atb.nrel.gov/transportation/2022/index

Annual Technology Baseline: The 2022 Transportation Update

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Webinar logistics slides are not included in this published version.

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- **Biofuels:** Ling Tao, NREL
- **Biofuels and GREET* Analysis:** Hao Cai and Uisung Lee, Argonne National Laboratory
- **Hydrogen and GREET* Analysis:** Adarsh Bafana, Argonne National Laboratory
- **Vehicles:** Paige Jadun and Arthur Yip, NREL; Amgad Elgowainy, Ehsan Islam, Aymeric Rousseau, Ram Vijayogopal, Argonne National Laboratory
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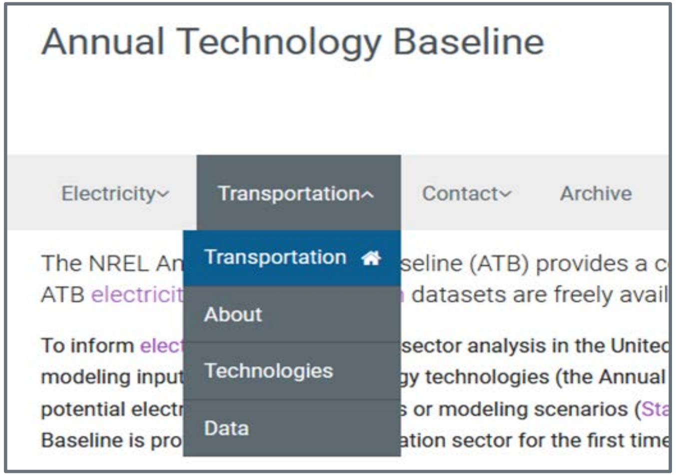
* GREET = Greenhouse gases, Regulated Emissions, and Energy use in Transportation

Agenda

- Why the ATB?
- ATB Project Overview
- Website Demonstration
- Questions and Comments

Why the ATB?

- The *rapid pace of technology development* results in reports of technology progress quickly becoming outdated, making it difficult for researchers to find *current, credible, and consistent* information in one place.
- By enabling *understanding of technology cost and performance across energy sectors,* the ATB informs transportation sector analysis nationwide.



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The ATB Targets Analytic Transparency and Consistency

Objective: develop and publish energy technology cost and performance scenarios that are credible, comparable, transparent, and reflect potential technology advancement.

EERE* Analysis Consistency

- Ensure consistent assumptions across technologies
- Provide comparability across EERE/national laboratory projects and publications

Third-Party Analysis

- Provide access to assumptions
- Leverage national laboratory expertise

* EERE = U.S. Department of Energy Office of Energy Efficiency and Renewable Energy

ATB Project Overview

What Are the Content and Purpose of the ATB?

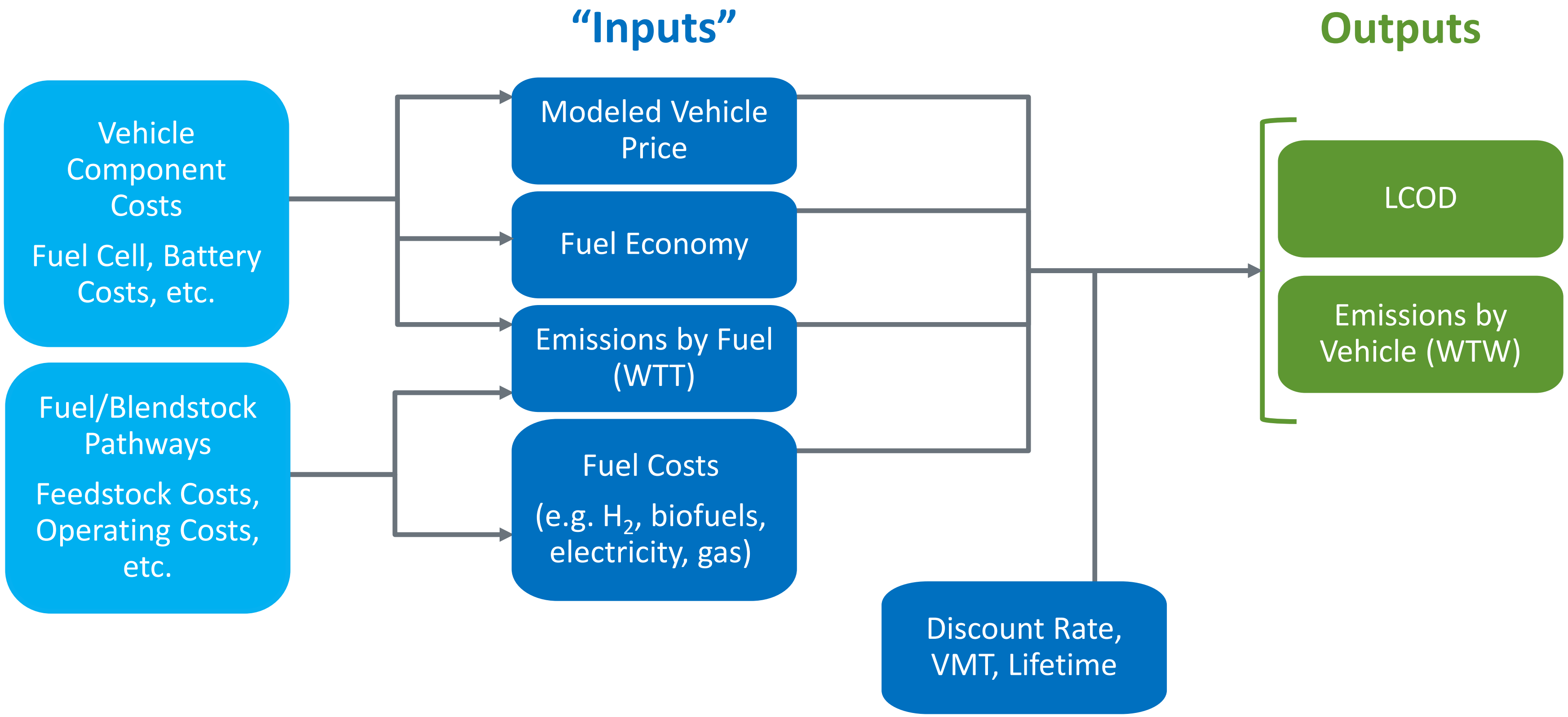
The ATB is a …

- Website and summary dataset of cost and performance estimates for selected vehicles and fuels
- Link to publicly available resources
- Set of scenarios that highlight potential technological improvements
- Platform for interactive exploration, selection, and download of specific data.

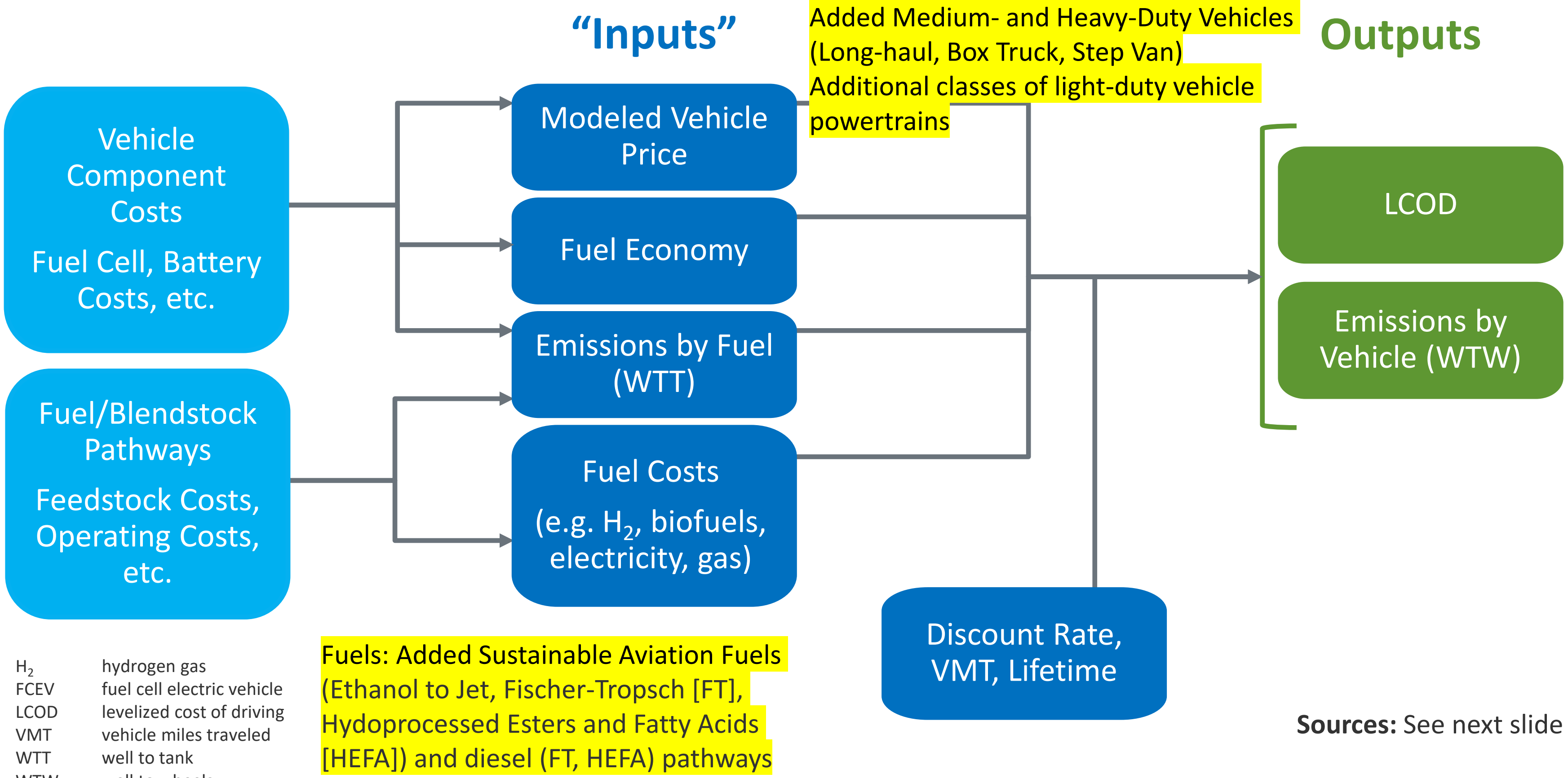
The ATB is *not* a …

- Primary analysis
- Model
- Set of all-encompassing future scenarios.

The Transportation ATB Highlights Key Data



Transportation ATB Highlights Key Data – Changes in 2022



H_2	hydrogen gas
FCEV	fuel cell electric vehicle
LCOD	levelized cost of driving
VMT	vehicle miles traveled
WTT	well to tank
WTW	well to wheels

Sources: See next slide

Summary of Transportation ATB 2022 Data Sources

Key Inputs	Primary Sources
Modeled Vehicle Price and Fuel Economy	Argonne's annual Autonomie modeling (Islam et al. 2022) Low-volume multipliers used for fuel cell electric vehicles based on James et al. (2018), and in alignment with TEMPO-based market penetrations (Ledna et al. 2022)
Fuel Costs	**Biofuels:** Published U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy techno-economic analysis reports **Hydrogen:** Liftoff report, California Energy Commission (Baronas and Chen 2021), and NREL data on fuel cell bus station costs. **Gasoline, diesel, and ethanol:** U.S. Energy Information Administration (EIA) and EIA Annual Energy Outlook (AEO) (various updated years, not 2023) **Electricity:** EIA, AEO, and NREL Standard Scenarios (Cole et al. 2021) **Recharging and refueling:** Borlaug et al. (2020); Bennett et al. (2022)
Fuel Emissions (WTT)	Argonne's GREET model (Wang et al. 2022)
Other LCOD calculation assumptions (Discount Rate, VMT, Lifetime)	Elgowainy et al. (2016); Burnham et al. (2021); Brooker et al. (2021); Hunter et al. (2021)

Transportation ATB: Assumptions for Energy Systems Analysis

Core Data

Base Year and Projected Data for…

- Fuel Economy
- Vehicle Price
- Fuel Cost
- WTT Emissions
- Financing Assumptions
- Levelized Cost of Driving
- WTW Emissions

WTT = well to tank; WTW = well to wheels

Product Suite

atb.nrel.gov

- User guidance
- Additional analyses
- Methodologies
- Comparison to other projections (e.g., EIA)

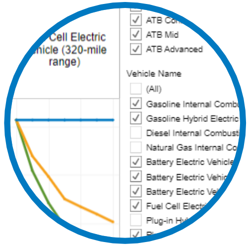
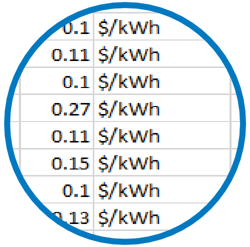


Tableau Workbook

- Summary of selected data (no calculations)
- Cost and performance projections, 2020–2050
- Interactive charts
- Visual exploration



Formatted Data

- Database-friendly summaries
- Cost and performance projections, 2020–2050
- Structured format

Presentation Slides

- Webinar presentation
- Summary presentation

What Is the Value of the ATB?

Transparency, Consistency, Credibility, and Accessibility

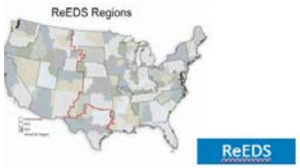
- **Consolidates** data from—and for use within— DOE's Sustainable Transportation analysis
- **Summarizes** data to high level needed for systemwide analysis
- **Organizes** data in highly structured format, enabling:
  - Display of data in interactive charts
  - Exploration, selection, and download of specific data.

Data are free, publicly available, and easily accessible.

Electricity ATB Has a 9-Year Record of Success

Model Inputs

Resource Planning Model



Regional Energy Deployment System

System Advisor Model

Analyses

Important Scenario Analyses Used ATB Projections

External Users

Federal Agencies Bureau of Land Management, U.S. Department of Energy and labs, U.S. Environmental Protection Agency	**Grid Operators** North American Electric Reliability Corporation, Midcontinent Independent System Operator, Pennsylvania-New Jersey-Maryland Interconnection, New York Independent System Operator	**Utilities** Hawaii Electric Company, Dominion Energy, Xcel Energy
Consultants Rhodium Group, Navigant, M.J. Bradley & Associates, Analysis Group	**Nonprofits** Resources for the Future, Environmental Defense Fund, Union of Concerned Scientists	**Academia** Stanford University, University of Maryland, University of Texas, Duke University, University of Colorado, Colorado School of Mines
State Officials Hawaii, Michigan, California	**International** Chilean Ministry of Energy, Global Carbon Capture and Storage Institute, Institute, Canadian Institute for Integrated Energy Systems	**Media** Utility Dive

Technology Specifics:
Web Demo

- Fuels
- Vehicles

Annual Technology Baseline

Electricity Transportation Contact Archive Login

- About
- Technologies
  - Light-Duty Vehicles
  - NEW Medium- and Heavy-Duty Vehicles
  - NEW Aviation
  - Fuels
- Data

Technologies

The 2022 Transportation Annual Technology Baseline (ATB) provides detailed cost and performance data, estimates, and assumptions for vehicle and fuel technologies in the United States.

The Transportation ATB includes current and projected estimates: time-series through 2050 for light, medium, and heavy-duty on-road vehicle technologies; scenarios for conventional and alternative fuels. It details the assumptions used to calculate those costs, such as natural gas and electricity prices, discount rates, and vehicle miles traveled. At this time, the ATB does not include other vehicles such as buses, 2- and 3-wheeled motorized vehicles, or non-road vehicles such as aircraft, vessels, locomotives, and those for industry and agriculture.

Explore interactive charts of vehicle and fuels data using the technology menu to the left, or explore the 2022 Transportation ATB documentation below.

Annual Technology Baseline

NREL Transforming ENERGY

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About

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Light-Duty Vehicles

Medium- and Heavy-Duty Vehicles

Aviation

Fuels

Data

Technologies

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Explore interactive charts of vehicle and fuels data using the technology menu to the left, or explore the 2022 Transportation ATB documentation below.

Annual Technology Baseline

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Technologies
Light-Duty Vehicles
Medium- and Heavy-Duty Vehicles
Aviation
Fuels
On-Road Fuels
Blendstocks
Aviation Fuels
Marine Fuels

Fuels

The Transportation Annual Technology Baseline (ATB) provides price or cost, production, and emissions estimate for selected fuels in four categories:

- On-Road Fuels, including ethanol and petro- and bio-based diesel fuel
- Blendstocks, including ethanol and diesel bio-based blendstock
- Aviation Fuels, including conventional jet fuel and sustainable aviation fuel
- Marine Fuels, including conventional heavy fuel oil and bio-based marine fuel.

The update separates on-road fuels from blendstocks and adds aviation fuels

Biofuel pathways presented in the ATB rely on ues such as corn stover, forest residues, sludges, fats, oil ss feedstocks can cause market prices at any given point e ATB. The supply curve costs and quantities of these ATB are encouraged to refer to other literature for this

On-Road Fuels

The Transportation Annual Technology Baseline (ATB) provides fuel price or cost and emissions for select on-road vehicle fuels, including gasoline and ethanol, diesel fuel, natural gas, electricity, and hydrogen.

Finished fuel prices are meant to represent retail prices, and they include estimated taxes (for fuels that are currently taxed) and distribution costs. Blendstock data do not include taxes or distribution costs.

We use the U.S. Energy Information Administration Annual Energy Outlook 2021 for current and projected petroleum fuel prices. Projected fuel prices are associated with particular years; however, because ATB does not provide a time-series trajectory, we present fuel price at a frozen level for all years, offering different scenarios for a range of fuel price values.

Fuel Scenarios

For non-petroleum fuels, the Transportation ATB presents five fuel scenarios, which include current market, current modeled, or future modeled conditions at low or high production volume scales, based on techno-economic modeling of potential technology advancement.

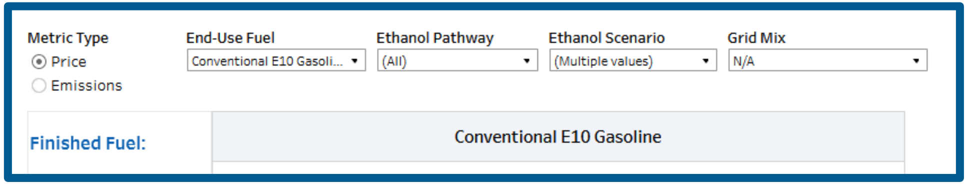
- The Current Market scenario represents fuel price and emissions data for fuels that are commercially available, with the exact source, timing, averaging, and other details described in the references. Current

Fuels Scenarios (from ATB Definitions Page)

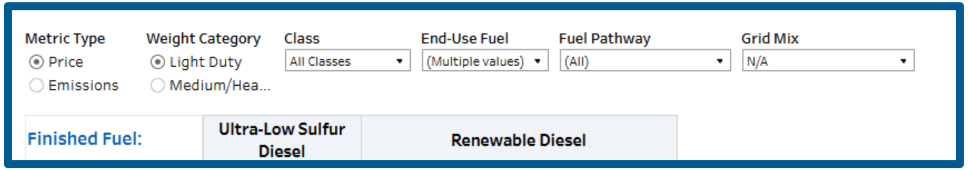
- **Current Market:** In the Current Market scenario, fuel price and emissions data are shown for fuels that are commercially available; the exact source, timing, averaging, and other details are described in the references. Current Market fuel prices are primarily based on data from the U.S. Energy Information Administration. Current Market fuel prices include taxes, but may differ from observed retail prices because of market volatility and local market conditions. See specific notes and references on the fuels pages for specific dates and averaging methods.
- **Current Modeled, Current Volume:** In this scenario, fuel metrics are based on techno-economic modeling of the current technology at current market production volume of the specific fuel pathway as specified in the notes and references on the fuels pages.
- **Current Modeled, High Volume:** In this scenario, fuel metrics are based on techno-economic modeling of the current technology at high market production volume of the specific fuel pathway. Timing of this scenario depends on when high production volume is achieved.
- **Future Modeled, Low Volume:** In this scenario, fuel metrics are based on a future technological state modeled at low market production volume of the specific fuel pathway, as might be the case for a pioneer plant.
- **Future Modeled, High Volume:** In this scenario, fuel metrics are based on a future technological state, based on engineering-economic modeling at high market production volume of the specific fuel pathway, often called "n^{th} plant." Timing of this scenario depends on when high production volume of the specific fuel pathway is achieved.

Explore Fuels Data via Interactive Tables

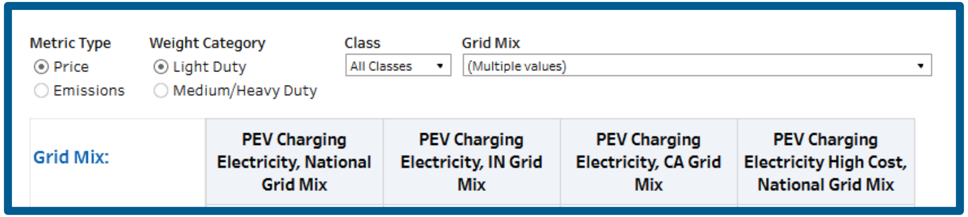
Gasoline and Ethanol



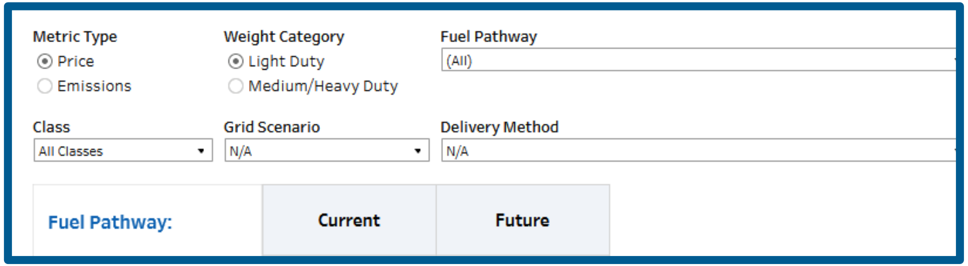
Petro- and Bio-Based Diesel Fuel



Electricity



Hydrogen



Update Includes Selected SAF Pathways

Annual Technology Baseline

NREL Transforming ENERGY

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Aviation Fuels

Explore the fuel price and emissions intensity of aviation fuel.

Emissions estimates use the Argonne National Laboratory's GREET model (Wang et al., 2022). The underlying source for a value in the table can be seen by placing your mouse cursor over that value. The data sources are also cited—with hyperlinked linked references—in the Key Assumptions section below.

Metric Type: (•) Price ( ) Emissions

Fuel Pathway: (All)

Grid Mix: N/A

	Conventional Jet Fuel	Sustainable Aviation Fuel		
Fuel Pathway:	Conventional Jet Fuel	Biofuel ETJ (Jet) from Corn	Biofuel FT (Jet) from Forest Residue	Biofuel HEFA (Jet) from used cooking oil
Fuel Scenario:	Current Market	Future Modeled, Hig..	Future Modeled, Hig..	Future Modeled, Hig..
Fuel Price ($/gge)	1.62	4.71	4.66	5.51

Electricity Example

Metric Type: ◯ Price ◉ Emissions | Weight Category: ◉ Light Duty ◯ Medium/Heavy Duty | Class: All Classes | Grid Mix: Multiple values

Grid Mix:	PEV Charging Electricity, National Grid Mix	PEV Charging Electricity, IN Grid Mix	PEV Charging Electricity, CA Grid Mix	PEV Charging Electricity High Cost, National Grid Mix
Class:	*All Classes*	*All Classes*	*All Classes*	*All Classes*
Select Pathway:	Baseline	Lowest Cost		
CO_2e WTT (g/mmBtu)	129000	235000	79500	129000
CO_2e WTW (g/mmBtu)	129000	235000	79500	129000
NO_x WTT (g/mmBtu)	96.1	167	57.4	96.1
NO_x WTW (g/mmBtu)	96.1	167	57.4	96.1
PM_{10} WTT (g/mmBtu)	13.2	29.4	4.35	13.2
PM_{10} WTW (g/mmBtu)	37.2	53.4	28.3	37.2
SO_x WTT (g/mmBtu)	76.9	178	19.5	76.9
SO_x WTW (g/mmBtu)	76.9	178	19.5	76.9

In this table, you can explore the fuel prices and emissions data for all of the electricity fuel pathways in the ATB. Use the filters on the top to choose a me..

For documentation, see website https://atb.nrel.gov

Metric Type: ◉ Price ◯ Emissions | Weight Category: ◉ Light Duty ◯ Medium/Heavy Duty | Class: All Classes | Grid Mix: Multiple values

Grid Mix:	PEV Charging Electricity, National Grid Mix	PEV Charging Electricity, IN Grid Mix	PEV Charging Electricity, CA Grid Mix	PEV Charging Electricity High Cost, National Grid Mix
Fuel Scenario:	Current Market	Current Market	Current Market	Current Market
Class:	*All Classes*	*All Classes*	*All Classes*	*All Classes*
Select Pathway:	Baseline	Lowest Cost		
Fuel Price ($/gge)	3.29	3.24	3.82	4.53
Fuel Price ($/kWh)	0.100	0.0985	0.116	0.138

In this table, you can explore the fuel prices and emissions data for all of the electricity fuel pathways in the ATB. Use the filters on the top to choose a me..

For documentation, see website https://atb.nrel.gov

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The 2022 Transportation Annual Technology Baseline (ATB) provides detailed cost and performance data, estimates, and assumptions for vehicle and fuel technologies in the United States.

The Transportation ATB includes current and projected estimates: time-series through 2050 for light, medium, and heavy-duty on-road vehicle technologies; scenarios for conventional and alternative fuels. It details the assumptions used to calculate those costs, such as natural gas and electricity prices, discount rates, and vehicle miles traveled. At this time, the ATB does not include other vehicles such as buses, 2- and 3-wheeled motorized vehicles, or non-road vehicles such as aircraft, vessels, locomotives, and those for industry and agriculture.

Explore interactive charts of vehicle and fuels data using the technology menu to the left, or explore the 2022 Transportation ATB documentation below.

Vehicles Scenarios (from ATB Definitions page)

- **Advanced Trajectory:** In the Advanced trajectory, technology advances occur with breakthroughs, increased public and private R&D investment, and other market conditions that lead to significantly improved cost and performance levels, but the technologies do not necessarily reach their full technical potential. Vehicle technologies advance substantially and achieve high performance, low cost, or both. Attaining this level of cost improvement is assumed to be very uncertain.
- **Mid Trajectory:** In the Mid trajectory, technology cost and performance improve at moderate levels, with continued industry growth and R&D investment (both public and private). Vehicles include moderate technology advancements (in between the currently manufactured technology and the Advanced trajectory) to achieve higher performance, lower costs, or both, and attaining this level of cost improvement is assumed to be moderately uncertain.
- **Constant Trajectory:** In the ATB Constant trajectory, technology cost and performance from the base year are shown through 2050, without further advancement in R&D or markets. This cost level is extended through 2050 for reference only; it does not imply frozen costs and performance are anticipated.

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Light-Duty Vehicles

The 2022 Transportation Annual Technology Baseline (ATB) provides current and future projections of cost and performance for select light-duty vehicles and fuels (and for select Medium- and Heavy-Duty Vehicles).

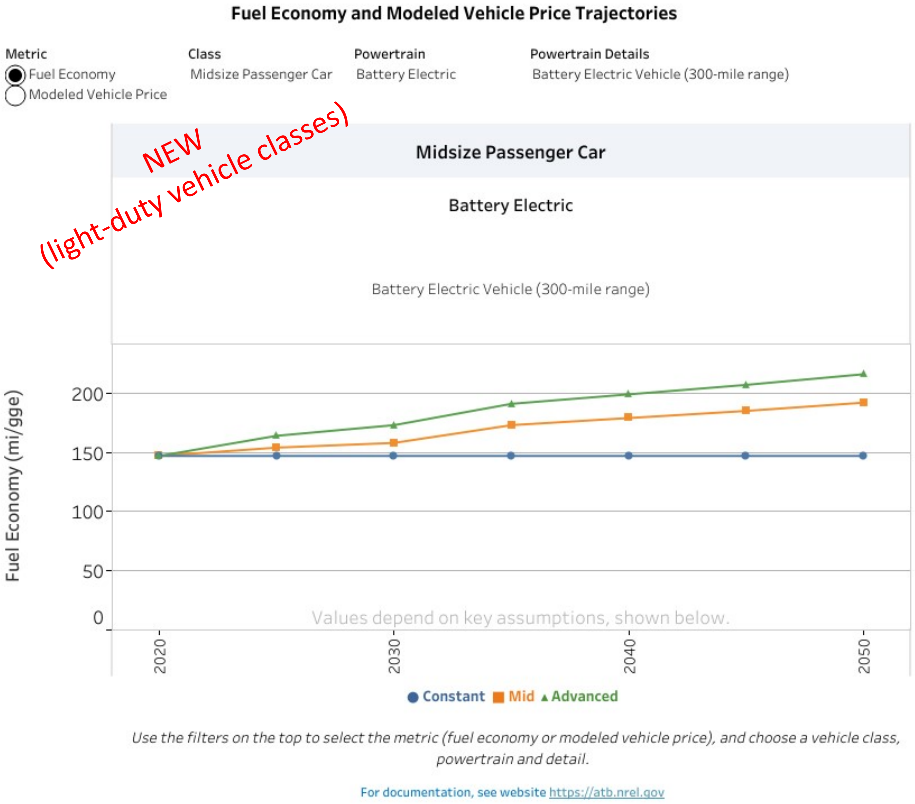
The Transportation ATB provides data in a series of interactive charts for either a single year or a trajectory out to 2050 showing:

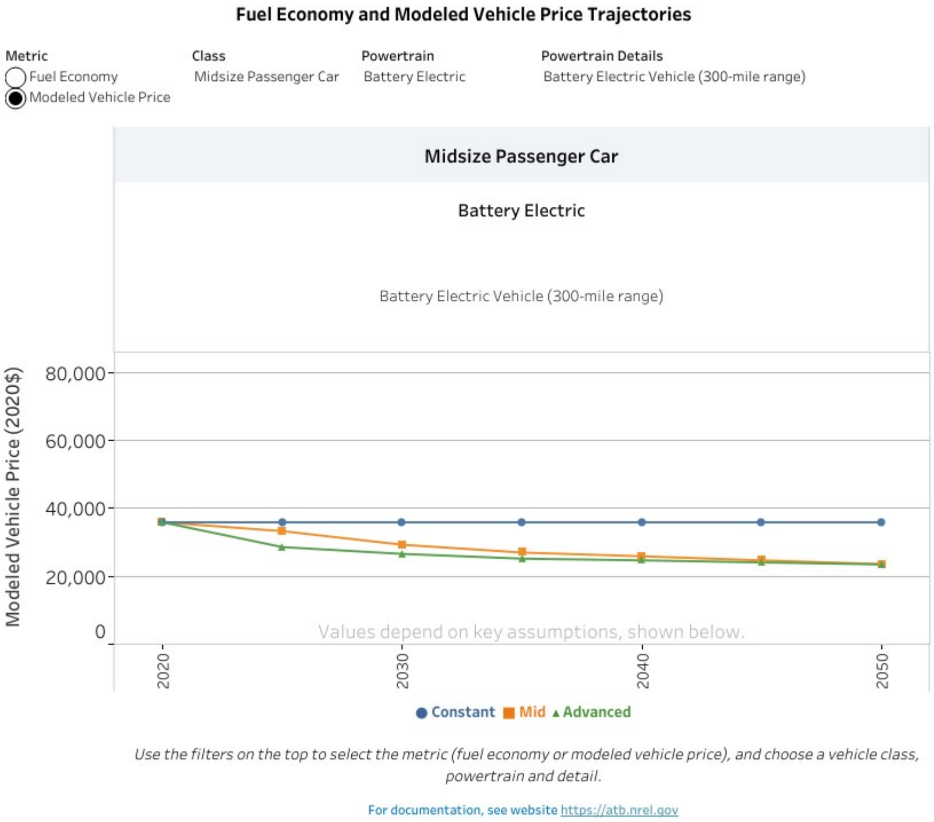
- Fuel economy, which is reported in miles per gallon gasoline equivalent and represents how efficiently a vehicle converts fuel during operation
- Modeled Vehicle Price, which represents an estimated cost, including manufacturing costs and profit, to the consumer purchasing a new vehicle
- Levelized cost of driving, which is an indicator of the cost of operation over the vehicle lifetime on a per-mile basis
- Emissions, which represent the well-to-wheels emissions (including emissions from fuel production to vehicle operation).

The Transportation ATB presents these metrics for individual powertrains and in comparison with other powertrains.

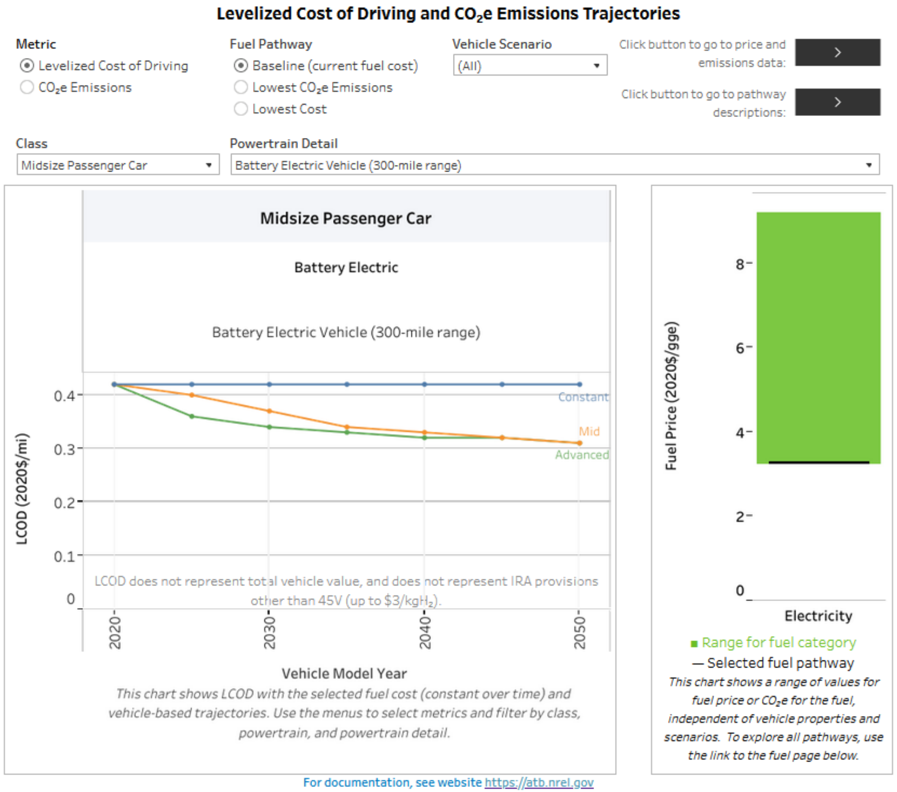
Vehicle Metrics – Battery Electric Vehicle Example

NEW
(light-duty vehicle classes)

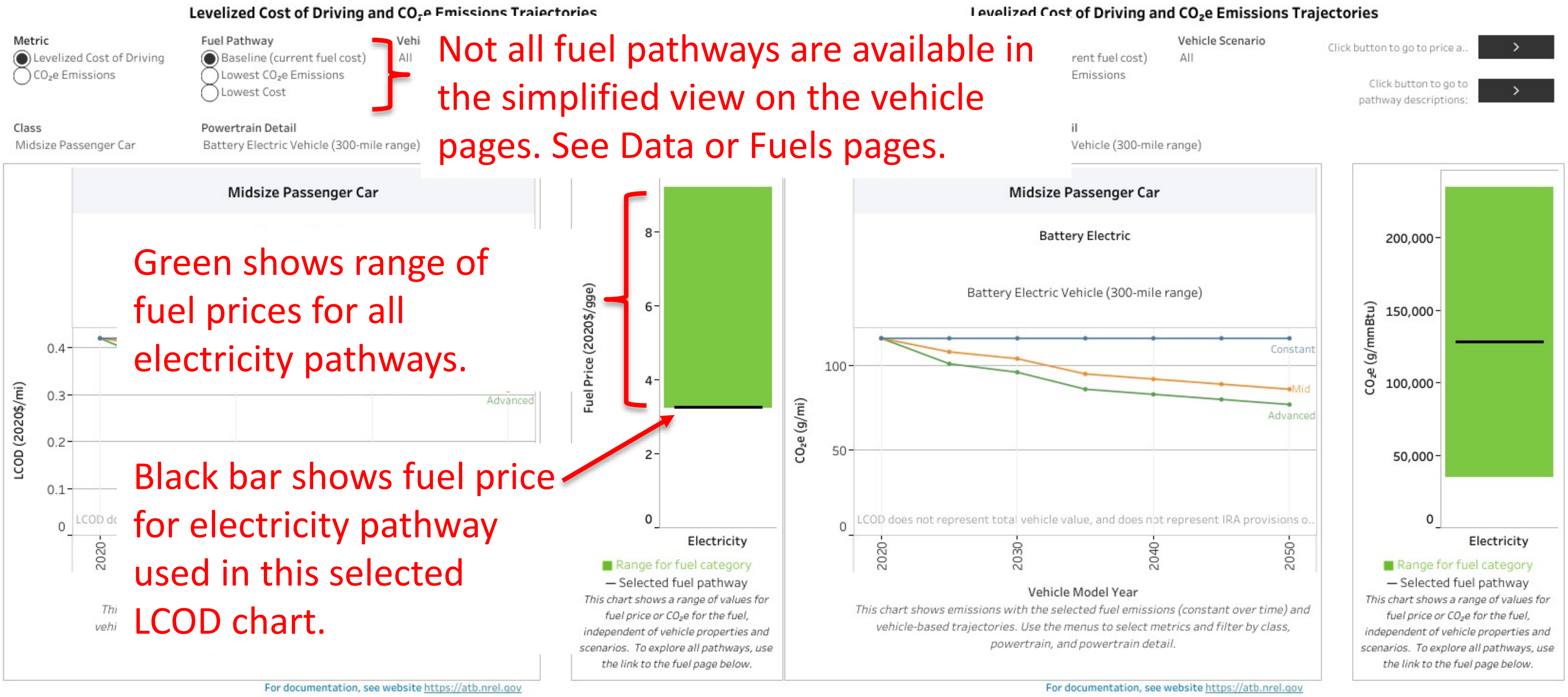




Vehicle and Fuel Metrics – Battery Electric Vehicle Example

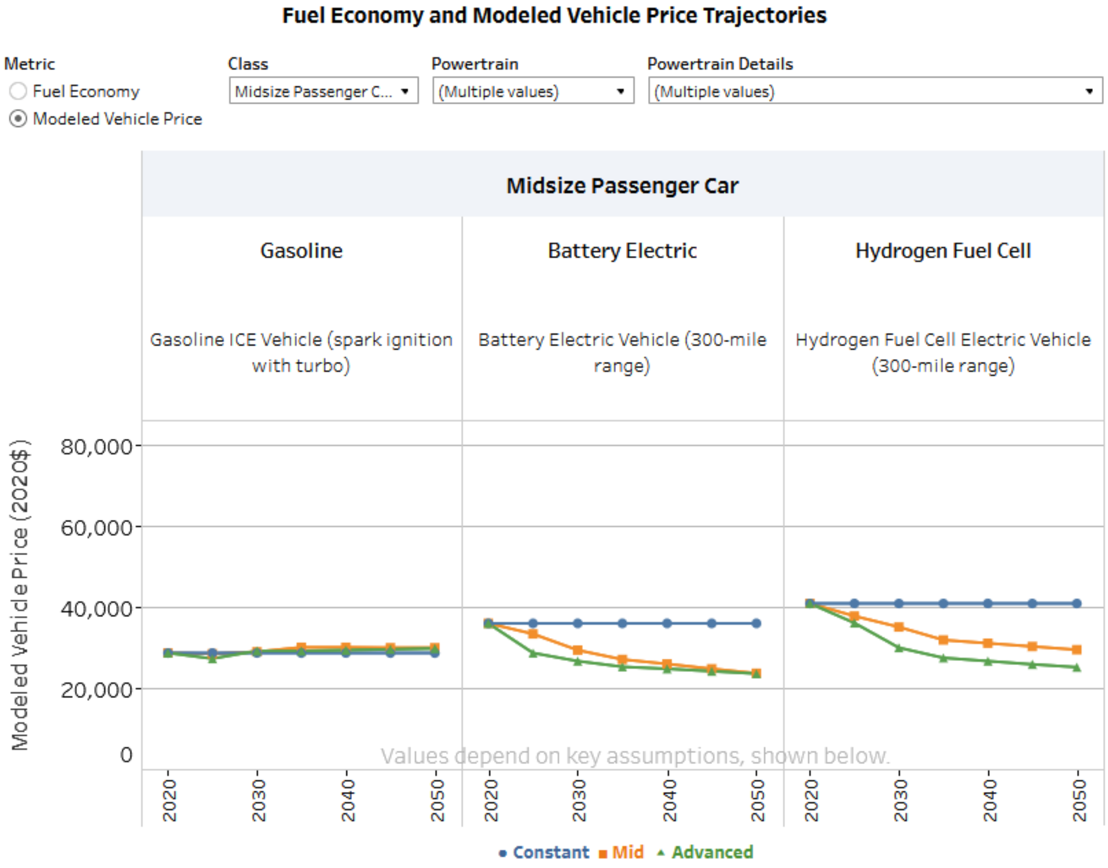


Vehicle and Fuel Metrics – Battery Electric Vehicle Example



Light-Duty Vehicle Comparison Example

Modeled Vehicle Price



Use the filters on the top to select the metric (fuel economy or modeled vehicle price), and choose a vehicle class, powertrain and detail.

For documentation, see website https://atb.nrel.gov

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    - Fuel Cell MDHD
    - Comparison of MDHD Vehicles
  - Aviation
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- Data

NEW

Medium- and Heavy-Duty Vehicles

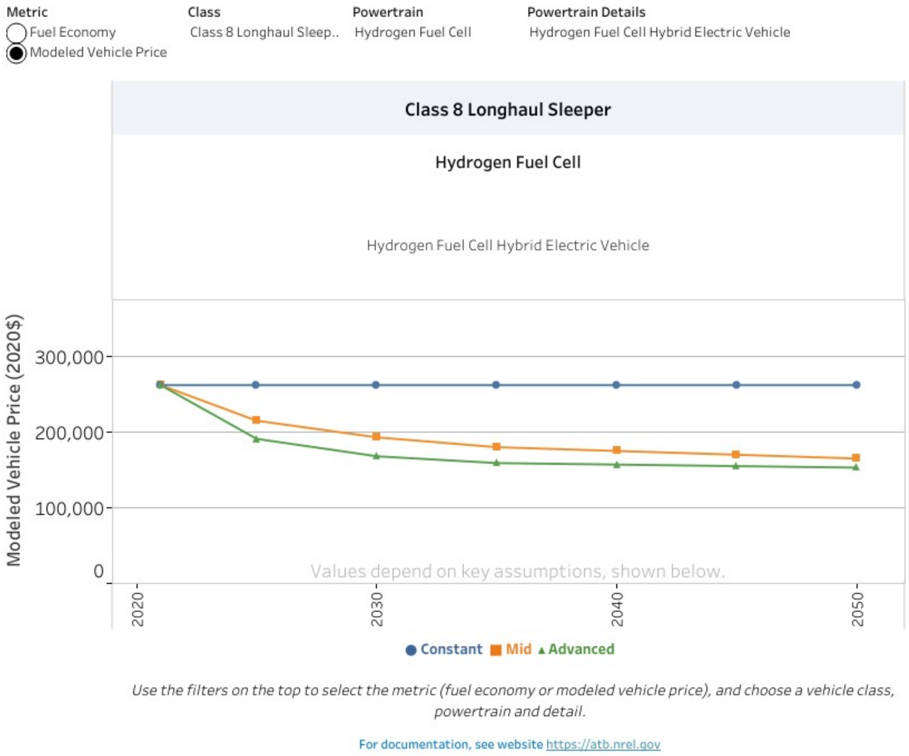
The 2022 Transportation Annual Technology Baseline (ATB) provides current and future projections of cost and performance for select medium- and heavy-duty vehicles and fuels (and for select Light-Duty Vehicles).

The Transportation ATB provides data in a series of interactive charts for either a single year or a trajectory out to 2050 showing:

- Fuel Economy, which is reported in miles per diesel gallon equivalent and represents how efficiently a vehicle converts fuel during operation.
- Modeled Vehicle Price, which represents an estimated cost, including manufacturing costs and profit, to the consumer purchasing a new vehicle
- Levelized Cost of Driving, which is an indicator of the cost of operation over the vehicle lifetime on a per-mile basis
- Emissions, which represent the well-to-wheels emissions (including emissions from fuel production to vehicle operation).

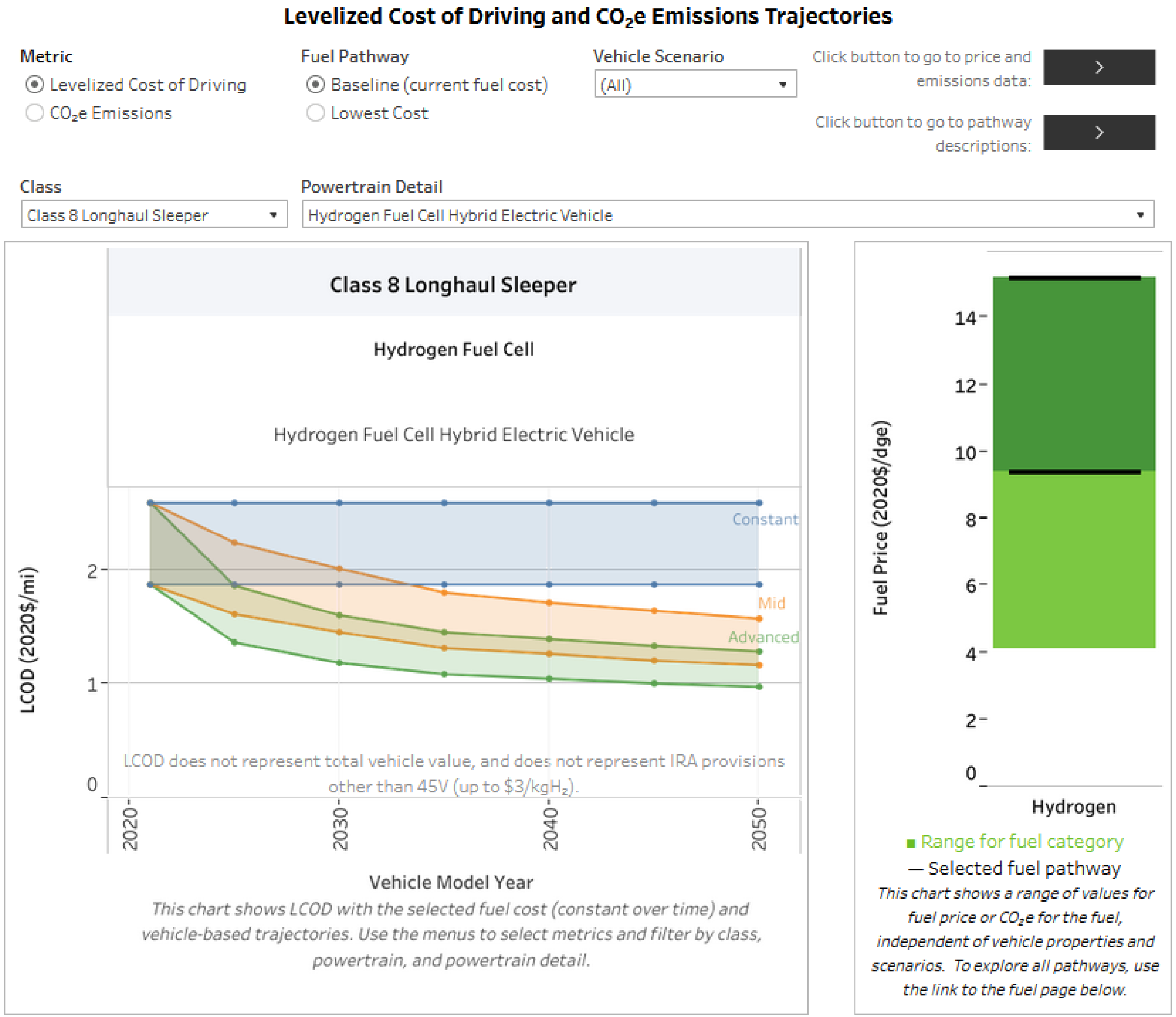
The Transportation ATB presents these metrics for individual powertrains and in comparison with other powertrains.

Fuel Economy, Modeled Vehicle Price: FCEV Example



ATB Constant: Technologies do not advance from 2020 levels.
ATB Mid: Technologies improve at moderate levels, with continued industry growth and R&D investment.
ATB Advanced: Technology advances occur with breakthroughs, increased public and private R&D investment, and other market conditions that lead to significantly improved cost and performance levels but do not necessarily reach the full technical potential.

LCOD and CO_2e: FCEV Example



For documentation, see website https://atb.nrel.gov

Simplified Fuel Options on Vehicle Pages Pathways

Selected Fuel Pathways by Fuel Category

Weight Category

- (•) Light Duty
- ( ) Medium/Heavy Duty

Fuel Category	Metric Type	Baseline (current fuel cost)	Lowest CO_2e Emissions	Lowest Cost
Gasoline	Both	Conventional BOB *Starch Ethanol*	Conventional BOB *Cellulosic Thermochemical Ethanol from Forest Residue*	Conventional E10 Gasoline 2050 Low Price *Starch Ethanol*
Diesel	Both	Ultra-Low Sulfur Diesel	Biofuel FT (Diesel) from Forest Residue	Ultra-Low Sulfur Diesel 2050 Low Price
Natural Gas	Both	Natural Gas	Natural Gas	Natural Gas
Electricity	Both	PEV Charging Electricity, National Grid Mix	PEV Charging Electricity, Future High RE Penetration Grid Mix	PEV Charging Electricity, IN Grid Mix
Hydrogen	Emissions	Steam Methane Reforming *Tube-Trailers*	Low temperature electrolysis *On-Site Production*	
	Price	Current		Future

For documentation, see website https://atb.nrel.gov

See Fuels pages or Data page (Tableau Workbook) for all fuel options.

FCEV: Baseline and Lowest Cost Fuel Example

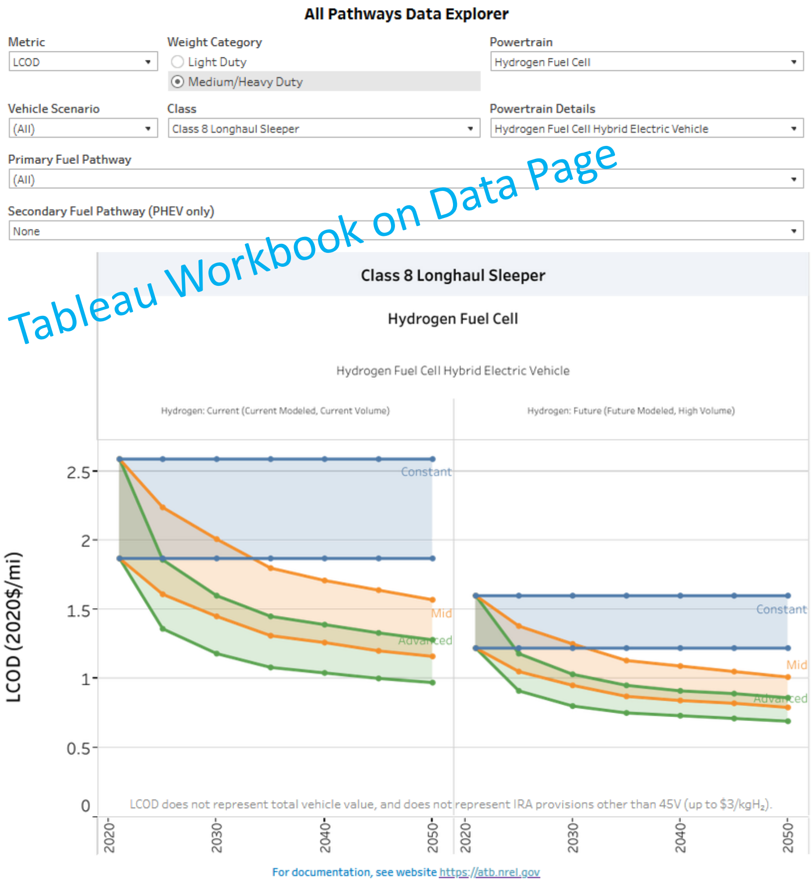
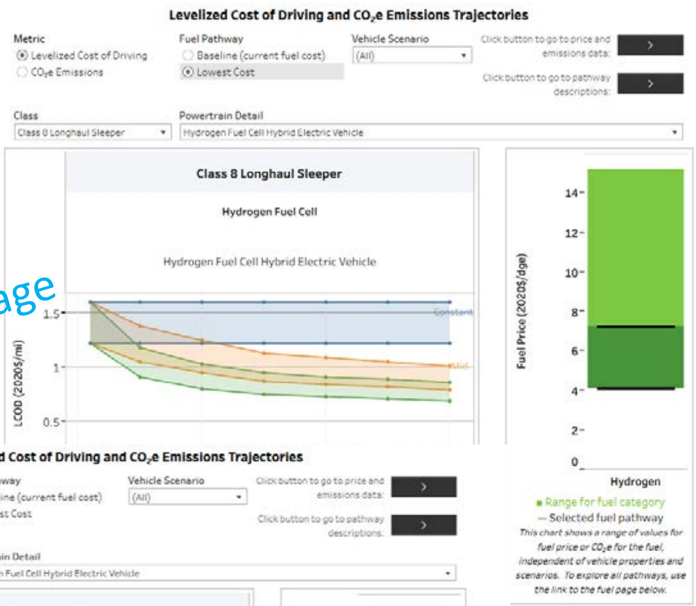


Tableau Workbook on Data Page



FCEV Page

Multi-powertrain view available on "Comparison" vehicles pages or on "Data" page in embedded Tableau workbook.

Example shows comparison of Modeled Vehicle Price on "Comparison of MDHD Vehicles" page.

Annual Technology Baseline

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- About
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Definitions

Definitions of common terms in the 2022 Transportation ATB are presented below.

Vehicles

Battery Electric Vehicles

Battery electric vehicles (BEVs) use a battery pack to store the electrical energy that powers the motor. The batteries are charged by plugging the vehicle into an electric power source (DOE, 2019). For additional background, see the Alternative Fuels Data Center's All-Electric Vehicles webpage.

The battery cost assumptions used in the Annual Technology Baseline modeled vehicle price trajectories are shown

Fuels

Alternative Jet Fuel

Sustainable aviation fuel (SAF), also called alternative jet fuel, alternative aviation fuel, "biojet" or aviation biofuel, is derived from biomass. Up to specified blending limits that vary by pathway, it can be used directly in airplanes that use regular, petroleum-based aviation fuel (DOE, 2019).

Scenarios

Vehicle Scenarios

Vehicle scenarios in the Transportation ATB incorporate assumptions on both the level of technology advancement achieved in each powertrain (e.g., lightweighting, engine efficiency) and the projected costs for the assumed technologies through 2050. Assumptions for assigning values in the Advanced and Mid trajectories reflect lab

Metrics

All costs are converted to 2020 dollars using the gross domestic product implicit price deflator (FRED, 2022).

Fuel Economy

For the purposes of the Transportation ATB, fuel economy is tank-to-wheels fuel economy, reported in miles per

Definitions cover vehicles, fuels, scenarios, and metrics.

Key assumptions and references detailed at the bottom of each fuel or vehicle webpage.

Example of Web Page Sections

Definitions

For detailed definitions, see:

Key Assumptions

The data and estimates presented here are based on the following key assumptions:

References

The following references are specific to this page; for all references in this ATB, see References.

Data Downloads Include Excel, Tableau, and Slides

2022 Transportation ATB Data

Download the 2022 Transportation ATB Data

For convenience, the transportation data used on this website is provided as an Excel workbook which contains tabs for fuel-only data, vehicle-only data, fuels merged with vehicles data (including LCOD and other calculated values) as well as a tab for marine fuel data:

2022_atb_vehfuels_download_v1.xlsx

We also provide Tableau workbooks that are used for all of the visualizations on the site:

2022_atb_tableau_download_v1.zip

A major source of the 2022 Transportation ATB vehicles and emissions data is Argonne National Laboratory, which develops and applies the Autonomie simulation tool and GREET model (Wang et al., 2022). Links to data from the Argonne National Laboratory report (Islam et al., 2022) on modeled vehicle price and fuel economy are available here.

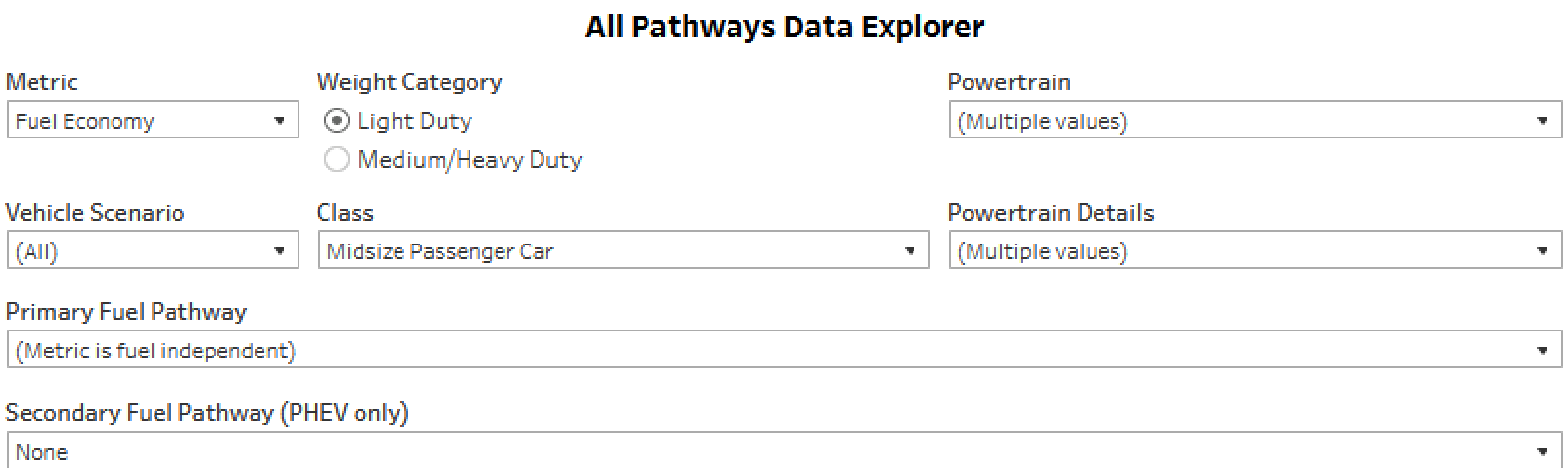
Tableau Workbook

2022 Transportation ATB Webinar

Explore All Data via Interactive or Downloadable Workbook

Tableau Workbook

View a Tableau workbook to further explore the data, including levelized cost of driving and emissions estimates with additional fuel pathways.



Conclusion

The ATB Vision

The Vision

The ATB—a flagship analytic product—facilitates access to credible, consistent, transparent, timely, relevant, and public data about current and future energy technologies and systems from a lab/DOE perspective for a large and diverse audience.

Please let us know your comments on what additional datasets or data metrics would be useful.

Sign up for updates!

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Thank You!

Questions? Please let us know at https://atb.nrel.gov/contact/.

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Acronyms and Abbreviations

ATB	Annual Technology Baseline
ANL	Argonne National Laboratory
BOB	blendstock for oxygenate blending
DOE	U.S. Department of Energy
EERE	Office of Energy Efficiency and Renewable Energy
EIA	U.S. Energy Information Administration
ETJ	ethanol to jet
FT	Fischer-Tropsch
FCEV	fuel cell electric vehicle
GREET	Greenhouse gases, Regulated Emissions, and Energy use in Transportation
H_2	hydrogen gas
H2A	Hydrogen Analyses Production Models
HDSAM	Hydrogen Delivery Scenario Analysis Model
HEFA	hydroprocessed esters and fatty acids
LCOD	levelized cost of driving
MDHD	medium- and heavy-duty vehicles
NREL	National Renewable Energy Laboratory
PEV	plug-in electric vehicle (includes both battery-electric and plug-in hybrid electric)
SAF	sustainable aviation fuel
TEMPO	Transportation Energy and Mobility Pathway Options Model
VMT	vehicle miles traveled
WTT	well to tank
WTW	well to wheels