Analysis of

Emission Reduction Potential of Electric Vehicles

in a world of increasing demand for coal

2024 AI BOOTCAMP | MODULE 17 GROUP PROJECT

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PROJECT OBJECTIVE

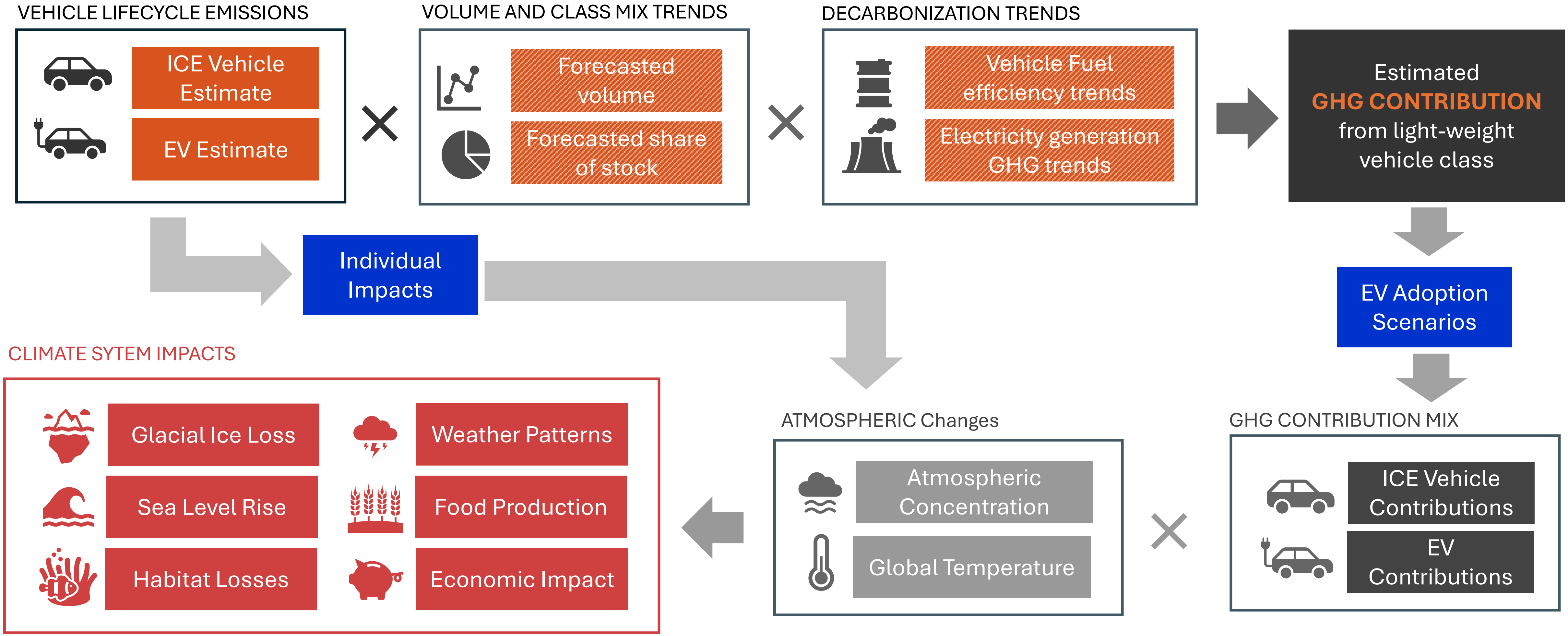
In this project, the University of North Carolina Charlotte / Chapel Hill AI Bootcamp project team conducted a data analysis to examine GHG emission-reducing potential of replacing passenger vehicles with electric.

PROJECT GOAL To examine the climate impacts from replacing internal combustion vehicles (ICEV) with electric vehicles (EV) in the US on an individual and collective basis

US GREENHOUSE GAS EMISSIONS BY ECONOMIC SECTOR IN 2022 (EPA)

APROACH

Our general approach was to assess the average lifecycle emission of an individual ICE vehicle and EV today. We also vehicle volume predictions and fuel efficiency changes over time to determine evaluate implications of individual and general EV adoption.



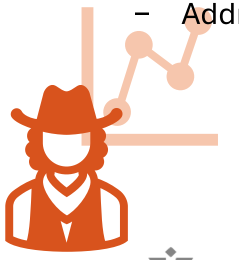
DATA ANALYSYS & MODEL OPTIMIZATION

Data Wrangling

- **Data Acquisition**
  - CSV downloads
  - HTML tables
  - Desktop research (data contents)

- **Data Exploration**
  - US LDV Sales, Fed Reserve Econ Data (1976 to 2023)
  - NHTSA Fuel Economy Standards (1978 to 2031)
  - EPA Real-world Vehicle Efficiency and Emissions (1975 to 2023)
  - EIA BEV and PHEV Sales and Stock (2013 to 2023)
  - EIA EV Outlook (2010 to 2035)
  - EIA Elec Consumption by LDV (2018 to Q1 2024)
  - IAE EV Lifecycle data
  - EIA Net Avoided Emissions and Avoided Share (2023 to 2035)
  - Our World in Data climate system change
  - Flow and stock models by vehicle type

- **Date Cleaning**
  - Parsing of date data during CSV imports
  - Use of .split method to remove text from numeric data (e.g., “Prelim. 2023” to “2023”)
  - Use of .to_datetime and .dt.year to clean date data
  - Addressing partial year and missing values



Data Modeling and Analysis

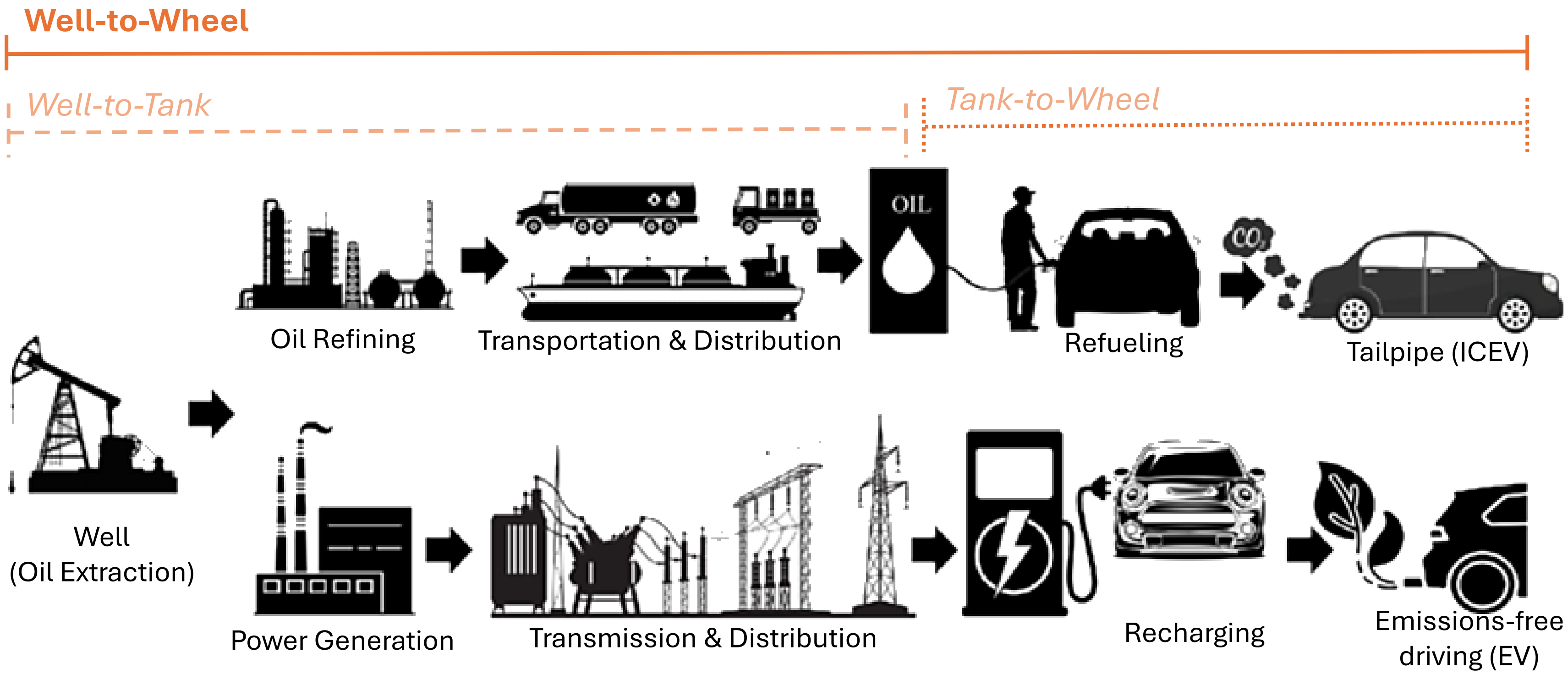
- **Vehicle emissions**
  - Future vehicle sales predictions using historic sales data
  - Prediction of future car vs. truck share sales
  - Average emission per mile projections for ICE vehicle (using historic share of sales and MPG, predicted vehicle sales and forward-looking emission standards)

- **Electricity generation emissions**
  - Future emission predictions using historic electricity generation, fuel mix and emissions data (ultimately assumed NDC and US decarbonization commitments)

- **GHG Impacts**
  - Assessment of GHG emissions impact to atmospheric carbon contribution (in parts per million)
  - Correlation between atmospheric carbon contribution and climate system changes

	Year	MPG (all)	Annual CO2	MPG (car)	Car CO2 (g/mi)	MPG (light truck)	Truck CO2 (g/mi)	Total Light Veh Sales	Car Sales	Truck Sales	Car Sales Share (%)	Truck Sales Share (%)	...	PHEV Stock	PHEV Sales	Total EV Sales	ICE Sales	BEV Retirements	PHEV Retirements	ICE Retirements	Total EV Stock	ICE Stock	Total Light Veh Stock	Annual gCO2	Cummulative mmtCO2
0	1975	13.06	680.60	12.68	706.54	11.42	779.08	0.000	0.000	0.000	0.000000	0.000000	...	0.000	0.000	0.0000	0.0000	0.0000	0.000	0.0000	0.0000	0.0000	0.0000	0.000000e+00	0.000000
1	1976	14.22	625.02	13.44	678.64	12.06	737.31	155.593	119.932	35.661	0.770806	0.229194	...	0.000	0.000	0.0000	155.5930	0.0000	0.000	0.0000	0.0000	262.5930	262.5930	2.362583e+09	0.002363
2	1977	15.07	590.00	14.45	623.76	13.05	681.63	173.829	132.551	41.278	0.762537	0.237463	...	0.000	0.000	0.0000	173.8290	0.0000	0.000	0.0000	0.0000	280.8290	280.8290	2.327378e+09	0.004690
3	1978	15.84	561.62	15.15	605.96	12.66	703.38	179.674	133.967	45.707	0.745611	0.254389	...	0.000	0.000	0.0000	179.6740	0.0000	0.000	0.0000	0.0000	286.6740	286.6740	2.350627e+09	0.007041
4	1979	15.91	559.69	16.25	552.04	11.94	750.80	165.216	126.706	38.510	0.766911	0.233089	...	0.000	0.000	0.0000	165.2160	0.0000	0.000	0.0000	0.0000	272.2160	272.2160	2.117512e+09	0.009158
5	1980	19.16	465.94	18.20	500.77	14.91	602.55	134.309	107.782	26.527	0.802493	0.197507	...	0.000	0.000	0.0000	134.3090	0.0000	0.000	0.0000	0.0000	241.3090	241.3090	1.633985e+09	0.010792
6	1981	20.52	436.04	19.17	480.45	16.03	560.79	126.768	102.413	24.355	0.807877	0.192123	...	0.000	0.000	0.0000	126.7680	0.0000	0.000	0.0000	0.0000	233.7680	233.7680	1.506987e+09	0.012299
7	1982	21.07	424.64	21.40	418.17	16.33	555.68	124.360	95.754	28.606	0.769974	0.230026	...	0.000	0.000	0.0000	124.3600	0.0000	0.000	0.0000	0.0000	231.3600	231.3600	1.352857e+09	0.013652
8	1983	20.95	425.53	21.62	412.10	16.87	534.37	145.437	110.145	35.292	0.757338	0.242662	...	0.000	0.000	0.0000	145.4370	0.0000	0.000	0.0000	0.0000	252.4370	252.4370	1.449749e+09	0.015102
9	1984	21.00	424.03	21.38	418.15	16.99	525.76	170.367	124.682	45.685	0.731844	0.268156	...	0.000	0.000	0.0000	170.3670	0.0000	0.000	0.0000	0.0000	277.3670	277.3670	1.611802e+09	0.016713
10	1985	21.32	417.31	22.03	405.36	17.19	518.54	185.311	131.738	53.573	0.710902	0.289098	...	0.000	0.000	0.0000	185.3110	0.0000	0.000	0.0000	0.0000	292.3110	292.3110	1.664723e+09	0.018378
11	1986	21.84	407.04	22.11	406.52	17.89	498.07	192.606	136.868	55.738	0.710611	0.289389	...	0.000	0.000	0.0000	192.6060	0.0000	0.000	0.0000	0.0000	299.6060	299.6060	1.686535e+09	0.020065
12	1987	21.97	404.61	22.33	401.70	18.06	492.81	178.327	122.048	56.279	0.684406	0.315594	...	0.000	0.000	0.0000	178.3270	0.0000	0.000	0.0000	0.0000	285.3270	285.3270	1.596661e+09	0.021661
13	1988	21.86	406.52	22.49	399.57	17.72	501.88	185.236	126.546	58.690	0.683161	0.316839	...	0.000	0.000	0.0000	185.2360	0.0000	0.000	0.0000	0.0000	292.2360	292.2360	1.641143e+09	0.023303
14	1989	21.42	414.93	22.16	405.21	17.43	510.58	174.347	117.322	57.025	0.672922	0.327078	...	0.000	0.000	0.0000	174.3470	0.0000	0.000	0.0000	0.0000	281.3470	281.3470	1.608113e+09	0.024911

FINDINGS (Vehicle Lifecycle Emissions)



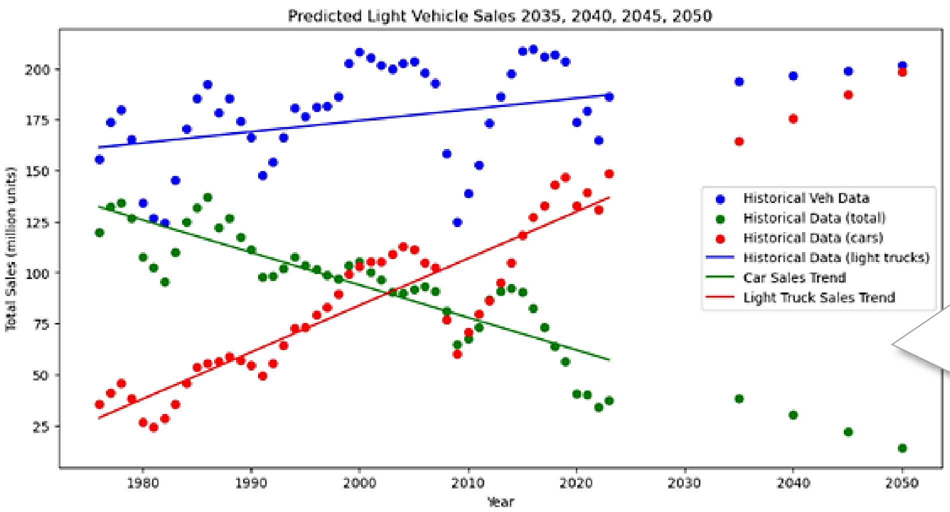
Determination of vehicle lifecycle emissions for light-weight ICEV and EV (plug-in hybrid and battery electric)

* Estimates based on 2023 data and do not account for emissions from vehicle disposal.

Powertrain	Vehicle production	Battery production	Well-to-tank	Tank-to-wheel	Embodied CO_2e	Tailpipe CO_2e	Grid decarbonization	Electricity CO_2e	**Lifecycle CO_2e**
ICEV	3.7	—	11.5	30.9	15.2	30.9	—	—	**46.1**
PHEV	4.4	1.3	11.7	15.8	17.4	15.8	1.9	**10.9**	**42.2**
BEV	3.3	5.3	14.5	—	23.1	—	4.8	**8.9**	**27.2**

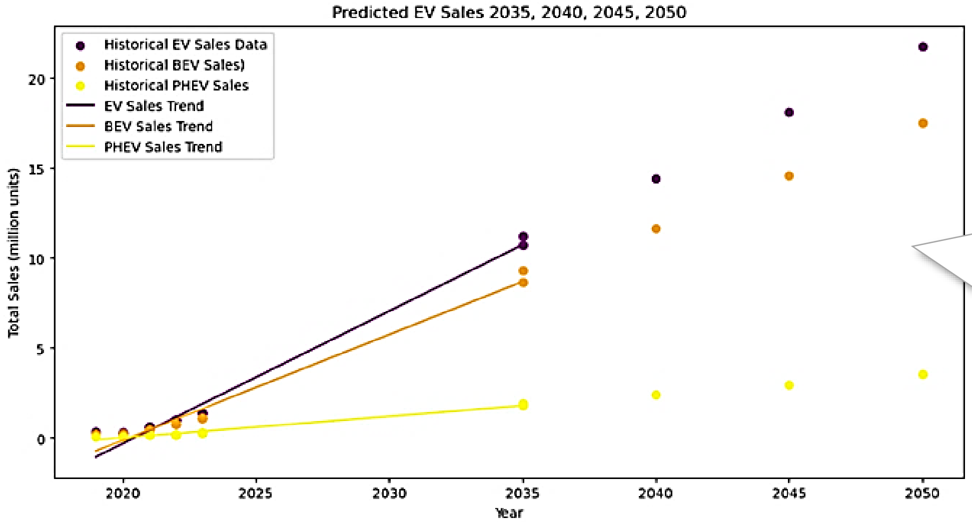
[1] 2023 International Energy Agency (IEA) 2023 data used ICEV lifecycle data; IEA, Energy Information Agency (EIA) and modeling predictions used to calculate

FINDINGS (Light-Weight Vehicle Sales and Stock)



Light Vehicle Sales predictions based on historic and forecasted sales by class

(not reflective of behavioral economics, expected policies or EV incentives)



EV Sales predictions includes adjustment for proposed EPA rules

(56% of new vehicle sales are electric by 2032 at least 13% plug-in hybrids)

[1] See *vehicle_and_emission_analysis.ipynb* file for data and modeling details.

Linear regression model prediction of total new vehicle sales and new electric vehicle sales in the light-weight vehicle class through 2050.

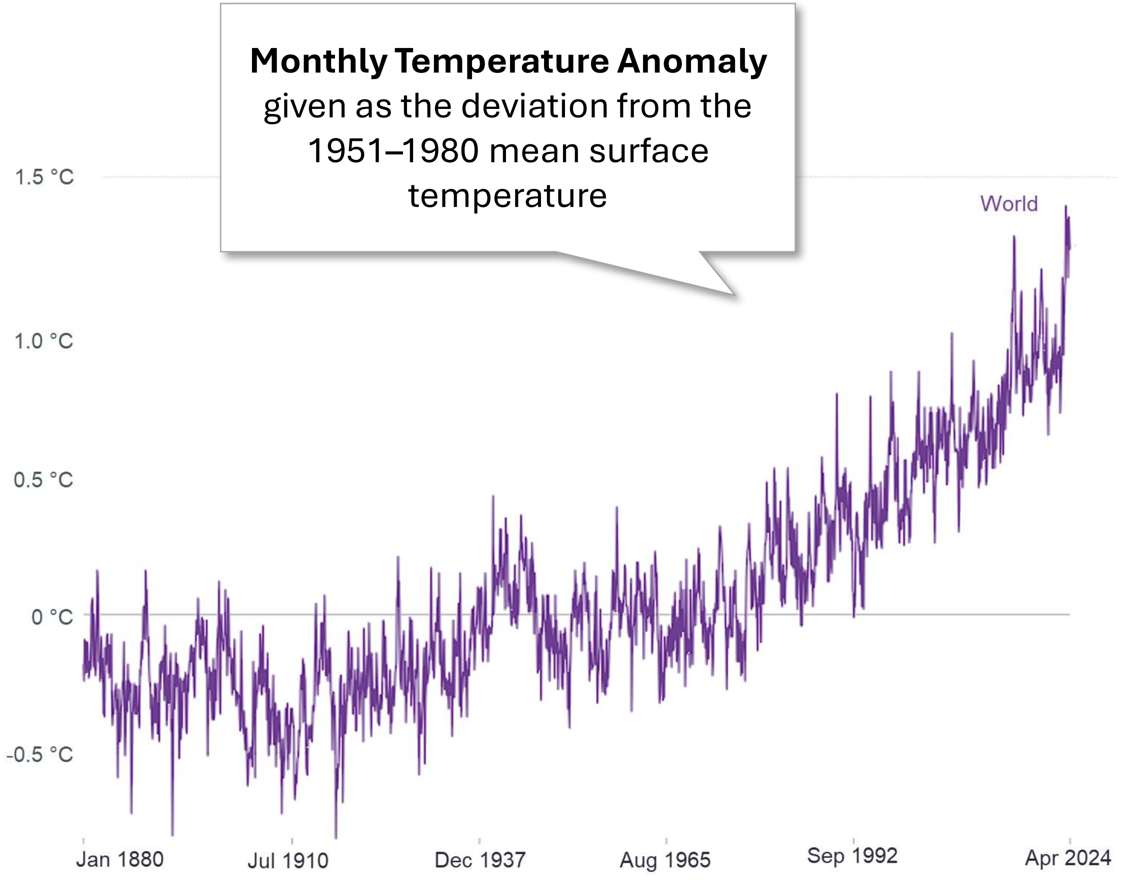
Analysis, based solely on historic sales data, suggests that light trucks will continue to overtake the share of light vehicle sales in the US market.

Given the differential in efficiency standards between cars and trucks, this trajectory would have a **material impact to GHG emissions by 2050.**

NHTSA Minimum Efficiency Standards

Model Year	Car MPG	Light Truck MPG
2024	54.50	37.50
2025	58.90	39.30
2026	64.80	42.40
2027	66.10	42.40
2028	65.20	43.20
2029	72.50	54.90
2030	80.10	62.10
2031	91.60	70.80

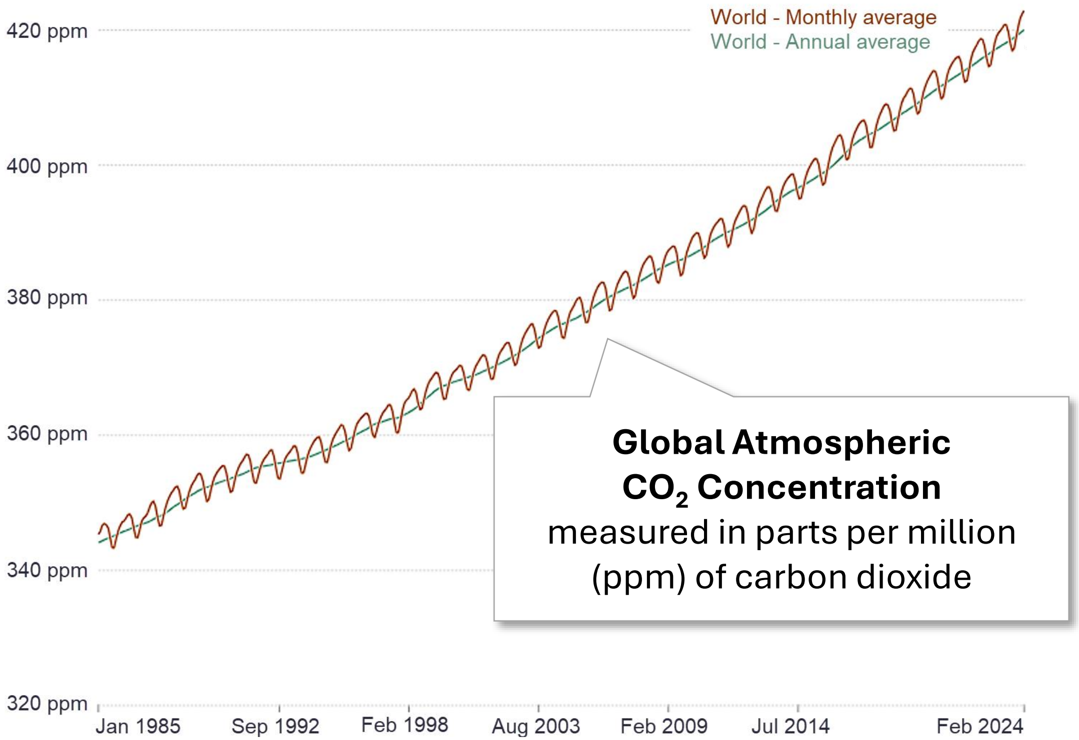
FINDINGS (Climate Change Impacts)



SOURCE: National Oceanic and Atmospheric Administration (NOAA)

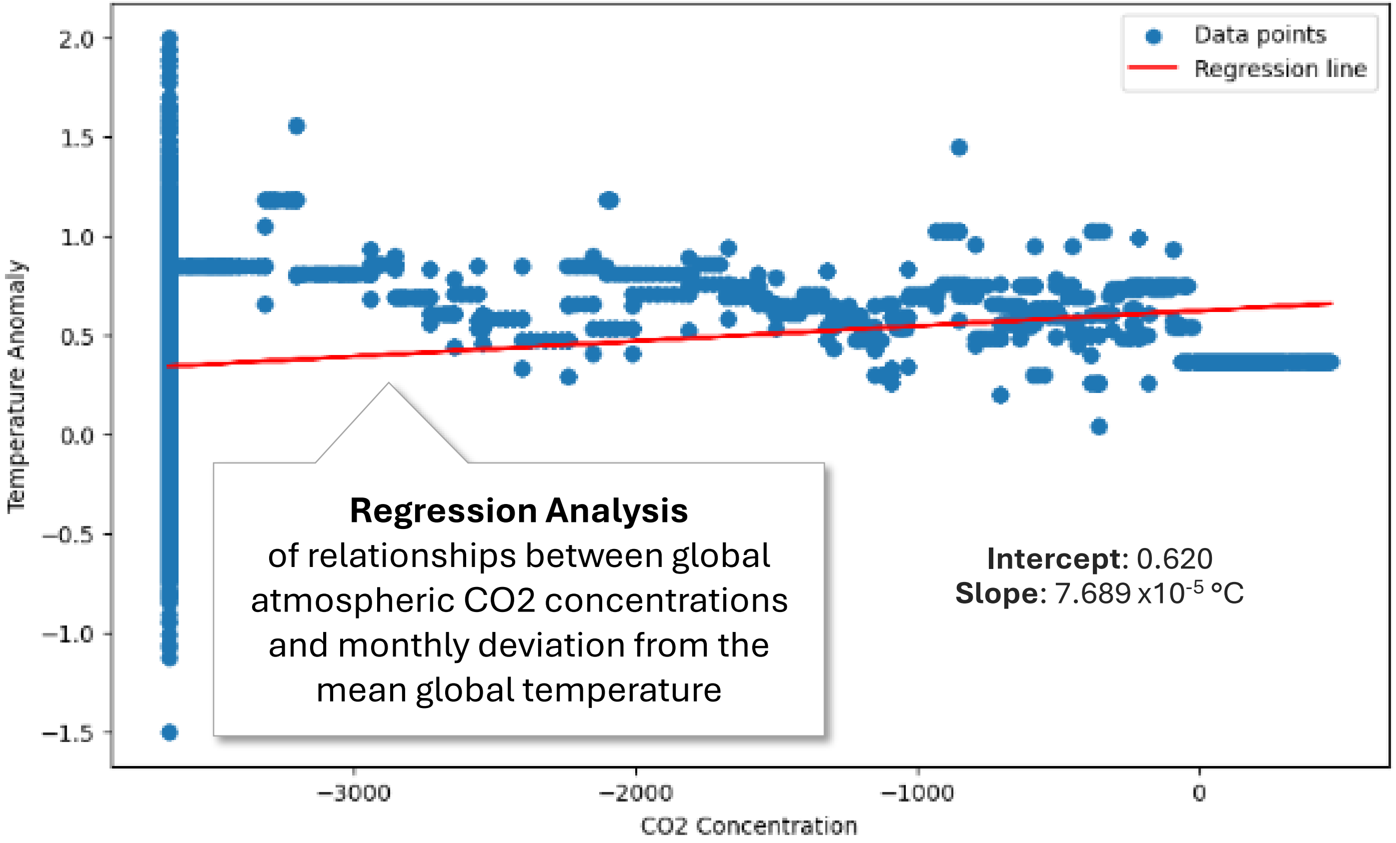
Global temperature measures from 1880 to 2024 show a steadily increasing temperature anomaly.

We note a **rise in global concentration of atmospheric CO2 similar to that of the rise in global temperature anomaly**, as illustrated in the 40-year trend below.



FINDINGS (Climate Change Impacts)

Analysis of the relationship between atmospheric CO_2 concentrations and the monthly global temperature anomaly results in a slightly positive slope



This provides a measurable of the positive correlation between carbon emissions and global temperature anomalies.

This relationship allows us to measure the contribution to global temperature anomalies at an individual vehicle level using vehicle lifecycle emissions.

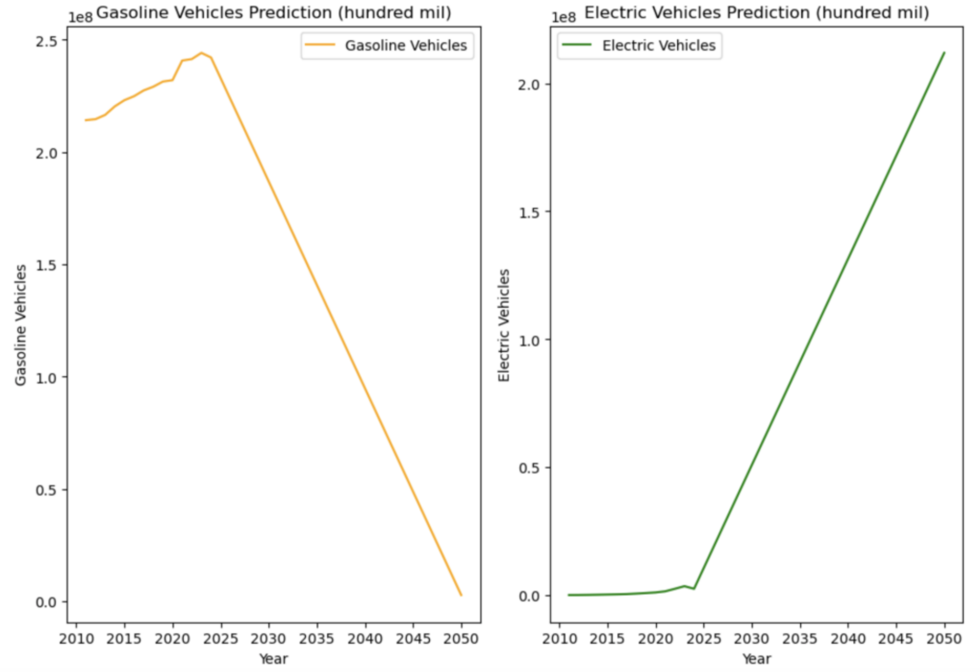
Individual Vehicle Impact Global Temperature Anomaly

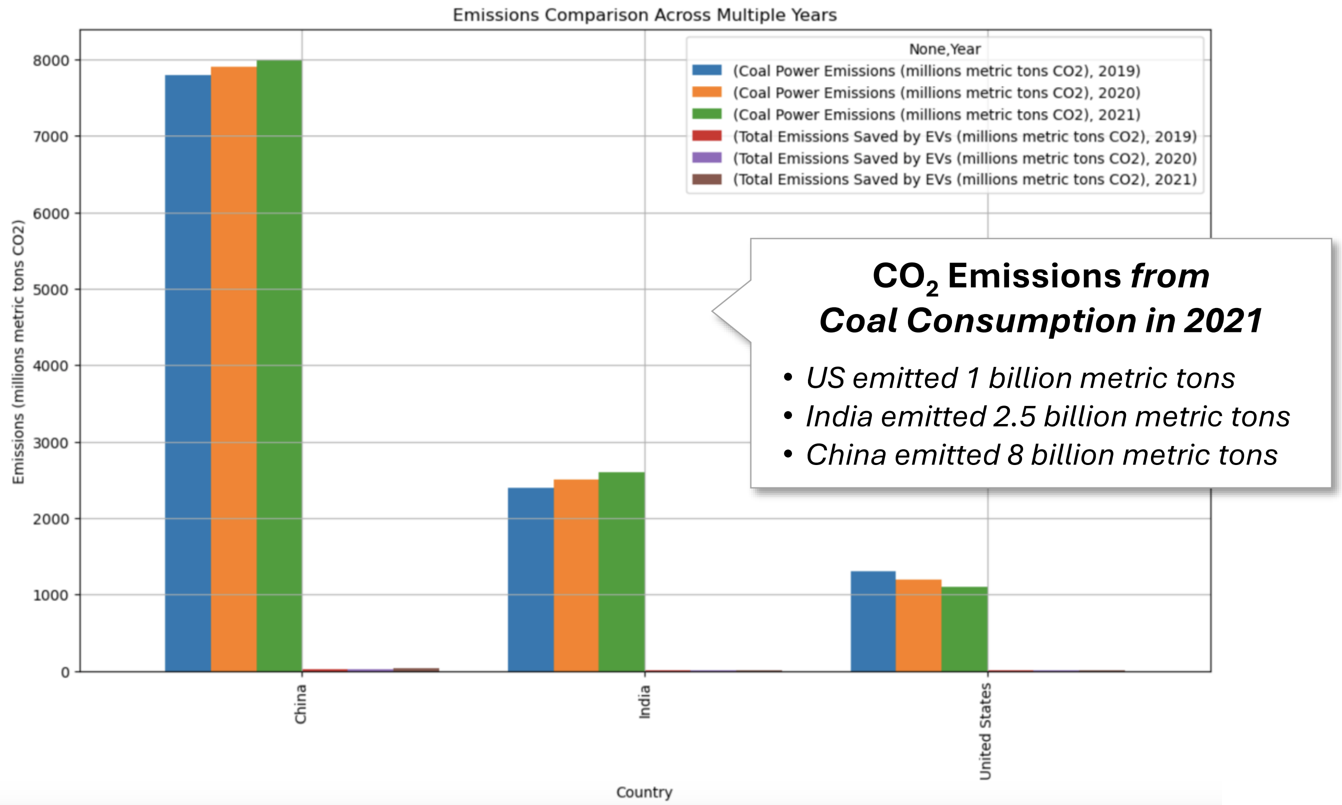
Powertrain	Deviation Contribution
Internal Combustion Engine Vehicle (ICEV)	3.43×10^{-12} °C
Plug-in Hybrid Electric Vehicle (PHEV)	3.13×10^{-12} °C
Battery Electric Vehicle (BEV)	2.02×10^{-12} °C
Impact from switching from ICEV to BEV:	**1.41×10^{-12} °C**

Number of transitions from ICEV to BEV needed to see a measurable impact: **Approximately 70 million**

FINDINGS (100% Adoption Scenario)

Assume each EV saves about 2.6 metric tons of CO2 annually compared to an internal combustion engine (ICE) vehicle.





Potential CO_2 Emissions Saved Annually from **100 % EV adoption in US**	282,000,000 cars X 2.6 MMT CO_2 **733,200,000 metric tons of CO_2**

For context, 100% EV adoption in the US would account for roughly:

- ▶ 73% of the CO_2 emissions from US coal use, **OR**
- ▶ 26% of the CO_2 emissions from India coal use, **OR**
- ▶ 9% of the CO_2 emissions from China coal use

ADDITIONAL INVESTIGATION AREAS

Many opportunities to expand and refine this analysis:

DATA

- Opportunity to better **normalize data** sets before use (i.e., additional adjusts for inconsistent baseline assumptions)
- Opportunity to develop **bottoms-up and top down-forecasting** vs using existing datasets (e.g., EV Outlook)

MODELING

- Opportunity to make better use of **guardrail values** to adjust predications (e.g., manufacturing capacity limits)
- Opportunity to include more **time-varying factors** or economic factors into model (e.g., GHG phase out policies, tariffs, etc.)
- More **advanced ML models** (e.g., Autoregressive Integrated Moving Average, ARIMA, weighted sum of past values mean and various random error terms for future data predictions)

Reference Content

Contributors
- Jamie Bond | @JBondAI (role)
- Jason Campbell | @JCamp-12 (role)
- Elliot Sancrant | @ElliottSancrant (role)

Data Providers
- Energy Information Agency (EIA)
- Environmental Protection Agency (EPA)
- Federal Reserve Economic Data (FRED)
- International Energy Agency (IEA)
- Alternative Fuels Data Center (AFDC)
- Our World In Data

Data Sources
- See project GitHub repository for a full list of data sources: github.com/jbondAI/AI_Project_2

Required Tools Use
- Python
- Pandas
- Matplotlib
- Prophet
- Time series analysis

Analysis of **Emission Reduction Potential of Electric Vehicles** in a world of increasing demand for coal

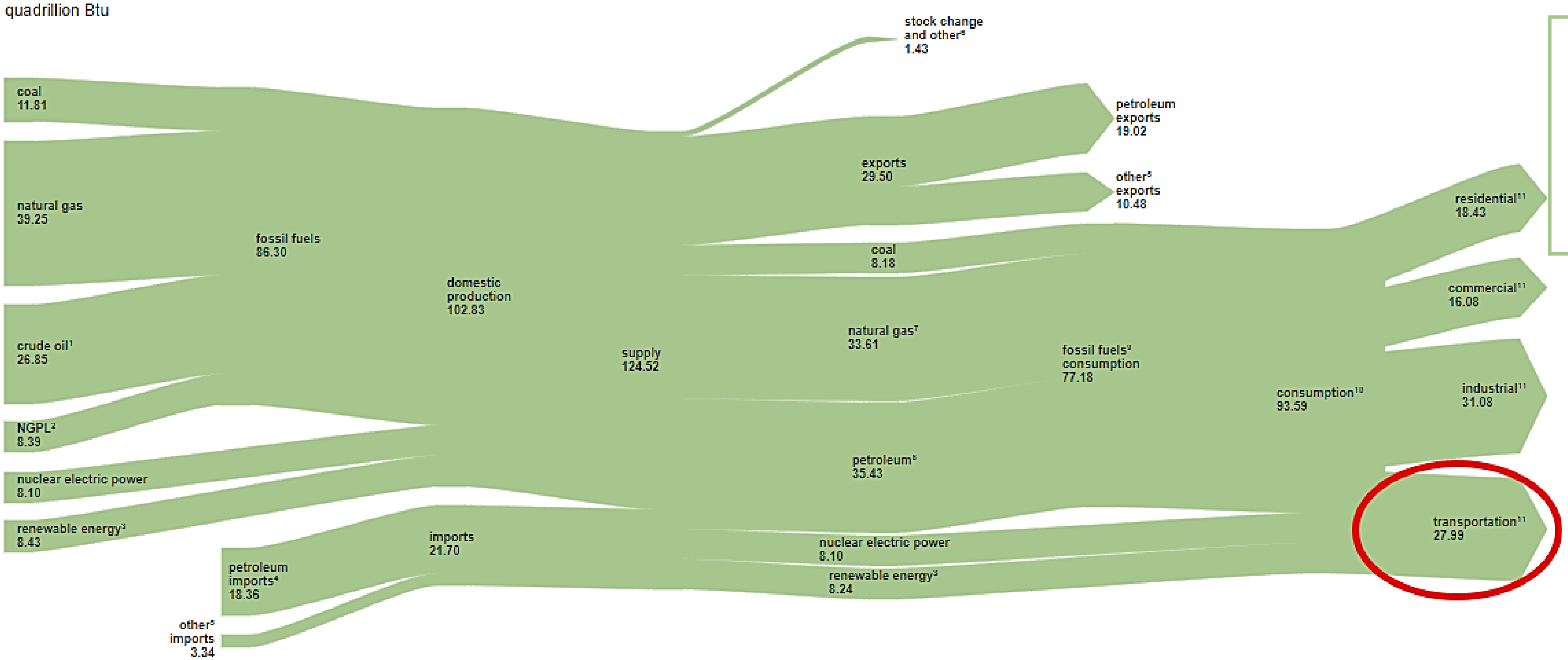
REFERENCE MATERIAL

INCLUDES

- 2023 US Energy Flow Diagrams for Total Energy Electricity and Petroleum
- US Share of Global GHG Emissions from Transportation
- Transportation Lifecycle GHG Intensity
- Pathway Using Low-carbon Transport Technologies
- Well-to-Wheel Avoided Emissions by Country from Stated Policy and Announced Pledges

REFERENCE MATERIAL | US Energy Flow (All Energy)

US energy flow (measured in quadrillion BTUs) in 2023



[1] Includes lease condensate. | [2] Natural gas plant liquids. | [3] Conventional hydroelectric power, biomass, geothermal, solar, and wind. | [4] Crude oil and petroleum products. Includes imports into the Strategic Petroleum Reserve. | [5] Natural gas, coal, coal coke, biomass, and electricity. | [6] Adjustments, losses, and unaccounted for. | [7] Natural gas only; excludes supplemental gaseous fuels. | [8] Petroleum products supplied. | [9] Includes -0.03 quadrillion Btu of coal coke net imports. | [10] Includes 0.06 quadrillion Btu of electricity net imports. | [11] Total energy consumption, which is the sum of primary energy consumption, electricity sales to ultimate customers, and electrical system energy losses. Losses are allocated to the end-use sectors in proportion to each sector's share of total electricity sales. See Note 1, "Electrical System Energy Losses," at the end of U.S. Energy Information Administration (EIA), *Monthly Energy Review* (April 2024), Section 2. See Note 2, "Other Energy Losses," at the end of U.S. Energy Information Administration (EIA), *Monthly Energy Review* (April 2024), Section 2. | Notes: • Data are preliminary. • Values are derived from source data prior to rounding for publication. • Totals may not equal sum of components due to independent rounding.

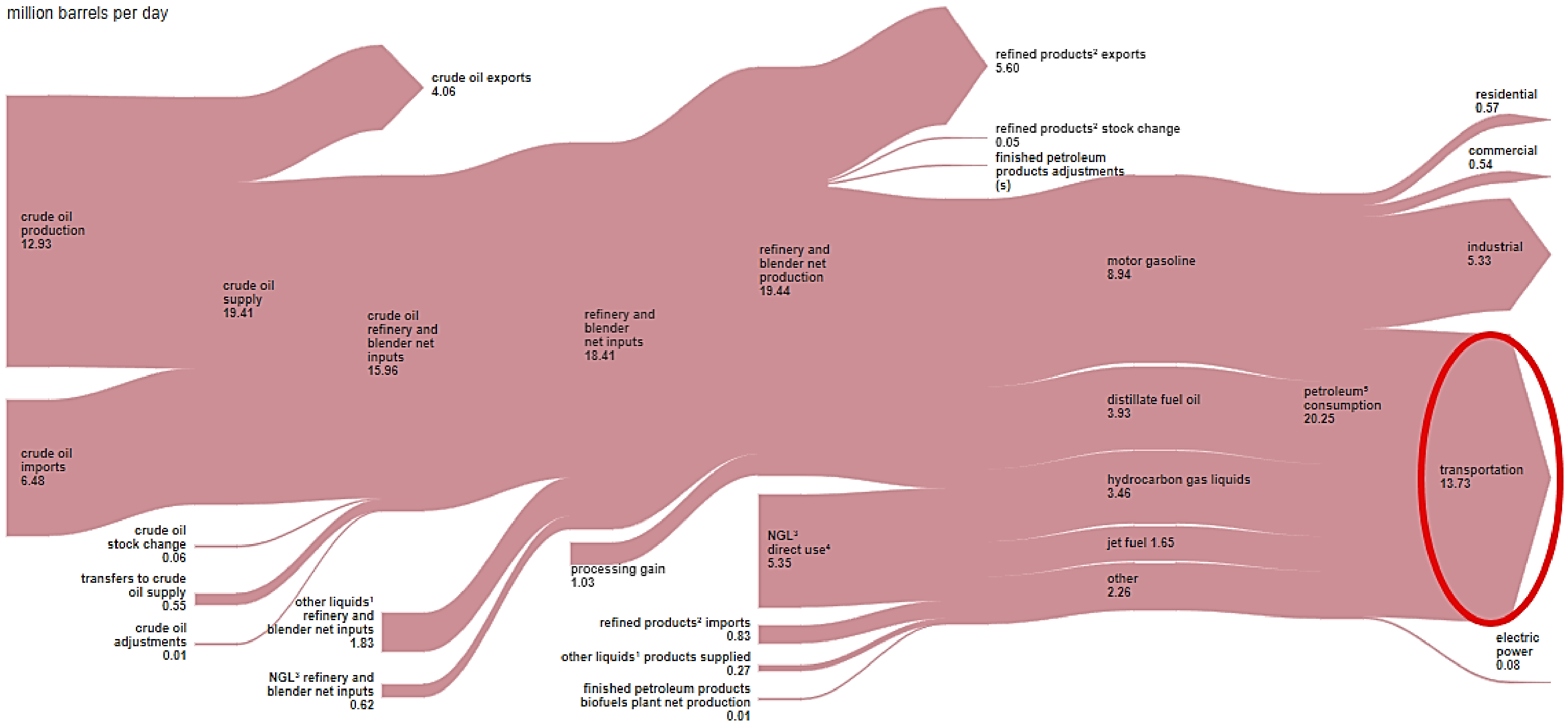
eia Sources: U.S. Energy Information Administration (EIA), *Monthly Energy Review* (April 2024),

Transportation accounted for 27.99 of the 93.59 quadrillion BTU of US energy use in 2023

(roughly 30% of US energy consumption)

REFERENCE MATERIAL | US Energy Flow (Petroleum)

US petroleum consumption (measured in millions of barrels per day) used for transportation in 2023



Transportation accounted for 13.73 of the 20.25 millions of barrels per day in US petroleum consumption in 2023

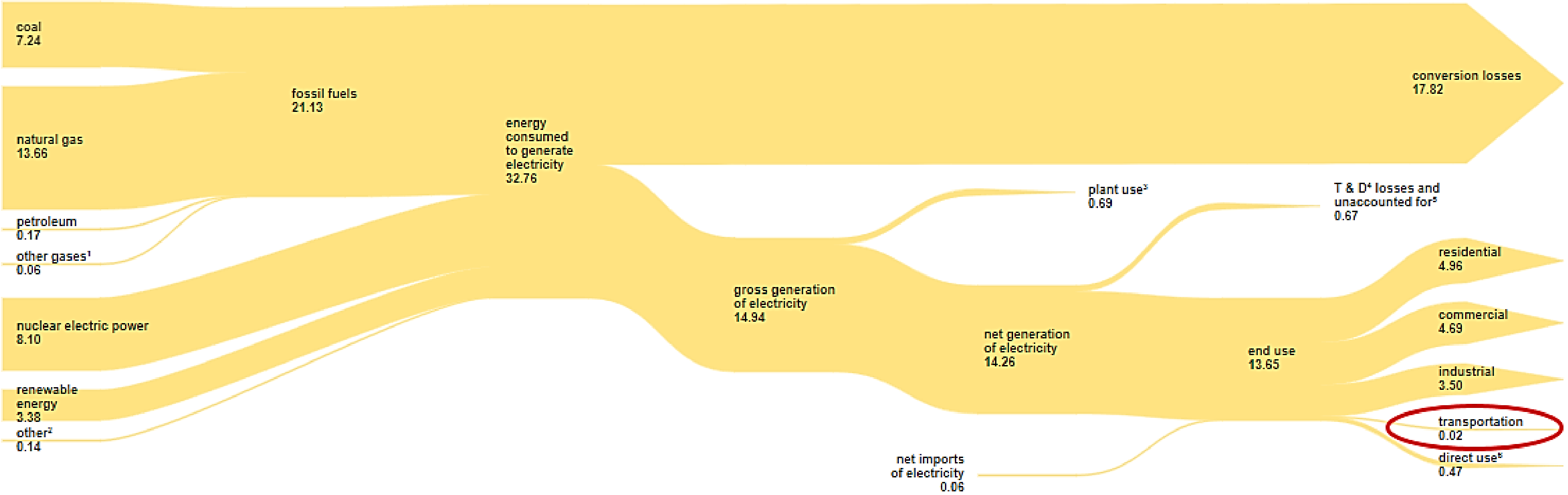
(68% of US petroleum consumption)

[1] Unfinished oils, hydrogen/biofuels/other hydrocarbons, and motor gasoline and aviation gasoline blending components. | [2] Finished petroleum products and hydrocarbon gas liquids. | [3] Natural gas liquids. | [4] Field production (6.431), transfers to crude oil supply (-0.436), and biofuels plant net production (-0.024) minus refinery and blender net inputs (0.622). | [5] Petroleum products supplied. | Notes: • Data are preliminary. • Values are derived from source data prior to rounding for publication. • Totals may not equal sum of components due to independent rounding.

eia Sources: U.S. Energy Information Administration (EIA), *Monthly Energy Review* (April 2024),

REFERENCE MATERIAL | US Energy Flow (Electricity)

US electricity (measured in quadrillion BTUs) used for transportation in 2023



[1] Blast furnace gas and other manufactured and waste gases derived from fossil fuels. | [2] Batteries, chemicals, hydrogen, pitch, purchased steam, sulfur, miscellaneous technologies, and non-renewable waste (municipal solid waste from nonbiogenic sources, and tire-derived fuels). | [3] Electric energy used in the operation of power plants. | [4] Transmission and distribution losses (electricity losses that occur between the point of generation and delivery to the customer). | [5] Data collection frame differences and nonsampling error. | [6] Use of electricity that is 1) self-generated, 2) produced by either the same entity that consumes the power or an affiliate, and 3) used in direct support of a service or industrial process located within the same facility or group of facilities that house the generating equipment. Direct use is exclusive of station use. | Notes: • Data are preliminary. • Data are for utility-scale facilities. • See Note 1, "Electrical System Energy Losses," at the end of U.S. Energy Information Administration (EIA), Monthly Energy Review (April 2024), Section 2. • Net generation of electricity includes pumped storage facility production minus energy used for pumping. • Values are derived from source data prior to rounding for publication. • Totals may not equal sum of components due to independent rounding.

eia Sources: U.S. Energy Information Administration (EIA), *Monthly Energy Review* (April 2024),

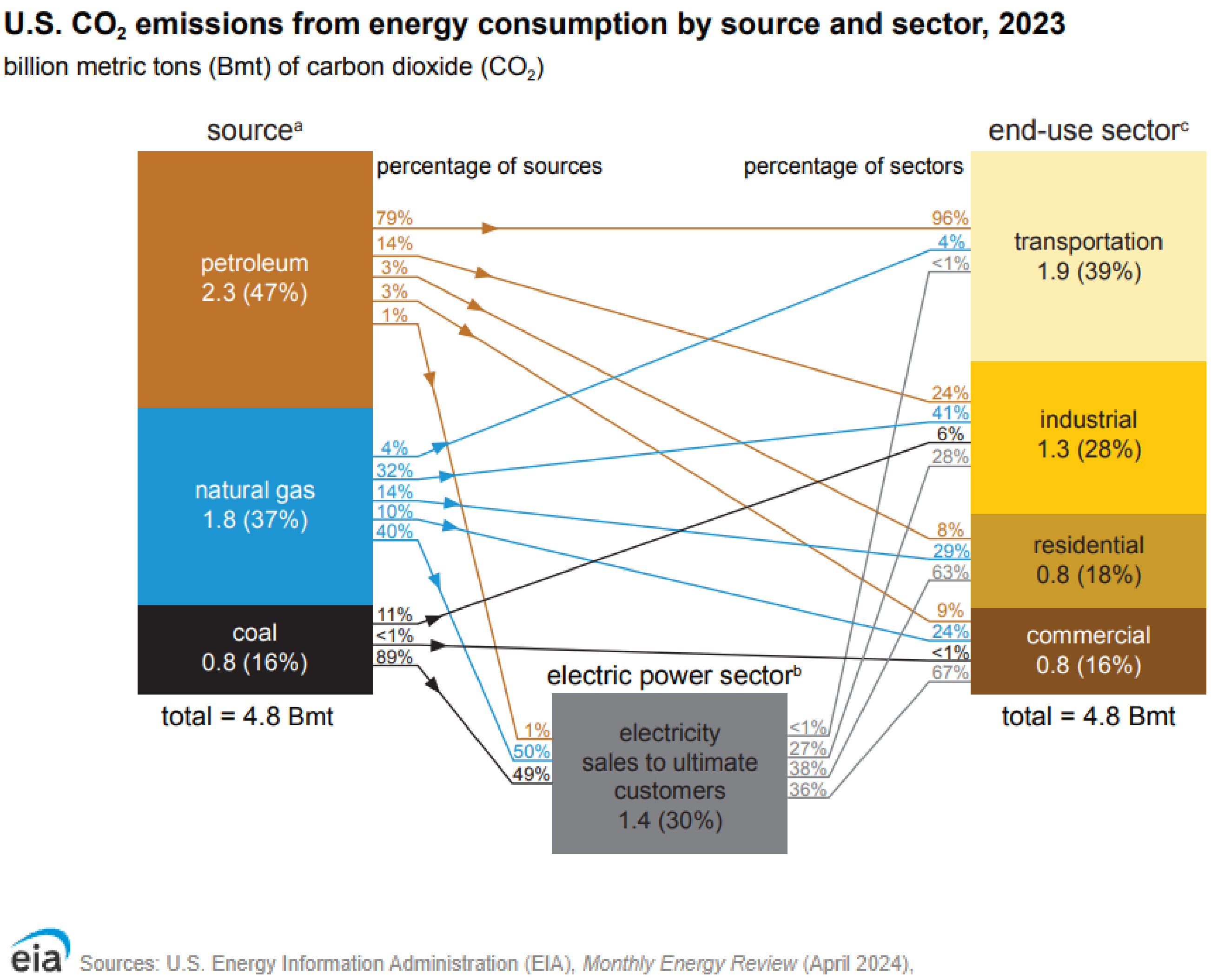
In 2023, electric transportation accounted for 0.02 quadrillion BTU of US electricity use.

0.02 quadrillion BTU
x 3,412 BTU/kWh
= 5,861,371,043 kWh
(roughly 669 MW of electricity demand)

The most recent commercial nuclear reactor, Georgia Power's Plant Vogtle Unit 4 brought online in May 2024, is a 1,114 MW unit.

This illustrates that the entirety of the US electric transportation sector operations could have been fueled by a single emissions-free commercial nuclear reactor unit.

REFERENCE MATERIAL | US Emissions Flow Diagram (End-Use by Sector)



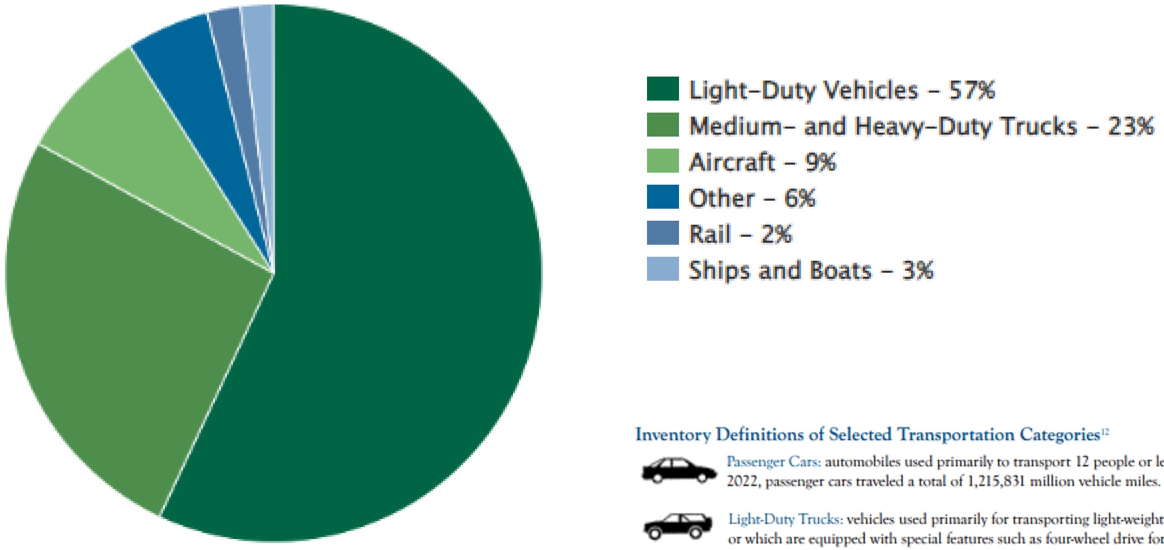
In 2023, transportation accounted for 1.9 of the 4.8 billion metric tons (Bmt) of CO2 emissions in the US

(39% of all US end-use energy consumption)

Less than 1% of the 1.4 Bmt in emissions from electricity end use consumption is associated with transportation

Approximately 96% of the 2.3 Bmt in emissions from petroleum end use consumption is associated with transportation

REFERENCE MATERIAL | US Transportation Sector GHG Emission by Source



Light Duty vehicles (passenger cars and light duty trucks) accounted for 57% of GHG emission in the transportation sector

Inventory Definitions of Selected Transportation Categories[12]

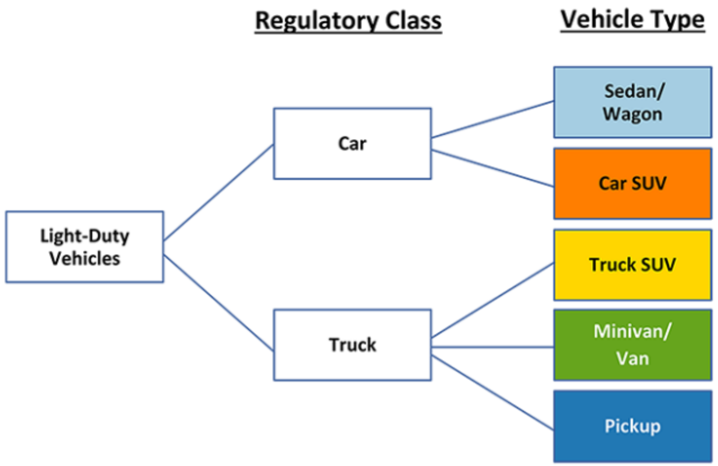
Passenger Cars: automobiles used primarily to transport 12 people or less. In 2022, passenger cars traveled a total of 1,215,831 million vehicle miles.

Light-Duty Trucks: vehicles used primarily for transporting light-weight cargo or which are equipped with special features such as four-wheel drive for off-road operation. In the U.S., this category also includes many vehicles that primarily transport passengers such as sport utility vehicles (SUVs) and minivans. The gross vehicle weight rating (GVWR) normally ranges around 8,500 pounds or less. GVWR is the maximum weight a vehicle is designed to carry when passengers, fuel, cargo, and any other additions to the vehicle are accounted for. In 2022, light-duty trucks traveled a total of 1,634,533 million vehicle miles.

Medium- and Heavy-Duty Trucks: vehicles with GVWR of more than around 8,500 pounds. In the Inventory, single unit trucks and combination trucks represent the medium- and heavy-duty truck category, including tractor-trailers and box trucks used for freight transportation. In addition, this category includes some vehicles that are not typically used for freight movement such as service and utility trucks. In 2022, medium- and heavy-duty trucks traveled a total of 325,692 million vehicle miles.

Pipelines: systems that transport liquids, gases, or slurries through either above or below ground pipes. In the Inventory, the pipelines category includes emissions from the combustion of natural gas used to power pumps and other distribution equipment, while leaks and other emission sources from pipelines are assigned to the natural gas systems category.

Regulatory Classes and Vehicle Types Used in This Report



SOURCE: 2023 EPA Automotive Trends Report (Full Report)

eia Sources: U.S. Energy Information Administration (EIA), *Monthly Energy Review* (April 2024),

REFERENCE MATERIAL | US GHG Emissions

Share of US transportation GHG emissions from 1990 to 2019 (measured in gigatons of CO_2 equivalent per year)

SOURCE: IPCC Sixth Assessment Report

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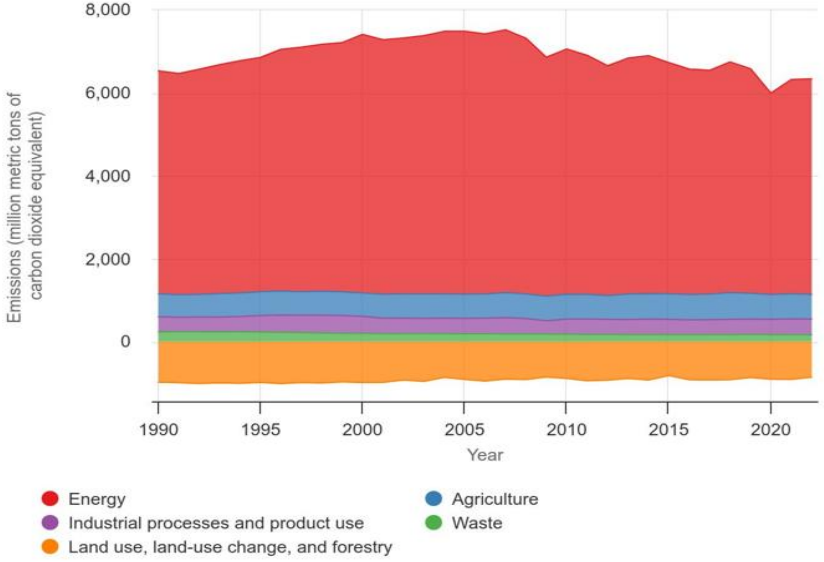
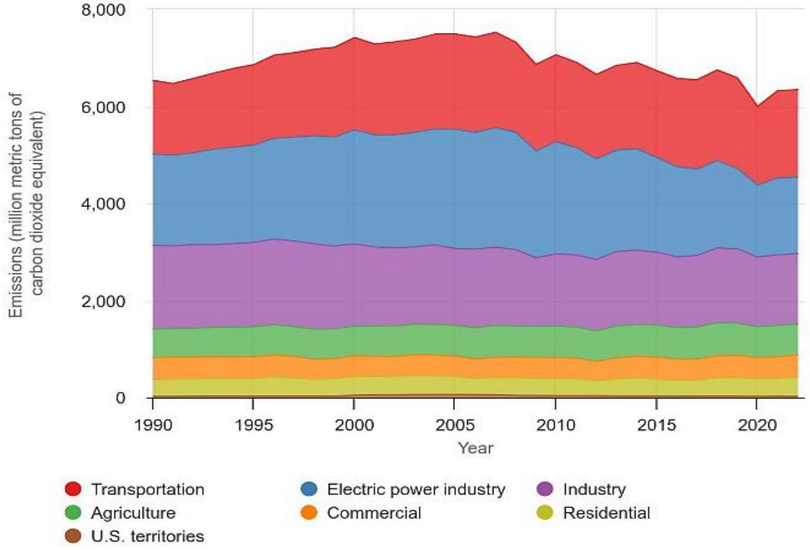
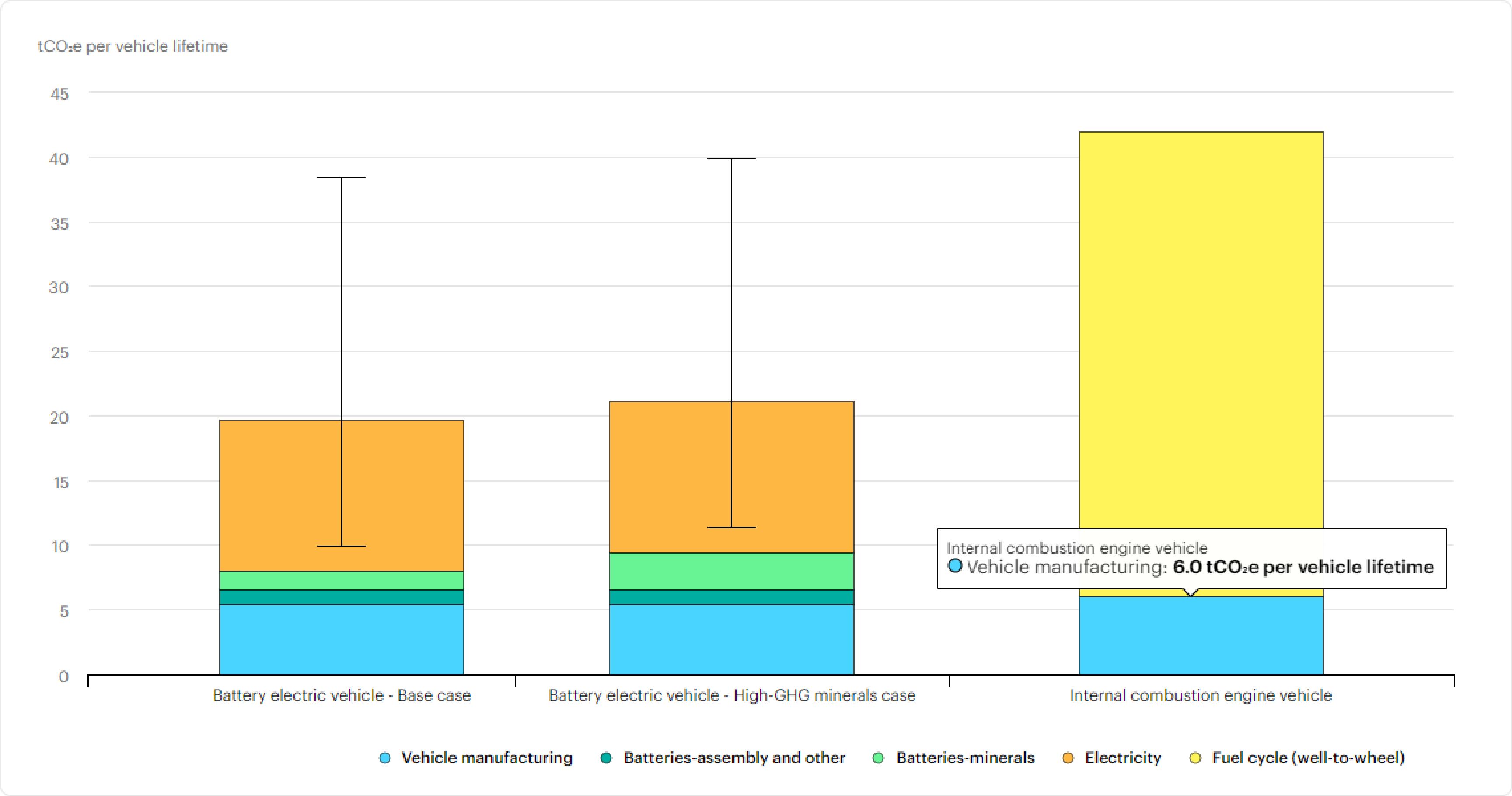
US GHG emissions emitted by economic sector and end use from 1990 to 2020 (measured millions of metric tons of CO2 equivalent)





SOURCE: US Environmental Protection Agency

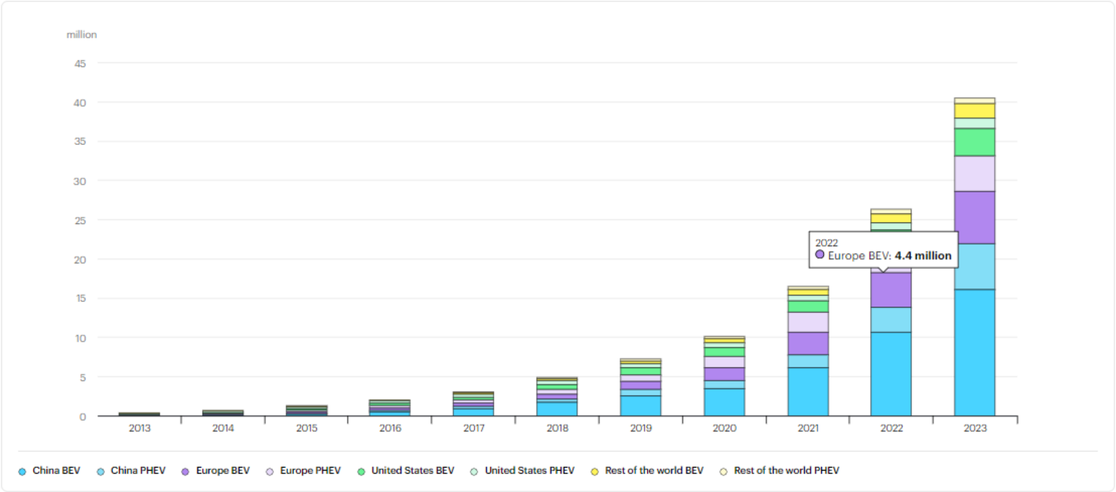
REFERENCE MATERIAL | Lifecycle Emissions



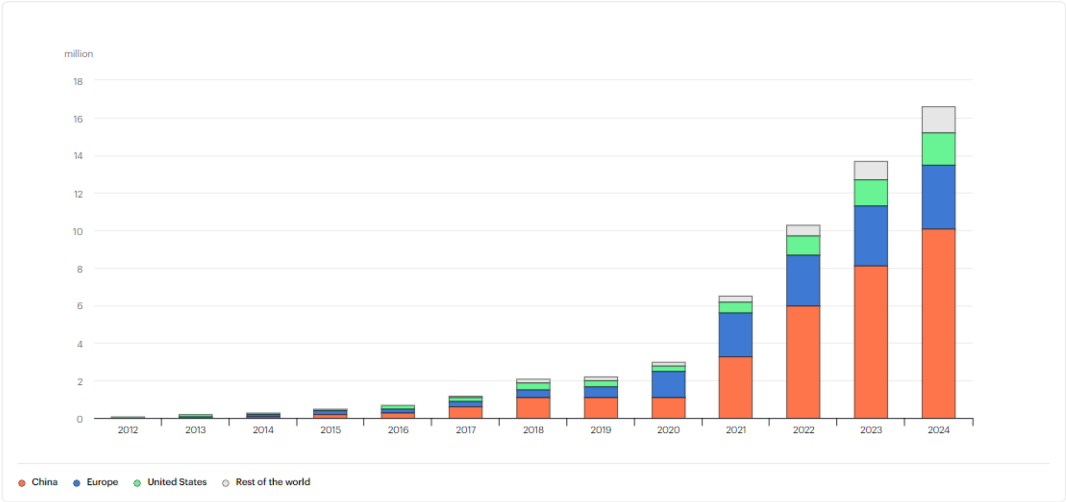
SOURCE: US Environmental Protection Agency

REFERENCE MATERIAL | Global Electric Vehicle Outlook Data (datasets included)

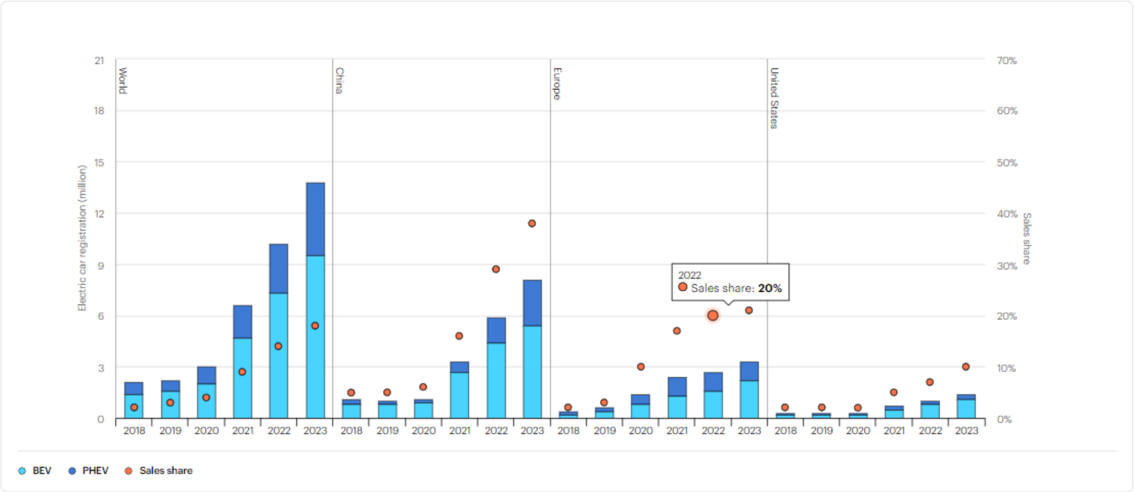
Global electric car stock, 2013-2023
Last updated 30 Apr 2024



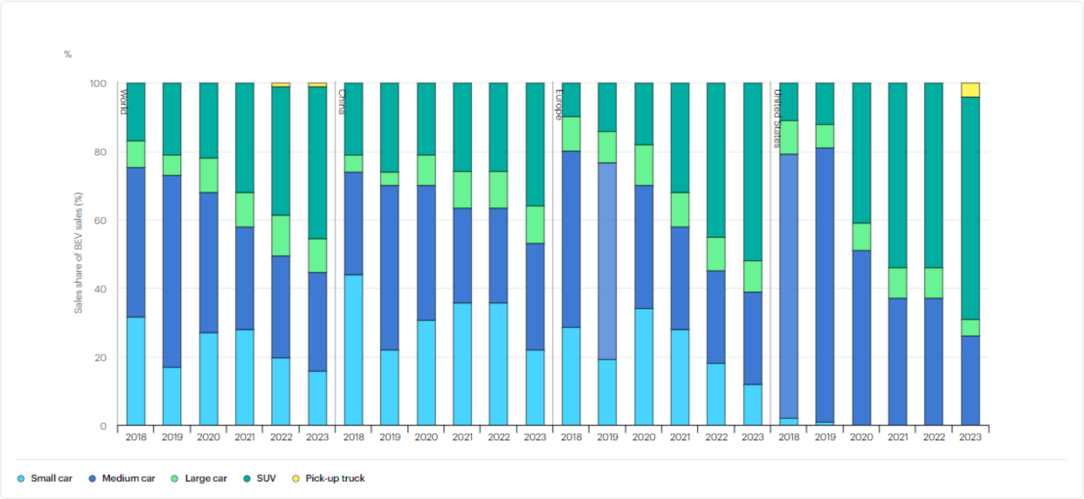
Electric car sales, 2012-2024
Last updated 22 Apr 2024



Electric car registrations and sales share in China, United States and Europe, 2018-2023
Last updated 30 Apr 2024



Breakdown of battery electric car sales in selected countries and regions by segment, 2018-2023
Last updated 30 Apr 2024



SOURCE: EIA [Global EV Outlook 2024](#)

IEA (2024), Electric car sales, 2012-2024, IEA, Paris https://w

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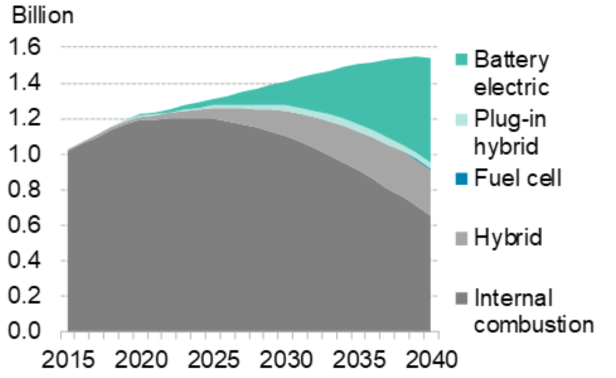
SOURCE: US Environmental Protection Agency

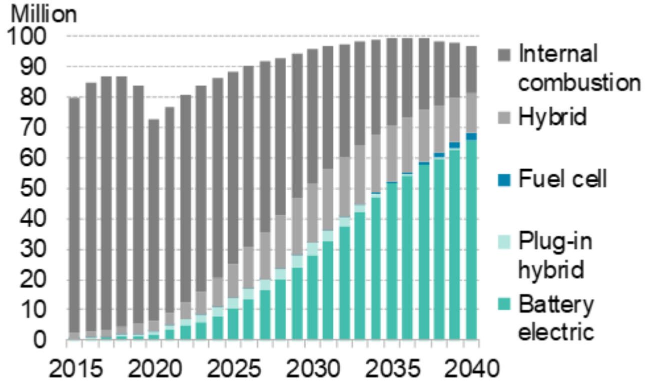
REFERENCE MATERIAL | Global Vehicle Forecasts

Global passenger vehicle fleet outlook by drivetrain - Economic Transition Scenario



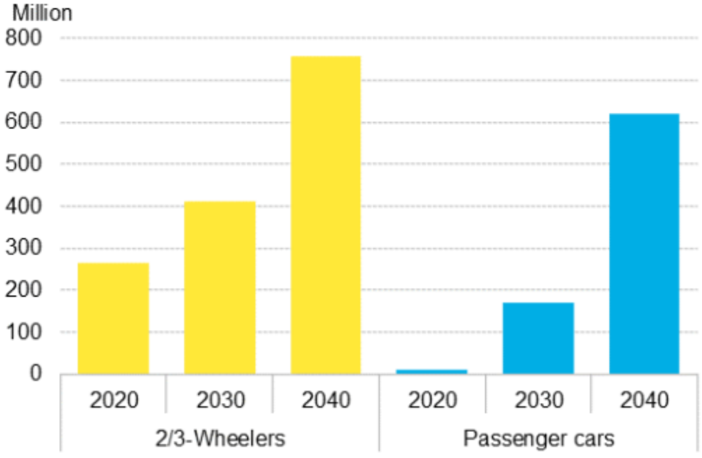
Source: BNEF. Note: EVs include battery-electric and plug-in hybrid electric vehicles. Europe includes the EU, the U.K. and EFTA countries.

Global passenger vehicle sales outlook by drivetrain - Economic Transition Scenario



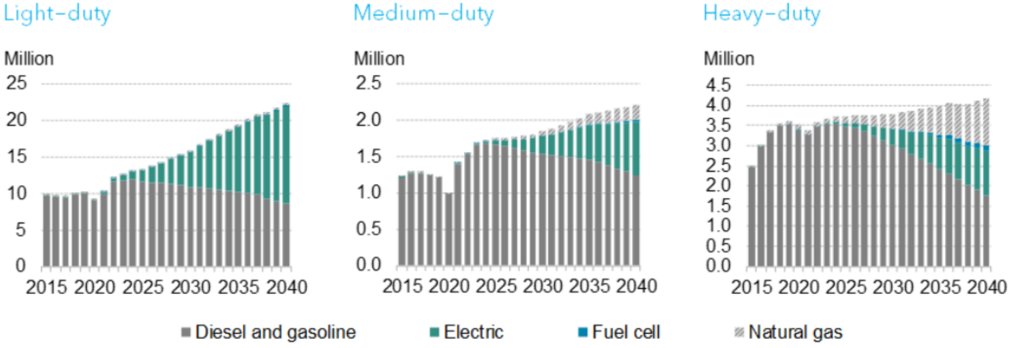
Source: BNEF.

Number of EVs on the road - Economic Transition Scenario

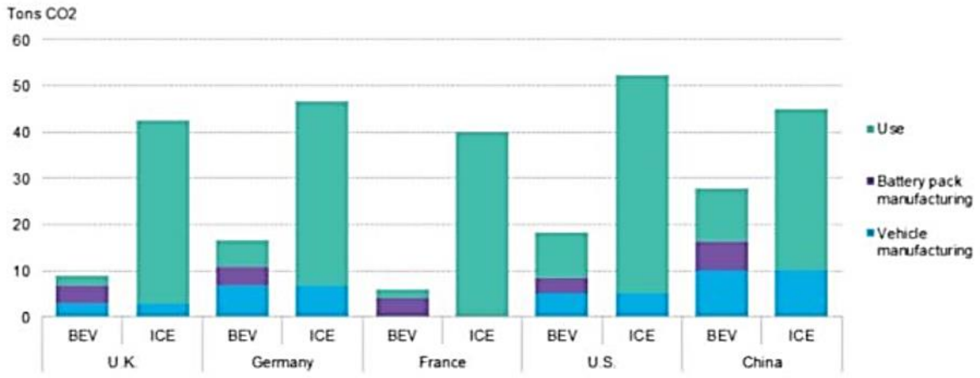


Source: BNEF. Note: LCVs = light commercial vehicles. M/HCVs = medium/heavy commercial vehicles. es.

Global commercial vehicle sales outlook by drivetrain and segment - Economic Transition Scenario



Source: BNEF. Note: Electric includes battery-electric, plug-in hybrid electric and range-extender; natural gas includes compressed and LNG.



SOURCE: IPCC Sixth Assessment Report

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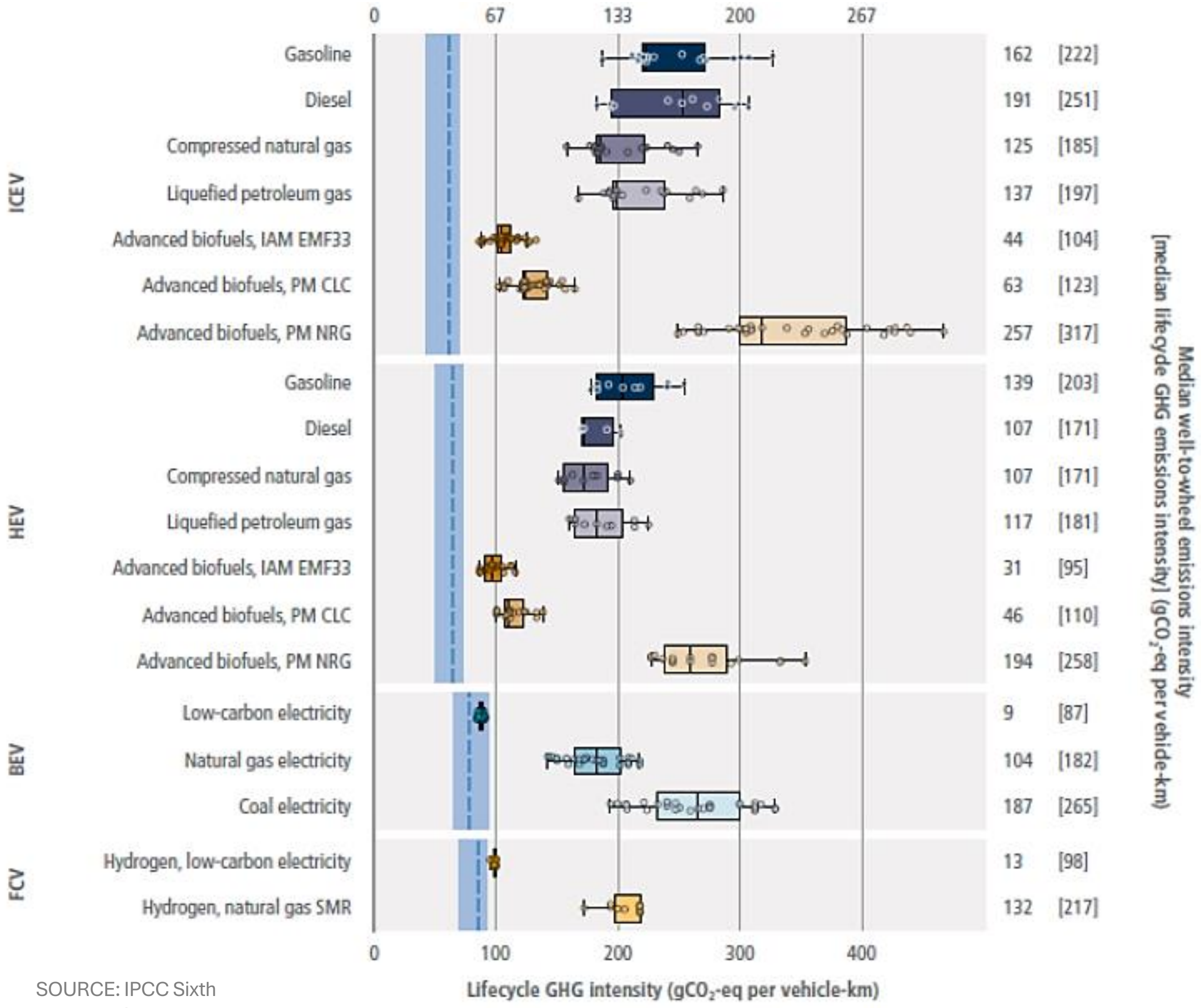
Source: BloombergNEF, New Energy Outlook 2020

SOURCE: US Environmental Protection Agency

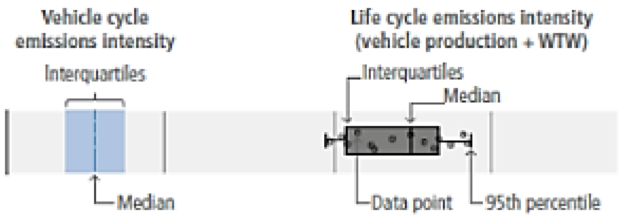
REFERENCE MATERIAL | Transportation Lifecycle GHG Intensity

Transportation lifecycle GHG intensity
(Measured in gigatons of CO2 equivalent per passenger-km)



SOURCE: IPCC Sixth Assessment Report

CHART LEGEND



- **Primary x-axis** reports units in gCO2-eq vkm–1, assuming a vehicle life of 180,000 km.
- **Secondary x-axis** uses units of gCO2-eq pkm–1, assuming a 1.5 occupancy rate.
- **Values in the figure** rely on the 100-year GWP value embedded in the source data, which may differ slightly from the updated 100-year GWP values from WGI.
- **Blue shaded area** represents the interquartile range for combined vehicle manufacturing and end-of-life phases.
- **Length of the box and whiskers** represent the interquartile range of the operation phase for different fuel chains, while their placement on the x-axis represents the absolute lifecycle climate intensity, that is, includes manufacturing and end-of-life phases.
- **Individual markers** indicate a data point.

TERMS USED

‘Advanced biofuels’ refers to the use of second-generation biofuels and their respective conversion and cultivation emission factors.

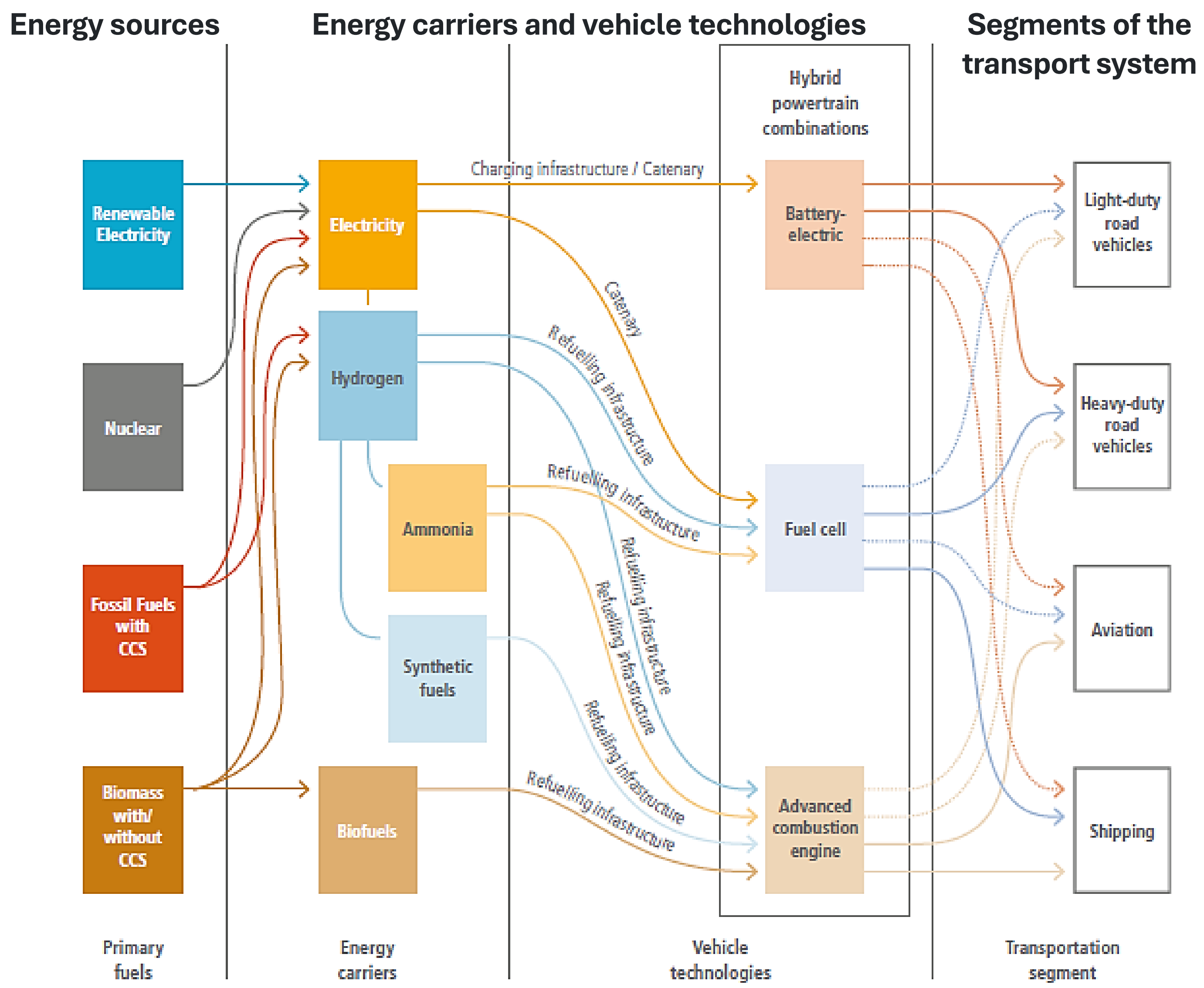
‘IAM EMF33’ refers to emissions factors for advanced biofuels derived from simulation results from the integrated assessment models EMF33 scenarios.

‘PM’ refers to partial models, where *‘CLC’* is with constant land cover and *‘NRG’* is with natural regrowth.

‘Hydrogen, low-carbon electricity’ is produced via electrolysis using low-carbon electricity.

‘Hydrogen, natural gas SMR’ refers to fuels produced via steam methane reforming of natural gas.

REFERENCE MATERIAL | Pathways for low-carbon transport technologies



Primary pathways are shown with solid lines, while dotted lines represent secondary pathways.

SOURCE: IPCC Sixth Assessment Report Working Group III: Mitigation of Climate Change

REFERENCE MATERIAL | Well-to-Wheels Emission

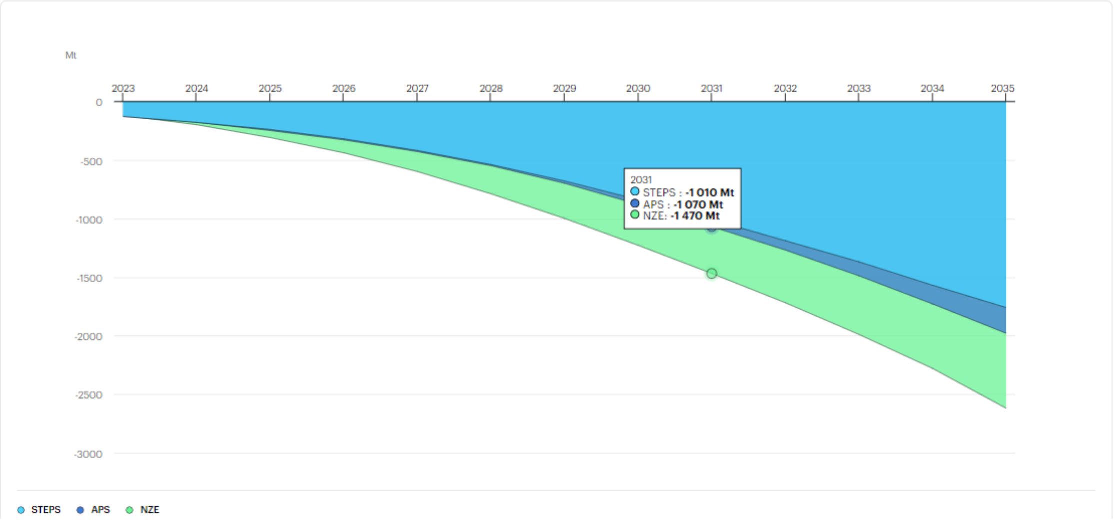
In the STEPS (stated policies), the emissions avoided by using EVs rather than ICE equivalents (alongside continued improvements to ICE fuel economy) reach over 2 Gt of CO_2 equivalent (CO_2-eq) in 2035.

Additional emissions from electricity generation for EVs are far smaller, at over 380 Mt CO_2-eq, meaning there is a net saving of 1.8 Gt CO_2-eq in 2035 in the STEPS.

Sustained decarbonisation of power generation helps deliver even more emission reductions in the APS (announced pledges), in which net emissions avoided by switching to electric reach around 2 Gt CO_2-eq in 2035.

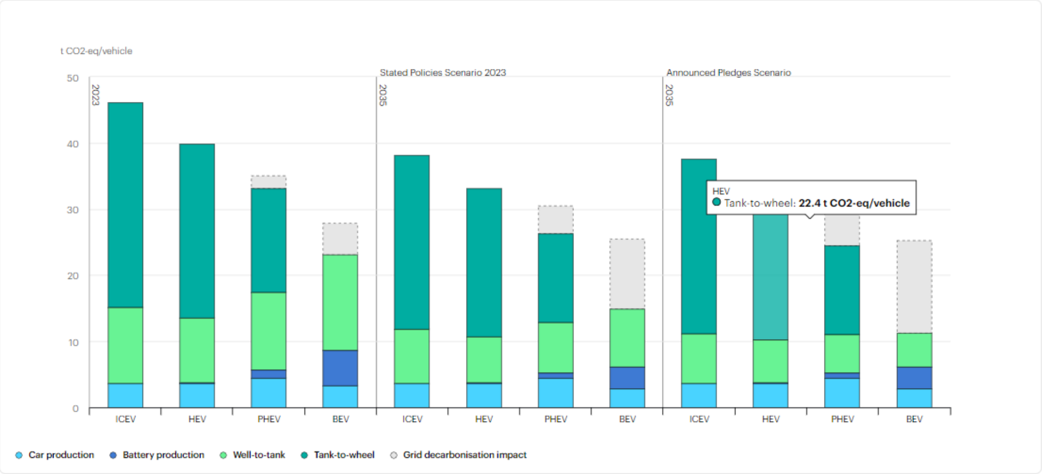
Net avoided well-to-wheel greenhouse gas emissions from electric vehicle deployment, 2023-2035

Last updated 25 Mar 2024



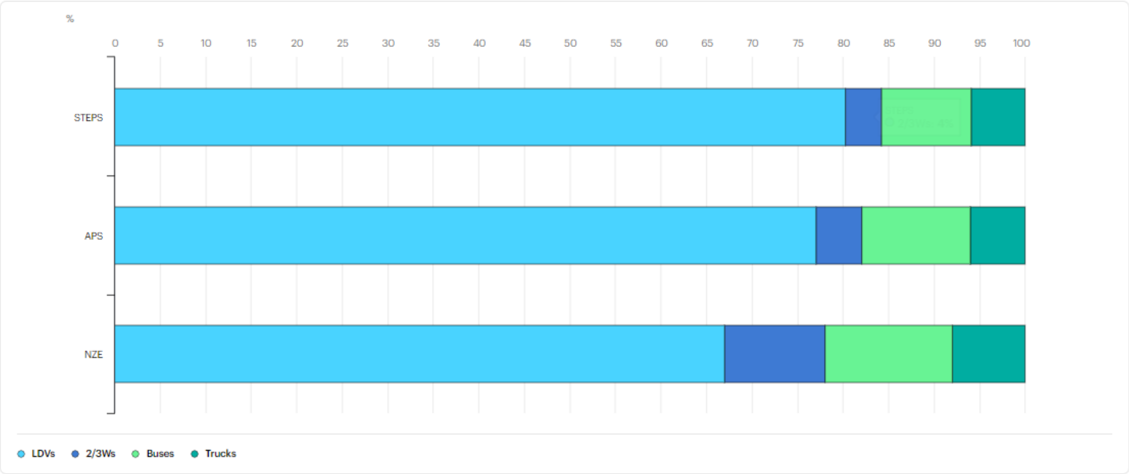
Comparison of global average lifecycle emissions by powertrain in the Stated Policies and Announced Pledges Scenarios, 2023-2035

Last updated 25 Mar 2024



Net avoided well-to-wheel share of avoided emissions by mode, 2023-2035

Last updated 25 Mar 2024



SOURCE: IPCC Sixth Assessment Report

SOURCE: IPCC Sixth Assessment Report Working Group III: Mitigation of Climate Change