Electric Vehicle Forecast

PJM Interconnection

High level description of
methodology and assumptions

November 2023

S&P Global
Commodity Insights

Contents

We start our analysis with the base case scenario which encompasses all sectors of economy and is global in nature

Scenario description

Inflections is the S&P Global Commodity Insights base-case scenario. It represents **the integration of regional and sector analysis** from across Commodity Insights, illustrating the pace of change in long-term global energy supply, demand and trade, based on current views and assumptions about markets, policy, consumer behavior and technology.

In this scenario a broad range of fundamental changes across government, markets and society set a **sustained long-term energy transition** in motion. Once underway, this transition is faster than any of our previous base-case outlooks, and in 2050, GHG emissions are lower than ever before. But the resurgence in fossil use through the mid-2020s has lasting consequences for the structure of energy markets.

Key themes of this scenario include:

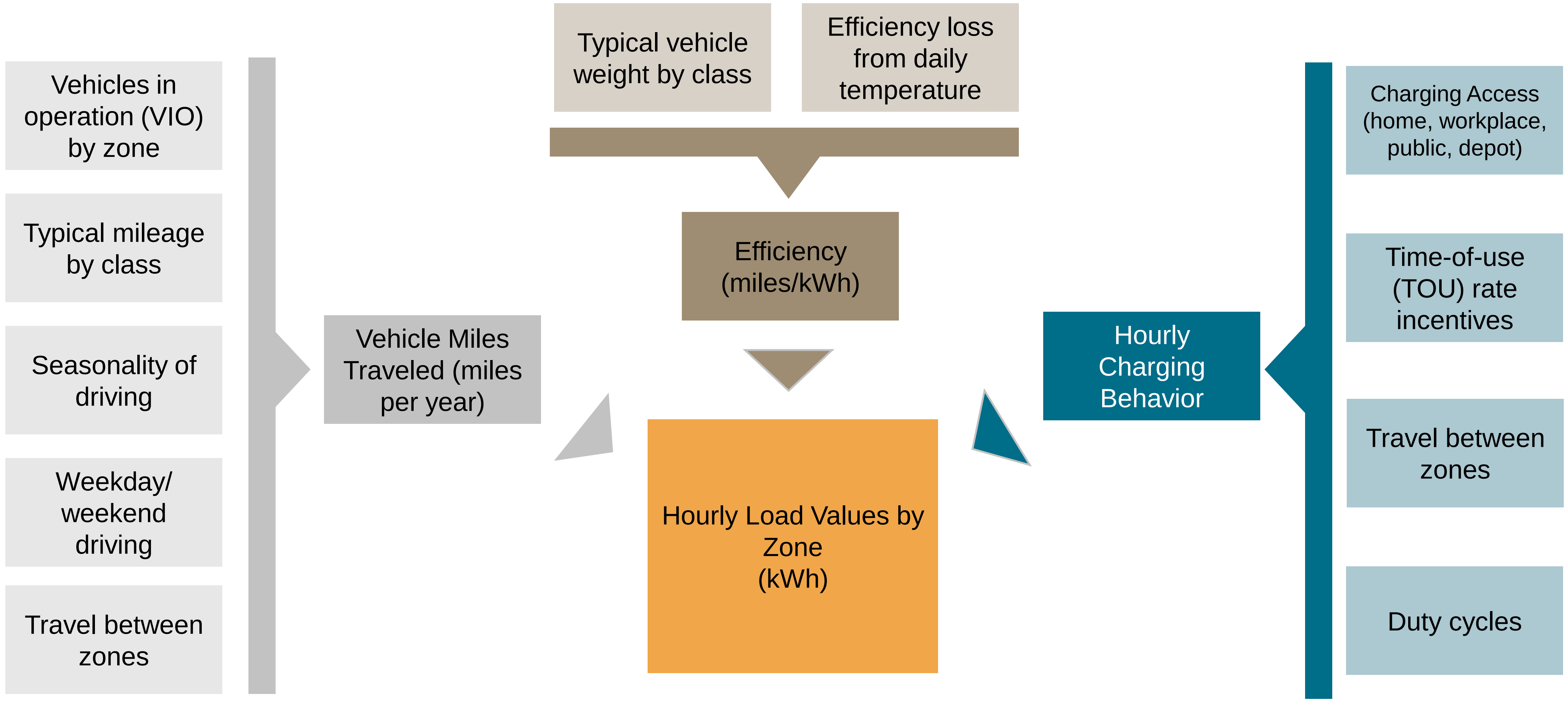
- Clean energy technology market and manufacturing leadership is becoming a central aspect of global economic and geopolitical rivalries
- The support mechanisms tasked with carrying out clean energy technology policy objectives vary substantially across regions and technologies
- Robust demand for renewables and batteries is also raising potential hurdles related to future supplies of strategic materials, parts and equipment, labor and capital being sufficient to satisfy all government ambitions and market demands
- Clean energy ambitions face major hurdles in permitting and grid development

Key indicators (global)

		History		Inflections	
		2019	**2020**	**2022**	**2050**
Real GDP	(billion 2022 $)	$94,807	$91,625	$100,065	$203,763
	Average growth	2.9%	2.7%	2.8%	2.6%
		(1990–2019)	(1990–2020)	(1990–2022)	(2022–50)
Primary energy consumption	(MMtoe)	14,685	14,115	15,007	17,303
	Average growth	1.8%	1.8%	1.7%	0.5%
		(1990–2019)	(1990–2020)	(1990–2022)	(2022–50)
EV shares of LV market[1]	Sales	1.7%	3.1%	10.0%	63.1%
	Fleet	0.4%	0.6%	1.6%	43.0%
Primary energy intensity of GDP	(metric tons of oil equivalent per million 2022 $)	155	154	150	85

Notes:
1. Includes battery-electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs) and fuel-cell electric vehicles (FCEVs).
Source: S&P Global Commodity Insights

Hourly load shapes are the result of the three key variables: vehicle miles traveled (VMT), vehicle efficiency, and charging behavior



Source: S&P Global Commodity Insights

Demand forecasts are created in 3 layers: top-down (national) and bottom-up (metro) to arrive at state/zone level

An established **multi-factor demand forecast model** integrates sales trends, household growth estimates, customer brand and dealer loyalty, leasing return-to-market, and hundreds of demographic purchase predictor variables, to create an EV adoption prediction at the granular **census tract level** geography. Bottom-up demand analysis at census tracts is then **reconciled** with our industry-leading national and State level forecasts to observe macro-economic boundaries.

National Level

Industry-leading Sales-based Powertrain Forecast based on:

- Economic Market Framework
- Federal Legislation, Taxation, Emission Targets, etc.
- OEM Production Forecast and Model Policy Outlook
- Registration Segment Trends

State/Zone Level

National → State level forecasting based on:

- State Economics
- Demographic Growth Prediction
- State Legislation, i.e., ZEV States etc.

Metro Level

Metro level demand identification based on:

- Demographic Profiles (psychographic household data to identify likely buyers at census tract level)
- Household Growth/Decline (projections at census tract level)
- S&P Loyalty Database (return-to-market potential and loyalty)
- Charging Infrastructure supporting EV adoption

Source: S&P Global Mobility

There are number of state and regional level key drivers we consider in the EV forecast

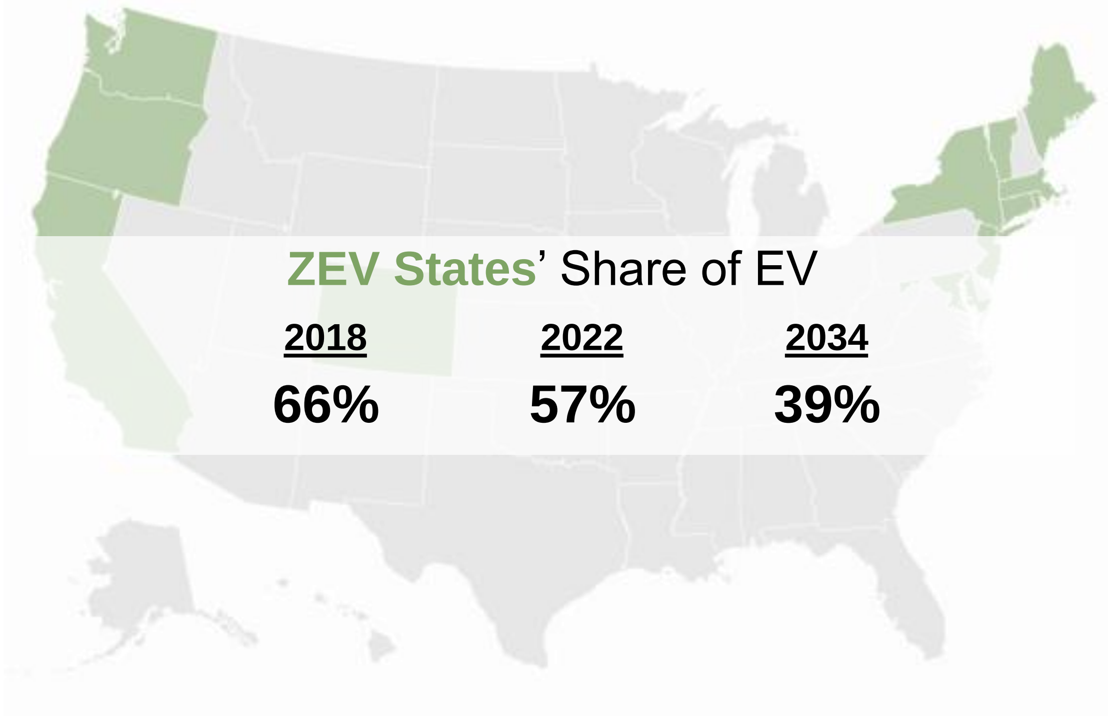
National Forecast Drivers

+

State and Region level:

- Segment preferences
- Brand performance
- Fuel-type share
- State legislation
  - ZEV requirements
  - ICE bans

As the EV market matures, volume will become less concentrated in ZEV states



Source: S&P Global Commodity Insights

Purchase Predictor Drivers

Household Insights and Vehicle Buyer Profiles to Forecast EV Adoption

How EV, Hybrid and ICE buying households compare

Internal Combustion HHs

- HH Income $150K+: 32%
- Under 55: 58%
- Multicultural: 31%

Hybrid HHs

- HH Income $150K+: 38%
- Under 55: 58%
- Multicultural: 33%

EV HHs

- HH Income $150K+: 55%
- Under 55: 68%
- Multicultural: 39%

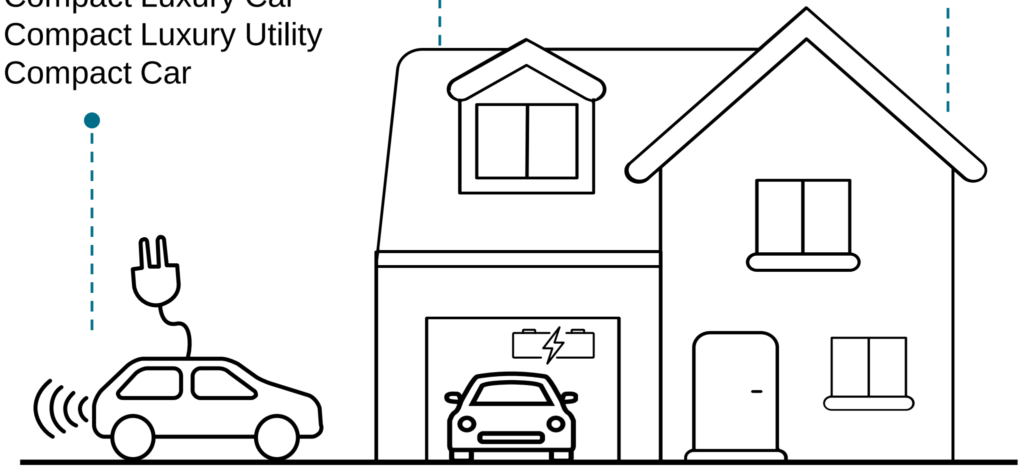
Source: S&P Global Mobility: Rolling 12 months through October 2022

EV households: Most active vehicle shoppers

EV Purchase Patterns
- **New vehicle every 2 years: 23%**
- **Own 2+ new: 46%**

Top Segments ~50% of new purchases
- Compact Utility,
- Compact Luxury Car
- Compact Luxury Utility
- Compact Car

EV Household Profile
- 56%: HHI $100K+
- 70%: Thriving financial profile
- 55%: Age 30-59
- 70%: Prime life stage



Gas Purchase Patterns
- **New vehicle every 2 years: 16%**
- **Own 2+ new: 32%**

Gas Household Profile
- 26%: HHI $100K+
- 63%: Thriving financial profile
- 44%: Age 30-59
- 59%: Prime life stage

Top Segments ~45% of new purchases
- Compact Utility,
- Full size ½ Ton Pick-up
- Upper Mid-Size Utility
- Compact Car

Source: S&P Global Mobility: New-To-New CYTD October 2022

There are number of micro-level key drivers we consider in developing the EV forecast

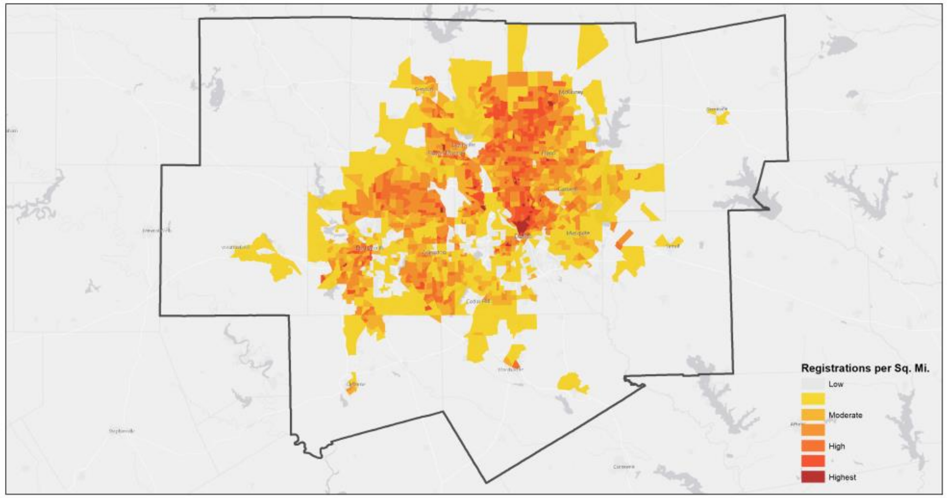
State/Regional Forecast Drivers

+

Census Tract level:

- Historical Registrations and Share
- Demographic Growth
  - Household Volume
  - Household Income
- EV Purchase Predictors

Registration Density



Source: S&P Global Mobility

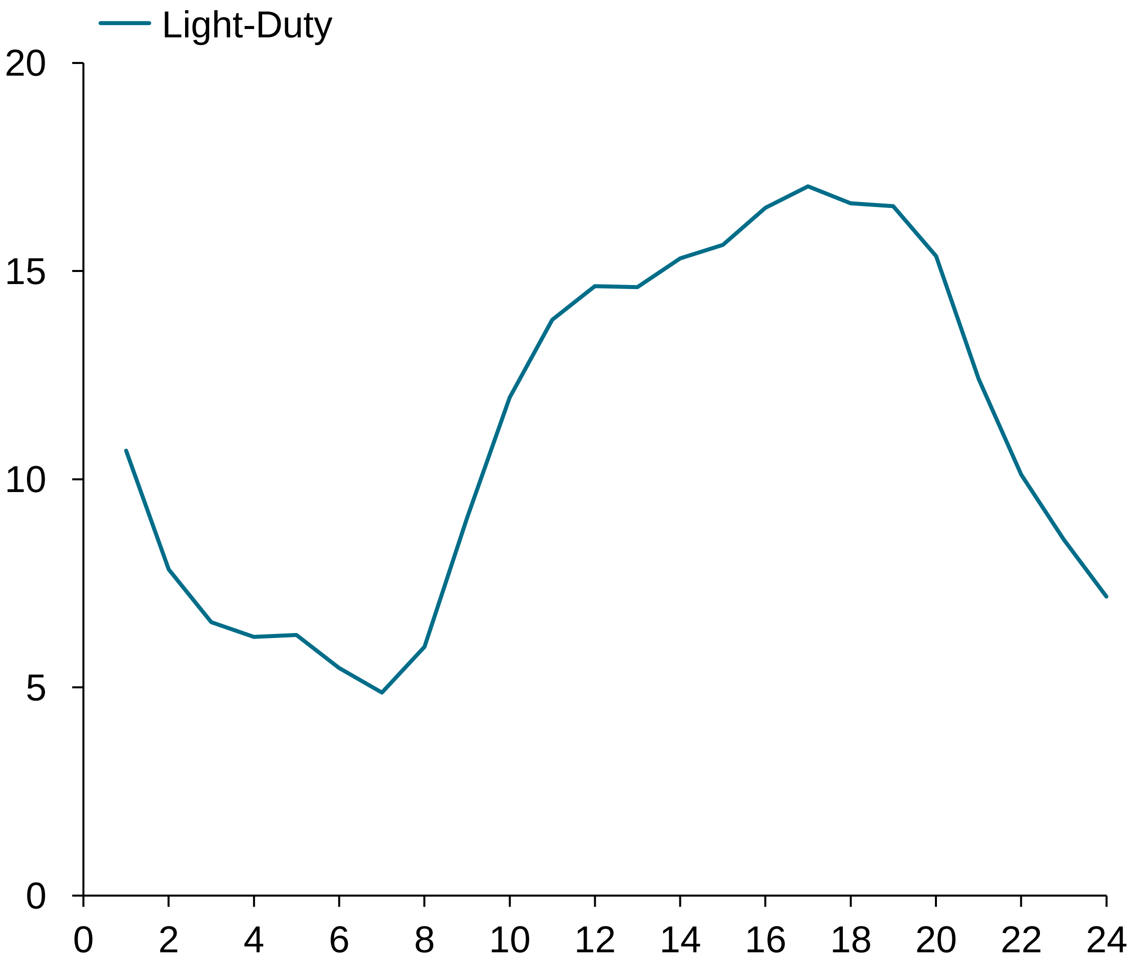
VIO, mileage, and efficiency for each vehicle type throughout the study time horizon are calculated based on a mix of field data and assumptions

	Description	Methodology	Sources
Vehicles in Operation (VIO)	The total amount of vehicles that are on the road throughout the year	VIO forecast is created by forecasting yearly BEV sales, applying a scrappage rate by age class, and adding the forecast years together to calculate VIO	S&P Global Mobility
Mileage	The number of miles driven each year by vehicle type	VMT is calculated by the number of vehicles on the road and their mileage. Average annual mileage per vehicle and vehicle usage patterns are also factored. SPGCI data was also supplemented by California Air Resource Board data.	S&P Global Mobility, California Air Resource Board
Efficiency	The numbers of miles driven per each kWh of charging	Field/manufacturer data is used where available (e.g., Tesla Model 3) to estimate the overall efficiency of the segment. Where such data is not available theoretical efficiency is calculated based on vehicle weight. Incremental efficiency improvements are considered through 2030 and no improvements assumed thereafter.	Manufacturer published data, S&P Global Mobility

Source: S&P Global Mobility

Light duty vehicle charging shape is the result of the aggregation of different types of charging strategies which are changing throughout the day, month and year

Light Duty average charging load in 2039 (GW)



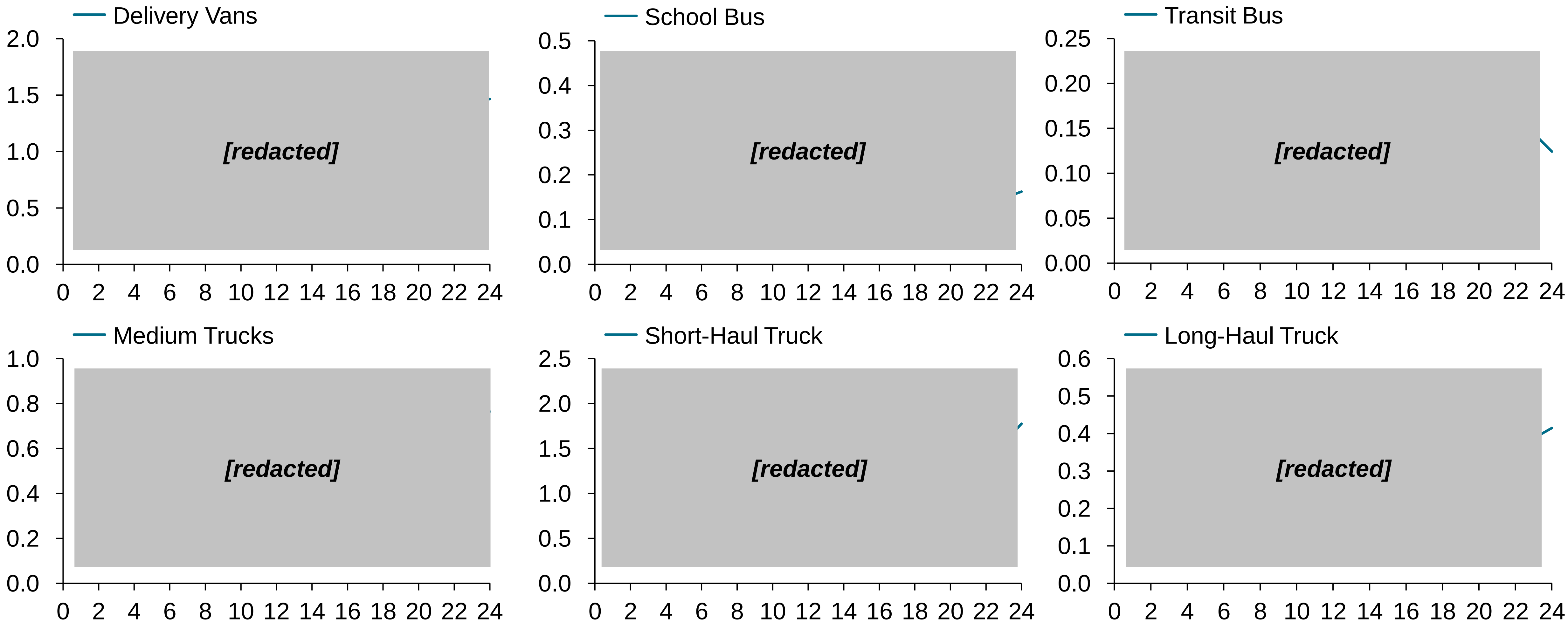
Source: S&P Global Commodity Insights

The light duty charging shapes is a combination of different charging strategies:

Charging Strategy	Home Charging	Description	Preferred charging time	Type of charger
Immediate	Yes	Will choose to charge as soon as they get home, regardless of cost.	Evening	[Redacted]
TOU - As soon as possible (ASAP)	Yes	Starts to charge as soon as the on-peak pricing ends.	Late night to midnight	[Redacted]
TOU – As late as possible (ALAP)	Yes	Starts to charge a few hours before commuting for the day.	Early morning	[Redacted]
Work and public charger	No	Reliant on public and workplace charging	Middle of the day	[Redacted]
Ride - hailing	[Redacted]	Typically relies on public charging	Middle of the day	[Redacted]

Medium and heavy-duty vehicle charging shapes are specific to the types of vehicles and their duty cycle

MDHD average charging load by class in 2039 (GW)



Source: S&P Global Commodity Insights

Charging shapes were adjusted based on several factors, such as vehicle efficiency changes with daily temperatures, efficiency improvements over time, TOU rate impact

Adjustment	Description	Source and notes
Efficiency improvements	As technology evolves, the fleet of electric vehicles becomes more efficient and the average miles per kWh increases.	S&P Global Mobility
Seasonality of driving	Light-duty: historical data for miles driven per month was considered. Medium and Heavy duty: No seasonality was applied, except for school buses (less miles in the summer).	S&P Global Mobility
Weekday and Weekend driving	Adjustment on weekends to reduce the miles driven.	S&P Global Mobility
Commuting between zones	Some zones see inflow or outflow of vehicles during the day as people travel to work into different metropolitan areas.	S&P Global
Daily temperature impacts on efficiency	Loss in battery efficiency as temperature fluctuates due to the need of heating or cooling the cabin.	NREL (EVIPro), Department of Energy
Access to home charging	The trend seen is that more people will buy EVs even without access to home charging. EV owners will increase charging in the middle of the day at the workplace/public chargers.	S&P Global Mobility – Charging Infrastructure
Time-of-use (TOU) rates impact	Evolution of TOU rates will nudge people to not charge in hours of high demand in the system.	S&P Global

Source: S&P Global Commodity Insights

Contents

Summary of forecast assumptions and inputs

Project phase	Type of vehicles	Assumptions and inputs
EV Forecast	Light-duty	EV national targets and performance relative to targets.
	Light-duty	EPA regulations.
	Medium and heavy-duty	EV national targets and performance relative to targets by class.
	Medium and heavy-duty	Description of vehicle types within classes 3 – class 8 by function.
	All	Approach to developing EV forecast. Key economic inputs, policies and incentives.
Charging impacts	All	Miles per kWh per vehicle type (Normal operating conditions).
	Light-duty	Miles driven (Weekday/Weekend).
	Light-duty	Loss in battery efficiency due to temperature.
	Light-duty	Access to home and workplace charging.
	Light-duty	Type of home/workplace charging (Level 2 vs Level 1).
	Light-duty	Penetration of managed charging.
	Medium, and heavy-duty	Miles driven and charging strategy based on duty cycles.
	Medium, and heavy-duty	Loss in battery efficiency due to temperature.

Source: S&P Global Commodity Insights

SPGCI maintains base-case scenario (Inflections, 2023-2050) which builds on integration of regional and sectoral analysis of energy future and will serve as foundation for this project

Scenario description

Inflections is the S&P Global Commodity Insights base-case scenario. It represents **the integration of regional and sector analysis** from across Commodity Insights, illustrating the pace of change in long-term global energy supply, demand and trade, based on current views and assumptions about markets, policy, consumer behavior and technology.

In this scenario a broad range of fundamental changes across government, markets and society set a **sustained long-term energy transition** in motion. Once underway, this transition is faster than any of our previous base-case outlooks, and in 2050, GHG emissions are lower than ever before. But the resurgence in fossil use through the mid-2020s has lasting consequences for the structure of energy markets.

Key themes of this scenario include:

- Clean energy technology market and manufacturing leadership is becoming a central aspect of global economic and geopolitical rivalries
- The support mechanisms tasked with carrying out clean energy technology policy objectives vary substantially across regions and technologies
- Robust demand for renewables and batteries is also raising potential hurdles related to future supplies of strategic materials, parts and equipment, labor and capital being sufficient to satisfy all government ambitions and market demands
- Clean energy ambitions face major hurdles in permitting and grid development

Key indicators (global)

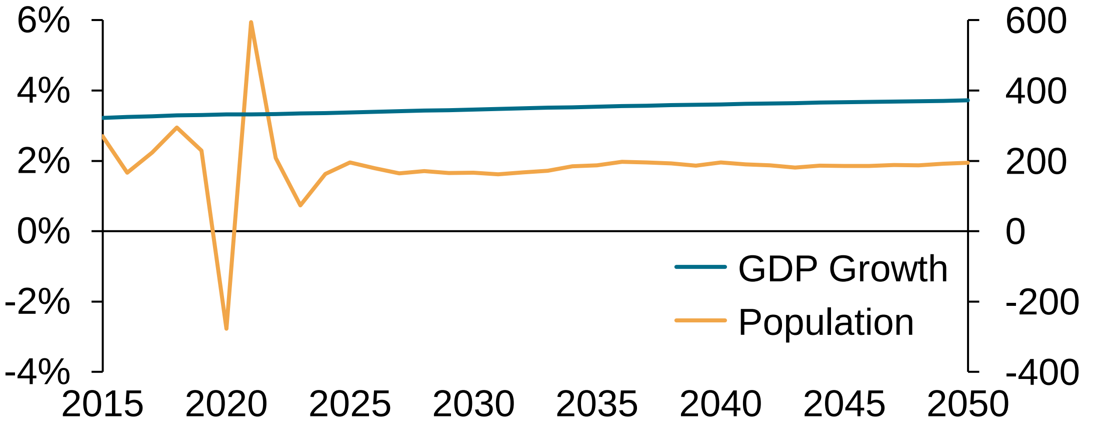
		History		Inflections	
		2019	**2020**	**2022**	**2050**
Real GDP	(billion 2022 $)	$94,807	$91,625	$100,065	$203,763
	Average growth	2.9%	2.7%	2.8%	2.6%
		(1990–2019)	(1990–2020)	(1990–2022)	(2022–50)
Primary energy consumption	(MMtoe)	14,685	14,115	15,007	17,303
	Average growth	1.8%	1.8%	1.7%	0.5%
		(1990–2019)	(1990–2020)	(1990–2022)	(2022–50)
EV shares of LV market[1]	Sales	1.7%	3.1%	10.0%	63.1%
	Fleet	0.4%	0.6%	1.6%	43.0%
Primary energy intensity of GDP	(metric tons of oil equivalent per million 2022 $)	155	154	150	85

Notes:
1. Includes battery-electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs) and fuel-cell electric vehicles (FCEVs).
Source: SPGCI

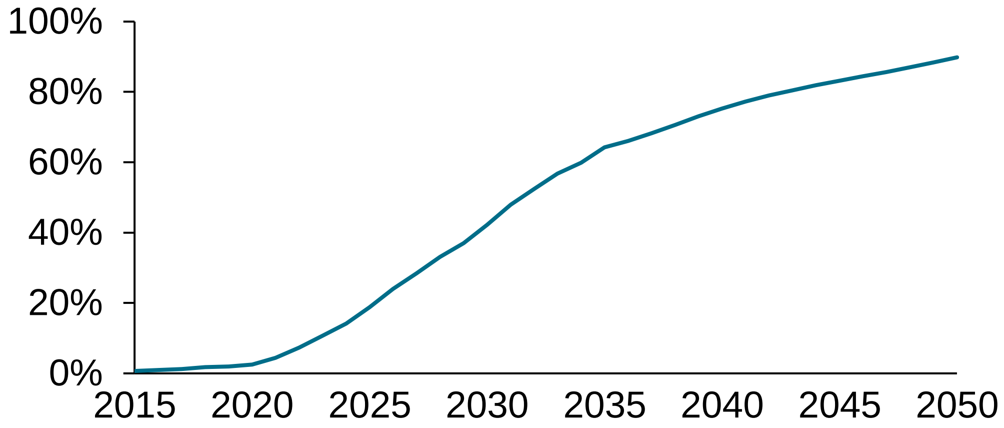
SPGCI base case assumptions for US general economic indicators and light vehicle metrics

Sample indicators

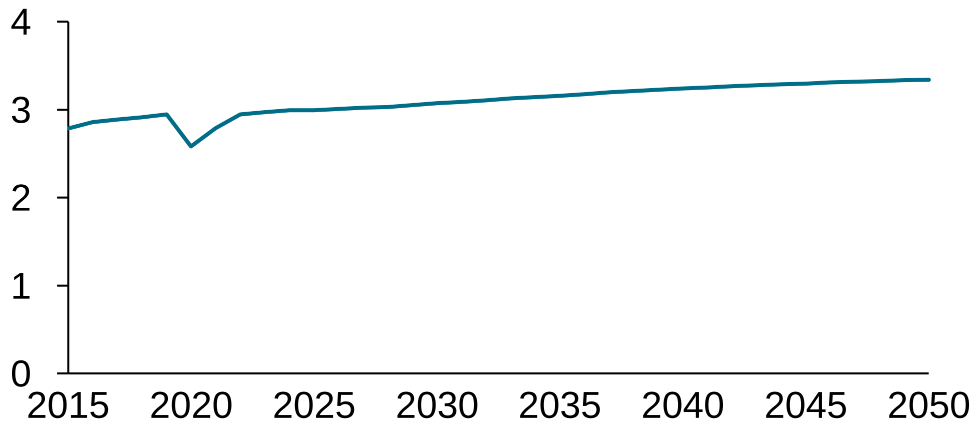
US GDP growth[1] (%, left) and population (millions, right)



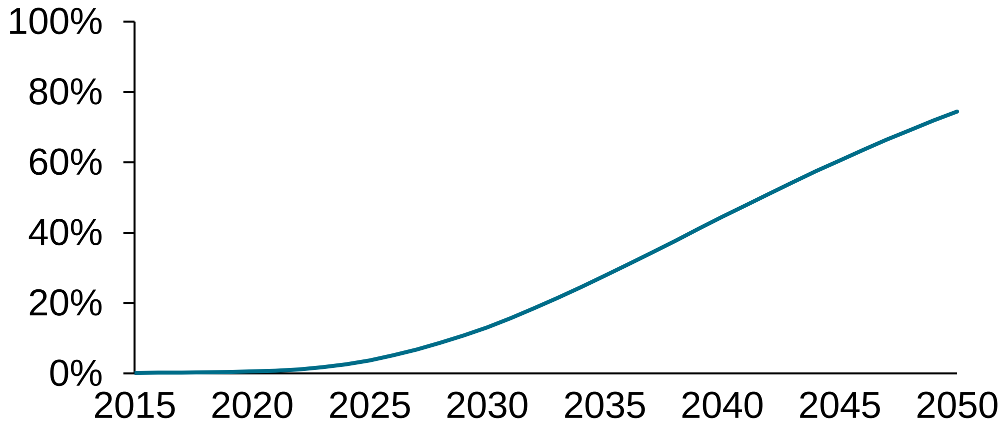
US EV sales as percent of light vehicle sales (%)[2]



Total light vehicle miles traveled in the US (trillion)



US EVs as total on-road light vehicle fleet (%)[2]



Notes:
1. Percent change in real economic growth from year earlier.
2. Includes battery-electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs) and fuel-cell electric vehicles (FCEVs).

Source: SPGCI

We made several assumptions and developed inputs based on our base case scenario to develop PJM territory specific EV forecast

Type of vehicle applicability	Assumptions and inputs	Value	Sources and notes
Light-duty	EV national targets and performance relative to targets.	[Redacted]	S&P Global Mobility
Light-duty	EPA regulations.	[Redacted]	S&P Global Mobility
Medium and heavy-duty	EV national targets and performance relative to targets by class.	[Redacted]	S&P Global Mobility
Medium and heavy-duty	Description of vehicle types within classes 4 – class 8 by function.	• Delivery vans • School buses • Transit buses • All medium trucks • Long-haul heavy truck • Short-haul heavy truck	S&P Global Mobility

Source: S&P Global Commodity Insights

We made several assumptions and developed inputs for evaluating light-duty EV charging impacts

Type of Vehicle Applicability	Assumptions and inputs	Value	Source and notes
Light-Duty	Miles driven (Weekday/Weekend)	[Redacted]	S&P Global Mobility
Light-Duty	Miles per kWh (normal operating conditions)	[Redacted]	S&P Global Mobility
Light-Duty	Loss in battery efficiency due to temperature fluctuations.	- 40% additional energy at 20 Fahrenheit (heating) - 17% additional energy at 86 Fahrenheit (cooling) *Non-linear curve corresponding to several observations. Historical daily average weather (last 10 years) for study horizon by zone.	NREL (EVIPro), Department of Energy
Light-duty	Access to home and workplace charging.	[Redacted]	S&P Global Mobility – Charging Infrastructure
Light-duty	Type of home charging (Level 2 vs Level 1).	[Redacted]	S&P Global Mobility – Charging Infrastructure
Light-duty	Charging strategy (For drivers with access to home charging)	[Redacted]	S&P Global Energy Transition Consulting

Source: S&P Global Commodity Insights

We made several assumptions and developed inputs for evaluating MDHD charging impacts

Type of Vehicle Applicability	Assumptions and inputs	Value	Source and notes
Medium and Heavy Duty	Miles driven (Weekday/Weekend)	Delivery Vans: [Redacted] miles per year ([Redacted] of miles driven during weekdays) School bus: [Redacted] miles per year ([Redacted] of miles driven during weekdays) Transit bus: [Redacted] miles per year ([Redacted] of miles driven during weekdays) Medium trucks: [Redacted] miles per year ([Redacted] of miles driven during weekdays) Short-haul trucks: [Redacted] miles per year ([Redacted] of miles driven during weekdays) Long-haul trucks: [Redacted] miles per year ([Redacted] of miles driven during weekdays)	S&P Global Mobility
Medium and Heavy Duty	Miles per kWh (normal operating conditions)	Delivery Vans: [Redacted] miles/kWh (2024) to [Redacted] miles/kWh (2039) School bus: [Redacted] miles/kWh (2024) to [Redacted] miles/kWh (2039) Transit bus: [Redacted] miles/kWh (2024) to [Redacted] miles/kWh (2039) Medium trucks: [Redacted] miles/kWh (2024) to [Redacted] miles/kWh (2039) Short-haul trucks: [Redacted] miles/kWh (2024) to [Redacted] miles/kWh (2039) Long-haul trucks: [Redacted] miles/kWh (2024) to [Redacted] miles/kWh (2039)	S&P Global Mobility
Medium and Heavy Duty	Loss in battery efficiency due to temperature fluctuations.	Delivery vans, school buses and transit buses: -40% additional energy at 20 Fahrenheit (heating) -17% additional energy at 86 Fahrenheit (cooling) Medium, Short-haul and Long-haul trucks: -[Redacted]% additional energy at 20 Fahrenheit (heating) *Non-linear curve corresponding to several observations. *Historical daily average weather (last 10 years) for study horizon by zone.	NREL (EVIPro), Department of Energy, S&P Global Mobility

Source: S&P Global Commodity Insights

Disclaimer

S&P Global Commodity Insights (“SPGCI”) divisional independence. SPGCI is a business division of S&P Global Inc. (“S&P Global”). S&P Global also has the following divisions: S&P Dow Jones Indices, S&P Global Market Intelligence, S&P Global Mobility, and S&P Global Ratings, each of which provides different products and services. S&P Global keeps the activities of its business divisions separate from each other in order to preserve the independence and objectivity of their activities in accordance with the S&P Global Divisional Independence and Objectivity Policy. Client’s receipt of SPGCI reports, data and information under this Agreement may also affect Client’s ability to receive services and products from other S&P Global divisions in the future.

S&P Global Commodity Insights publishes commodity information, including price assessments and indices. S&P Global Commodity Insights maintains clear structural and operational separation between its price assessment activities and the other activities carried out by S&P Global Commodity Insights and the other business divisions of S&P Global to safeguard the quality, independence and integrity of its price assessments and indices and ensure they are free from any actual or perceived conflicts of interest.

Limitation of Advice and Reliance. The Deliverables should not be construed as financial, investment, legal, or tax advice or any advice regarding Client’s corporate or legal structure, assets or, liabilities, financial capital or debt structure, current or potential credit rating or advice directed at improving Client’s creditworthiness nor should they be regarded as an offer, recommendation, or as a solicitation of an offer to buy, sell or otherwise deal in any investment or securities or make any other investment decisions. The Deliverables should not be relied on by Client in making any investment or other decision. Client may not use the Deliverables to transmit, undertake or encourage any unauthorized investment advice or financial promotions, or to generate any advice, recommendations, guidance, publications or alerts made available to its own customers or any other third-parties. Nothing in the Deliverables constitutes a solicitation by SPGCI or its affiliates of the purchase or sale of any loans, securities or investments. SPGCI personnel are not providing legal advice or acting in the capacity of lawyers under any jurisdiction in the performance of Services or delivery of Deliverables.