Annual Technology Baseline: The 2020 Transportation Update

Laura Vimmerstedt, Paige Jadun, Chris Kinchin, and Matteo Muratori (NREL)

Amgad Elgowainy, Dave Gohlke, Ehsan Islam, and Aymeric Rousseau (Argonne National Laboratory)

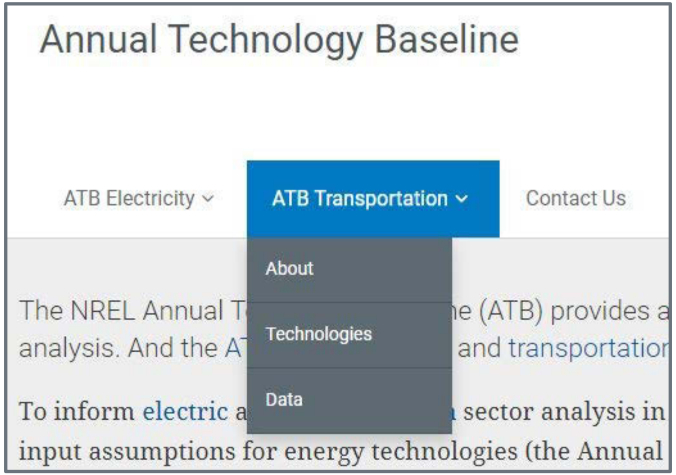
August 2020

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- The *rapid pace of technology development* results in reports of technology progress becoming rapidly outdated, making it difficult for researchers to find *current, credible, and consistent* information in one place.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.



atb.nrel.gov

ATB Project Overview

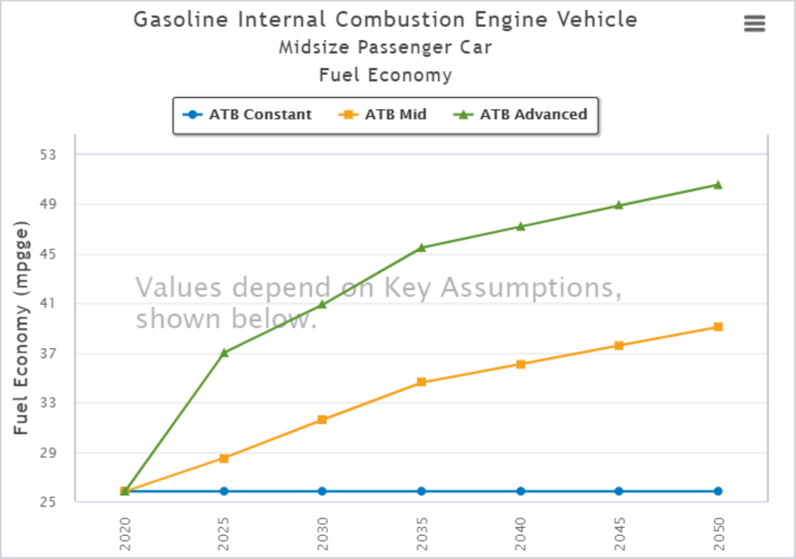
What are the content and purposes of the ATB?

The ATB is a …

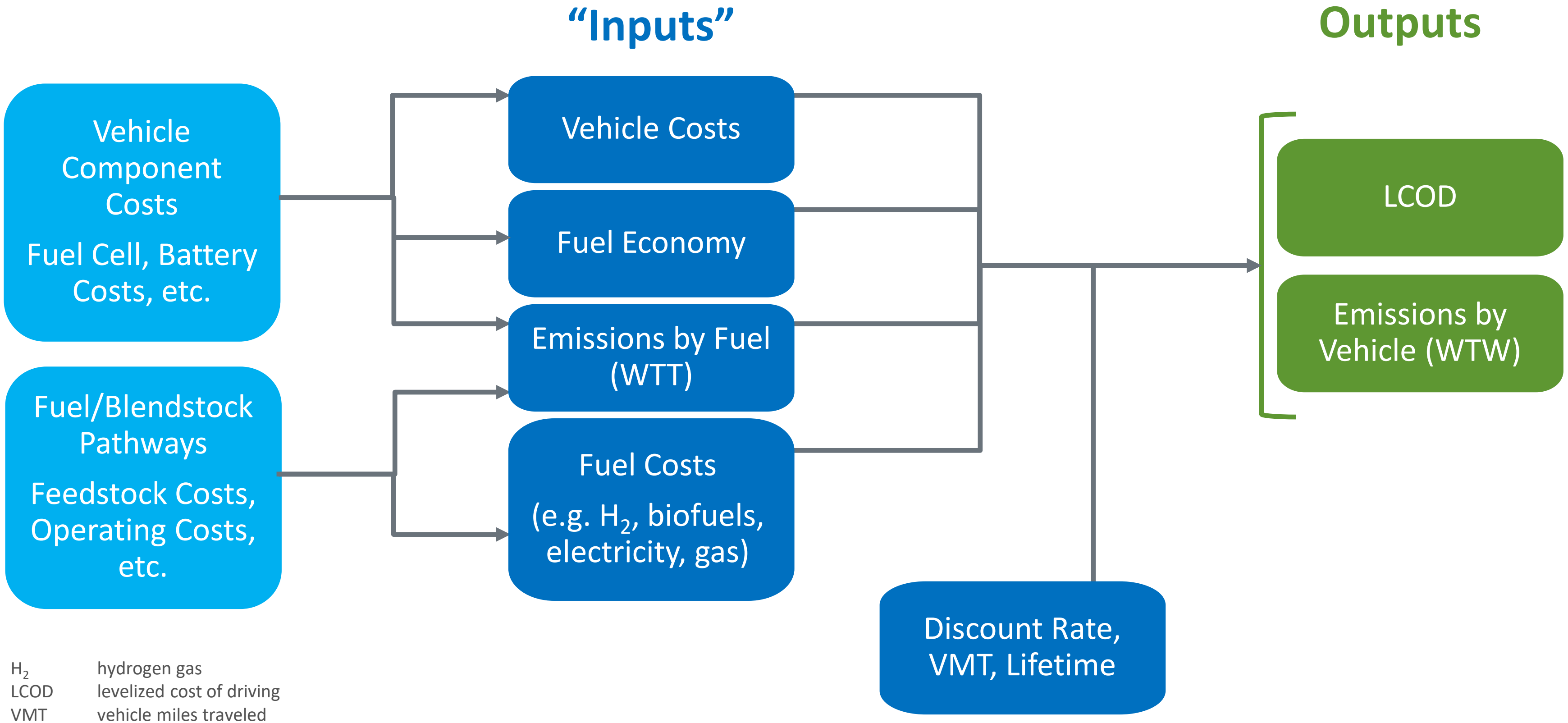
- Website and summary data set of cost and performance estimates for selected vehicles and fuels
- Link to publicly available resources
- A set of scenarios that highlight potential technological improvements
- Platform for interactive exploration, selection, and download of specific data.

The ATB is *not* a …

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



The ATB highlights key data.



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

Sources: See next slide

Summary of ATB 2020 Data Sources

Input	Primary Sources
Vehicle Component Costs (Fuel Cell, Battery Costs, etc.)	Technology trajectories based on EERE data, public reports, and technology targets and input into Autonomie modeling (Islam et al. 2020)
Vehicle Costs and Fuel Economy	Autonomie modeling (Islam et al. 2020); includes low-volume manufacturing estimates for fuel cell electric vehicles
Fuel/ Blendstock Pathways (Feedstock Costs, Operating Costs, etc.)	Published EERE techno-economic analysis (TEA) reports for biofuel pathways; H2A modeling and public reports for hydrogen pathways
Fuel Costs	Biofuels: Published EERE TEA reports Hydrogen: H2A and HDSAM models, public reports Gasoline, diesel, and ethanol: U.S. Energy Information Administration (EIA) and EIA Annual Energy Outlook (AEO) Electricity: EIA, AEO, and NREL Standard Scenarios (Cole et al. 2019)
Fuel Emissions (WTT)	GREET model
Discount Rate, VMT, Lifetime, and Charging Infrastructure	Consistent with other EERE analyses, including Elgowainy et al. (2016); Melaina et al. (2016); Bento, Roth, and Zuo (2018); and Lu (2006)

What is the value of the ATB?

Transparency, Consistency, Credibility, and Accessibility

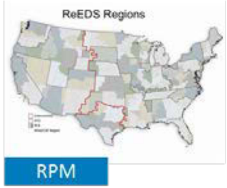
- **Consolidates** data from—and for use within — DOE's Sustainable Transportation analysis
- **Summarizes** data to high level needed for system-wide analysis
- **Organizes** data in highly structured format, enabling:
  - Display of data in interactive charts
  - Exploration, selection, and download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

Data is free, publicly available, and easily accessible.

The ATB for electricity has six-year record of success.

Model Inputs

Resource Planning Model



Regional Energy Deployment System

Analyses

Important Scenario Analyses Used ATB Projections

External Users

- Federal Agencies
- Consultants
- State Energy Offices
- Grid Operators
- Nonprofits
- International Organizations
- Utilities
- Academia
- Media

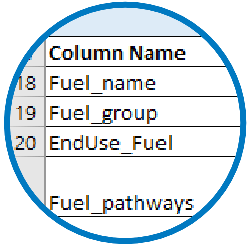
The ATB: Assumptions for Energy Systems Analysis

Core ATB Data

Base Year and Projected Data for…

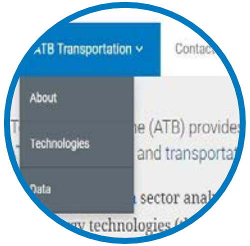
- Fuel Economy
- Vehicle Cost
- Fuel Cost
- Fuel Emissions
- Financing Assumptions
- Levelized Cost of Driving
- Emissions

ATB Product Suite



Spreadsheet

- Detailed citations
- Cost and performance projections, 2020–2050



atb.nrel.gov

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

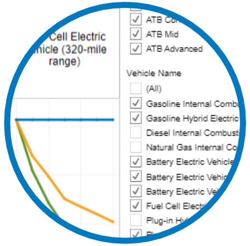
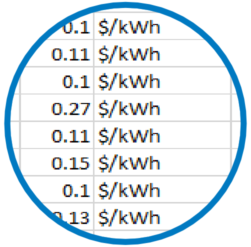


Tableau Workbook

- Summary of selected data (no calculations)
- Cost and performance projections, 2018–2050
- Interactive charts
- Visual exploration



Formatted Data

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

Presentation Slides

- Webinar presentation
- Summary presentation

Technology Specifics: Web Demo

- Fuels
- Vehicles

Annual Technology Baseline

ATB Electricity ⌄ | ATB Transportation ⌄ | Contact ⌄

- About
- Technologies
  - Light-Duty Vehicles
  - Fuel Technologies
- Data

Technologies

The 2020 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 through 2050 for light-duty vehicle technologies as well as conventional and alternative fuels, and it details the assumptions used to calculate those costs, such as gas and electricity prices, discount rates, and vehicle miles traveled. The 2020 Transportation ATB vehicle data are specifically for midsize passenger cars.

Explore the 2020 Transportation ATB:

VEHICLE TECHNOLOGIES | FUEL TECHNOLOGIES

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, reported in miles per gallon gasoline equivalent and representing how efficiently a vehicle converts fuel during operation
- Vehicle cost, which represents an estimated cost, including manufacturing costs plus profit, to the consumer purchasing a new vehicle.
- Levelized cost of driving, 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).

Annual Technology Baseline

ATB Electricity | ATB Transportation | Contact

- About
- Technologies
  - Light-Duty Vehicles
  - Fuel Technologies
    - On-Road Fuels
    - Jet Fuel
    - Marine Fuel
- Data

Fuel Technologies

The Transportation Annual Technology Baseline (ATB) provides price or cost, production, and emissions estimates for selected fuels.

The Transportation ATB presents fuels in three categories:

ON-ROAD FUELS | JET FUELS | MARINE FUELS

Diverse types of data are presented. Some fuel production pathways represent today's commercially available fuels, where data are available on high production volume market prices. Other data are estimated costs for current or future fuel production technologies, and may represent low or high volumes of production. In some cases, blendstock data are more readily accessible than fuel data.

A fuel is directly used in a vehicle, while a blendstock is one component of a fuel. Fuel price data include taxes for all fuels currently taxed, while blendstock data do not include taxes. Data for biofuels and hydrogen come from U.S. Department of Energy national laboratory analyses; data for petroleum-based fuels and conventional electricity sources come from other sources, primarily the U.S. Energy Information Administration.

- About
- Technologies
  - Light-Duty Vehicles
  - Fuel Technologies
    - On-Road Fuels
      - Gasoline and Ethanol
      - Ethanol
      - BOB
      - Diesel
      - Diesel Bio
      - Natural Gas Fuel
      - Electricity
      - Hydrogen
    - Jet Fuel
    - Marine Fuel
- Data

Fuel Pathway	Steam Meth Reform Future High	Biomass gasification	Low temp electrolysis Future	Hi temp electrolysis Future	Steam Meth Reform	Byproduct (ChlorAlk)	Byproduct (Cracking)	Low temp electrolysis	Hi temp electrolysis	Byproduct (ChlorAlk High)
Scenario	Future Model, High Vol	Future Model, High Vol	Future Model, High Vol	Future Model, High Vol	Current Model, Current Vol	Current Model, Current Vol	Current Model, Current Vol	Current Model, High Vol	Current Model, High Vol	Current Model, High Vol
Fuel Price ($/gge)	3.40	4.50	7.12	5.91	12.07	11.81	12.02	12.05	11.03	7.29
Fixed Capital Investment ($)	136,000,000	151,000,000	31,300,000	37,400,000	182,000,000	-	-	63,200,000	76,100,000	-
Fixed Operating Cost ($/yr)	7,710,000	13,200,000	3,130,000	4,250,000	9,280,000	-	-	5,000,000	6,510,000	-
Mature Industry Feedstock Production Cost ($/yr)	120,000,000	52,600,000	87,000,000	49,900,000	75,800,000	-	-	81,100,000	43,700,000	-
Other (non-feedstock) Variable Operating Cost ($/yr)	13,400,000	7,310,000	166,000	209,000	10,100,000	-	-	166,000	209,000	-
Throughput Capacity (MT/day)	341.00	140.00	23.70	43.80	341.00	-	-	22.60	41.20	-

- About
- Technologies
  - Light-Duty Vehicles
  - Fuel Technologies
    - On-Road Fuels
      - Gasoline and Ethanol
      - Ethanol
      - BOB
      - Diesel
      - Diesel Bio
      - Natural Gas Fuel
      - Electricity
      - Hydrogen
    - Jet Fuel
    - Marine Fuel
- Data

Fuel Pathway	PEV Charging Electricity, Future National Grid Mix	PEV Charging Electricity, Future High RE Penetration Grid Mix	PEV Charging Electricity, Future Low RE Penetration Grid Mix	DCFC Charging, Natl Grid	PEV Charging, Natl Grid	PEV Charging, CA Grid	PEV Charging, IN Grid	PEV Charging High Cost, Natl Grid
Scenario	Future Model, High Vol	Future Model, High Vol	Future Model, High Vol	Current Market	Current Market	Current Market	Current Market	Current Market
Fuel Price ($/gge)	3.37	3.71	3.37	9.10	3.71	5.05	3.37	4.38
Fuel Price ($/kWh)	0.10	0.11	0.10	0.27	0.11	0.15	0.10	0.13
CO2e Emissions (Well to Tank) (g/mmBtu)	95,900	43,000	115,000	139,000	139,000	80,000	251,000	139,000
NOX Emissions (Well to Tank) (g/mmBtu)	70.60	30.50	85.60	96.50	96.50	72.50	138.00	96.50
SOX Emissions (Well to Tank) (g/mmBtu)	121.00	48.60	132.00	220.00	220.00	43.90	516.00	220.00
PM Emissions (Well to Tank) (g/mmBtu)	23.40	25.00	23.90	32.50	32.50	25.50	48.00	32.50

- About
- Technologies
  - Light-Duty Vehicles
  - Fuel Technologies
    - On-Road Fuels
      - Gasoline and Ethanol
      - Ethanol
      - BOB
      - Diesel
      - Diesel Bio
      - Natural Gas Fuel
      - Electricity
      - Hydrogen
    - Jet Fuel
    - Marine Fuel
- Data

Fuel Pathway	Cellulosic Biochemical Ethanol	Cellulosic Thermochemical Ethanol	Cellulosic Biochemical Ethanol Low Volume	Starch Ethanol
Scenario	Future Model, High Vol	Future Model, High Vol	Future Model, Low Vol	Current Market
Plant Gate Fuel Price ($/gge)	3.75 - 3.96	3.65	5.31 - 5.52	2.25
Fixed Capital Investment ($)	417,000,000	563,000,000	479,000,000	-
Fixed Operating Cost ($/yr)	12,500,000	27,100,000	12,500,000	-
Mature Industry Feedstock Production Cost ($/yr)	54,200,000	45,800,000	75,000,000	-
Other (non-feedstock) Variable Operating Cost ($/yr)	25,000,000	4,170,000	34,400,000	-
Power Sales Revenue ($/yr)	6,250,000	-	6,250,000	-
Throughput Capacity (dt/day)	2,200	2,200	2,200	-
Total Product Yield (Gal/dt)	79.00 - 84.00	84.00	71.00 - 75.00	-

- About
- Technologies
  - Light-Duty Vehicles
  - Fuel Technologies
    - On-Road Fuels
    - Jet Fuel
    - Marine Fuel
- Data

Fuel Name	Alt Jet	Conventional Jet
Fuel Pathway	Biofuel (Jet)	Conventional Jet Fuel
Scenario	Future Model, High Vol	Current Market
Fuel Price ($/gge)	3.38 - 5.63	1.95
Fixed Capital Investment ($)	365,000,000 - 521,000,000	-
Fixed Operating Cost ($/yr)	15,600,000 - 26,100,000	-
Mature Industry Feedstock Production Cost ($/yr)	56,300,000 - 69,800,000	-
Other (non-feedstock) Variable Operating Cost ($/yr)	26,100,000 - 49,000,000	-
Power Sales Revenue ($/yr)	5,210,000	-
Throughput Capacity (dt/day)	2,200	-
Total Product Yield (Gal/dt)	50.00 - 80.00	-
Coproducts Sales Revenue ($/yr)	5,210,000 - 24,000,000	-
CO2e Emissions (Well to Tank) (g/mmBtu)	-55,900 - 5,280	14,400
NOX Emissions (Well to Tank) (g/mmBtu)	-	26.70

Key assumptions and references are detailed at the bottom of each fuel web page.

Example of Documented Assumptions on Web Page

Key Assumptions

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

- The high and low fuel prices are associated with particular years; because we do not provide a time-series trajectory, we show fuel price at a frozen level for all years so we can offer a range of fuel price values. In the levelized cost of driving and emissions charts, this approach clearly distinguishes effects of fuels from those of vehicle technologies because fuels remain constant while vehicle technologies change over time.
- The fuel price for hydrogen includes the production cost and the cost of infrastructure for hydrogen delivery and dispensing. We do not add a tax to hydrogen, because hydrogen is not currently taxed.
- Current hydrogen prices are highly variable due to the nascent market maturity. Fuel costs are often included in leases for fuel cell electric vehicles, are not paid by the user at the pump. The hydrogen price at the pump in California is approximately $16.50/kg (California Energy Commission and California Air Resources Board 2019). For the ATB, we base the Current market scenario on modeled production costs and current delivery and dispensing costs, as described below.
- The delivery and dispensing cost for the steam methane reforming Current market scenario is $12.53/ gge of the $13.70/gge. The estimate is the average of the range of current cost estimates from Rustagi et al. (2018) of $12.07/gge–$12.99/gge (corresponding to $11.80/kg-$12.70/kg in 2017$ from the original source). This range corresponds to the costs of hydrogen delivery and dispensing from two common station types today- a 180 kg/day station supplied by a gaseous tube trailer, and a 350 kg/day station supplied by a liquid tanker.
- The delivery and dispensing cost for the other non- Current market scenario pathways is estimated at $10.89/gge in the Current Modeled technology, Current Volume scenario, based on mid-volume tube-trailer delivery and low-volume manufacturing; $6.27/gge in the Current Modeled, High Volume scenario based on high-volume tube-trailer delivery and high-volume manufacturing; and $2.05/gge in the Future Modeled, High Volume scenario, based on the ultimate, high-volume hydrogen delivery and dispensing cost target. All delivery costs were modeled in the Hydrogen Delivery Scenario Analysis Model 3.2 (Argonne National Laboratory 2019c) and are based on gaseous hydrogen delivery. All values are converted based on 1.019 gge/kg hydrogen and updated to 2018 dollars (the delivery and dispensing costs above correspond to $10.65/kg, $6.13/kg, and $2.00/kg in 2016$ from HDSAM, respectively).

Annual Technology Baseline

NREL Transforming ENERGY

ATB Electricity | ATB Transportation | Contact

- About
- Technologies
  - Light-Duty Vehicles
  - Fuel Technologies
- Data

Technologies

The 2020 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 through 2050 for light-duty vehicle technologies as well as conventional and alternative fuels, and it details the assumptions used to calculate those costs, such as gas and electricity prices, discount rates, and vehicle miles traveled. The 2020 Transportation ATB vehicle data are specifically for midsize passenger cars.

Explore the 2020 Transportation ATB:

VEHICLE TECHNOLOGIES   FUEL TECHNOLOGIES

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, reported in miles per gallon gasoline equivalent and representing how efficiently a vehicle converts fuel during operation
- Vehicle cost, which represents an estimated cost, including manufacturing costs plus profit, to the consumer purchasing a new vehicle.
- Levelized cost of driving, 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).

Annual Technology Baseline

NREL Transforming ENERGY

ATB Electricity ATB Transportation Contact

- About
- Technologies
  - Light-Duty Vehicles
    - Gasoline
    - Diesel
    - Natural Gas
    - Gasoline Hybrid
    - Plug-in Hybrid (20-mile)
    - Plug-in Hybrid (50-mile)
    - Battery Electric (200-mile)
    - Battery Electric (300-mile)
    - Battery Electric (400-mile)
    - Fuel Cell (320-mile)
    - Comparison
  - Fuel Technologies
- Data

Light-Duty Vehicles

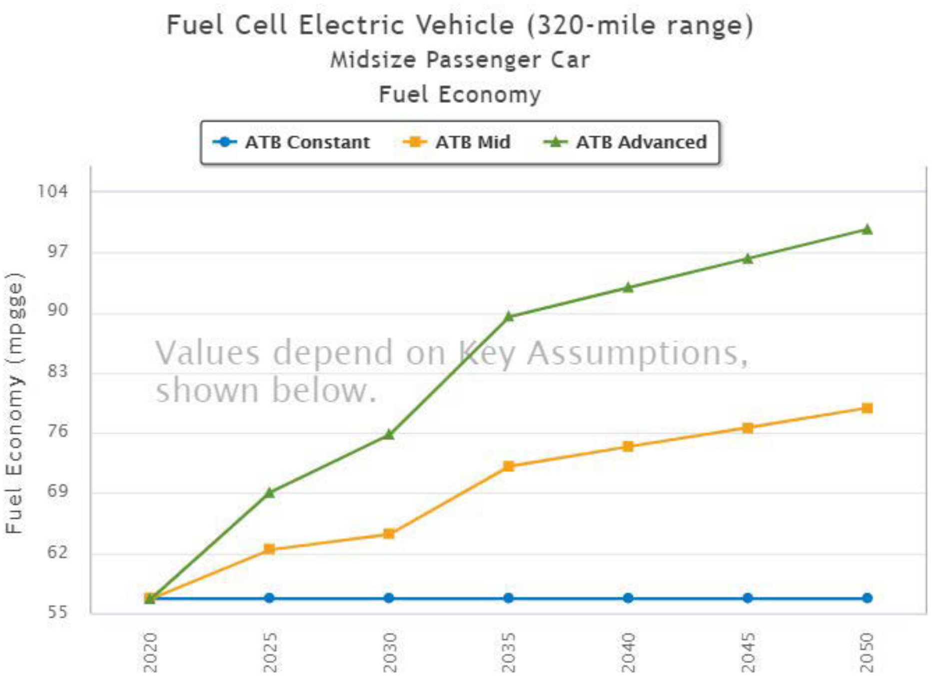
The 2020 Transportation Annual Technology Baseline (ATB) provides current and future projections of cost and performance for select light-duty vehicles and fuels. The 2020 Transportation ATB vehicle data are specifically for midsize passenger cars.

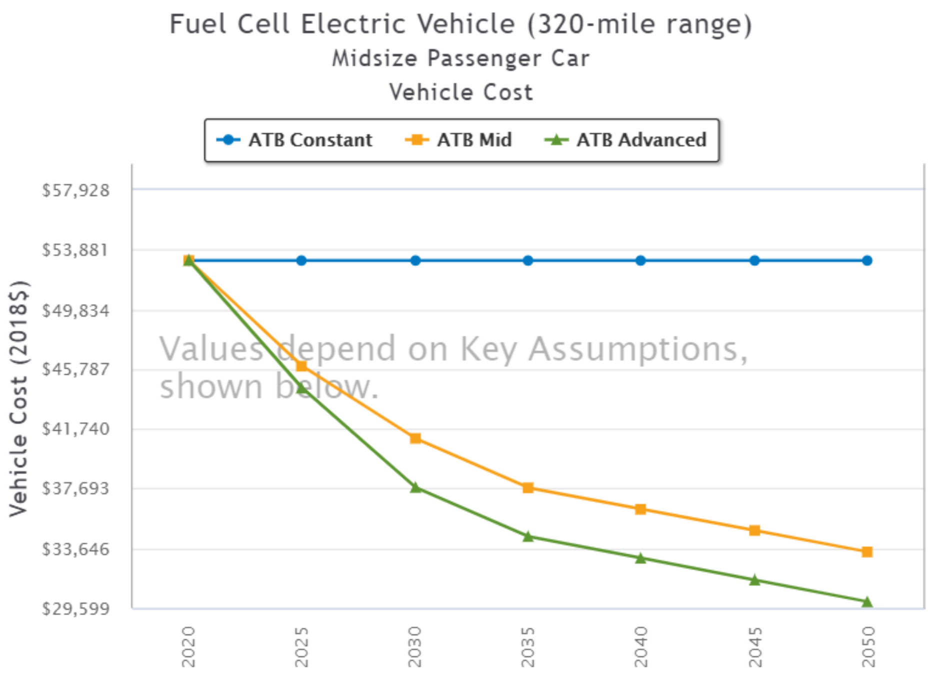
The Transportation ATB provides data in a series of interactive charts for either a single year or a trajectory out to 2050 showing:

- Fuel economy, reported in miles per gallon gasoline equivalent and representing how efficiently a vehicle converts fuel during operation
- Vehicle cost, which represents an estimated cost, including manufacturing costs plus profit, to the consumer purchasing a new vehicle.
- Levelized cost of driving, 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.

Cost, Fuel Economy: 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.

Fuel Cell Electric Vehicle (320-mile range)

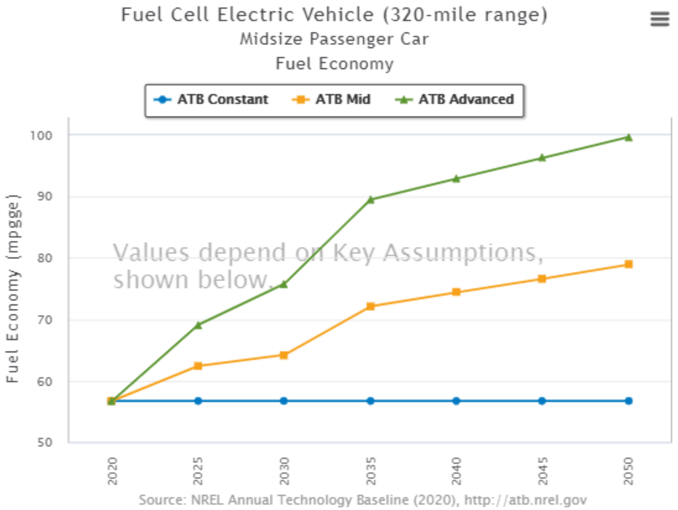
Explore key cost and performance metrics for fuel cell electric vehicles, including vehicle cost, fuel economy, levelized cost of driving, and emissions. Caveats for comparing powertrains are listed in the light-duty vehicle Comparison page.

Fuel Economy

The chart below shows fuel economy, which depends on fuel type. Fuel economy is also used to calculate levelized cost of driving.

Select Fuel Pathway

- ◉ Baseline
- ○ Lowest Cost
- ○ Lowest CO2e Emissions



ATB Electricity ATB Transportation Contact

- About
- Technologies
  - Light-Duty Vehicles
    - Gasoline
    - Diesel
    - Natural Gas
    - Gasoline Hybrid
    - Plug-in Hybrid (20-mile)
    - Plug-in Hybrid (50-mile)
    - Battery Electric (200-mile)
    - Battery Electric (300-mile)
    - Battery Electric (400-mile)
    - Fuel Cell (320-mile)
    - Comparison
  - Fuel Technologies
- Data

Battery Electric Vehicle (300-mile range)

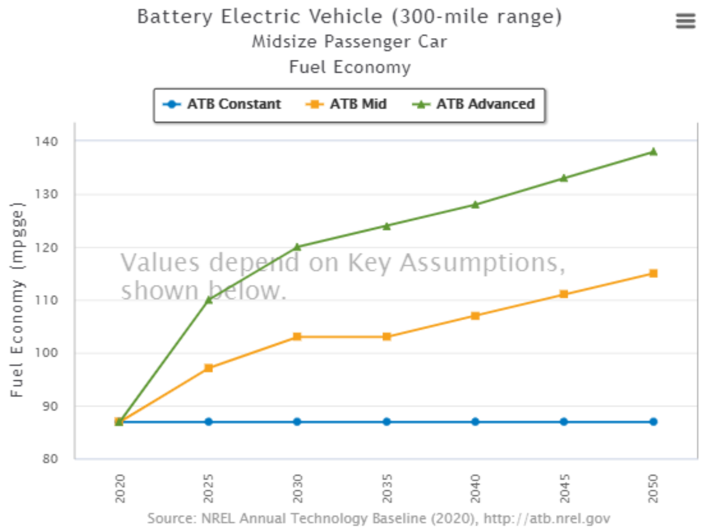
Explore key cost and performance metrics for 300-mile-range battery electric vehicles, including vehicle cost, fuel economy, levelized cost of driving, and emissions. Caveats for comparing powertrains are listed in the Light-Duty Vehicle Comparison page.

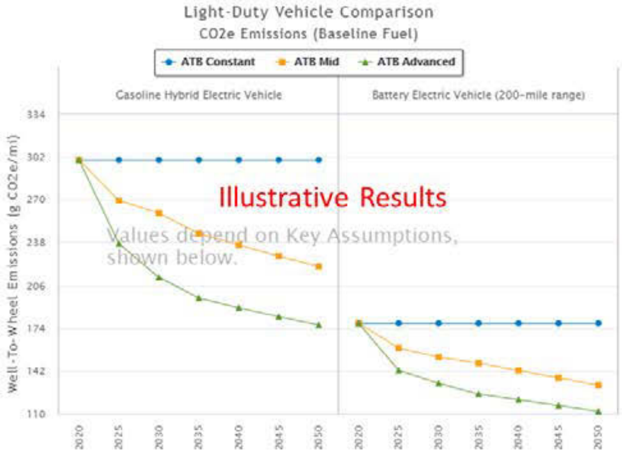
Fuel Economy

The chart below shows fuel economy, which depends on fuel type. Fuel economy is also used to calculate levelized cost of driving.

Select Fuel Pathway

- Baseline
- Lowest Cost
- Lowest CO2e Emissions

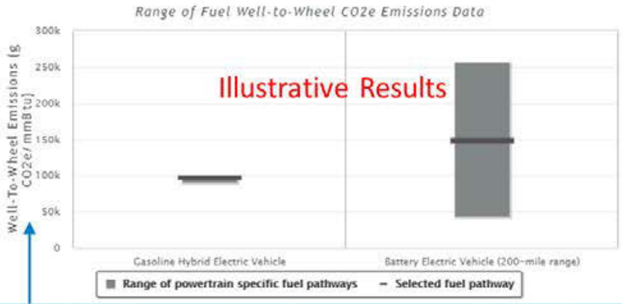


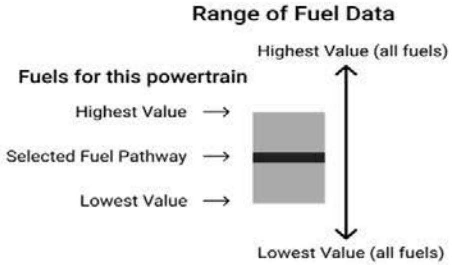


Trajectories show the levelized cost of driving or emissions for a given powertrain on a per mile basis.

Estimates are calculated using a selected fuel pathway, for which the cost and emissions are held constant over time.

Therefore, changes over time are attributable only to projected vehicle cost and performance. This approach clearly distinguishes effects of fuels from those of vehicle technologies because fuels remain constant while vehicle technologies change over time.





Fuel data shows well-to-wheels emissions (with the emissions chart) and cost (with the LCOD chart) for both the selected fuel (black line) and the range of fuels in the ATB (grey for emissions bars/green for cost).

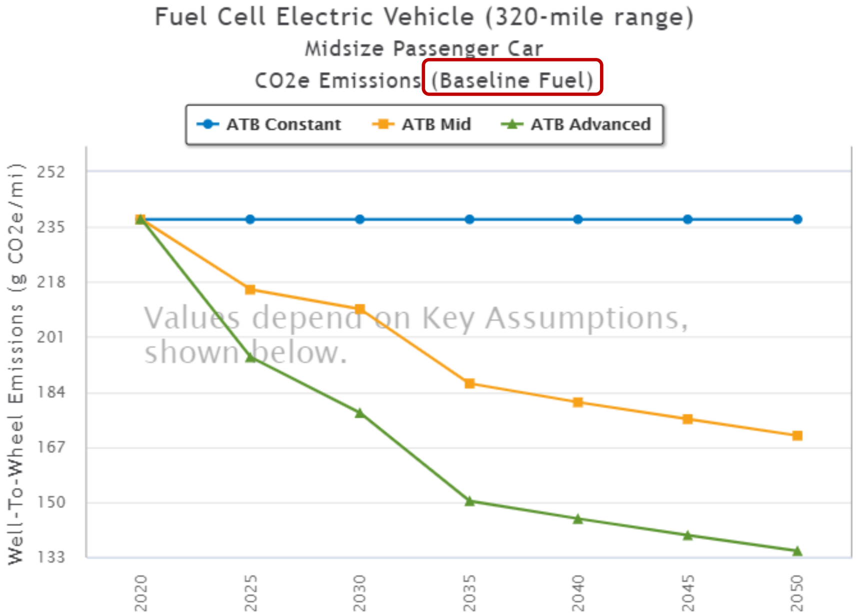
The fuel cost per gge and emissions per mmBtu are constant over time, clearly distinguishing the effect of fuels from those of vehicle technologies. Different fuel scenarios can be selected using the fuel pathway selector.

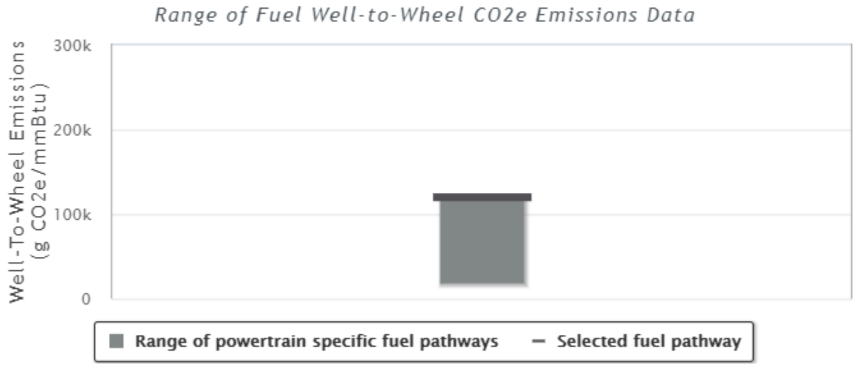
Hovering over the bar will report the cost ($/gge) or emissions (g/mmBtu) for the selected fuel and the maximum and minimum costs or emissions of the available fuels for the relevant powertrain.

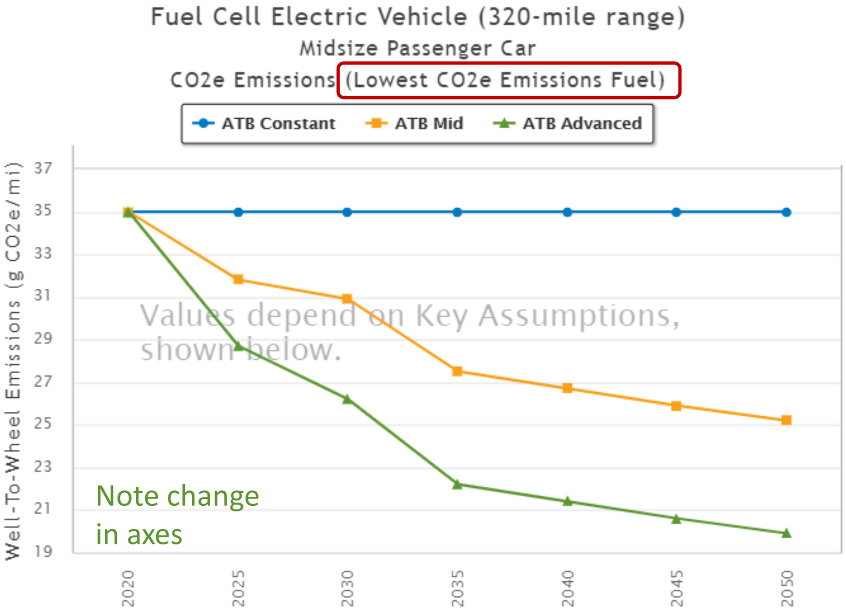
Selected Fuel Pathways

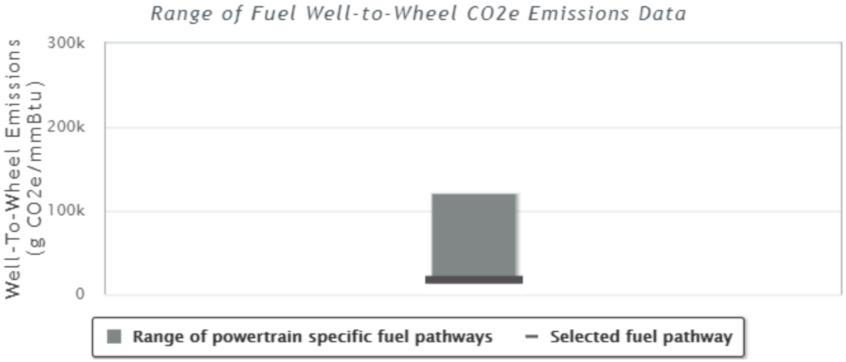
Selected Fuel Pathways by Powertrain

Powertrain	Baseline Fuel Pathway	Lowest Cost Fuel Pathway	Lowest CO_2e Emissions Fuel Pathway
Gasoline internal combustion engine vehicle, hybrid electric vehicle, charge-sustaining plug-in hybrid electric vehicle	Conventional gasoline (E10) with starch ethanol	Conventional gasoline (E10) with starch ethanol	Reformulated E15 gasoline with cellulosic thermochemical ethanol
Diesel internal combustion engine vehicle	Conventional low-sulfur diesel	Conventional low-sulfur diesel (2050 low price)	Biofuel (diesel)
Compressed natural gas internal combustion engine vehicle	Natural gas	Natural gas	Natural gas
BEV, charge-depleting plug-in hybrid electric vehicle	Plug-in electric vehicle charging electricity,national grid mix	Plug-in electric vehicle charging electricity, future low RE penetration grid mix	Plug-in electric vehicle charging electricity, future high RE penetration grid mix
Fuel cell electric vehicle	Steam methane reforming (Current Modeled, Current Volume)	Steam methane reforming (Future Modeled, High Volume)	Low-temperature electrolysis (Future Modeled, High Volume)


Fuel Cell Electric Vehicle (320-mile range)
Midsize Passenger Car
CO2e Emissions (Baseline Fuel)
ATB Constant
ATB Mid
ATB Advanced
Well-To-Wheel Emissions (g CO2e/mi)
252
235
218
201
184
167
150
133
Values depend on Key Assumptions, shown below.
2020
2025
2030
2035
2040
2045
2050


Range of Fuel Well-to-Wheel CO2e Emissions Data
Well-To-Wheel Emissions (g CO2e/mmBtu)
300k
200k
100k
0
Range of powertrain specific fuel pathways
Selected fuel pathway


Fuel Cell Electric Vehicle (320-mile range)
Midsize Passenger Car
CO2e Emissions (Lowest CO2e Emissions Fuel)
ATB Constant
ATB Mid
ATB Advanced
Well-To-Wheel Emissions (g CO2e/mi)
37
35
33
31
29
27
25
23
21
19
Values depend on Key Assumptions, shown below.
Note change in axes
2020
2025
2030
2035
2040
2045
2050


Range of Fuel Well-to-Wheel CO2e Emissions Data
Well-To-Wheel Emissions (g CO2e/mmBtu)
300k
200k
100k
0
Range of powertrain specific fuel pathways
Selected fuel pathway

Key assumptions and references detailed at the bottom of each vehicle web page.

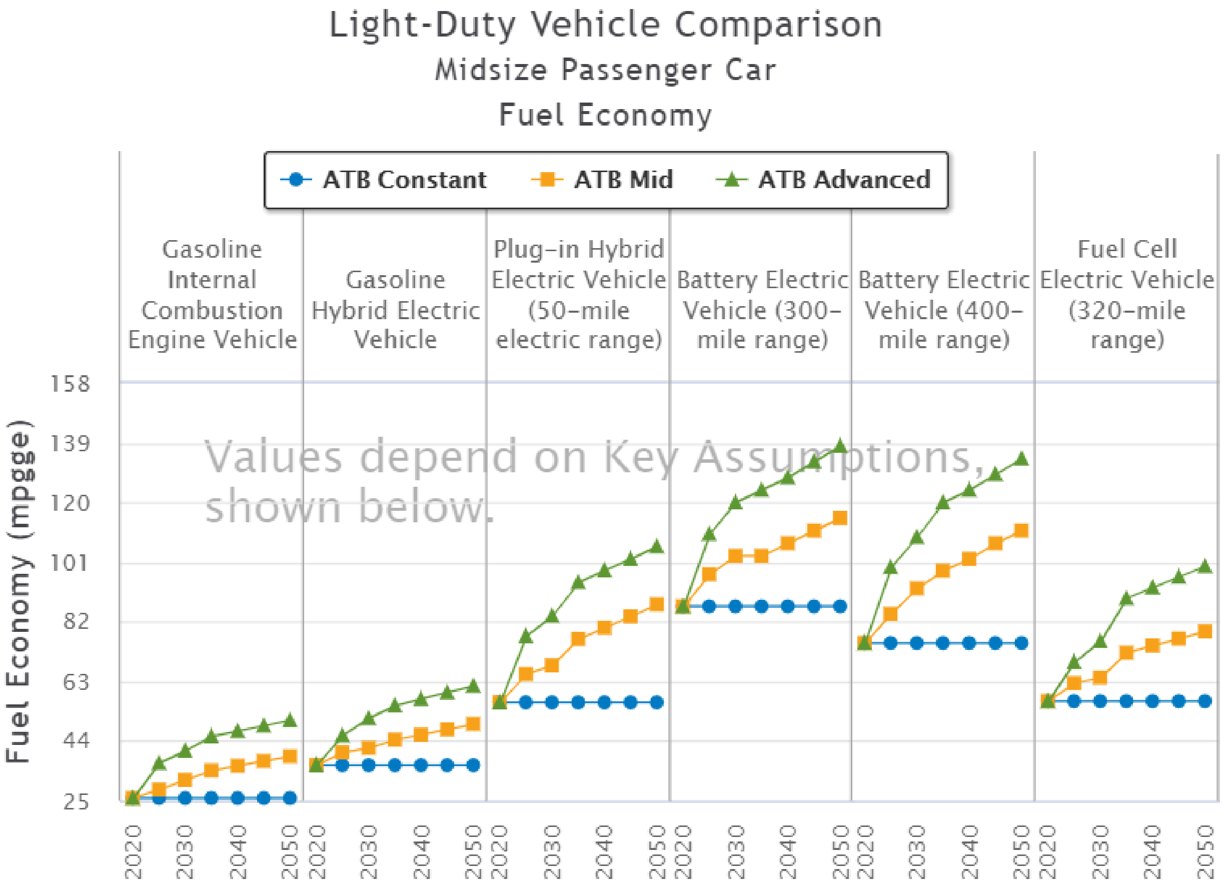
Example of Documented Assumptions on Web Page

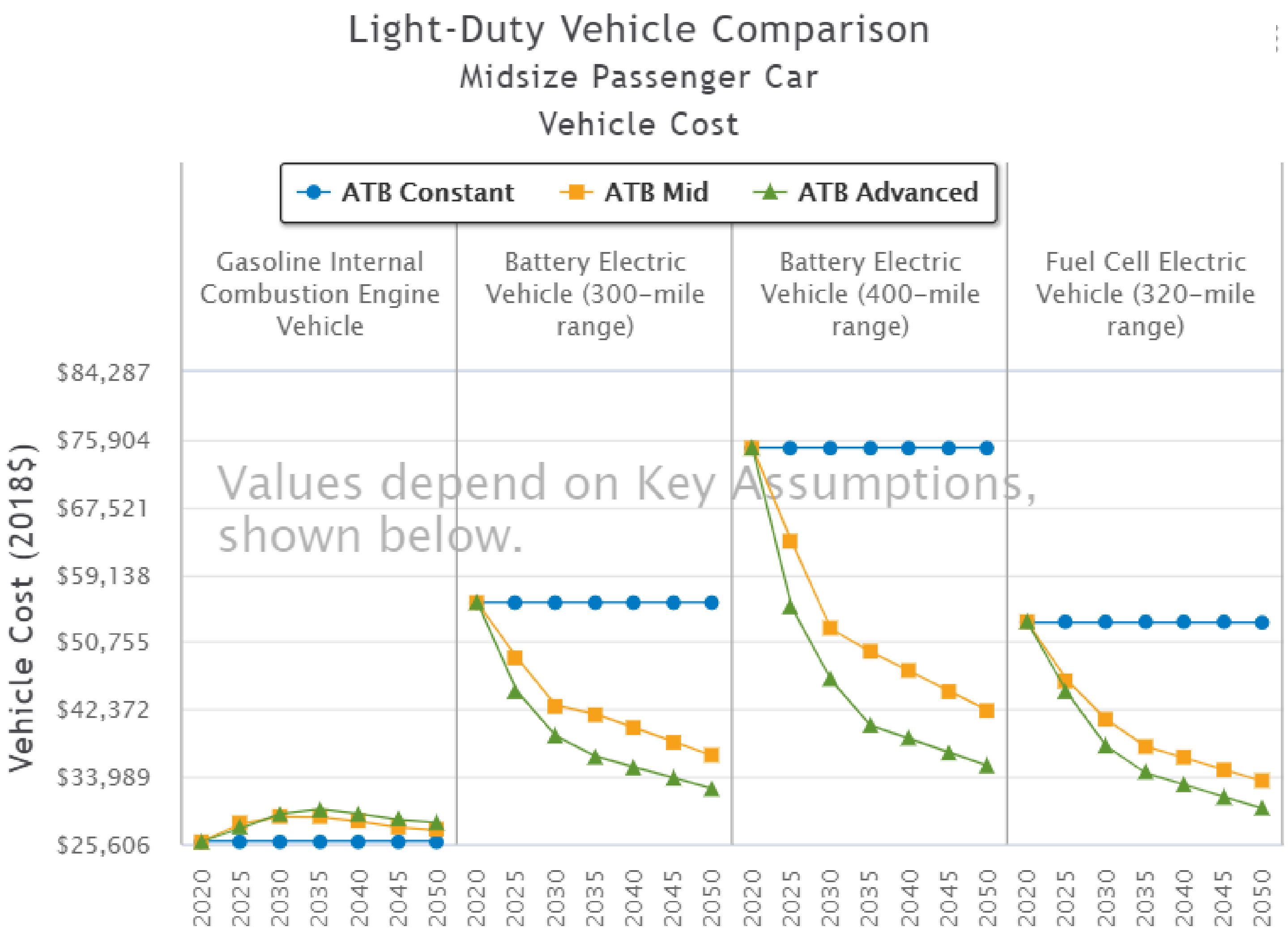
Key Assumptions

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

- The cost and fuel economy trajectories for fuel cell electric vehicles are based on estimates of commercially available technologies in the respective years. Estimates of fuel cell costs and hydrogen storage vessel costs were based on an assumption of low production volume manufacturing today that gradually increases to high production volume manufacturing by 2050. These costs were adapted from James et al. (2018) and Adams, et al. (2019). All other vehicle component assumptions (e.g. lightweighting and aerodynamic improvements over time) are consistent with Islam et al. (2020). The ATB Mid trajectory corresponds to the Base performance, Low technology progress case. The ATB Advanced trajectory corresponds to the Base performance, High technology progress case. The ATB Constant trajectory is set to the 2020 values in the Base performance, Low technology case and held constant through 2050.
- The assumed fuel cell and hydrogen storage tank cost trajectories can be found in the definition for fuel cell electric vehicles.
- Fuel cell electric vehicles are currently manufactured at low production volume, and are available for sale or lease in the US for approximately $58,300 or $379-$389/month. Today, the purchase or lease of the vehicle commonly includes access to hydrogen fuel for free for up to 3 years or $13,000-$15,000 (Honda 2020; Hyundai 2020; Baronas and Achtelik 2019).
- The Transportation ATB presents estimates for a representative, single size of light-duty vehicle (midsize); we do not account for variations in make, model, and trim or for pricing incentives or geographic heterogeneity that influence prices in the market. As a result, representative values shown here may differ from specific models available on the market.

Multi-Powertrain View Enables Comparison




Light-Duty Vehicle Comparison
Midsize Passenger Car
Vehicle Cost
ATB Constant
ATB Mid
ATB Advanced
Gasoline Internal Combustion Engine Vehicle
Battery Electric Vehicle (300-mile range)
Battery Electric Vehicle (400-mile range)
Fuel Cell Electric Vehicle (320-mile range)
Vehicle Cost (2018$)
$84,287
$75,904
$67,521
$59,138
$50,755
$42,372
$33,989
$25,606
Values depend on Key Assumptions, shown below.
2020
2025
2030
2035
2040
2045
2050

Annual Technology Baseline

NREL Transforming ENERGY

ATB Electricity ATB Transportation Contact

- About
- Definitions
- Literature Context
- References
- Technologies
- Data

Definitions

Definitions of common terms in the 2020 Transportation ATB are presented below.

See definitions for:

VEHICLES FUELS SCENARIOS METRICS

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.

The battery cost assumptions used in the Annual Technology Baseline vehicle cost trajectories are shown below and are presented at the *battery pack level*. The ATB Mid trajectory corresponds with the Base performance, Low technology progress case in Islam et al. (2020), which reaches around $120/kilowatt-hour in 2050. The ATB Advanced trajectory follows the Base performance, High technology progress case from Islam et al. (2020) which reaches around $80/kilowatt-hour in 2050, consistent with goals from the Vehicle Technologies Office (Boyd 2018). The ATB Constant trajectory is held constant at the 2020 value for ATB Mid. Costs are shown are for usable energy.

Note that estimates used in the ATB Advanced trajectory are higher than some recent battery cost estimates from other references (Lutsey and Nicholas 2019; Kah 2019; BloombergNEF 2019). Some variations may be attributed to differences in the level of reporting; the Transportation ATB presents battery costs for usable energy at the pack level. The cost estimates are consistent with the U.S. Department of Energy Vehicle Technologies Office.

- About
- Technologies
- **Data**

Download Combined Vehicle & Fuel Data:

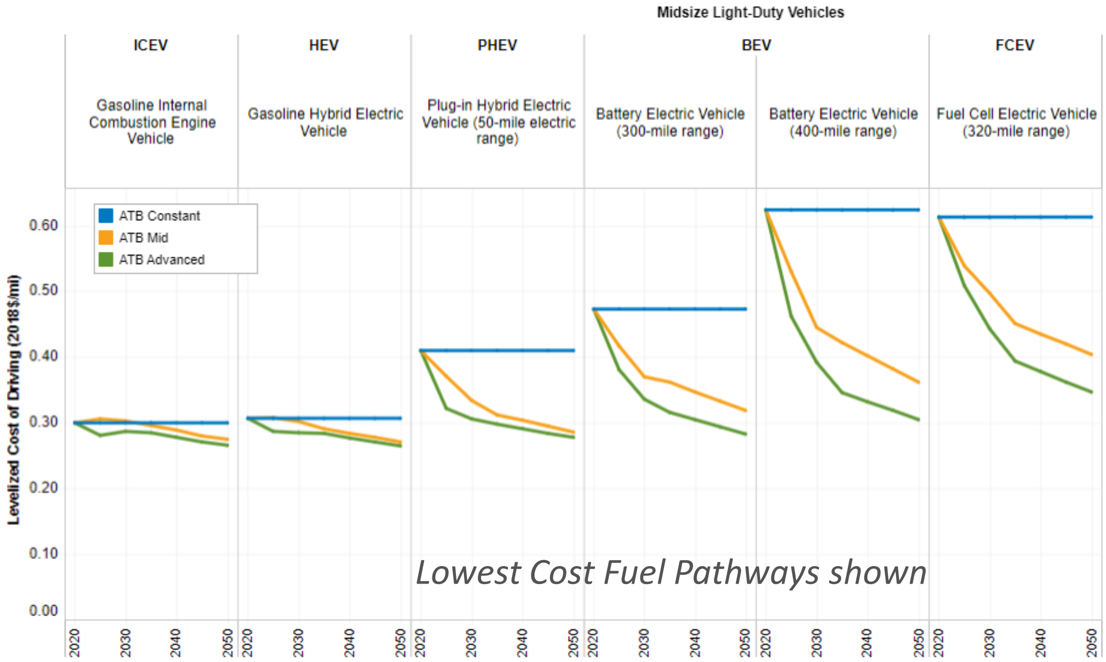
DOWNLOAD 2020 ATB VEHICLE & FUEL DATA

The full data set can be download and explored in an embedded Tableau workbook.

Tableau Workbook

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

Cost Trajectory | Cost Year | Fuel Econ. Trajectory | Fuel Econ Year | LCOD+Fuels Trajectory | LCOD Year | Emissions+Fuels Trajectory | Emissions Year | Fuels Comp View | Powertrain View (1 Fuel)



Scenario name
- [x] (All)
- [x] ATB Constant
- [x] ATB Mid
- [x] ATB Advanced

Vehicle Name
- [ ] (All)
- [x] Gasoline Internal Combustion Engine Vehicle
- [x] Gasoline Hybrid Electric Vehicle
- [ ] Diesel Internal Combustion Engine Vehicle
- [ ] Natural Gas Internal Combustion Engine Vehicle
- [ ] Battery Electric Vehicle (200-mile range)
- [x] Battery Electric Vehicle (300-mile range)
- [x] Battery Electric Vehicle (400-mile range)
- [x] Fuel Cell Electric Vehicle (320-mile range)
- [ ] Plug-in Hybrid Electric Vehicle (20-mile electric range)
- [x] Plug-in Hybrid Electric Vehicle (50-mile electric range)

BEV: Battery electric vehicle
BOB: Blendstock for Oxygenate Blending
DCFC: Direct-current fast charger
FCEV: Fuel cell electric vehicle
HEV: Hybrid electric vehicle
ICEV: Internal combustion engine vehicle
PEV: Plug-in electric vehicle
PHEV: Plug-in hybrid electric vehicle
RE: Renewable Energy

Complete Fuel Pathway
For PHEVs, the first term is charge depleting fuel, and second term is charge sustaining fuel
Multiple fuel pathways currently appear as different lines. Hover over the data point to see the fuel pathway.

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 data sets or data metrics would be useful.

Sign up for updates!

To receive occasional email updates and announcements about the Annual Technology Baseline, sign up at atb.nrel.gov/contact/register.

Acknowledgements

This work was funded by the U.S. Department of Energy's Strategic Priorities and Impact Analysis portfolio, Hydrogen and Fuel Cell Technologies Office, Vehicle Technologies Office, and Bioenergy Technologies Office, all within the Office of Energy Efficiency and Renewable Energy.

Thank You!

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

www.nrel.gov

NREL/PR-6A20-77319

This project is led by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Strategic Priorities and Impacts Analysis, Bioenergy Technologies Office, Fuel Cell Technologies Office, and Vehicle Technologies Office. The views expressed in this presentation do not necessarily represent the views of the DOE or the U.S. Government.

NREL Transforming ENERGY

References

Bento, Antonio, Kevin Roth, and Yiou Zuo. 2018. "Vehicle Lifetime and Scrappage Behavior: Trends in the U.S. Used Car Market." *The Energy Journal* 39(1). https://doi.org/10.5547/01956574.39.1.aben.

Cole, Wesley, Nathaniel Gates, Trieu Mai, Daniel Greer, and Paritosh Das. 2019. *2019 Standard Scenarios Report: A U.S. Electricity Sector Outlook*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-TP-6A20-74110. https://doi.org/10.2172/1580330.

Elgowainy, Amgad, Jeongwoo Han, Jacob Ward, Fred Joseck, David Gohlke, Alicia Lindauer, Todd Ramsden, et al. 2016. *Cradle-to-Grave Lifecycle Analysis of U.S. Light-Duty Vehicle-Fuel Pathways: A Greenhouse Gas Emissions and Economic Assessment of Current (2015) and Future (2025–2030) Technologies*. Argonne National Laboratory. ANL/ESD-16/7. Rev. 1. https://doi.org/10.2172/1324467.

Islam, Ehsan Sabri, Ayman Moawad, Namdoo Kim, and Aymeric Rousseau. 2020. *Energy Consumption and Cost Reduction of Future Light-Duty Vehicles Through Advanced Vehicle Technologies: A Modeling Simulation Study Through 2050*. Argonne National Laboratory. ANL/ESD-19/10/. https://www.autonomie.net/pdfs/ANL - Islam - 2020 - Energy Consumption and Cost Reduction of Future Light-Duty Vehicles through Advanced Vehicle Technologies A Modeling Simulation Study Through 2050.pdf.

Lu, S. 2006. *Vehicle Survivability and Travel Mileage Schedules*. National Highway Traffic Safety Administration (NHTSA) National Center for Statistics and Analysis. DOT HS 809 952. https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/809952

Melaina, Marc, Brian Bush, Joshua Eichman, Eric Wood, Dana Stright, Venkat Krishnan, David Keyser, et al. 2016. *National Economic Value Assessment of Plug-in Electric Vehicles: Volume I*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5400-66980. https://doi.org/10.2172/1338175.

Acronyms and Abbreviations

ATB	Annual Technology Baseline
DOE	U.S. Department of Energy
EERE	Office of Energy Efficiency and Renewable Energy, DOE
EIA	U.S. Energy Information Administration
FCEV	fuel cell electric vehicle
GREET	Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation
H2A	Hydrogen Analyses
HDSAM	Hydrogen Delivery Scenario Analysis Model
LCOD	levelized cost of driving
VMT	vehicle miles traveled
WTT	well to tank
WTW	well to wheels