5}$ emissions – High EV uptake</td>
</tr>
<tr>
<td>ICE</td>
<td>PEV</td>
<td>Total emissions</td>
</tr>
<tr>
<td>112,500</td>
<td>210</td>
<td>112,710</td>
</tr>
<tr>
<td>83,000</td>
<td>130</td>
<td>29,500</td>
</tr>
<tr>
<td>210</td>
<td>50</td>
<td></td>
</tr>
</tbody>
</table>

Emissions stated in Metric Tons (MT)

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  – Transportation Climate Initiative (TCI) and Carbon pricing
• Appendix – II (Movement 101)
• Appendix – III (Summary of research)
Ricardo reviewed multiple studies to generate medium and heavy duty trucks PEV penetration outlook scenarios and impact on parc

U.S. Medium and Heavy Duty

**Medium Duty PEV uptake scenarios**

- Higher potential for electrification compared to heavy duty based on use-cycles, especially in regional and urban haul applications.

**Heavy Duty PEV uptake scenarios**

- Lower potential for electrification due to use-cycles, especially in long haul applications.

**Medium Duty Parc scenarios**

- Increasing parc projected in medium duty category due to shifting dynamic of hub-and-spoke and last-mile delivery.

**Heavy Duty Parc scenarios**

- Flat parc projected in heavy duty (HD) category due marginally declining YOY sales, impacted by uptake in medium duty trucks.

U.S. Medium Duty EV Penetration Scenarios

Note: % breakdown by powertrain considered for each year’s annual new vehicle sales


Impact of Transportation - Related Environmental Initiatives

Project # Co21273, 22 May 2020

U.S. Medium Duty Parc Scenarios

U.S. Medium Duty Vehicle Parc Scenarios

U.S. Medium Duty Vehicle Parc - Low PEV uptake scenario
(<5% PEV penetration by 2040)

Volume in Millions (000,000's)

<table>
<thead>
<tr>
<th>Year</th>
<th>Fuel cell</th>
<th>BEV</th>
<th>PHEV</th>
<th>CNG</th>
<th>Flex fuel (E-85)</th>
<th>Gasoline</th>
<th>Diesel</th>
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<tbody>
<tr>
<td>2020</td>
<td>3.5</td>
<td>1%</td>
<td>38%</td>
<td>61%</td>
<td>1%</td>
<td>61%</td>
<td></td>
</tr>
<tr>
<td>2025</td>
<td>3.8</td>
<td>1%</td>
<td>36%</td>
<td>62%</td>
<td>2%</td>
<td>62%</td>
<td></td>
</tr>
<tr>
<td>2030</td>
<td>4.2</td>
<td>2%</td>
<td>36%</td>
<td>62%</td>
<td>2%</td>
<td>61%</td>
<td></td>
</tr>
<tr>
<td>2035</td>
<td>4.6</td>
<td>3%</td>
<td>35%</td>
<td>61%</td>
<td>3%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2040</td>
<td>5.1</td>
<td>3%</td>
<td>35%</td>
<td>61%</td>
<td>3%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

~<5% PEV penetration in parc by 2040


U.S. Medium Duty Vehicle Parc - High PEV uptake scenario
(~20% PEV penetration by 2040)

Volume in Millions (000,000's)

<table>
<thead>
<tr>
<th>Year</th>
<th>Fuel cell</th>
<th>BEV</th>
<th>PHEV</th>
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<td>1%</td>
<td>36%</td>
<td>62%</td>
<td>2%</td>
<td>62%</td>
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<tr>
<td>2030</td>
<td>4.2</td>
<td>0%</td>
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<td>59%</td>
<td>3%</td>
<td>59%</td>
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<tr>
<td>2035</td>
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<td>54%</td>
<td>3%</td>
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<tr>
<td>2040</td>
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<td>1%</td>
<td>27%</td>
<td>48%</td>
<td>3%</td>
<td>48%</td>
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</tr>
</tbody>
</table>

~20% PEV penetration in parc by 2040

Note: % breakdown by powertrain considered for each year’s vehicle stock

U.S. Heavy Duty EV Penetration Scenarios

U.S. Heavy Duty EV Penetration Scenarios

Low PEV uptake scenario
(<5% PEV penetration by 2040)

High PEV uptake scenario
(~30% PEV penetration by 2040)

Note: % breakdown by powertrain considered for each year's annual new vehicle sales

U.S. Heavy Duty Parc Scenarios

U.S. Heavy Duty Parc Scenarios

U.S. Heavy Duty Vehicle Parc - Low PEV uptake scenario
(<5% PEV penetration by 2040)

Volume in Millions (000,000's)

<table>
<thead>
<tr>
<th>Year</th>
<th>Fuel cell</th>
<th>BEV</th>
<th>PHEV</th>
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<th>Flex fuel (E-85)</th>
<th>Gasoline</th>
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<td></td>
<td></td>
<td>98%</td>
<td>98%</td>
<td>2%</td>
</tr>
<tr>
<td>2025</td>
<td>5.6</td>
<td></td>
<td></td>
<td></td>
<td>98%</td>
<td>98%</td>
<td>2%</td>
</tr>
<tr>
<td>2030</td>
<td>6.0</td>
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<td></td>
<td>98%</td>
<td>98%</td>
<td>2%</td>
</tr>
<tr>
<td>2035</td>
<td>6.2</td>
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<td></td>
<td>98%</td>
<td>98%</td>
<td>2%</td>
</tr>
<tr>
<td>2040</td>
<td>6.3</td>
<td></td>
<td></td>
<td></td>
<td>98%</td>
<td>98%</td>
<td>2%</td>
</tr>
</tbody>
</table>

<~5% PEV penetration in parc by 2040

U.S. Heavy Duty Vehicle Parc - High PEV uptake scenario
(~10% PEV penetration by 2040)

Volume in Millions (000,000's)

<table>
<thead>
<tr>
<th>Year</th>
<th>Fuel cell</th>
<th>BEV</th>
<th>PHEV</th>
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<th>Flex fuel (E-85)</th>
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</tr>
</thead>
<tbody>
<tr>
<td>2020</td>
<td>5.2</td>
<td></td>
<td></td>
<td></td>
<td>98%</td>
<td>98%</td>
<td>2%</td>
</tr>
<tr>
<td>2025</td>
<td>5.6</td>
<td></td>
<td></td>
<td></td>
<td>98%</td>
<td>98%</td>
<td>2%</td>
</tr>
<tr>
<td>2030</td>
<td>5.9</td>
<td>2%</td>
<td></td>
<td></td>
<td>95%</td>
<td>92%</td>
<td>1%</td>
</tr>
<tr>
<td>2035</td>
<td>6.2</td>
<td>1%</td>
<td></td>
<td></td>
<td>92%</td>
<td>86%</td>
<td>1%</td>
</tr>
<tr>
<td>2040</td>
<td>6.3</td>
<td>4%</td>
<td></td>
<td></td>
<td>86%</td>
<td></td>
<td>4%</td>
</tr>
</tbody>
</table>

~10% PEV penetration in parc by 2040

Note: % breakdown by powertrain considered for each year’s vehicle stock


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Following general assumptions were made for projecting impact of Movements in 2040

**Assumptions made for Movement impact assessment**

<table>
<thead>
<tr>
<th>Assumption</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Subsidies</strong></td>
<td>Continued federal tax credit and state level subsidies and incentives offered till 2030. Subsidies taper off 2030+</td>
</tr>
<tr>
<td><strong>ZEV mandate</strong></td>
<td>Limited to the 12 states that adopted ZEV mandate until 2040</td>
</tr>
<tr>
<td><strong>Charging Infrastructure</strong></td>
<td>Legislation passed 2030+ to reduce range anxiety equitable access to charging stations similar to New Jersey S2252</td>
</tr>
<tr>
<td><strong>CAFE standard</strong></td>
<td>SAFE rule implemented (~1.5% CAGR fuel economy improvement till 2040)</td>
</tr>
<tr>
<td><strong>LCFS</strong></td>
<td>Considering 20% Carbon Intensity (CI) reduction by 2030; assuming 30% CI reduction by 2040</td>
</tr>
<tr>
<td><strong>RFS</strong></td>
<td>Assuming RFS continues in current format with discretionary waivers until 2040</td>
</tr>
<tr>
<td><strong>Cleaner Trucks Initiative</strong></td>
<td>Standards not defined yet. Assuming mandate impacts lower load condition of medium and heavy duty trucks limiting NO(_X) emissions to 0.6 g/mile across entire operating profile. Impacts only from MY2025+</td>
</tr>
<tr>
<td><strong>Transportation Climate Initiative (TCI)</strong></td>
<td>Limited to the 12 states signatory to the program. Compliance begins in 2022 and aims to achieve 20%-25% CO(_2) reduction by 2032 and increases to 30%-35% reduction target by 2040</td>
</tr>
<tr>
<td><strong>Carbon pricing</strong></td>
<td>Assuming a carbon pricing legislation on transportation fuel is passed in 2025+ timeframe with max cost of per ton of CO2 lagging TCI states carbon pricing</td>
</tr>
<tr>
<td><strong>Vehicle restriction / ICE ban</strong></td>
<td>Assuming only major cities such as Los Angeles, New York and Seattle pass vehicle restriction laws</td>
</tr>
<tr>
<td><strong>Congestion pricing</strong></td>
<td>Assuming only major cities such as Los Angeles, New York and Seattle pass congestion pricing laws</td>
</tr>
<tr>
<td><strong>Autonomous mobility</strong></td>
<td>Assuming only major cities operate autonomous vehicles until 2030 in geofenced zones</td>
</tr>
</tbody>
</table>

*Source: Ricardo analysis*
Select movements cost impact assessment methodology is provided below.

Example of Movements cost assessment methodology

- Telecommuting can be implemented at negligible cost
- Maximum incremental cost of fuel per gallon from LCFS to range from ~$0.3 in 2020 to ~$0.6 - $0.8 in 2040
- For annual vehicle miles travelled (VMT) of 13,000 miles and average fuel efficiency of 35 miles/gallon i.e. ~300 gallons fuel costs over a 15 year duration will range from ~$2,000 - $2,500 per consumer at expected average
- Additionally, marginal reduction in fuel economy from biofuels will result in maximum incremental annual fuel cost of $200 per consumer i.e. over a 15 year duration will result in an additional $3,000 cost
- Total cost to consumer from LCFS over 15 year duration = $5,000 - $5,500
- Maximum yearly incremental cost for fuel in TCI states is estimated to range from ~$100 in 2022 to max of $150 in 2032
- Total cost to consumer from TCI over 15 year duration = $1,500 - $2,300
- Cost of access to congestion pricing zone in New York ranges from $5 - $12 per vehicle
- Annual cost of access = $5 * 260 days (working days per year) = ~$1,300
- Total cost to consumer to access congestion pricing zone year round over 15 year duration is >$15,000
- Incremental cost to meet ZEV mandate is ~$8,000 - $12,000 higher per vehicle than a comparable ICE vehicle
- Total maximum cost to consumer from ZEV mandate = $8,000 - $12,000

Source: Ricardo analysis
I m p a c t  o f  T r a n s p o r t a t i o n - R e l a t e d  E n v i r o n m e n t a l  I n i t i a t i v e s

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A positive but limited impact expected based on alternative fuels. Electrification will be the main driver to achieve expected reductions.

Low Carbon Fuel Standard (LCFS) – GHG Emissions Impact

- When Low Carbon Fuel Standard (LCFS) is adopted does not matter for pass cars. If other alternative fuel types such as cellulosic fuels come into play then additional GHG emissions reduction come into play
- Credit mix expected to be supported majorly through Starch ethanol, Electricity, and bio and renewable diesels
- For gasoline and substitutes i.e. passenger cars, majority GHG emissions impact is through starch ethanol which is maxed through blend wall of 10% ethanol and through EV charging infrastructure
  - Higher GHG impact feasible only through alternative ethanol blends such as cellulosic ethanol. However, Ricardo has not seen evidence supporting commercial viability of cellulosic fuels
- For heavy duty fleet, GHG reductions estimated to be provided majorly through renewable diesel which does not require powertrain technology change

![Graph showing GHG emissions impact with expected reductions for 2020, 2030, and 2040 with CARB and Ricardo estimates]

**Note:** Both high fuel demand, low ZEV penetration and low fuel demand with high ZEV penetration scenarios from CARB considered in the estimates – excludes emission reduction impact of ZEV uptake

Source: CARB illustrative compliance scenario, Aug 2018; Ricardo analysis
Higher incremental cost of $0.6-$0.8 estimated per gallon of transportation fuel to meet LCFS targets

Low Carbon Fuel Standard (LCFS) – Cost of Compliance

- Low Carbon Fuel Standard (LCFS) credit clearance market (CCM) price at all time high in Q3 2019 of ~$207 / MT of CO$_2$
- CARB adopted Resolution 19-27, which was passed in 2019, to moderate CCM prices and mitigate impact on fuel prices.
- **Highest cost scenario**: no cap on CCM and assumed CI reduction of 40% by 2040, cost per gallon of fuel (gasoline and diesel) is expected to increase to ~$1.5 per gallon in the year 2040
- **Lowest cost scenario**: CARB estimates that with cap on CCM and 25% CI reduction target in 2040 limits the cost increase per gallon of fuel to ~$0.5 by 2030
- **Expected cost scenario**: Ricardo assumed credit price capped at $200/MT for 30% CI reduction target by 2040 and cost of fuel is expected to increase to ~$0.6 - $0.8 per gallon by 2040

Note: Incremental cost of fuel assumes considers both gasoline and diesel and assumes that incremental cost per gallon of each fuel type are similar i.e. within $0.01 - $0.02 difference

Limited and a lower impact on GHG emissions from RFS compared to LCFS on a normalized basis if RFS continues with current format

Renewable Fuel Standard (RFS) – GHG Emissions Impact

- Continued discretionary waivers and lack of confidence in the RIN market has reduced the estimated impact of Renewable Fuel Standard (RFS)
- High emission impact scenario: considers high fuel demand into 2040, meeting E10 blend wall of 15B gallons per year and a stable RIN market leading to increase in uptake of other alternative fuels such as biodiesel, and other advanced biofuels. Estimated emissions reduction of ~180MMT CO$_2$ in the year 2040
- Low emission impact scenario: considers low fuel demand into 2040 (based on AEO outlook) which limits E10 use i.e. <15B gallons and an unstable RIN market leading to limited uptake of other alternative fuels. Estimated emissions reduction of ~80MMT CO$_2$ in the year 2040

Note: Both high fuel demand, higher alternative fuels uptake (i.e RIN market stabilized) and low fuel demand with low alternative fuels uptake (i.e. RIN market unstable with waivers continued) scenarios considered in the estimates

RFS levies a lower incremental cost per gallon of fuel compared to LCFS; expected to continue if RFS implementation does not change

Renewable Fuel Standard (RFS) – Cost of Compliance

- Renewable Fuel Standard (RFS) continues to suffer from wild swings in RIN prices i.e. ~30% fluctuation YOY compared to a baseline of 2015 prices due to changing federal policies
- **Highest cost scenario**: considers a stable RIN market leading to increase in uptake of other alternative fuels other than ethanol. Cost per gallon of fuel (gasoline and diesel) is expected to increase by ~$0.5 per gallon in the year 2040
  - Higher cellulosic fuel demand considered under this scenario
  - Increased demand considered for other alternative fuels such as biodiesel, and other advanced biofuels
- **Lowest cost scenario**: considers a volatile RIN market with continued discretionary waivers and limited uptake of alternative fuels i.e. status quo continued scenario. Cost per gallon of fuel (gasoline and diesel) is expected to increase by ~$0.3 - $0.35 per gallon in the year 2040

**Note**: Incremental cost of fuel assumes considers both gasoline and diesel and assumes that incremental cost per gallon of each fuel type are similar i.e. within $0.01 - $0.02 difference

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Trucks meeting 0.6 g/mile target across all load conditions reduces NO\textsubscript{X} emissions of new vehicles by ~80%

Cleaner Trucks Initiative (CTI) – Emissions

- CTI to impact only model years 2025+ and assuming CTI will target of 0.6 g/mile NO\textsubscript{X} emissions across all load profiles of diesel truck operation
  - Assuming ~40%-50% improvement over current in-use emissions yields significant avoided emissions over vehicle operating lifetime
  - Current distance specific NO\textsubscript{X} emission ranges from 3.6 – 4 g/mile

- Cleaner Trucks Initiative (CTI) expected impact on NO\textsubscript{X} emissions reduction ~70-80% of expected impact from CTI and electrification for both medium and heavy duty trucks

- Average useful life including rebuilds considered as follows based on EPA’s estimate:
  - Medium duty diesel trucks – 500k miles
  - Heavy duty diesel trucks – 900k miles

Note: Only new vehicle sales lifetime avoided NO\textsubscript{X} emissions displayed in the plot to the left. Lifetime emissions calculated based on EPA’s useful life estimate

Source: https://ww3.arb.ca.gov/research/veh-emissions/low-nox/low-nox.htm ; Ricardo analysis
Fuel economy could potentially improve or reduce by 1% - 2% based on technologies used to comply with emissions targets

Cleaner Trucks Initiative (CTI) – Fuel Economy

- CTI mandates, though not defined yet, could potentially drive higher PEV uptake, which would improve average fuel economy or could potentially be met by ICE powertrains only which would marginally improve or reduce average fuel economy based on emissions reduction technology deployed to meet targets
- CTI to impact only model years 2025+
- Based on technologies deployed, can expect improvement in fuel efficiency or marginal fuel efficiency loss of ~1-2% compared to baseline
  - CARB NO\textsubscript{X} emissions reduction strategies study which EPA is assessing for CTI rule making found marginal increase in fuel consumption for technologies such as advanced after treatment etc.
  - Additionally, CARB also found that technologies such as cylinder deactivation could drive both lower NO\textsubscript{X} and CO\textsubscript{2} emissions
- Weighted average impact of electrification on fuel economy for medium duty trucks in year 2040 ranges from min of ~12 mpg to max ~15 mpg
- Weighted average impact of electrification on fuel economy for heavy duty trucks in year 2040 ranges from min of ~8 mpg to max ~11 mpg

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Impact of Transportation - Related Environmental Initiatives

Project # Co21273, 22 May 2020

Average incremental yearly fuel costs from TCI and carbon pricing are not significant enough to shift consumer behavior

Transportation Climate Initiative (TCI), Carbon pricing – Cost of Compliance

- Average yearly incremental cost for fuel in TCI states is estimated to range from ~$30 - $90 in 2022 to max of $160 - $230 in 2040
  - Cost per ton of CO₂ in TCI is estimated to range from $5 in 2022 to $70 in 2040
- Total estimated cumulative incremental fuel cost impact from TCI per person ranges from ~$1,000 - $2,500 over 2022 – 2040 duration
- Similarly average yearly incremental cost for fuel from Carbon Pricing if implemented in 2025+ time frame is estimated to range from ~$30 - $80 in 2025 to max of $100 - $150 in 2040
  - Carbon pricing assumed to be implemented in 2025+ time frame nationally with cost per ton of carbon assumed to lag TCI pricing

Note: Average baseline cost of an gasoline is considered as $0 on the Y-axis

Both TCI and carbon pricing are reliant on technology breakthrough in PEVs to impact vehicle demand compared to other Movements

Transportation Climate Initiative (TCI), Carbon pricing – Vehicle Demand

- Only in the long term, as PEVs attain cost parity with ICEs, do TCI and carbon pricing enable shift in vehicle demand
- The average cost of carbon with TCI from 2022 - 2032 is expected to range from $5 - $30 per ton of CO2 and is expected to drive limited impact on vehicle demand
- Incremental price ranges for TCI are <10% during the TCI implementation period to drive meaningful change. Ricardo estimated cost of 2X – 5X to drive any meaningful change in vehicle demand in short term
- However, in the long term as incremental annual cost of fuel increases over $150+ per year range, supports PEVs achieve TCO parity in comparison to an ICE driving vehicle demand, lower GHG emissions and improved average fleet fuel economy
- Total estimated incremental fuel cost impact from TCI per person ranges from ~$1,000 –$2,500 over 2022 – 2040 duration

Impact on fuel economy from TCI and carbon pricing is heavily reliant on uptake of fuel efficient vehicles

Transportation Climate Initiative (TCI), Carbon pricing – Fuel Economy

- Weighted average impact of electrification on fuel economy for combined pass car and light trucks in year 2040 ranges from ~55 mpg to ~90 mpg
  - ~90mpg takes into account 60% of sales in 2040 are PEVs
  - ~55mpg considers PEV sales limited to 10% of annual LDV sales in 2040. 10% PEV scenario also considers marginal improvement in fuel economy till 2040 from SAFE rule implementation

- TCI and carbon pricing, both gas taxes, have limited impact on new vehicles average fuel economy in the short run. Reduced total cost of ownership of PEVs through technology breakthrough allows TCI and carbon pricing to have a larger impact in the 2030+ timeframe

- TCI and carbon pricing have limited direct causal effect on fuel efficiency of vehicles. Both rely on assumption that increased fuel prices, cause consumers to reduce fuel consumption or shift to fuel efficient vehicles
  - Multiple studies have found demand of gasoline from price shift to be inelastic to marginally elastic
  - A congressional study found that 10% increase in fuel costs in short term lead to 0.6% decline in average fuel consumption and 4% decline if higher costs persists for a sustained period of ~15 years

Note: Fuel economy impact considers on road light duty fuel economy mpg for both passenger cars and light trucks

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    • Subsidies / Incentives
    • ZEV mandate
    • Charging infrastructure
    • CAFE
    • Renewable Fuel Standard (RFS)
    • Low Carbon Fuel Standard (LCFS)
    • Cleaner Truck Initiative (CTI)
    • Transportation Climate Initiative (TCI)
    • Carbon pricing
    • Vehicle use type restrictions / ICE bans
    • Congestion pricing
    • Connected and autonomous vehicles
    • Shared mobility

  – Excluded Movements: Vehicle retirement program, Tolls, Parking benefits

• Appendix – III (Summary of research)
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Appendix – II (Movement 101)

Assessed U.S. and global Movements for 2040 impact:

- Telecommuting
- Subsidies / Incentives
- ZEV mandate
- Charging infrastructure
- CAFE
- Renewable Fuel Standard (RFS)
- Low Carbon Fuel Standard (LCFS)
- Cleaner Truck Initiative (CTI)
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- Carbon pricing
- Vehicle use type restrictions / ICE bans
- Congestion pricing
- Connected and autonomous vehicles
- Shared mobility

Excluded Movements: Vehicle retirement program, Tolls, Parking benefits

Appendix – III (Summary of research)
Telework Enhancement Act of 2010 mandates each federal agency to establish a telecommuting policy and maximize it where applicable

**Movement “101”: Telecommuting**

### Legislation:
- Telework Enhancement Act of 2010

### History:
- Earliest iteration passed in 1990 as the "Treasury, Postal Service and General Government Appropriations Act, 1991 Public Law 101-509, §624"
- Updated in 2001 as the "Transportation and Related Agencies Appropriations Act of 2001 (Public Law 106-346)". Required each executive agency to establish a telecommuting policy allowing eligible employees to telecommute to the maximum extent possible without diminished employee performance

### Geography:
- United States – applicable for federal agencies

### Objective:
- Act passed in 2001 began as an effort to address transportation concerns and manage real estate costs
- Grew into an important flexible work arrangement and a recruitment and retention tool for the Federal Government, culminating in Telework and Enhancement Act of 2010
- Telework Enhancement Act of 2010 applies to all federal executive agencies and applies to federal employees as defined by section 2105 of title 5 USC

### Outlook:
- Post COVID-19, telecommuting impact on emissions can be assessed by government and organizations for telecommuting strategy roll-out. Some states such as Utah, Tennessee etc. are implementing initiatives to maximize telecommuting


**Legislation Applicable Regions**
- Applicable only for federal agencies across U.S.
Impact of Transportation - Related Environmental Initiatives

EU telework agreement provides autonomy to each member state on implementation; Canada telework policy limited to federal positions

Movement “101”: Telecommuting

Legislation:
- European Framework Agreement on Telework; Telework Policy - Canada

History:
- The European Framework Agreement on Telework was concluded and signed in 2002 by social partners such as BusinessEurope (formerly UNICE), the European Association of Craft, Small and Medium sized Enterprises (UEAPME) etc.
- This agreement is not implemented through a European directive, but adopted by each member state based on their labor practices and regulations
- Canada – Telework Policy became effective in 1999

Geography:
- EU + UK + Norway; Canada

Objective:
- European Framework Agreement on Telework: As more employees have been able to work from remote locations, in the context of the European Employment Strategy, the European Council invited social partners to negotiate agreements to modernize the organization of work
- Canada – Telework Policy: to allow employees to work at alternative locations, thereby achieving a better balance between their work and personal lives, while continuing to contribute to the attainment of organizational goals – policy applicable only for positions in federal service

Outlook:
- 2022 European Framework Agreement on Telework laid down rules to ensure protection of teleworkers. Post COVID-19, further guidelines and improvement on telework policies can be expected

Many states are promoting alternative adoptions by providing extra incentives, tax credits and registration fee reductions (1/2)

Movement “101”: Subsidies

<table>
<thead>
<tr>
<th>Legislation:</th>
</tr>
</thead>
<tbody>
<tr>
<td>- State-level subsidies for EVs</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>History:</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Clean Vehicle Rebate Project (CVRP), Property-Assessed Clean Energy (PACE), California</td>
</tr>
<tr>
<td>- New York State Energy Research and Development Authority (NYSERDA)</td>
</tr>
<tr>
<td>- Port Authority of New York &amp; New Jersey (PANYNJ)</td>
</tr>
<tr>
<td>- Jacksonville Electric Authority (JEA), Florida</td>
</tr>
<tr>
<td>- Maryland Energy Administration (MEA)</td>
</tr>
<tr>
<td>- Massachusetts Offers Rebates for Electric Vehicles (MOR-EV)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Geography:</th>
</tr>
</thead>
<tbody>
<tr>
<td>- All states except AK, AR, ME, NE, OK, SC and VW</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Objective:</th>
</tr>
</thead>
<tbody>
<tr>
<td>- CVRP - Offers up to $2,500 for the purchase or lease of BEVs. Qualifying low-income households also receive an additional $2,000 for purchase or lease of EV after 1st Nov, 2016</td>
</tr>
<tr>
<td>- NYSERDA offers $2000 and MOR-EV offers $1,500 of rebate for purchase/lease of BEV</td>
</tr>
<tr>
<td>- JEA offers $1000 in rebate for purchase/lease of qualified PEV</td>
</tr>
<tr>
<td>- PACE – Finances residential property owners to install EV supply equipment (EVSE)</td>
</tr>
<tr>
<td>- NYSERDA offers a rebate of $8,000 for EVSE installed. MEA offers EVSE rebate as well</td>
</tr>
<tr>
<td>- PANYNJ - EVs are eligible for the Clean Pass Program and receive a discounted toll rate</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Outlook:</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Subsidies are critical PEV uptake drivers in short-to-medium term. Continued incentivization of PEV through subsidies required for PEV uptake. As PEVs achieve cost parity, subsidies are scaled back beyond 2030+ timeframe</td>
</tr>
</tbody>
</table>

Many states are promoting alternative adoptions by providing extra incentives, tax credits and registration fee reductions (1/2)

Movement “101”: Subsidies

Legislation:
- State-level subsidies for EVs

History:
- San Diego Gas and Electric (SDG&E)’s rebate program, San Diego, California
  - Program ended on 30th September, 2017
- Massachusetts Electric Vehicle Incentive Program (MassEVIP), Massachusetts
  - Started on 22nd April, 2013 (Earth Day)

Geography:
- CT, IL, DC, CO, DE, FL, GA, IN, KY, MD, PA, CA (San Diego)

Objective:
- SDG&E – Annual rebates up to $20,000 or tax credits of $50 on purchase of EVs and HEVs
- Connecticut, Illinois, and the District of Columbia have low annual registration fees for EVs or alternative fuel vehicles
- $10,000 rebate by electric utility companies on purchase of Nissan Leaf in Colorado, Delaware, Florida, Georgia, Indiana, Kentucky, Maryland and Pennsylvania in 2017
- MassEVIP - 50% (up to $25,000) grants off the cost of Level 1 or Level 2 workplace EVSE for employers with 15 or more employees in a non-residential place of business

Outlook:
- Subsidies are critical PEV uptake drivers in short-to-medium term. Continued incentivization of PEV through subsidies required for PEV uptake. As PEVs achieve cost parity, subsidies are scaled back beyond 2030+ timeframe

Subsidies / Incentives are indirect drivers on fuel economy, GHG emissions and cost of compliance

Cumulative impact through 2040

Several countries offer subsidies to drive EV uptake; EU considering VAT exemption for EVs to drive demand post COVID-19

Movement “101”: Subsidies

Legislation:
- Global subsidies

History:
- Different developments in UK and EU as of 2019
  - Germany – Landmark Climate package launched in Nov, 2019 with aims to boost EV sales
  - France – Paris Climate Accord aims to promote sales of EV and charging stations
  - UK - Society of Motor Manufacturers and Traders (SMMT) seeks govt. help for battery manufacturing investments, incentives and infrastructure spending

Geography:
- Germany, France, UK, Norway, Sweden, Netherlands, Denmark, Italy

Objective:
- Germany – Handouts of €6000 on purchase of EV for less than €40,000
  - Govt. also plans for 1M charging station by 2025
- France - €6000 plus conversion bonus to buyers scrapping an old vehicle for an EV
- UK - Offers grants and rebates on pure EVs of as much as £3,500
- Netherlands - Low sales-tax applied to the first €50,000 of the price tag of an EV. No road tax
- Sweden - Customers get bonus of as much as $6,300 at purchase of an EV
- Denmark cancelled planned tax increase on EV and Norway exempts EVs of most taxes

Outlook:
- Several EU countries will continue to incentivize EV adoption through subsidies to meet respective emission targets. Electric cars to get a boost in Europe as part of COVID-19 recovery plan, VAT exemption considered

ZEV mandate requires OEMs selling vehicles in signatory states to sell a percentage of vehicles to be xEVs to meet credit requirements

Movement “101”: ZEV Mandate

Legislation:
- CARB Zero-Emission Vehicle (ZEV) program

History:
- Originally part of the Low Emission Vehicles (LEV) program, ZEV program was established as a standalone regulation in 1999
- In 2012, CARB adopted a set of regulations to control emissions from passenger vehicles, collectively called “Advanced Clean Car” program
- ZEV program is a part of the Advanced Clean Car program that mandates increasing ZEV floor requirements through 2025+

Geography:
- California and 11 other states (CT, ME, MA, VT, RI, OR, NY, NJ, MD, CO, WA)

Objective:
- CARB states mobile sources account for well over half of the emissions which contribute to ozone and particulate matter and ~40 percent of the greenhouse gas emissions in California
- Zero Emission Vehicles are required to help meet California’s air quality standards and GHG reduction goals as parts of CARB’s Advanced Clean Cars program
- Requires automakers that sell more than 20,000 vehicles per year to produce a percentage of vehicles sold in CA to comply with ZEV or Transitional ZEV requirements which increase yearly
  - ZEV credits requirement: 7% in 2019, 9.5% in 2020 and 22% by 2025

Outlook:
- ZEV mandate states account for ~30% of annual U.S. vehicle sales, which drives higher model eligibility and mandates sales of vehicles to meet requirements. As subsidies are reduced beyond 2030, ZEV mandate takes precedence in long term

Source: [https://ww2.arb.ca.gov/our-work/programs/zero-emission-vehicle-program](https); [https://www.zevstates.us/](https); [https://phev.ucdavis.edu/wp-content/uploads/zev-mandates-policy-guide.pdf](https)
China’s NEV policy mandates manufacturers to meet incremental credit based requirements through xEV sales

### Movement “101”: ZEV Mandate

<table>
<thead>
<tr>
<th>Legislation:</th>
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<tbody>
<tr>
<td>China NEV Mandate</td>
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<table>
<thead>
<tr>
<th>History:</th>
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</thead>
<tbody>
<tr>
<td>In 2017, China’s Ministry of Industry and Information Technology (MIIT) launched New-Energy Vehicle (NEV) mandate policy for passenger cars.</td>
</tr>
<tr>
<td>The NEV mandate sets annual NEV credit targets at a percentage of the conventional passenger vehicle market.</td>
</tr>
<tr>
<td>NEVs subsidies are proposed to be phased out after 2020.</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Geography:</th>
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<tbody>
<tr>
<td>China</td>
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<table>
<thead>
<tr>
<th>Objective:</th>
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<tbody>
<tr>
<td>Chinese government views NEVs as a pathway for energy security, controlling urban air pollution, and meeting emission targets.</td>
</tr>
<tr>
<td>China also hopes to leapfrog competing global automotive regions with its NEV policy.</td>
</tr>
<tr>
<td>Chinese government envisages xEVs to account for 25% of vehicle sales in China by 2025 and 60% of all sales by 2035.</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Outlook:</th>
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<tbody>
<tr>
<td>Expected to continue to increase in stringency of targets and backing through subsidies to continue to support the NEV policy. After a blip in EV sales in 2019 from subsidy roll-back, China decided to extend subsidies for additional two years through 2023 to support EV sales.</td>
</tr>
</tbody>
</table>

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**Impact of Transportation - Related Environmental Initiatives**

**Project # C021273, 22 May 2020**

**EV Freedom Act is a federal level legislation, still under legislative process, that seeks to address EV charging infrastructure issues**

**Movement “101”: Charging Infrastructure (Federal)**

<table>
<thead>
<tr>
<th>Legislation:</th>
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<tbody>
<tr>
<td>- EV Freedom Act, HR 5770</td>
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<table>
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<tr>
<th>History:</th>
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<tbody>
<tr>
<td>- EV Freedom Act HR 5770 was introduced by representatives Andy Levin and Alexandria Ocasio-Cortez on February 2020 to establish national network of electric vehicle charging stations</td>
</tr>
<tr>
<td>- The act has not been approved and is currently under legislative process</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Geography:</th>
</tr>
</thead>
<tbody>
<tr>
<td>- United States</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Objective:</th>
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</thead>
<tbody>
<tr>
<td>- The findings of the act noted increase in sales of EVs, new model launches and investment by OEMs and lack of infrastructure to support increasing demand. The act aims to establish network of electric vehicle charging stations along eligible roads to improve consumer experiences and encourage the widespread adoption of light, med and heavy-duty EVs by - eliminate “range anxiety” - allowing drivers to charge vehicles more quickly; and - equitable access to charging stations</td>
</tr>
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<table>
<thead>
<tr>
<th>Outlook:</th>
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</thead>
<tbody>
<tr>
<td>- Legislation expected to reduce range anxiety equitable access to charging stations similar to New Jersey S2252</td>
</tr>
</tbody>
</table>

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NJ’s S2252 bill passed (01/2020) mandates establishing a statewide public charging system to support 330k PEVs by 2025

Charging Infrastructure – New Jersey

Goals / Impact from New Jersey’s S2252 Legislation

- S2252 (signed into law in 01/2020) establishes goals and incentives for the increased use of plug-in EVs and infrastructure in New Jersey (NJ)
- The bill codifies goal of 330,000 registered light-duty electric vehicles by 2025 and directs state-owned light-duty vehicles to be electric by 2035. Goal of putting NJ on a path to a 100% clean energy by 2050
- The legislation creates a “Plug-in Electric Vehicle Fund” and will be funded by approximately $30 million from the Clean Energy Fund each year. The bill authorizes the use of Regional Greenhouse Gas Initiative (RGGI) funds as well.
  - The Clean Energy Fund is supported by a surcharge on electricity (both public and commercial)
- The legislation directs the Department of Environmental Protection and Board of Public Utilities to establish goals for the electrification of medium and heavy-duty vehicles
  - Plan to install at least 600 DCFC and 1,000 Level 2 public community chargers at ~300 locations by end of 2025
  - End of 2019, NJ has 87 DCFC stations with 341 plugs and 330 stations with 767 plugs

Program supported through surcharge on electricity in addition to revenue from RGGI

S2252 codifies establishing state wide public EVSE network to support 330k PEVs by 2025

Norway and France have charging infrastructure rollout legislation. Other regions have directives to support increased EV adoption

Movement “101”: Charging Infrastructure

Legislation:
- Norsk Elbilforening – Norway, Energy Transition Law, no 2015-992 - France

History:
- Norway – Latest iteration of EV support legislation was rolled out in 2012
- France – Energy transition law was adopted in 2014 and ratified in 2015

Geography:
- Norway, France, Netherlands

Objective:
- Norway - By 2017 the Norwegian Government launched a program to finance the establishment of at least two multi-standard fast charging stations every 50 km on all main roads in Norway. With the exceptions of Finnmark and Lofoten, there has successfully been established fast charging stations on all main roads in Norway
- France - Law on Energy Transition for Green Growth” (LTECV), the French Government has set the target of 7 million public and private charging points for electric vehicles by 2030.

Outlook:
- Norway and France mandated EVSE installations. Other regions in EU and around the globe are supporting EVSE through subsidies and public and private partnerships

Other Global Legislation

Impact of Transportation - Related Environmental Initiatives

Project # Co21273, 22 May 2020

CAFE includes targeted incentives for advanced technologies that promote fuel economy improvements and GHG reductions

Movement “101”: Corporate Average Fuel Economy (CAFE)

Legislation:
- Corporate Average Fuel Economy

History:
- First enacted by Congress in 1975, the purpose of CAFE is to reduce energy consumption by increasing the fuel economy of cars and light trucks
- Regulated by National Highway Traffic and Safety Administration (NHTSA)
- 21st May, 2010 – Joint final rules by NHTSA and EPA for CAFE as well as GHG regulations for passenger cars and light trucks built in 2017 and beyond

Geography:
- United States

Objective:
- CAFE standards (rolled back in 2020) impacting passenger car and light trucks impacts 2017-2021 model years and were mandated to achieve combined fleet-wide fuel economy of 40.3-41.0 mpg
  - Required to reach 55 mpg by 2026 (5% year-on-year growth in fleet fuel economy between 2020 – 2025 model years)
- SAFE rule, implemented in March 2020, mandates 1.5% fleet fuel economy improvement impacting model years 2021 - 2026

Outlook:
- Stringency must be increased for emissions benefits as fleet fuel economy growth rate of 1.5% per year from SAFE rule forecasted till 2040 results in fleet average mpg of 55 in 2040, compared to rolled back CAFE standards, which mandated that 55mpg be achieved by 2025

Japan, China, and South Korea have fuel economy standards similar to CAFE standards in U.S.

Movement “101”: Corporate Average Fuel Economy (CAFE)

**Legislation:**
- Energy Conservation Law - Japan; Corporate Average Fuel Consumption – China; etc.

**History:**
- Japan - Energy Conservation Law was enacted in 1976 and fuel efficiency standards were adopted in 1979 amendments which were applicable beginning in 1985. Standards were last amended in 2019 for vehicles starting in MY 2030.
- China – Corporate Average Fuel Consumption (CAFC) was first adopted in 2004 (National Standard GB 19578-2004) as Phase I. Phase V proposed in 2019 impacting MY 2021-2025.
- South Korea – Average Fuel Economy (AFE) program took effect in 2006. Standards impacting fuel economy of MY2016 – MY2020 were adopted in 2014.

**Geography:**
- Japan, China, Korea

**Objective:**
- Japan - Energy Conservation Law mandates an average fleet gasoline-equivalent fuel economy of 25.4 kilometers per liter by 2030; a 32.4% improvement over the fleet average for fiscal year 2016.
- China – CAFC phase V proposed standards mandate average fuel consumption of new passenger cars to be reduced to 4 l/100km in 2025.
- South Korea – AFE targets 24.3 km/L fuel economy for passenger vehicles in 2020.

**Outlook:**
- Japan, South Korea and China fuel economy standards forecasted to be more stringent compared to U.S. CAFE standards to drive their EV policies.

Increased difficulty in meeting standards impacts the cost of compliance, resulting in significant financial burden for refiners

Movement “101”: Biofuel Blending – Renewable Fuel Standard (RFS)

Legislation:
- Renewable Fuel Standard (2) Mandate

History:
- RFS 2020 rule – 6th Feb, 2020

Geography:
- United States

Objective:
- Blend following renewables into traditional fuels
  - Biomass-based diesel
  - Cellulosic biofuel
  - Advanced biofuel
  - Total renewable fuel
- Aim of blending 36 Billion gallons of renewable fuel with gasoline by 2022

Outlook:
- EPA expected to grant waivers for 2021 and 2022 as RFS will not be able to meet volume target requirements

### Impact of Transportation - Related Environmental Initiatives

**EU has assigned individual national targets in order to achieve 80 - 95% GHG emission reduction by 2050**

#### Movement “101”: Biofuel Blending

<table>
<thead>
<tr>
<th>Legislation:</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Renewable Fuels Directive II (RED II)</td>
</tr>
</tbody>
</table>

#### History:

- Renewable Energy Directive (RED) signed in 2009. Aimed at fulfilling 20% of EU’s energy needs with renewables by 2020
- To be upgraded to RED II – 21st December, 2020
  - Overall EU target has been raised to achieve 32% of EU’s energy needs by 2030

#### Geography:

- European Union

#### Objective:

- 14% of transportation fuel must come from renewable sources by 2030
  - Advanced biofuels and biogas produced from feedstock must be at 0.2% usage in 2022, 1% in 2025 and 3.5% in 2030
- It also sets limits on high ILUC (Indirect Land Use Change) biofuels using criteria for:
  - Determining the high ILUC-risk feedstock
  - Certifying low ILUC-risk biofuels, bioliquids and biomass fuels

#### Outlook:

- All European Union member states were required to submit a National Renewable Energy Action Plan (NREAP) that detailed how each member state intends to meet their target

---

Low Carbon Fuel Standard (LCFS) is designed to reduce the lifecycle carbon intensity (CI) of transportation fuels

Movement “101”: Low Carbon Fuel Standard (LCFS) Mandate

Legislation:
- Low Carbon Fuel Standard (LCFS) Mandate

History:
- The LCFS was adopted in 2009 and became effective in 2011; was re-adopted in 2015
- Under the AB 32 Scoping Plan, CARB identified LCFS as one of the nine discrete early action measures to reduce California’s greenhouse gas (GHG) emissions that cause climate change
- Amended in 2018 to strengthen the carbon intensity (CI) benchmarks through 2030 and align with California’s 2030 GHG emission reduction target

Geography:
- California, Oregon, British Columbia (Canada), Washington (under consideration)

Objective:
- LCFS sets Carbon Intensity (CI) Standards that reduce over time for gasoline, diesel and fuels that replace them
  - CI is the lifecycle measure of fuel GHG emissions from production to consumption
  - Fuels in California transportation fuel pool that have a CI lower than the target established by CARB generate LCFS credits
- The goal of California’s LCFS program is to reduce 20 percent of carbon emissions throughout the entire energy life cycle by 2030

Outlook:
- LCFS has an established market for credit transactions that exceeded $2 Billion in 2018
- Other states like Oregon, Washington and British Columbia are joining California to reduce GHG, which is evident from the Pacific Coast Collaborative (PCC) agreement

Fuels Quality Directive (FQD) will be phased out after 2020 as decarbonization of transport fuels will be addressed in RED II

### Movement “101”: Low Carbon Fuels Standard

<table>
<thead>
<tr>
<th><strong>Legislation:</strong></th>
<th>Fuels Quality Directive (FQD)</th>
</tr>
</thead>
</table>

| **History:** |
| In 2009, EU passed the FQD along with the Renewable Energy Directive (RED) regulation supporting increased use of renewable fuels. FQD became effective from 1st January, 2011 |
| Member States should reduce the GHG intensity of fuels in road vehicles and non-road machinery by 6% by 2020 |
| Beyond 2020, FQD will be rolled into an updated RED II |

| **Geography:** |
| European Union |

| **Objective:** |
| Fuel suppliers are required to annually report the following information: |
| Total volume of each type of fuel supplied, indicating its origin and purchase location |
| Life cycle GHG emissions per unit of energy |
| **Optional target:** Reduced carbon intensity of the fuel mix by 10% |

| **Outlook:** |
| EU aims for reduction of CO2 emissions by 40% and growth in renewable energy consumption by 27% by 2030. Fuels Quality Directive (FQD) to be phased out after 2020 as decarbonization of transport fuels will be addressed through Renewable Fuels Directive II (RED II) |

Cleaner Truck Initiative in proposal stage and expected to impact in 2025+; aims to target NO\textsubscript{x} emissions reduction in low-load operation

Movement “101”: Cleaner Trucks Initiative

**Legislation:**
- Cleaner Trucks Initiative

**History:**
- In November 2018, EPA announced that it would pursue the Cleaner Trucks Initiative (CTI) to update NO\textsubscript{x} emissions standards for heavy-duty trucks
- 6\textsuperscript{th} January, 2020 – EPA signed an Advance Notice of Proposed Rule (ANPR) soliciting pre-proposal comments on a rulemaking effort known as the Cleaner Trucks Initiative (CTI)
- Existing standard of 0.2 g/bhp-hr is being met mostly under highway operation, but not under low load conditions (idle, stop-&-go and city traffic)

**Geography:**
- All states

**Objective:**
- CTI rulemaking intends to update NO\textsubscript{x} emissions standards for heavy-duty trucks which were last updated in 2001
- EPA states “Heavy-duty vehicles are the largest contributor to mobile source emissions of NO\textsubscript{x} and will be one of the largest mobile source contributors to ozone in 2025”
- CTI focusses on emission control under low-load conditions—when trucks are at idle, moving slowly, or in stop-and-go traffic

**Outlook:**
- CTI is still in proposal phase and is expected to impact model years 2025+ on-highway diesel commercial trucks

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Transportation Climate Initiative seeks to reduce transportation emissions and develop a clean energy economy in 13 regions in U.S.

**Movement “101”: Transportation Climate Initiative**

### Legislation:
- The Transportation and Climate Initiative (TCI)

### History:
- In 2010, eleven states and District of Columbia signed a declaration of intent to create the Transportation Climate Initiative (TCI) – a regional transportation approach to help the states build clean energy economy
- In 2018, Virginia announced support and formally joined the TCI collaboration
- In December New Hampshire withdrew from the agreement citing gas-tax impact on rural and disadvantaged communities

### Geography:
- Eleven participating states & DC (CT, DE, ME, MD, MA, NJ, NY, PA, RI, VT, VA, DC)

### Objective:
- The TCI seeks to improve transportation, develop the clean energy economy and reduce carbon emissions from the transportation sector. Sub-initiatives are grouped into 5 areas:
  1) Clean Vehicles and Fuels
  2) Sustainable Communities
  3) Freight Efficiency
  4) Information & Communication Technology
  5) Policy Design Process
- The Clean Vehicles and Fuels program supports the deployment of clean vehicles and fueling infrastructure in TCI states

### Outlook:
- Released a draft MOU for a regional cap-and-invest program to curb emissions from transportation and invest proceeds from program in low-carbon transportation

Transportation Climate Initiative (TCI) is a still-in-work “cap & invest” initiative that is estimated to start in 2022

### Transportation Climate Initiative (TCI)

#### TCI timeline

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>2020</td>
<td>Draft MOU released end of 2019</td>
</tr>
<tr>
<td></td>
<td>Final MOU to be released, and TCI jurisdictions to decide participation in the program</td>
</tr>
<tr>
<td>2021</td>
<td>Participating jurisdictions develop a model rule and take any needed legislative steps</td>
</tr>
<tr>
<td></td>
<td>Participating jurisdictions conduct a rulemaking process to adopt the model rule</td>
</tr>
<tr>
<td>2022</td>
<td>Compliance period of program begins</td>
</tr>
</tbody>
</table>

- TCI is a regional “cap and invest” program consisting of 12 North-Eastern and Mid-Atlantic states, where transportation fuel suppliers shall be required to hold allowances to cover resulting reported emissions.

- The draft MOU is based on the determination that more than 40% of GHG emissions within TCI states are emitted by the transportation sector.

- TCI projects that through cap and invest program, CO2 will be reduced by 20% - 25% by 2032. Revenue from the sale of allowances is projected to range from minimum ~$1.4B in 2022 to max of ~$7B by 2032 based on cap reduction targets. Revenue from allowance auctions will be returned to participating jurisdictions for investment in other measures to reduce transportation emissions.

- The MOU specifies that jurisdictions that sign the MOU will:
  - Implement a regional cap on CO2 emissions from on-road diesel and gasoline;
  - Develop a process to auction CO2 emissions allowances and require fuel suppliers to hold and report off-setting allowances.

Source:
- https://www.jdsupra.com/legalnews/transportation-climate-initiative-seeks-60056/
Ten states currently pricing carbon with impact limited mostly to power gen sector. Legislation under review for nationwide adoption

### Movement “101”: Carbon Pricing

<table>
<thead>
<tr>
<th>Legislation:</th>
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<tbody>
<tr>
<td>- American Opportunity Carbon Fee Act</td>
<td></td>
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<table>
<thead>
<tr>
<th>History:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>- In April 2019 Sheldon Whitehouse, Brian Schatz, Martin Heinrich, and Kirsten Gillibrand reintroduced the <strong>American Opportunity Carbon Fee Act</strong> to charge for the emissions driving climate change</td>
<td></td>
</tr>
<tr>
<td>- The legislation aims to reduce the nation’s GHG emissions by approx. 51% by 2029</td>
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<table>
<thead>
<tr>
<th>Geography:</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>- United States (currently under review)</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Objective:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>- Imposing a carbon fee on mined, processed, refined, or imported fossil fuels</td>
<td></td>
</tr>
<tr>
<td>- The bill would result in US beating carbon emissions target outlined in the <strong>2016 Paris Agreement</strong> and deliver 2x carbon reductions by 2030 compared to <strong>Clean Power Plan</strong></td>
<td></td>
</tr>
<tr>
<td>- The revenue would be used to deliver at least $10 billion annually to the states to assist them in dealing with the costs of climate change and transition to a low carbon economy</td>
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<table>
<thead>
<tr>
<th>Outlook:</th>
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<tbody>
<tr>
<td>- Several similar proposals such as Coons bill, Larson bill, Fitzpatrick bill etc. are under consideration in the legislative branches of the U.S. government</td>
<td></td>
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</tbody>
</table>

**Energy Taxation Directive (ETD) establishes minimum duty rates that States must apply to energy products for fuel, transport, & electricity**

**Movement “101”: Carbon Pricing**

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<tr>
<th>Legislation:</th>
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<tbody>
<tr>
<td>• Energy Taxation Directive (ETD)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>History:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Energy Taxation Directive adopted in 2003, was designed to avoid competitive distortions in the energy sector within the Internal Market</td>
</tr>
<tr>
<td>• Current scope is incoherent with EU’s Emission Trading System (ETS), a scheme for trading of GHG emission allowances</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Geography:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• European Union</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Objective:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• ETD establishes the minimum excise duty rates that member states must apply to energy products for fuel and transportation</td>
</tr>
<tr>
<td>• Revised directive aims to restructure the energy taxation method; supporting movement towards low-carbon and energy-efficient economy</td>
</tr>
<tr>
<td>– Measures to put a price on CO2 emitted by sectors outside the EU ETS: higher the emissions of fuel, higher the CO2 tax</td>
</tr>
<tr>
<td>– Linking the level of taxes with energy content of fuel</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Outlook:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Proposal in place to reform Energy Taxation Directive (ETD) carbon pricing scheme with aim to make EU carbon neutral by 2050</td>
</tr>
</tbody>
</table>

**Other Global Legislation**


[Diagram showing regions impacted by Carbon Pricing]
Multiple legislation and trading schemes are in place around the world to mitigate GHG emissions

Movement “101”: Carbon Pricing

Legislation:
- National Determined Contributions (Resolution 797-E/2017), Cap-and-trade program

History:
- National Determined Contributions (Resolution 797-E/2017), Argentina, started in 2017
- Carbon Taxation (No Formal Name), Alberta, Canada, started on January 1, 2017
- New Zealand’s Energy Trading Scheme (NZ ETS), started in 2008 and amended in 2012
- South Korea’s Cap-and-Trade Program, started on January 12, 2015

Geography:
- Global (Argentina, Canada, New Zealand, South Korea)

Objective:
- Argentina - Labeling light duty vehicles for each new model starting 2018 with an Energy Efficiency vehicle label
- Canada - Alberta household will pay direct carbon costs (gasoline, diesel and natural gas) of $150 to $200
- New Zealand - Reduction of carbon emissions or purchase NZ emission units from foresters who plant trees to absorb CO2
- South Korea - Cut transportation emissions by 30% below current levels by 2020

Outlook:
- Most of countries have legislation that encompass all the sectors emitting GHG; they do not exclusively tax carbon for the transportation sector

No LEZs in U.S cities. New Jersey only state mandating >85% of new vehicle sales by ZEVs by 2040; other states proposals in draft/rejected

Movement “101”: Vehicle use types / restrictions / Low or Zero emission zones

**Legislation:**
- AB 40 – California; HB 2593 – Hawaii; S2252 – New Jersey; H.Res.109 - USA

**History:**
- California – AB40 was introduced by CARB in 2019 for 2040 gasoline passenger car phaseout in California; proposal was not adopted
- New Jersey – S2252 was proposed in 2018 and passed legislature in 2020
- Washington DC – DC Act 22-583 passed in 2019 mandates all fleet vehicles (public & private) be ZEV by 2045
- SB 275 – New Hampshire; HB 2515 – Washington; DC Act 22-583 – District of Columbia; HB 2593 – Hawaii are other states with ICE ban proposals

**Geography:**
- New Jersey, California, New Hampshire, Washington

**Objective:**
- New Jersey – S2252 states that >85% of all light duty vehicles sold or leased in state of New Jersey be plug-in electric vehicles by December 31st, 2040
- California – AB40 (not adopted) mandated CARB to develop a comprehensive strategy to ensure sales of all new light vehicles are zero emission vehicles by 2040
- USA – H.Res.109 i.e. Green New Deal, which did not pass Senate, called for need to replacing ICE vehicles in addition to other initiatives to tackle climate change

**Outlook:**
- Major cities such as Los Angeles, New York and Seattle have conducted studies evaluating vehicle restriction laws. Effective impact from vehicle restrictions / ICE bans, but localized due to limited deployment areas, and also potential headwinds from citizens / groups

Major cities worldwide have implemented low emission zones to improve air quality

Movement “101”: Vehicle use types restrictions (Low or Zero emission zones)

Legislation:
- Clean Air Action – Amsterdam; Ultra Low Emission Zone (ULEZ) – London

History:
- Amsterdam – The city’s Clean Air Action plan to ban diesel passenger cars from November 2020 with emission standards lower than 4 from the city’s low emission zone.
- South Korea - Seoul introduced restriction for emission vehicles from city center in 2017
- Brussels – LEZ in place since 2018
- Beijing – LEZ in effect from 2017

Geography:

Objective:
- Beijing LEZ – continuation of policies initiated in 2008 during Beijing Olympics to minimize pollution. Access to LEZ restricted based on emission standards
- Madrid – introduced Zero emissions zone for Madrid Central region since 2019 banning entry to all ICE vehicles with some exceptions. Measured NO2 reduction of around 40%
- London – ULEZ in effect in central area of London to reduce air pollution and protect public health. NOx emissions estimated to reduce by 45%. Operating petrol and diesel passenger cars must meet Euro 4 and Euro 6 standards

Outlook:
- Majority of cities with low emission zones have tabled proposals to implement zero emission zones or ultra low emission zones by 2040 timeframe

Proposals outlined by major car production and sales regions to ban combustion engine cars beginning in 2030

Movement “101”: Vehicle use types restrictions (ICE ban)

**Legislation:**
- Mobility Law – France; Low-emission mobility strategy COM (2016) 501 final - Germany

**History:**
- France – Proposal in place to ban sale of new gasoline and diesel vehicles by 2040
- Netherlands – “Confidence in Future” plan to ban ICE sales by 2030
- United Kingdom – Proposal to ban sales of ICE powered vehicle by 2035
- Germany – Federal council (Bundesrat) passed a non-binding resolution to ban vehicles combustion engines from 2030
- China – Study underway for potential ban on sales of new combustion engine cars by 2040

**Geography:**
- Spain, Portugal, Britain, Ireland, Netherlands, Norway, Denmark

**Objective:**
- United Kingdom – ICE ban from 2035 to meet target of net carbon neutrality by 2050
- France – New ICE vehicle sales ban from 2040 to target carbon neutrality by 2050
  - France implemented a bonus-malus scheme (Italy and Sweden also have such schemes) incentivizing xEVs and penalizing pure ICEs
- Germany – ICE ban proposal to comply with climate agreement i.e. reduce German Co2 emissions by 95% by 2050

**Outlook:**
- Major passenger car sales and production regions have tabled proposals to ban new internal combustion engine car sales from 2030

For global Movements assessment limited to current impact. Impact till 2040 not assessed in the study.
Zone based congestion pricing legislation adopted only by New York City in U.S.; feasibility studies underway in other regions

Movement “101”: Congestion Pricing

<table>
<thead>
<tr>
<th>Legislation:</th>
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</thead>
<tbody>
<tr>
<td>The Traffic Mobility Act, Article 44-C</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>History:</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Traffic Mobility Act, also called as Central Business District Tolling Program was passed in April 2019</td>
</tr>
<tr>
<td>Legislation mandates the Triborough bridge and tunnel authority to establish and implement the program in coordination with New York City department of transportation by “no sooner than Dec 31, 2020”</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Geography:</th>
</tr>
</thead>
<tbody>
<tr>
<td>New York City (Central Business District only)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Objective:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Will implement congestion pricing on vehicles entering Central Business district (CBD) in New York</td>
</tr>
<tr>
<td>To mitigate traffic congestion and vehicular throughput in CBD</td>
</tr>
<tr>
<td>Leverage funds (aim to raise $15B in bonds from revenue) raised from congestion pricing for improving public transit</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Outlook:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seattle, San Francisco and Los Angeles are other U.S. cities conducting feasibility studies to adopt congestion pricing</td>
</tr>
</tbody>
</table>

London, Stockholm, Milan and Singapore are few prominent examples of cities that implemented cordon congestion pricing

Movement “101”: Congestion Pricing

Legislation:
- London Congestion Charge; Milan Area C, Trängselskatt i Stockholm etc.

History:
- London Congestion Charge was introduced in 2003. Commuters are charged a £11.50 daily fee for driving a vehicle within the Congestion Charge Zone (CCZ) between 07:00 and 18:00, Monday to Friday.
- Area C, a congestion charge program in Milan was introduced in 2012, replacing the earlier Ecopass program.
- Trängselskatt i Stockholm was implemented in 2007 after a trial period of seven months.

Geography:
- Singapore, London (UK), Stockholm (Sweden), Milan (Italy), Valletta (Malta) etc.

Objective:
- London Congestion Charge was introduced to mitigate traffic and reduce air and noise pollution in the Central London area.
- Milan’s Area C objective was to reduce chronic traffic jams, reduce smog and particulate matter and to leverage revenue gained from congestion charge to improve sustainable transport.
- Trängselskatt i Stockholm, Electronic Road Pricing (ERP) in Singapore are other congestion pricing programs globally.

Outlook:
- More cities around the world are conducting congestion charge implementation feasibility studies. Few proposal have been shelved due to public criticism.

Source: https://tfl.gov.uk/modes/driving/congestion-charge#; https://www.skatteverket.se/privat/skatte/bilochtrafik/trangselskatt/stockholm.4_2b543913a42158ac80006765.html; https://www.comune.milano.it/area-tematiche/mobilita/area-c

For global Movements assessment limited to current impact. Impact till 2040 not assessed in the study.
With steady growth, states will adopt further measures to formally incorporate Shared Mobility into their overall transport system.

**Movement “101”: Shared Mobility**

**Legislation:**
- Transit Priority Program

**History:**
- Created in 2011 under Senate Bill 310
- Program links car sharing to larger land-use policy goals

**Geography:**
- California, United States

**Objective:**
- Reduction of vehicle miles by promoting development that supports transit use
- Policies under a TPP project include:
  - Parking for bikeshare
  - Provide car sharing onsite or nearby – Developer must provide a carshare vehicle for the first 20 units and one vehicle for every 50 units thereafter
- In turn, TPP project provides expedited and reduced permitting costs, as well as a height and density bonuses

**Outlook:**
- Multiple states have enacted legislation regarding car sharing that includes: Incentives to use car sharing, addressing car-sharing taxation, electrification of car sharing fleets and creating a regulatory framework for shared mobility

Federal level regulation yet to be implemented for autonomous vehicles; two acts under legislative review

**Movement “101”: Connected and Autonomous Vehicles**

<table>
<thead>
<tr>
<th>Legislation:</th>
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<tbody>
<tr>
<td>• SELF Drive Act and AV START Act</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>History:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Both SELF Drive Act and AV START Act are pending approval in legislation</td>
</tr>
<tr>
<td>• SELF Drive Act was passed by the Congress in 2017; yet to pass Senate</td>
</tr>
<tr>
<td>• AV START Act was introduced in Senate in 2017 and is yet to be approved</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Geography:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• United States</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Objective:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• The bills aim to do the following:</td>
</tr>
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<td></td>
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</tbody>
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<table>
<thead>
<tr>
<th>Outlook:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Various states have adopted and enacted legislation regulating use and testing of autonomous vehicles. However, a federal level regulation is still in legislative approval process</td>
</tr>
</tbody>
</table>

EU working to harmonize rules as multiple legislation in place & will likely cause disruption as vehicles drive on diverse regions road systems

Movement “101”: Connected and Autonomous Vehicles

Legislation:
- Centre for Connected and Autonomous Vehicles (CCAV), Autonomous Vehicle Bill

History:
- Centre for Connected and Autonomous Vehicles (CCAV), UK was established in 2015
- Autonomous Vehicle Bill, Germany, was started in 2017
- Direccio General de Trafico (DGT), Spain, approved in November, 2015
- Italy passed its first law regulating testing of autonomous vehicles in February, 2018
- Legislative framework under review in France allowing testing of autonomous cars on roads starting 2019, with an aim to deploy ‘highly automated’ vehicles between 2020 and 2022

Geography:
- Global (UK, Germany, Spain, Italy, France)

Objective:
- CCAV, UK - Working on legislation to allow testing on motorways in the country
- Autonomous Vehicle Bill, Germany - Modification of existing Road Traffic Act to define the requirements for a fully automated vehicle, while also addressing the rights of a driver
- DGT, Spain - Reduce road accidents and prepare Spain’s infrastructure and regulatory policy for driving autonomous vehicles
- Italy - Activity permitted on ‘specific roads’ with road operator’s approval of testing procedure

Outlook:
- In 2018, the European Commission published the EU strategy on connected and automated mobility along with guidelines developed together with EU countries to harmonize the exemption procedure for EU approval of automated vehicle

Executive summary

Project report

Appendix – I (Project report addendum)

Appendix – II (Movement 101)
- Assessed U.S. and global Movements for 2040 impact:
  - Telecommuting
  - Subsidies / Incentives
  - ZEV mandate
  - Charging infrastructure
  - CAFE
  - Renewable Fuel Standard (RFS)
  - Low Carbon Fuel Standard (LCFS)
  - Cleaner Truck Initiative (CTI)
  - Transportation Climate Initiative (TCI)
  - Carbon pricing
  - Vehicle use type restrictions / ICE bans
  - Congestion pricing
  - Connected and autonomous vehicles
  - Shared mobility

  Excluded Movements: Vehicle retirement program, Tolls, Parking benefits

Appendix – III (Summary of research)
California offers Consumer Assistance Program (CAP), an incentive program to retire older high polluting vehicles

Movement “101”: Vehicle Retirement Program (excluded from analysis)

**Legislation:**
- Incentive Program: Consumer Assistance Program (CAP), AB 616

**History:**
- Earliest iteration passed in 1997 as a repair assistance program and upgraded to a full fledged retirement program in 2007 as Consumer Assistance Program, AB 616
- Operated by Bureau of Automotive Repair (BAR)
- Participation in the program is based on meeting eligibility requirements and the availability of funds each fiscal year (July 1 – June 30)

**Geography:**
- California

**Objective:**
- Program aimed at reducing emissions through retirement of high polluting vehicles
- Consumer Assistance Program (CAP) offers eligible consumers $1,000-$1,500 incentive to retire their operational vehicle
- Other county/regional programs exist in California that provide incentives to retire/replace vehicles
- Offered only in California

**Outlook:**
- Retirement programs are short-term in nature i.e. funded annually, has limited applicability based on vehicle eligibility and budget is limited to few thousand vehicles resulting in minimal impact on vehicle demand

In 2019 CAP enabled ~53k vehicles retirement whereas U.S. parc is ~284M vehicles. 2019 CAP was allocated budget of ~$33M, whereas technology cost of CAFE standard is >$10B

Source: https://www.bar.ca.gov/Consumer/Consumer_Assistance_Program/CAP_Vehicle_Retirement_Program.aspx
California CAP support in 2019 limited to ~3% of total new vehicle registrations in California market and ~0.02% of U.S. parc

Movement “101”: Vehicle Retirement Program (excluded from analysis)

- CAP supported retirement of ~53k vehicles in 2019 i.e. ~3% of new car registrations in California in 2019
  - New car registrations in California in 2019 at ~1.9M

- Annual budget for CAP program fluctuates between ~$30M - $40M
  - Fund supported by a portion of revenue from motor vehicle inspection program

- CAFE standard technology compliance cost of ~$33 Billion is limited to MY 2022 – 2025 and is based on EPA final determination (2017)


<table>
<thead>
<tr>
<th>Year</th>
<th>CAP Impact (in 000's retired / repaired)</th>
<th>CAP Budget vs Cost of Compliance for CAFE ($M)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CAP Impact</td>
<td>Expenditure (in $M)</td>
</tr>
<tr>
<td>2015</td>
<td>58.7/7.9</td>
<td>$33M</td>
</tr>
<tr>
<td>2016</td>
<td>53.5/5.6</td>
<td>$36M</td>
</tr>
<tr>
<td>2017</td>
<td>53.5/4.4</td>
<td>$37M</td>
</tr>
<tr>
<td>2018</td>
<td>55.3/3.4</td>
<td>$37M</td>
</tr>
<tr>
<td>2019</td>
<td>55.0/2.4</td>
<td>$33M</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Year</th>
<th>Automotive Volume (in Millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017</td>
<td>California New Vehicle Registrations: 270.4M</td>
</tr>
<tr>
<td>2018</td>
<td>Total California VIO: 279.1M</td>
</tr>
<tr>
<td>2019</td>
<td>Total U.S. VIO: 284.5M</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Year</th>
<th>Expenditure (in $M)</th>
<th>Technology Cost (in $M)</th>
<th>Cost to comply with CAFE for MY 22 - 25</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>$33M</td>
<td>$33,000M</td>
<td></td>
</tr>
<tr>
<td>2016</td>
<td>$36M</td>
<td>$36,000M</td>
<td></td>
</tr>
<tr>
<td>2017</td>
<td>$37M</td>
<td>$37,000M</td>
<td></td>
</tr>
<tr>
<td>2018</td>
<td>$37M</td>
<td>$37,000M</td>
<td></td>
</tr>
<tr>
<td>2019</td>
<td>$33M</td>
<td>$33,000M</td>
<td></td>
</tr>
</tbody>
</table>
France and Romania run incentive programs for replacing eligible older vehicles with lower emitting new/used vehicles

### Movement “101”: Vehicle Retirement Program (excluded from analysis)

<table>
<thead>
<tr>
<th>Legislation:</th>
<th>France; Rabla - Romania</th>
</tr>
</thead>
<tbody>
<tr>
<td>History:</td>
<td>France - Prime à la conversion is a vehicle scrappage scheme that provides bonus ranging from €200 - €6,300 for purchase of a new lower emitting vehicle based on eligibility. Initially launched in 2007, a revised version was introduced in 2019. Romania – Rabla scheme introduced in 2000 is an ongoing vehicle retirement program that provides vouchers ranging from €1,350 - €10,000 for replacing an eligible diesel car with a new vehicle.</td>
</tr>
<tr>
<td>Geography:</td>
<td>France, Romania</td>
</tr>
<tr>
<td>Objective:</td>
<td>France - Prime à la conversion aims to incentivize purchase of low emission vehicles. Romania – Rabla was introduced to help get older diesel vehicles off the roads to help improve air quality. In 2020, 60,000 vouchers worth €1,350 allocated. 3,000 vouchers worth €10,000 allocated for 2020.</td>
</tr>
<tr>
<td>Outlook:</td>
<td>Vehicle retirement programs duration is constrained by budgets for such schemes, where in most countries are allocated on an annual basis.</td>
</tr>
</tbody>
</table>

FAST act approved in 2015 amended Section 166 of title 23, U.S.C.; grants bodies authority to convert HOV to HOT lane

Movement “101”: Tolls (excluded from analysis)

Legislation:
- Fixing America’s Surface Transportation (FAST) Act, 2015

History:
- Section 1411 of the Fixing America’s Surface Transportation (FAST) Act (Pub. L. 114-94), was signed into law on December 4, 2015
- Includes the most recent amendments to the prior HOV provisions
- Section 1411 amended the Section 166 of title 23, United States Code (U.S.C.) which contains the HOV provisions
- The FAST Act made changes to the statutory provisions that govern tolling on highways constructed or improved with Federal funds

Geography:
- United States

Objective:
- Act include provisions requiring the same treatment of over-the-road buses and public transportation vehicles on certain toll facilities
- Allows authorities to allow vehicles not otherwise exempt to use the HOV facility if the vehicle operator pays a toll i.e. convert HOV to HOT lanes
  - Ex: Extends regulating bodies authority to exempt low emission vehicles from HOV rules

Outlook:
- Tolls are used to mostly support infrastructure maintenance and manage usage demand through influencing driver behavior, but not to suppress overall vehicle demand. Ex: Updated rules in California limit EVs access to HOV lanes based on eligibility conditions

Cost of running the car, battery life, safety, purchase price are the key drivers influencing consumer’s BEV purchase

Movement “101”: Tolls (excluded from analysis)

Factors that positively influence decision to buy a BEV

- Environmentally friendly
- Cost of running the car: 50%
- Battery life: 50%
- Safety
- Performance
- Purchase price
- Government incentives (tax etc.)
- It’s the car of the future
- Design
- Fun to drive
- Noise level
- Status
- Other

Source: UBS Evidence Lab; Carmax survey (2300 respondents); Wall Street Journal

>60% EV owners have income >$140K

$60K Median US household income

~40% Live on the west coast
xEV HOV incentive is an xEV adoption factor in some states and not in other. Studies are inconclusive on HOV access as key purchase criteria.

Movement “101”: Tolls (excluded from analysis)

Georgia xEV YOY (% of annual sales)

<table>
<thead>
<tr>
<th>Year</th>
<th>BEV</th>
<th>PHEV</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>1.1%</td>
<td></td>
</tr>
<tr>
<td>2014</td>
<td>2.4%</td>
<td></td>
</tr>
<tr>
<td>2015</td>
<td>1.4%</td>
<td></td>
</tr>
<tr>
<td>2016</td>
<td>0.4%</td>
<td></td>
</tr>
<tr>
<td>2017</td>
<td>0.6%</td>
<td></td>
</tr>
</tbody>
</table>

- Georgia incentivizes xEVs with HOV access. However, after ending its subsidies program in 2015, xEV sales decreased by ~70% in the state though it continued to offer HOV access to xEVs
  - Georgia offered $5,000 tax credit on top of federal credit of $7,500 on BEV
  - In 2015 Georgia state lawmakers ended the incentive
  - Georgia was the 2nd largest EV market in U.S. prior to incentive roll-back
- Colorado Hybrid vehicle HOV access ending in May 2020
- Hardman, S., & Tal, G. study found that HOV lane access, workplace charging and free parking are not motivational factors but they do increase likelihood of repeat purchases
- Based on EIA analysis, the value of this incentive in California, New York, and Hawaii was more than double that of most other states that offered this incentive

Source: [https://www.codot.gov/programs/hybrids](https://www.codot.gov/programs/hybrids) ; Incentivizing Adoption of PEV – Argonne National Lab ; [https://www.eia.gov/analysis/studies/transportation/zeroemissions/pdf/zero_emissions.pdf](https://www.eia.gov/analysis/studies/transportation/zeroemissions/pdf/zero_emissions.pdf) ;
Parking incentives in Connecticut, California etc. aim to encourage people to reduce GHG emissions and use EV for transportation

Movement “101”: Parking Benefits (excluded from analysis)

**Legislation:**
- Alternative Fuel Vehicle (AFV) and HEV Parking, Low Emission Vehicle Parking

**History:**
- Alternative Fuel Vehicle (AFV) and Hybrid Electric Vehicle (HEV) Parking - New Haven, CT – Introduced prior to 2012
- Low Emission Vehicle Parking - San Jose, CA - No information on start date. Program will continue at least until June 30, 2020
- Alternative Fuel Vehicle (AFV) Parking Incentive – Arizona, allows eligible AFV to park without penalty in parking areas that are designated for carpool operators

**Geography:**
- New Haven, CT and San Jose, CA

**Objective:**
- New Haven, CT - Provides free parking on all city streets for HEVs and AFVs registered in the city. Owners must obtain a non-transferable pass from the Department of Traffic and Parking
- San Jose, CA - Free parking at city parking meters, parks and recreation facilities, and participating garages for vehicles that display a valid Clean Air Permit, available to vehicles eligible for a CARB Green or White State of California high occupancy vehicle lane stickers

**Outlook:**
- Limited number of cities / regions have introduced parking benefits for alternative fuel vehicles. Similar to Norway, parking benefits may be rescinded with increased EV penetration

Krause et al. (2013) found that whilst free parking can increase purchase intentions, only 1.7% of adopters were aware of the free parking already offered in regions that they live suggesting its actual impact on sales was low

Norway is reducing xEV parking incentive in a staggered manner to curb traffic congestion from increased xEV penetration

Movement “101”: Parking Benefits (excluded from analysis)

<table>
<thead>
<tr>
<th>Legislation</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZEV parking - Madrid, Norsk elbilforening - Norway</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>History</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amsterdam (Netherlands), Paris (France) - Preferential parking permit for electric vehicles offered at least since 2012 (start date unknown)</td>
</tr>
<tr>
<td>Madrid, Spain - In Madrid’s city center, drivers of a zero-emission vehicle can park without time limitation (Madrid City Council, 2018a)</td>
</tr>
<tr>
<td>Denmark - Electric cars are exempt from parking fees up to DKK 5,000 (€670) per year</td>
</tr>
<tr>
<td>Norway – max of 50% of parking fee can be charges on ZEVs in public parking facilities</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Geography</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amsterdam, Paris, Norway, Denmark, Madrid, Helsinki etc.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amsterdam – residents and companies owning an electric vehicle given priority on the waiting list for parking permits (Municipality of Amsterdam, n.d.)</td>
</tr>
<tr>
<td>Cities like Madrid, Berlin incentivize commuters to use xEVs through combination of parking incentives and LEZs</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Outlook</th>
</tr>
</thead>
<tbody>
<tr>
<td>EV parking benefits in Norway have been reduced in a staggered manner. Initially all EVs could avail free parking at public facilities, but with increased EV penetration, parking fee hiked to 50% to that of an ICE vehicle</td>
</tr>
</tbody>
</table>

## Executive summary

## Project report

## Appendix – I (Project report addendum)

## Appendix – II (Movement 101)

### Appendix – III (Summary of research)
- Telecommuting
- Subsidies, ZEV mandate, Charging network
- CAFE standard
- Biofuels: Low Carbon Fuel Standard (LCFS) and Renewable Fuel Standard (RFS)
- Carbon pricing and Transportation Climate Initiative (TCI)
- Low Emission Zone (LEZ) / ICE bans, Congestion pricing and Mobility initiative
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Studies opinions vary on impact of telecommuting of fuel savings ranging from no impact to ~$2B per year

Telecommuting – Fuel Economy

- Study “2017 State of Telecommuting in the U.S. Employee Workforce” a Flexjobs survey based study estimates ~3.9M employees in U.S telecommute half-time or more
  - Fuel savings ~$980M and VMT reduction of 7.8 billion miles; in 2017 U.S. total VMT was ~3 trillion miles
- 2008 survey by Consumer Electronic Association (CEA): states there are 3.9M people in U.S. who work from home at least one day / week
  - this practice saves about 840 million (U.S.) gallons of petrol, equivalent to taking two million cars off the road for a year
- 2013 Natural Resources Defense Council (NRDC) study “Driving Commuter Choice in America” estimates that by telecommuting 1 day / week consumer can save:
  - $150 - $300 annually on fuel by commuter type (urban, rural etc.)
  - Reduce U.S. VMT by 10 billion miles and fuel costs by ~$1.9B if 5% of U.S. population telecommuted 1 day /week
- 2018 study “Does telecommuting promote sustainable travel and physical activity? – Chakrabarti et al” assessing 2009 U.S NHTS states regression estimates show that telecommuting, regardless of frequency, is associated with relatively more annual miles driven

Estimated annual fuel savings

Source:
- https://afdc.energy.gov/data/10315
Additional studies reviewed also found that telecommuting has a net positive impact on fuel savings

Telecommuting – Fuel Economy

**Study summary**


- Estimates that the 4 million U.S. workers telecommute an average of one or more day per week and reduce primary energy consumption by an amount equal to 0.13 to 0.18 percent and 0.16 to 0.23 percent of U.S. annual primary energy consumption

- In addition, telecommuting decreases U.S. gasoline consumption by about 0.8 percent of U.S. light-duty vehicle gasoline consumption

**Additional Studies reviewed**

2005 study “Does telecommuting reduce vehicle-miles traveled? An aggregate time series analysis for the U.S. – Choo et al” which assessed impact of telecommuting on Vehicle Miles Travelled (VMT) 1988 – 1999 found that

- telecommuting reduced annual VMT by ~0.8%, which is estimated savings of $1.7B in 1998

1996 study “The travel and emissions impacts of telecommuting for the state of California Telecommuting Pilot Project” assessed impact of telecommuting and VMT in California

- Study monitored participants over two years 1988 – 1990 and observed a 77% decrease in VMT

- Also found an increase on non-commute personal trips – though a negligible impact

Studies estimate telecommuting reduces GHG emissions from ~4 million tonnes to 7.4 millions tonnes

Telecommuting – Low Emissions

- 2013 NRDC study “Driving Commuter Choice in America” estimates that if 5% of U.S population telecommutes 1 day / week, can reduce:
  - Annual transportation GHG emissions by ~0.5% i.e. 4.7 Million tonnes of CO₂
- ~7.4M tonnes of CO₂ savings estimated based on 2008 survey commissioned by Consumer Electronic Association (CEA):
  - Value calculated based on estimate of 840 million (U.S.) gallons of petrol and considering gasoline CO₂ emissions coefficient of 8.89 kg CO₂ per gallon
- Study “2017 State of Telecommuting in the U.S. Employee Workforce” a Flexjobs survey based study estimates 3 millions tonnes of GHG emissions savings based on estimated 3.9 millions telecommuters in 2017

Total U.S. emissions from transportation in 2017 was 1,872 million metric tonnes of CO₂

Post COVID-19, telecommuting and its impact on GHG emissions may be assessed for future telecommuting strategy roll-out (1/2)

Telecommuting – Impact from Covid-19

- China’s carbon emissions fell by around 25% over a four-week period, equivalent to around 200M tonnes of CO2 (MtCO2)
- Beginning in early March of 2020, EPA air quality data shows that Los Angeles experienced its longest stretch of "good" air quality since at least 1995
- Major cities in India registered ~70% drop in NOx emissions
- >40% decline in NOx emissions in Northern Italy
- Bay Area air quality shows marked improvement during shelter in place with AQI in single digits
Post COVID-19, telecommuting and its impact on GHG emissions may be assessed for future telecommuting strategy roll-out (2/2)

Comparison of NO2 emissions over Northern Italy

**Beginning of January 2020**

**End of March 2020**

Source: https://www.esa.int/ESA_Multimedia/Videos/2020/03/Coronavirus_nitrogen_dioxide_emissions_drop_over_Italy
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Opinions diverge on impact of subsidies on xEV demand ranging from no impact to ~30% of EV sales a direct result of subsidies

**Subsidies / Incentives – Vehicle Demand**

- U.S. Energy Information Administration (EIA) in its 2017 study found valuation of state-level electric vehicle incentives is not well correlated with market share of ZEVs and PHEVs
- Congress Budgetary Office (CBO) its 2012 study estimated that ~30% of current and future sales of electric vehicles will be attributable to the Federal tax credit, and ~70% would have occurred even without the credits
  - CBO determined Federal Tax Credit was likely to have the greatest impact on sales
- 2018 study “Effectiveness of Electric Vehicle Incentives in the U.S. – Jenn et al” for the period 2010 – 2015 found that every $1000 offered as a rebate or tax credit increases average sales of EVs (incl. BEV & PHEV) by 2.6%
  - Includes both federal and state incentives
  - This study does not consider EVSE network in its model
- 2016 survey based study “Exploring the impact of the federal tax credit on the plug-in vehicle market – Tal et al” attributes 32.5% of plug-in electric vehicle sales directly to federal tax credit

**Effect of Subsidies / Incentives on Vehicle Demand in U.S.**

**1. No impact**

**2. ~30% EV of sales due to Federal Tax credit**

**3. 2.6% increase in EV sales per $1k increase in incentive**

Other evaluated studies also found federal and state incentives along with charging infrastructure are critical drivers for xEV adoption.

### Subsidies / Incentives – Vehicle Demand

- **Net impact**

  - **~20% increase in PEV ownership in CA attributed to federal and state tax credit**
  
  - Study “An in-depth examination of EV incentives: Consumer heterogeneity and changing response over time” evaluating purchase decision of buyers in California from 2010 - 2017 found:
    - that federal and state tax credit are the two most important factors
    - “we found about a 20% increase in PEV owners who would not have purchased a PEV in 2016 compared to 2010 if the federal incentive were removed”

  - **~8% increase in BEV registrations per $1,000 incentive offered**

  - Study “Providing the Spark: Impact of financial incentives on battery electric vehicle adoption” assessing incentives and impact of sales during 2011 – 2015 states it found ~8% increase in new registrations of BEVs per thousand dollars of incentive offered

  - **~17% of PEV sales in 2015 due to federal tax credit**

  - Study “Measuring the cost-effectiveness of electric vehicle subsidies” found that only 17% of PEV sales in model year 2015 are attributable to the federal tax credit

- **Tax incentives along with EVSE network are primary factors for PEV adoption**

  - 2018 study “The role of demand-side incentives and charging infrastructure on plug-in electric vehicle adoption: analysis of US States” assessing 2008 – 2016 U.S. EV sales states:
    - “tax incentives of any type and EVSE network are dominant factors in driving PEV adoption”
    - This study also studies the impact of charging infrastructure as a purchase decision criteria

EIA found that state-level ZEV incentives was not well correlated with market share of ZEVs and PHEVs in 2016

**Subsidies / Incentives – Vehicle Demand**

- EIA found valuation of state-level ZEV incentives was not well correlated with market share of ZEVs and PHEVs in 2016
- Four states with the highest ZEV market shares, Washington, Oregon, Hawaii, and Georgia, had relatively low ZEV incentive values
  - EIA found that Oregon credited high adoption rates primarily to their extensive EVSE network. Also, the case for Washington and California
  - EIA found Hawaii had unique drivers such as highest gas prices in the country in addition to limited driving distance and robust EVSE network
  - Georgia appears as an outlier as states ZEV tax credit of $5,000 was discontinued in July 2015
  - EIA does acknowledge that “comparing sales and incentives over time shows that incentives, particularly rebates and tax credits, do have a direct impact on sales, at least in some states” referring to ZEV sales trend in Georgia

Studies indicate even in Europe subsidies and incentives are key factors influencing consumer purchase behaviors

Subsidies / Incentives – Vehicle Demand (Europe)

- Value of incentives in Norway translates to ~$11,000 - $20,000 (based on 25% VAT exemption and purchase tax)
- TCO analysis in “The effect of fiscal incentives on market penetration of electric vehicles: A pairwise comparison of total cost of ownership” states incentives in Norway made EVs cost competitive with ICE vehicles resulting in increased uptake
  - In 2019, Norway’s passenger plug-in sales was at 55% market share of total new car sales

80% of BEV owners surveyed in Norway in 2014 stated purchase tax and VAT exemption was the critical factor for BEV adoption
From “Incentives for promoting Battery Electric Vehicle (BEV) adoption in Norway” by Bjerkan et.al

An incentive of €1,000 would increase PEV sales shares on average by about 5–7% in Europe
Based on 2010 – 2017 Europe incentives and impact on plug-in sales study by Munzel et.al

<table>
<thead>
<tr>
<th>Country</th>
<th>Average of financial incentives as % of net price of EVs</th>
<th>Share of EVs in total new car registrations in 2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hungary</td>
<td>2%</td>
<td>19%</td>
</tr>
<tr>
<td>Germany</td>
<td>2%</td>
<td>20%</td>
</tr>
<tr>
<td>Italy</td>
<td>3%</td>
<td>33%</td>
</tr>
<tr>
<td>France</td>
<td>1%</td>
<td>4%</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>1%</td>
<td>42%</td>
</tr>
<tr>
<td>Netherlands</td>
<td>4%</td>
<td>14%</td>
</tr>
<tr>
<td>Norway</td>
<td></td>
<td>2%</td>
</tr>
</tbody>
</table>
ZEV mandate applies to ~30% of national new vehicle fleet; most estimates range at ~$400-$500* incremental cost per vehicle

ZEV Mandate – Cost of Compliance

- Two major studies are reviewed for ZEV mandate:
  - Cost Implications for Automaker Compliance of Zero Emissions Vehicle Requirements – UC Davis (2018)
  - A Macroeconomic Study of Federal and State Automotive Regulations (2017) - from Indiana University, funded by Auto Alliance (consists of 12 OEMs including GM, Ford, FCA, etc.)

- Both studies consider California and 9 other states that adopted ZEV mandate in their analysis

- ZEV low and ZEV high scenario cost difference impacted PHEV and BEV fleet mix to meet ZEV mandate
  - Cost estimate provided for meeting ZEV mandate with MY 2025

*Note: This estimate appears low per Ricardo analysis. We will review this assessment in upcoming weeks

Estimated annualized cost at ~17M vehicles per year

Source: https://doi.org/10.1021/acs.est.8b03635; https://oneill.indiana.edu/doc/research/working-groups/auto-report-032017.pdf
Studies estimate lifetime fuel savings of ZEVs range from ~$5,000 to ~$15,000 per vehicle

ZEV Mandate – Fuel Economy

- "Colorado Zero Emission Vehicle Program Will Deliver Extensive Economic, Health and Environmental Benefits" study by Environmental Defense Fund (EDF) estimates MY 2025 ZEVs will realize net lifetime savings of ~$5,000 - $10,000 in fuel costs
  - This study is specific to ZEV (includes both BEV and PHEV) mandate implementation impact in Colorado
- In the study “Impacts Of Electrification Of Light-duty Vehicles In The United States, 2010 – 2017" Argonne National Lab (ANL) estimated that an average BEV in 2017 avoided use of ~410 gallons of gasoline per vehicle and an average PHEV avoided use of ~260 gallons of gasoline per vehicle
  - Net lifetime savings on fuel estimated taking into account gasoline reference case from U.S. Annual Energy Outlook report 2019 and 12 year lifetime per vehicle

Source: 
Argonne cradle-to-grave lifetime analysis forecasts MY25 ZEV emissions to be at least 50% less compared to a MY25 ICE vehicle

ZEV Mandate – Emissions

- Argonne National Lab (ANL) Cradle-to-Grave lifetime analysis for ZEV emissions indicates impact varies broadly based on range of vehicle and power generation mix.
- MY2025 ZEV vehicles CO₂ lifetime emissions impact forecasted to be at least 50% lower compared to a MY 2025 ICE vehicle.

Other Studies

- A cradle-to-grave 2015 study by Union of Concerned Scientists stated that lifecycle lifetime CO2 emissions impact for a BEV90 and BEV210 is ~50% lower compared to a comparable ICE vehicle.
- A 2019 lifecycle assessment of cars CO2 emissions by International Energy Agency (IEA) states lifetime emissions impact of a 2018 BEV with a large battery is comparable with a small sized 2018 ICE vehicle.
  - However, IEA considers global passenger car in its analysis, and a small sized ICE vehicle footprint in Europe and other global regions is smaller compared to small sized ICE vehicle in U.S.

Note: BEV90 indicates ~90 miles of electric range and BEV210 indicates >200 miles of range.

Impact of ZEV mandate must be assessed considering BEV sales within California are driven by customer demand for Tesla Model 3

ZEV Mandate – Vehicle Demand

- 2019 combined EV and PHEV sales in California is ~146,000 units and is greater than volumes estimated for 2020. However, Tesla Model 3 sales skews the sales impact
  - Tesla Model 3 sales in 2019 was ~60,000 units which is ~40% of the total EV and PHEV sales in California
  - Tesla Model 3 was the 3rd best-selling sedan in California after Honda Civic (~76k units) and Toyota Camry (~63k units)
- ~15.4% BEV/PHEV penetration estimated in 2025 in 10 states that adopted ZEV mandate including California, which make up ~30% of national new vehicle sales

![ZEV Mandate – Minimum Expected ZEVs in California](image1)

Source: https://doi.org/10.1021/acs.est.8b03635, https://oneill.indiana.edu/doc/research/working-groups/auto-report-032017.pdf, CARB ZEV Regulation Fact Sheet;
Studies found significant correlation between EVSE network and PEV uptake. 2X impact on uptake per $ for EVSE compared to subsidies

Charging Infrastructure – Vehicle Demand

- Study “The role of demand-side incentives and charging infrastructure on plug-in electric vehicle adoption: analysis of US States-collaboration between Tufts University and NREL” assessing U.S. PEV sales between 2008 – 2016 found charging infrastructure significantly influences PEV purchases
  - one additional EVSE per capita is associated with a 7.2% increase in BEV purchases yet only a 2.56% increase in PHEV purchases
  - EVSE is a measure of public stations, not plugs

- Study “The Market for Electric Vehicles: Indirect Network Effects and Policy Design – Li et al” evaluating 2011 – 2013 U.S. PEV states that a 10% increase in the number of public charging stations would increase EV sales by about 8% (Considers only public EVSE network)
  - Also states, the increase in EV sales would have been twice as large if federal tax incentive were used to build charging stations instead of subsidizing EV purchase

- “The influence of financial incentives and other socio-economic factors on electric vehicle adoption – Willian Sierzchula et al” suggests that one vehicle charging station per 100,000 residents is associated with an EV market share increase of 0.12 percentage points
  - Also suggests that each charging station (per 100,000 residents) could have twice the impact EV market share than $1000 in consumer financial incentives
**Impact of Transportation - Related Environmental Initiatives**

Project # Co21273, 22 May 2020

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**Additional studies reviewed also found a positive correlation between strong EVSE network and EV uptake**

**Charging Infrastructure – Vehicle Demand**

**Study summary**

- Public charging station availability is positively correlated with PEV purchasing rate

**Additional studies reviewed**

- Study “Environmental and economic impacts of expanding electric vehicle public charging infrastructure in California’s counties” evaluating charging infrastructure and PEV adoption rate in 58 California counties found availability of public charging stations is positively correlated with PEV purchase in each county

- ICCT study “Identifying the leading regional electric vehicle markets in the United States” evaluating charging infrastructure and PEV adoption rate in U.S in 2015 found
  - Public charging infrastructure has been an important aspect in spurring EV sales, with leading markets typically increasing their electric vehicle public and workplace charging options

- ICCT study “Expanding the EV market in U.S. cities” assesses the 2015 - 2016 U.S. electric vehicle market and the actions driving it, focusing on the 50 most populous U.S. metropolitan areas
  - The leading EV markets tend to have at least 275 public chargers per million people, whereas half of the U.S. population lives in a market where available charging is less than 1/3 of that rate
  - The markets of Charlotte, Detroit, Kansas City, Minneapolis, Pittsburgh, Providence, and Virginia Beach each had approximately 30% to 80% charging infrastructure growth, corresponding with at least a doubling of their electric vehicle uptake from calendar year 2015 to 2016

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ICCT study – In 2016, regions with high EV market uptake had correspondingly high charge points per million population

Charging Infrastructure – Major National Markets

ICCT study “Emerging best practices for electric vehicle charging infrastructure” which evaluated EVSE network and EV sales in major EV regions found the following:

- Public charging infrastructure is a key to growing the electric vehicle market – used a multivariable regression to find correlation between EVSE network and PEV uptake
- The leading electric vehicle markets of Norway and the Netherlands have more than 10 times as many public charge points per capita as average markets, and leading markets in California and China had three to five times the average
- China, the world’s largest EV market by volume, in 2016 more than 100,000 Level 2 and 38,000 direct current (DC) fast charge points
- In California one public charger per 25 to 30 PEVs is typical. In the Netherlands, one public charger per 2 to 7 PEVs is typical. This ratio ranges from 3 to 6 in major markets in China
  - Shanghai, Beijing, and Shenzhen etc. as part of a federal program are required to provide one charge point for every 8 electric vehicles

Major EV markets continue to invest in charging infrastructure

Charging Infrastructure – Major National Markets

2018 PEV sales share and public charge points per million population in major markets

- **China**
  - Installed based of ~350,000 public charging points including L2 and DC fast charge points

- **Netherlands**
  - ~38,000 L@ and DC fast charge points
  - High reliance on public charge points especially in major metropolitan areas due to lack of home charging

- **Norway**
  - 49% of new car registration are PEVs
  - 8,100 L2 charger points
  - 1,100 Fast Charge points
  - Fewer total number of charge points compared to Netherlands as majority of charging is conducted at home

In Europe relationship between public charging infrastructure and EV uptake varies based on availability of home charging and use cases

Charging Infrastructure – Europe

Study summary

Europe – EV take-up is relatively insensitive at target levels below 5 or over 25 PEVs per charge point

Germany – Fast charging stations are more important than a dense network of charging points

Netherlands – Public charging infrastructure is important and a substitute to home charging

Germany - Public slow charging facilities do not increase PEV market shares

Studies reviewed - Europe

2017 Study “An exploratory policy analysis of electric vehicle sales competition and sensitivity to infrastructure in Europe” modelling PEV uptake in Europe between 1995 – 2050 found

- EV take-up is relatively insensitive at target levels below 5 or over 25 PEVs per charge point
- Charging infrastructure availability also appears to have the strongest impact on uptake once electric vehicle stock share exceeds 5%, which is currently the case only in Norway

Study “Consumer preferences for public charging infrastructure for electric vehicles” assessing EVSE network in Germany through survey based method found consumer prioritized fast charging stations over a dense network of charging points

Study “How much charging infrastructure do electric vehicles need? A review of the evidence and international comparison” assessing EVSE network in Netherlands and other regions found

- For Netherlands, public charging infrastructure an alternative to home charging due low availability of detached houses and concurrently home charging equipment

Study “Can public slow charging accelerate plug-in electric vehicle sales? A simulation of charging infrastructure usage and its impact on plug-in electric vehicle sales for Germany” which models EVSE network and PEV uptake in Germany until 2030 found

- Public slow charging facilities do not increase PEV market shares and they need to be subsidized for a long time

By end 2019 U.S. had installed public base of 78,000 L2 and DC fast charge public with ~18 PEVs per plug

Charging Infrastructure – U.S.

2019 U.S. Public Charging Network and PEV Sales (Cumulative)

U.S. Estimated to have ~20,000 public PEV charging stations (Level 2 and DC fast charging) in 2019

Note: Charging Network is counted by the outlet rather than by the geographical location i.e. does not indicate stations

Source: [https://afdc.energy.gov/data/10332](https://afdc.energy.gov/data/10332)
California accounts for $\frac{1}{3}$rd of U.S. EVSE network; has 28 PEVs per plug

California has ~25,000 L2 and DC charging plugs. 2nd highest state in U.S., Florida has <4,000 plugs

**Charging Infrastructure – California**

**California Public EVSE Network**
- 6,266 Stations
- 25,084 Charging plugs
- 700,110 PEVs (cumulative)
- ~28 PEVs per plug

**Bay Area Public EVSE Network**
- 2,092 Stations
- 9,634 Charging plugs
- ~40% Of charging plugs in CA

District of Columbia accounts for ~6% of U.S. EVSE network; has 5 PEVs per plug

Charging Infrastructure – District of Columbia

144 Stations

444 Charging plugs

2,817 PEVs (cumulative – June 2019)

~5 PEVs per plug

Note: PEVs from surrounding regions of Northern Virginia and Baltimore must be considered before assessing the low PEV to plug ratio

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Cost estimates to meet 2025 CAFE compliance range from $570 per vehicle to >$3,000 per vehicle

CAFE – Cost of Compliance

- Four major studies are reviewed for CAFE movement:
  - A Macroeconomic Study of Federal and State Automotive Regulations (2017) from Indiana University, funded by Auto Alliance (consists of 12 OEMs including GM, Ford, FCA, etc.)

- ICCT takes a favorable stance towards EPA and NHTSA cost analysis and disagrees with proposed SAFE Vehicles Rules as:
  - For technology costs, EPA Final Determination and NHTSA Technical Assessment Report vary to a certain degree on costs considered and penetration of fuel economy improvement technologies. However, the proposed SAFE Vehicles Rule considers >2X cost for implementing fuel efficient technologies
  - Additionally, SAFE Vehicles Rule considers >100X cost for crash and congestion stating that improved fuel economy results in higher driving and also continued use of older vehicles with lower scrap rate due to higher fuel economy ratings

Estimated Impact

Cost of Compliance

- Technology cost per vehicle ($) - Crash and Congestion cost per vehicle ($)

CAFE – Cost of Compliance

<table>
<thead>
<tr>
<th>Source</th>
<th>Cost Estimates</th>
</tr>
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<tbody>
<tr>
<td>EPA Final Determination (2017)</td>
<td>1 (technology) $502; 2 (crash) $68</td>
</tr>
<tr>
<td>NHTSA Technical Assessment Report (2016)</td>
<td>3 (technology) $758; 4 (crash) $54</td>
</tr>
<tr>
<td>Macroeconomic Study of Federal &amp; State Automotive Regulations - Low(2017)</td>
<td>5 (technology) $1,249; 4 (crash) $1,881</td>
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<tr>
<td>Macroeconomic Study of Federal &amp; State Automotive Regulations - High(2017)</td>
<td>5 (technology) $1,249; 4 (crash) $1,881</td>
</tr>
<tr>
<td>Proposed SAFE Vehicles Rule (2018)</td>
<td>Includes all costs $3,141</td>
</tr>
</tbody>
</table>

Estimated annualized cost at ~17M vehicles per year

Note: $X Estimated annualized cost at ~17M vehicles per year

Source: [EPA](https://www.epa.gov/energy/fuels-institute/impact-of-transportation-related-environmental-initiatives)
Studies estimate lifetime fuel savings impact of CAFE varies between ~$800 to ~$1,400 per vehicle

CAFE – Fuel Economy

- Proposed SAFE Vehicles Rule to freeze fuel economy standards at 37 mpg (estimated real-world at ~30 mpg) post 2020
- ICCT disagrees with Proposed SAFE Vehicles Rule calculation of fuel economy benefits stating that SAFE assumes progressive improvement in fuel economy at 1% per year in spite of freeze in fuel economy standards, enabling higher fuel economy savings projection

CAFE Fuel Economy Standards (in real-world mpg)

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<tr>
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</thead>
<tbody>
<tr>
<td>Historic Fleet mpg requirement</td>
<td>30.6</td>
<td>25.1</td>
<td>33.4</td>
<td>43.6</td>
<td>29.6</td>
</tr>
<tr>
<td>Proposed SAFE Fleet mpg requirement</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Existing CAFE Fleet mpg requirement</td>
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</table>

Estimation Impact

<table>
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<tr>
<th>Fuel Economy</th>
<th>Estimated Impact</th>
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</thead>
<tbody>
<tr>
<td>Negative</td>
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<tr>
<td>Neutral</td>
<td></td>
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<tr>
<td>Positive</td>
<td></td>
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</tbody>
</table>

Note: Estimated annualized savings at ~17M vehicles per year and vehicle life of 12 years

Variability in pricing considered for cost of carbon influences emissions reduction impact for each analysis

**CAFE – Emissions**

- SAFE Vehicles Rule reduces Social Cost of Carbon (SCC) impact by 85% reducing the overall benefits compared to prior analysis
  - The cost of carbon for EPA (2017) and NHTSA technical report (2016) if considered at ~$47 / ton
  - SAFE Vehicle Rule cost of carbon is ~$7 - $10 / ton

**CAFE – CO₂ Emission Targets**

- Existing CAFE Fleet CO₂ emissions target (g/mile)
- Proposed SAFE Fleet CO₂ emissions target (g/mile)

<table>
<thead>
<tr>
<th>Target Description</th>
<th>CO₂ Emission Target (g/mile)</th>
</tr>
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<tbody>
<tr>
<td>Baseline CO₂ emission target (2020)</td>
<td>213</td>
</tr>
<tr>
<td>Original target (to be met in 2025)</td>
<td>163</td>
</tr>
<tr>
<td>Proposed SAFE target (to be met in 2025)</td>
<td>240</td>
</tr>
</tbody>
</table>

-23% reduction

**CAFE – Emissions Impact**

- $0.6B
- $0.5B
- $0.1B

**Estimated Impact**

- Low Emissions
  - Negative
  - Neutral
  - Positive

**Note:** Estimated annualized savings at ~17M vehicles per year and vehicle life of 12 years

Proposed SAFE predicts positive impact on vehicle demand and IU study indicates negative impact from existing CAFE rules

**CAFE – Vehicle Demand**

- EPA (2017) and NHTSA technical report (2016) do not estimate impact to vehicle sales in their analysis.
- Proposed SAFE Vehicle Rule estimates 1 million additional new vehicle sales through MY 2029.
  - SAFE Vehicle Rule also states that existing CAFE standards will negatively impact new vehicle sales.
- Macroeconomic Study from Indiana University (IU) estimates roughly 0.5% - 1.5% decline in sales YOY for current CAFÉ standards.

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**CAFE – Vehicle Demand**

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<thead>
<tr>
<th>Source</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPA Final Determination (2017)</td>
<td>Not estimated in model</td>
</tr>
<tr>
<td>NHTSA Technical Assessment Report (2016)</td>
<td>Negative</td>
</tr>
</tbody>
</table>

**Estimated Impact**

- Vehicle Demand:
  - Negative
  - Neutral
  - Positive

---

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  - CAFE standard
  - **Biofuels: Low Carbon Fuel Standard (LCFS) and Renewable Fuel Standard (RFS)**
  - Carbon pricing and Transportation Climate Initiative (TCI)
  - Low Emission Zone (LEZ) / ICE bans, Congestion pricing and Mobility initiative
Low Carbon Fuel Std. (LCFS) and Cap and Trade (C&T) projected to save cum. ~$8 billion by 2025 in social cost of avoiding carbon emission

Low Carbon Fuel Standard (LCFS) – Low Emissions

- LCFS targets reducing Carbon Intensity* to 90% by 2020 and 80% by 2030 relative to 2010 levels
- Example of fuels that qualify: ethanol, biodiesel, CNG, hydrogen, electric, California reformulated gasoline, etc.
- According to CalStart, LCFS appears to have industry support in the industry (155 industry groups approve support for continuation of LCFS)

Carbon Intensity target, relative to 2010 level

150MT CO₂e (Total on-road transportation GHG emissions)

<table>
<thead>
<tr>
<th>Year</th>
<th>100%</th>
<th>90%</th>
<th>80%</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>100%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2020</td>
<td>90%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2030</td>
<td>80%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note: Carbon intensity is a measure of the GHG emissions released by the full lifecycle of a fuel, including production, transportation, and consumption

LCFS – GHG emissions impact (in $ Billions)

- Annual economic benefit from decreased carbon pollution ($ Billions)
- Estimated Impact
  - Low Emissions
    - Negative
    - Neutral
    - Positive


Assuming social cost of carbon $50/ton
Impact of Transportation - Related Environmental Initiatives

Project # C021273, 22 May 2020

LCFS and Cap-and-Trade estimated to result in cumulative savings of ~$7B by 2025 from decreased petroleum dependency

Low Carbon Fuel Standard (LCFS) – Fuel Economy

- From 2011–2017, the share of alternative fuels in California’s transportation energy grew from 6.1 percent to 8.5 percent. Of alternative fuel energy, the portion coming from non-liquid fuels increased from 7.6 percent to 13.5 percent over the period.

- Study “Driving California Forward - Environmental Defense Fund and the American Lung Association” which assess the fuel economy impact of LCFS for the years 2015 – 2025 was reviewed.

- The study estimates cumulative savings of ~$7B from reduced petroleum dependency between 2010 – 2025 through LCFS program.

- EDF study also states that California’s LCFS and Cap and Trade will result in reduced consumption of 21.4 billion gallons of gasoline and 11.8 billion gallons of diesel fuel by 2025, resulting in cumulative savings of >$100B

- UC Davis study corroborates EDF’s claim – Ricardo needs to scrutinize assumptions.

Note: $X$ Estimated annual fuel savings with LCFS in place compared with no-regulation.

~$2B in incremental cost in 2017 to fuel refiners from California’s LCFS and Cap-and-Trade program; cost expected to be >$9B by 2030

Low Carbon Fuel Standard (LCFS) – Cost of Compliance

- Three sources reviewed for LCFS movement:
  - Economic Analysis California Low Carbon Fuel Standard

- LCFS was established in 2007 and required refiners to reduce the carbon intensity (CI) of their fuels by 10 percent by 2020. New amendment provides glidepath to reduced CI incrementally till 2030

- Both ICF and Stillwater studies forecast incremental cost impact per gallon to meet LCFS standards

- Cost of Compliance stated is for refiners, and assumes the cost is transferred to the end users

Note: Estimated total incremental annual cost to refiners in 2025 based on fuel consumption in California

Biofuel blending – Renewable Fuel Standard (RFS)

Fuel nesting scheme for Renewable Fuel Standard (RFS)

Conventional renewable fuel (D6)
- Example feedstock: Corn starch
- Required lifecycle GHG reduction: 20% or more

Advanced biofuel (D5)
- Example feedstocks: Sugarcane, biobutanol, bionaphtha
- Required lifecycle GHG reduction: 50% or more

Cellulosic biofuel (D3)
- Example feedstocks: Corn stover, wood chips, miscanthus, biogas
- Required lifecycle GHG reduction: 60% or more

Biomass-based diesel (D4)
- Example feedstocks: Soybean oil, canola oil, waste oil, animal fats
- Required lifecycle GHG reduction: 50% or more

Note: EISA’s four renewable fuel standards are nested within each other. This means, the fuel with a higher GHG reduction threshold can be used to meet the standards for a lower GHG reduction threshold. For example, fuels or RINs for advanced biofuel (i.e., cellulosic, biodiesel or sugarcane ethanol) can be used to meet the total renewable fuel standards (i.e., corn ethanol).

## Renewable Fuel Standard (RFS): Annual volume standards that have been finalized for 2010 to 2020 (2/2)

### Biofuel blending – Renewable Fuel Standard (RFS)

#### Annual Volume Standards

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cellulosic biofuel</td>
<td>6.5</td>
<td>0.02</td>
<td>0.02</td>
<td>0.83</td>
<td>33</td>
<td>123</td>
<td>230</td>
<td>311</td>
<td>288</td>
<td>418</td>
<td>10,500</td>
<td>590</td>
<td>N/A</td>
</tr>
<tr>
<td>Biomass-based diesel</td>
<td>1.15</td>
<td>0.8</td>
<td>1.0</td>
<td>1.28</td>
<td>1.63</td>
<td>1.73</td>
<td>1.9</td>
<td>2.0</td>
<td>2.1</td>
<td>2.1</td>
<td>21.0</td>
<td>2.43\textsuperscript{4}</td>
<td>2.43\textsuperscript{4}</td>
</tr>
<tr>
<td>Advanced biofuel</td>
<td>0.95</td>
<td>1.35</td>
<td>2.0</td>
<td>2.75</td>
<td>2.67</td>
<td>2.88</td>
<td>3.61</td>
<td>4.28</td>
<td>4.29</td>
<td>4.92</td>
<td>15.0</td>
<td>5.09</td>
<td>N/A</td>
</tr>
<tr>
<td>Total renewable fuel</td>
<td>12.95</td>
<td>13.95</td>
<td>15.2</td>
<td>16.55</td>
<td>16.28</td>
<td>16.93</td>
<td>18.11</td>
<td>19.28</td>
<td>19.29</td>
<td>19.92</td>
<td>30.0</td>
<td>20.09</td>
<td>N/A</td>
</tr>
</tbody>
</table>

**Notes:**

1. All volumes are in billions of gallons, except cellulosic biofuel which is in millions of gallons. All volumes are ethanol-equivalent, except biomass-based diesel which is in gallons of biodiesel.
2. In a January 2013 decision, the D.C. Circuit Court vacated the 2012 cellulosic standard; the 2011 standard was also reset to 0.0, as the same methodology was used for both 2011 and 2012.
4. The biomass-based diesel standard for 2020 was set at 2.43 billion gallons in the RFS 2019 Final Rule (83 FR 63704, December 11, 2018).

Net GHG emissions reduction from RFS mandate is <5% compared to baseline of standard gasoline and diesel fuel use

Renewable Fuel Standard (RFS) – Emissions

- Renewable Fuels under RFS are targeted to achieve 20-60% GHG emissions reduction
- Std. ethanol currently accounts for 80% of all renewable fuels under this mandate (others: advanced, biodiesel and cellulosic fuel)
- If all motor fuels were replaced by renewable fuels, net GHG impact would be 20-60% reduction, however when compared to current gas and diesel use profile and std. ethanol use, it has a net impact of <5% GHG reduction

Total gas and diesel vs renewable fuel consumption (2019), billion gallons

- Gasoline and diesel
- Renewable fuel

RFS Emissions Reduction Target

- 20% (Std. Ethanol)
- 50% (Advanced and Biodiesel)
- 60% (Cellulosic)

- Std ethanol is 80% of all renewable fuels used
- Renewable fuels 10-15% of total motor fuel used

Net impact <5% GHG reduction accounting for total gas and diesel consumed vs renewable fuel

Estimated Impact

- Low Emissions
  - Negative
  - Neutral
  - Positive

Source: EPA https://www.epa.gov/renewable-fuel-standard-program, Ricardo analysis
Cost-benefit equation for consumers choosing std. ethanol based vehicles is neutral to slightly negative

Renewable Fuel Standard (RFS) – Fuel Economy

- E85 national average in March 2020 is $1.87/ gallon whereas gasoline is $2.10/ gallon (ratio of gasoline: E85 = 1: 0.85)
  - Ratio may fluctuate between 0.80 to 0.90
- E85 vehicle fuel economy is about 15-25% worse than comparable gasoline vehicle (ratio of gasoline: E85 = 1: 0.80)
  - Ratio may fluctuate between 0.75 to 0.85
- This translates to roughly $0.20/ mile impact for a C/D segment vehicle

For 20,000 miles per year:
**E85 vehicle costs $50-150/ year more to operate**

- **Consumers do not have an incentive to purchase E85 vehicles**
- **Advanced, biodiesel and cellulosic renewable fuels will provide fuel economy benefits but currently cost to produce remains prohibitive to overall equation**

Sources: E85prices.com, FuelEconomy.gov, EPA, Ricardo analysis
Industry is incurring combined $5-20B annual cost to comply with RFS mandate or purchase Renewable ID numbers (RINs)

Renewable Fuel Standard (RFS) – Cost of Compliance

- Refiners need to comply with Renewable Volume Obligation (RVO) or purchase Renewable ID No. (RIN). Price of RINs has increased over time and independent small refiners cannot pass on increased cost of purchasing RINs to consumers.
- Government has relaxed penalties on small refiners that cannot comply with RVOs, however that tends to disrupt RIN price balance.
- Currently there aren’t enough E85 fuel dispensers in the country to satisfy significantly higher production targets.
- Increase in ethanol use requires increased land allocation and water use that tends to conflict with other crop production opportunities with agricultural land availabilities.

[https://www.card.iastate.edu/products/policy-briefs/display/?n=1191](https://www.card.iastate.edu/products/policy-briefs/display/?n=1191)
[https://www.realclearenergy.org/articles/2019/04/05/the_unintended_consequences_of_the_renewable_fuel_standard_110422.html](https://www.realclearenergy.org/articles/2019/04/05/the_unintended_consequences_of_the_renewable_fuel_standard_110422.html)
Ricardo analysis.
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Revenue from allowance sales to be invested by TCI signatory regions to support low-carbon transportation initiatives

Transportation Climate Initiative (TCI)

Illustrative Portfolios of Clean Transportation Investments – Outlined in TCI Working Groups’ analysis

<table>
<thead>
<tr>
<th></th>
<th>Scenario A</th>
<th>Scenario B</th>
<th>Scenario C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric cars, light trucks and vans</td>
<td>5%</td>
<td>30%</td>
<td>54%</td>
</tr>
<tr>
<td>Low and zero-emission buses and trucks</td>
<td>21%</td>
<td>23%</td>
<td>27%</td>
</tr>
<tr>
<td>Transit expansion and upkeep</td>
<td>35%</td>
<td>18%</td>
<td>-</td>
</tr>
<tr>
<td>Pedestrian and bike safety, ride sharing</td>
<td>16%</td>
<td>14%</td>
<td>10%</td>
</tr>
<tr>
<td>System efficiency</td>
<td>7%</td>
<td>8%</td>
<td>8%</td>
</tr>
<tr>
<td>Indirect / Other</td>
<td>17%</td>
<td>8%</td>
<td>-</td>
</tr>
</tbody>
</table>

Source: [https://www.transportationandclimate.org/sites/default/files/TCI%20Public%20Webinar%20Slides_20191217.pdf](https://www.transportationandclimate.org/sites/default/files/TCI%20Public%20Webinar%20Slides_20191217.pdf)
Estimated end user incremental fuel cost could range between $2B - $5.6B in 2032 based on TCI cap reduction targets

Transportation Climate Initiative (TCI) – Cost of Compliance

- Study "Draft Memorandum of Understanding & 2019 Cap-and-Invest Modeling Results" from TCI committee reviewed for analysis. All cost of compliance impact scenarios provided are from this study.

- Fuel suppliers to TCI states would be required to hold allowances to cover emissions from regulated fuels.
  - Currently gasoline and diesel are under consideration in the preliminary MOU document released in 2019.
  - Allowances can be acquired through auction or through trade.
  - Allowance costs are assumed to be passed directly to consumers in the study.


TCI – Cost of Compliance

<table>
<thead>
<tr>
<th>Cap Reduction Target</th>
<th>Cost per Gallon</th>
</tr>
</thead>
<tbody>
<tr>
<td>20% Cap reduction</td>
<td>$0.09 per gallon</td>
</tr>
<tr>
<td>22% Cap reduction</td>
<td>$0.13 per gallon</td>
</tr>
<tr>
<td>25% Cap reduction</td>
<td>$0.27 per gallon</td>
</tr>
</tbody>
</table>

Cap reduction target is set against 2022 estimated emissions of 254 MMT CO₂ equivalent.

Average total transportation fuel spend, including gasoline and diesel, in TCI states in 2016 was ~$86 Billion

TCI GHG emissions impact may be only be 1% - 6% if TCI analysis reference case assumptions hold true, and limited to max of 19%

Transportation Climate Initiative (TCI) – Low Emissions

- TCI analysis projects ~6% - 19% GHG emissions reduction without TCI mandate
  - Implies net impact of only 1% - 6% with TCI in place
- Study "Draft Memorandum of Understanding & 2019 Cap-and-Invest Modeling Results" also estimates ~$3B - $10B in public health benefits from reduced NO\textsubscript{X}, particulate matter and preventative deaths

TCI states GHG emissions impact (million metric tons CO\textsubscript{2})

- Reference case with sensitivity analysis estimates GHG reduction of 6% to 19% without TCI

TCI CO\textsubscript{2} Emissions Reduction Target by 2032

- Cap reduction target is set against 2022 estimated emissions of 254 MMT CO\textsubscript{2} equivalent

- Net impact ~1% – 6% GHG reduction if reference case projection till 2032 holds true

Estimated Impact

- Low Emissions
  - Negative
  - Neutral
  - Positive

Fuel savings impact may range from ~$1B - $15B in fuel savings depending on net impact of TCI

Transportation Climate Initiative (TCI) – Fuel Economy

- Study "Draft Memorandum of Understanding & 2019 Cap-and-Invest Modeling Results" used to estimate fuel savings impact in 2032 in TCI states
  - Range calculated using minimal net GHG emissions impact and max GHG emissions impact
  - Both low and high fuel savings impact scenarios provided are based on this study
- TCI impact provided includes New Hampshire. New Hampshire withdrew from TCI in Dec 2019

Consumers in TCI states spent ~$86B in 2016 and are expected to spend >$60B in 2032

Total fuel savings range in TCI states in 2032 estimated based on min and max expected TCI impact based on cap reduction targets

Countries in Europe tax carbon at varying levels of jurisdiction with cost ranging from \$1 \textendash \$100 per ton

Carbon Taxes in Europe

- Finland was the first country in 1990 to introduce carbon tax. Currently 15 European countries have implement carbon taxes that range from \$1 per ton in Ukraine, Poland to \$100 in Sweden.
- Sweden levies the highest carbon tax rate in Europe at \$132 (U.S.) per ton of carbon emissions.
- Carbon taxes are levied on different types of greenhouse gases such as methane, CO$_2$, etc. Scope of each country’s carbon tax differs, resulting in varying shares of greenhouse gas emissions covered by the tax.
  - Ex: Spain applies carbon tax only on fluorinated gases, taxing only \%13 of its GHG emissions.
  - Norway for example abolished most of its exemptions and its carbon tax covers 60\% of its GHG emissions.
- All member states of the European Union (plus Iceland, Liechtenstein, and Norway) are part of EU Emissions Trading System (EU ETS), a market created to trade a capped number of greenhouse gas emission allowances.
  - Other European countries (non-EU) that levy carbon tax are also part of EU ETS except Switzerland.

## Carbon Tax Rates, Share of Covered Greenhouse Emissions, and Year of Implementation (as of 2019)

### Carbon Taxes in Europe

<table>
<thead>
<tr>
<th>Country</th>
<th>Carbon Tax Rate (per ton of CO2e)</th>
<th>Share of Jurisdiction’s Greenhouse Gas Emissions Covered</th>
<th>Year of Implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Denmark (DK)</td>
<td>€23.21</td>
<td>40%</td>
<td>1992</td>
</tr>
<tr>
<td>Estonia (EE)</td>
<td>€2.00</td>
<td>3%</td>
<td>2000</td>
</tr>
<tr>
<td>Finland (FI)</td>
<td>€62.00</td>
<td>36%</td>
<td>1990</td>
</tr>
<tr>
<td>France (FR)</td>
<td>€44.60</td>
<td>35%</td>
<td>2014</td>
</tr>
<tr>
<td>Iceland (IS)</td>
<td>€27.38</td>
<td>29%</td>
<td>2010</td>
</tr>
<tr>
<td>Ireland (IE)</td>
<td>€20.00</td>
<td>49%</td>
<td>2010</td>
</tr>
<tr>
<td>Latvia (LV)</td>
<td>€5.00</td>
<td>15%</td>
<td>2004</td>
</tr>
<tr>
<td>Norway (NO)</td>
<td>€52.09</td>
<td>62%</td>
<td>1991</td>
</tr>
<tr>
<td>Poland (PL)</td>
<td>€0.07</td>
<td>4%</td>
<td>1990</td>
</tr>
<tr>
<td>Portugal (PT)</td>
<td>€12.74</td>
<td>29%</td>
<td>2015</td>
</tr>
<tr>
<td>Slovenia (SI)</td>
<td>€17.00</td>
<td>24%</td>
<td>1996</td>
</tr>
<tr>
<td>Spain (ES)</td>
<td>€15.00</td>
<td>3%</td>
<td>2014</td>
</tr>
<tr>
<td>Sweden (SE)</td>
<td>€112.08</td>
<td>40%</td>
<td>1991</td>
</tr>
<tr>
<td>Switzerland (CH)</td>
<td>€83.17</td>
<td>33%</td>
<td>2008</td>
</tr>
<tr>
<td>Ukraine (UA)</td>
<td>€0.33</td>
<td>71%</td>
<td>2011</td>
</tr>
<tr>
<td>United Kingdom (GB)</td>
<td>€20.34</td>
<td>32%</td>
<td>2013</td>
</tr>
</tbody>
</table>

Impact of carbon tax on gasoline price appears moderate, however that on natural gas and coal prices appears significant

**Effects of Carbon Tax on Fuel Prices**

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>10 USD</th>
<th>20 USD</th>
<th>30 USD</th>
<th>40 USD</th>
<th>50 USD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline</td>
<td>0%</td>
<td>12%</td>
<td>25%</td>
<td>37%</td>
<td>50%</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>66%</td>
<td>132%</td>
<td>198%</td>
<td>264%</td>
<td>330%</td>
</tr>
<tr>
<td>Coal</td>
<td>10%</td>
<td>37%</td>
<td>50%</td>
<td>62%</td>
<td>66%</td>
</tr>
</tbody>
</table>

Carbon tax of $40/ton, results in:
- $0.40/gallon increase in gas price
- 50% increase in natural gas price
- 264% increase in coal price

Transportation accounts for ~50% of GHG emissions in US, so even if price impact on gas is marginal, the significant impact on energy cost creates headwinds for carbon pricing adoption.

2020 marked with Asia/Pacific region leading GHG emissions coverage through carbon pricing initiatives

Carbon Pricing Initiatives and GHG Emissions Coverage

- Europe has historically lead the charge in terms of number of initiatives and early-on emissions coverage
- Asia/Pacific region has caught up in the last five years overtaking Europe in covering emissions with carbon pricing initiatives

Highlighted areas include all regional, national, sub-national locations where carbon pricing initiatives (carbon tax or emissions trading system) have been implemented, scheduled, or are under consideration through 2019

Europe leads in both the steepest carbon tax pricing as well as revenue generation through taxation

Carbon Tax Prices and Revenues – Top Five

- European countries, particularly in the north have the highest carbon taxes globally
- Revenue generation however is expectedly higher on an aggregate level in mostly differing regions due to larger geographies and/or densities

Carbon revenue use varies globally with a notable amount being spent on environmental and climate related projects

Global Carbon Revenue Usage

Study summary

In 2014, ~27% of the carbon revenues collected globally totaling $28B were used to subsidize spending in energy efficiency or renewable energy

Additional Studies reviewed


- ~$28B collected by governments as “carbon revenues” each year in 56 countries and regions with “cap-and-trade” contributing ~23% and “carbon tax” contributing remaining 77% of the revenues
- ~ 27% of total carbon revenues (~$7.8B) is used to subsidize “green spending” i.e. energy efficiency and renewable energy initiatives. Rest are used for by regions for tax cuts, rebates etc.
- ~60% of green spending revenues are from cap-and-trade system i.e. ~70% of cap-and-trade revenues go towards green spending. Rest of green spending revenue is from carbon tax system

2019 World Bank Study “Using Carbon Revenues” assesses global carbon revenues for the year 2017-2018 covering 46 national and 28 sub-national jurisdictions

- Study estimates carbon revenues from carbon pricing increased from $22B in 2016 to $44B in 2018 with global GHG emissions covered increased from 13% in 2016 to 20% in 2018
- Also estimates that in 2018 ~42% (~$18.5B) of carbon revenues were allocated for environmental projects with remaining allocated towards general budget, tax-rebates, development and direct transfers. For example, California assigns all revenues from its ETS for climate-oriented projects
- Majority of the $18.5B driven by EU. EU ETS allocates ~80% of its carbon revenues totaling ~$16B towards environmental projects

Impact of Transportation - Related Environmental Initiatives

Project # C021273, 22 May 2020

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First enacted in 1992, EU emission controls set limits for air polluting nitrogen oxides (NO\textsubscript{x}) and particulate matter (PM) from engines.

Low Emission Zone (LEZ), Vehicle use type restrictions / ICE bans

<table>
<thead>
<tr>
<th>Euro Emissions Standard</th>
<th>Average vehicle registration age that meet the standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Euro 1</td>
<td>Most New Registrations Beginning on December 31, 1992</td>
</tr>
<tr>
<td>Euro 2</td>
<td>Most New Registrations Beginning on January 1, 1997</td>
</tr>
<tr>
<td>Euro 3</td>
<td>Most New Registrations Beginning on January 1, 2001</td>
</tr>
<tr>
<td>Euro 4</td>
<td>Most New Registrations Beginning on January 1, 2006</td>
</tr>
<tr>
<td>Euro 5</td>
<td>Most New Registrations Beginning on January 1, 2011</td>
</tr>
<tr>
<td>Euro 6</td>
<td>Most New Registrations Beginning on September 1, 2015</td>
</tr>
</tbody>
</table>

Source: https://urbanaccessregulations.eu/userhome/map
Diesel vehicles not meeting Euro 4 are not allowed in majority LEZs, whereas less stringent for gasoline vehicles (meeting Euro 1 allowed)

Low Emission Zone (LEZ), Vehicle use type restrictions / ICE bans

- London Ultra Low Emission Zone (ULEZ) rolled out in 2019 impacts both Light Duty Vehicles (LDV) and Heavy Duty Vehicles (HDV). Following standards have to be met to enter the ULEZ:
  - Euro 4 (NOx) for gasoline LDVs
  - Euro 6 (NOx and PM) for diesel LDVs
  - Euro VI (NOx and PM) for trucks, buses and coaches and other specialist heavy vehicles (NOx and PM)

- First enacted in 2008 by Berlin, as of date 47 cities in Germany operate an LEZ applicable to all LDVs. As of 2020, in most cities gasoline vehicles meeting Euro 1 and diesel vehicles meeting Euro 4 are allowed into LEZs

- Brussels in Belgium enacted an LEZ in 2018 where access standards are set till 2025 and are incremental in nature:
  - In 2018, diesel vehicles of Euro1 and earlier were not allowed access
  - In 2020, Euro 3 or earlier diesel LDVs and Euro 1 gasoline LDVs are denied access
  - In 2025, Euro 5 or earlier diesel LDVs ad Euro 2 or earlier gasoline LDVs are not allowed

Source: [https://urbanaccess regulations.eu/userhome/map](https://urbanaccessregulations.eu/userhome/map) ; [https://tfl.gov.uk/modes/driving/ultra-low-emission-zone/ways-to-meet-the-standard](https://tfl.gov.uk/modes/driving/ultra-low-emission-zone/ways-to-meet-the-standard) ; [https://environnement.brussels/sites/default/files/be_lez_depliant7volets_1485x210mm_en_ok_web.pdf](https://environnement.brussels/sites/default/files/be_lez_depliant7volets_1485x210mm_en_ok_web.pdf)
**LEZ implementation results in ~5% - 10% reduction in NO\textsubscript{X} and PM emissions based on stringency, exemptions and enforcement**

Low Emission Zone (LEZ), Vehicle use type restrictions / ICE bans

**Study summary**

**Study 1**
- Lisbon – implemented for both pass car & CV, >20% reduction in NO\textsubscript{X} and PM\textsubscript{10} between 2009-2016 in LEZ

**Study 2**
- Germany – avg reduction of 17% PM\textsubscript{10} and 7% NO\textsubscript{X} concentration in LEZ region

**Study 3**
- Brussels: 6.4% reduction in PM\textsubscript{2.5} and 4.7% reduction in NO\textsubscript{X} from LDV between 2018 - 2019 from its LEZ

**Studies reviewed - Europe**

Study “Impact of the implementation of Lisbon low emission zone on air quality” assessing impact of Low Emission Zone (LEZ) in Lisbon from 2009 - 2016 found significant improvements in NO\textsubscript{2} & PM\textsubscript{10}
- 22% reduction in NO\textsubscript{2} and 25% reduction in PM\textsubscript{10} between 2009 - 2016
- Only Zone 2 considered where only EURO 2 or higher vehicles are allowed. Zone 1 is smaller and only EURO 3 or higher vehicles are allowed

Study “Impacts of low emission zones in Germany on air pollution levels” assessing impact of LEZs in urban centers in Germany from 2002 - 2012 found that within LEZ areas the following
- ~17% reduction in PM\textsubscript{10} concentrations and ~7% reduction in NO\textsubscript{X} concentration. NO\textsubscript{X} reduced from ~125 µg/m\textsuperscript{3} to ~115 µg/m\textsuperscript{3}
- Study also does not see possibility for further reduction unless stringency is increased as vehicles qualified to operate in LEZs reached ~90%, with other vehicle meeting exception rules

Bruxelles Environnement, 2019 fact sheet
- Brussels implemented a progressive LEZ in 2018 covering all light duty vehicles
- In 2018 - 2019, vehicles with Euro 2 or lower were banned from entering LEZ

Congestion pricing in New York (limited to Central Business District) is expected to cost pass car commuters $6 - $12 per day

Congestion Pricing – Cost of compliance

- 2019 study by Regional Plan Association (RPA) “Congestion pricing in New York: Getting it right” provided recommendation on implementation of congestion pricing in New York’s Central Business District (CBD)
  - Recommended that pricing range from $6 - $9 during day and $3 during night for passenger vehicles, estimated to generate revenue of ~$1B - $1.1B
  - Pricing for commercial vehicles expected to be 2.5X of passenger vehicles
  - VMT reduction in congestion zone is ~3.8%
- Fix NYC Advisory Panel, Government panel appointed by NY Gov, in its report recommended following
  - Commercial vehicles would pay $25.34
  - For-hire cars would likely only pay $2 to $5
  - Personal vehicles would have to pay up to $11.52

Estimated annual revenue to city from congestion pricing

Congestion pricing in NYC estimated to reduce GHG emissions by ~1M tonnes i.e. ~6 - 7% of total transportation emissions in NYC

Congestion Pricing – Low Emissions

- 2019 study by Regional Plan Association (RPA) “Congestion pricing in New York: Getting it right” provided recommendation on implementation of congestion pricing in New York’s Central Business District (CBD)
  - Co2 emissions reduction is ~7% in congestion zone
- Congestion pricing estimated to eliminate ~1M tonnes of GHG emissions (tailpipe)
  - NYC total emissions in 2017 stood at 50M metric tonnes CO2 equivalent with 15M metric tonnes CO2 equivalent from road transportation

NYC Carbon Emissions in 2017, million metric tonnes CO₂

- 30% Stationary Energy
- 66% Transportation
- 4% Waste

Both RPA and Fix NYC studies estimate similar amount of emission reduction

Total transportation related emissions in New York City in 2017 was ~15 MMT of CO₂. Total GHG emissions was 50 MMT of CO₂

Estimated Impact

Low Emissions

- Negative
- Neutral
- Positive

London congestion pricing scheme estimated to have reduced vehicle volume by ~35% compared to year 2000 level

**Congestion Pricing – London**

- Prior to 2003 all-day average speeds in Central London averaged ~8.6 mph with 1/3rd of time spent at complete standstill
- London Congestion Charge (LCC) was implemented covering 21 square km in London in 2003 with a daily flat charge of £5. The charge was increased to £11.50 in 2014
- Based on 2011 estimate, LCC estimated to reduce 30,000 tonnes CO₂ annually
- Charging zone residents receive a 90 percent discount while certain vehicles are exempt, such as buses, taxis including private for hire (Uber) and electric vehicles and certain drivers, such as the disabled

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Because of congestion charge ~35% fewer cars crossing the congestion zone in 2017 compared with 2000

However, in between 2016 - 2017 bus ridership, after years of growth, decreased by 6% due to increased congestion. Caused by ~30% increase in private-for-hire (PFH) vehicles between 2000 – 2016 which are exempt from LCC

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Near term, consumers use mobility services in conjunction with private and public transport. Reduced vehicle ownership 2030+

Mobility initiatives – Shared, Connected and Autonomous vehicles

- Impact on fuel consumption and emissions are highly uncertain and could be either positive or negative from shared and autonomous mobility uptick

- Demographic shift and investment in public transit are other factors that impact vehicle demand

- Ride hailing services are ~1.5 – 4X more expensive than owning a private vehicle, breaking even in costs with car ownership at ~2,000 VMT on an annual basis. Ride hailing services account for ~2% of U.S. VMT

- Carsharing programs from OEMs such as Car2Go / Share Now from Daimler and BMW, Chariot from Ford, and Maven from GM scaled back in operations from market volatility and rising infrastructure costs. Zip car stated a fleet of ~12,000 vehicles across U.S. in its 2018 report

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