Transportation 2022:
Electric Vehicles Charge Ahead

May 4th, 2022

Meet Your Panelists

- Brian Olsen

- Trevor Swanson

Agenda

- Introduction
- Vehicle Types
- Battery/Motor Technology
- Fuel Cost/Emissions Comparison
- Market Availability
- Federal/State/Utility Incentives
- Recharging Stations
- Impact on the Grid
- Utility EV Planning
- Challenges

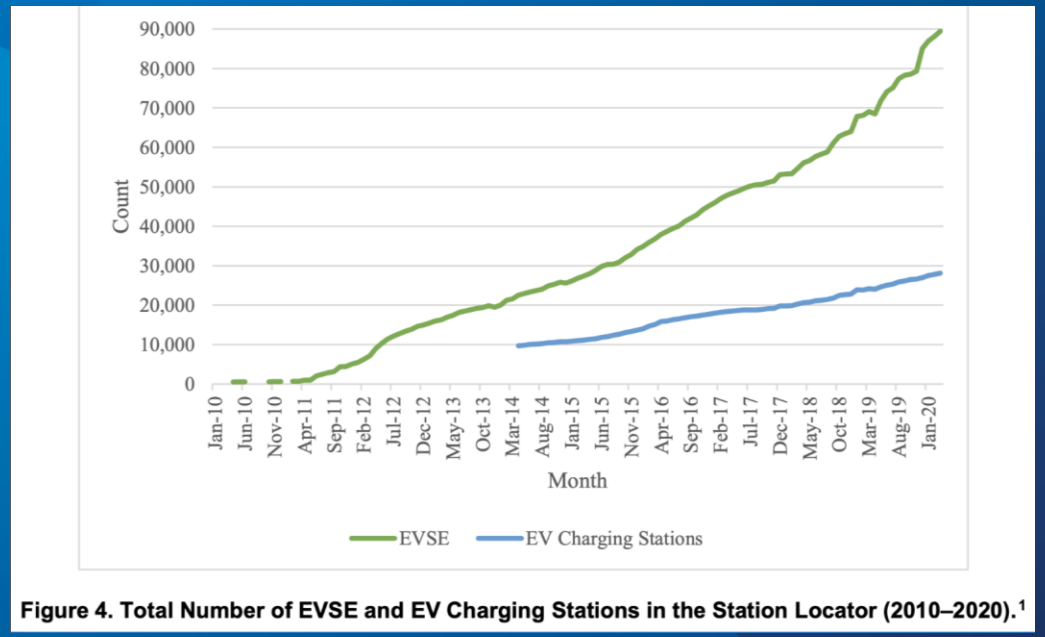


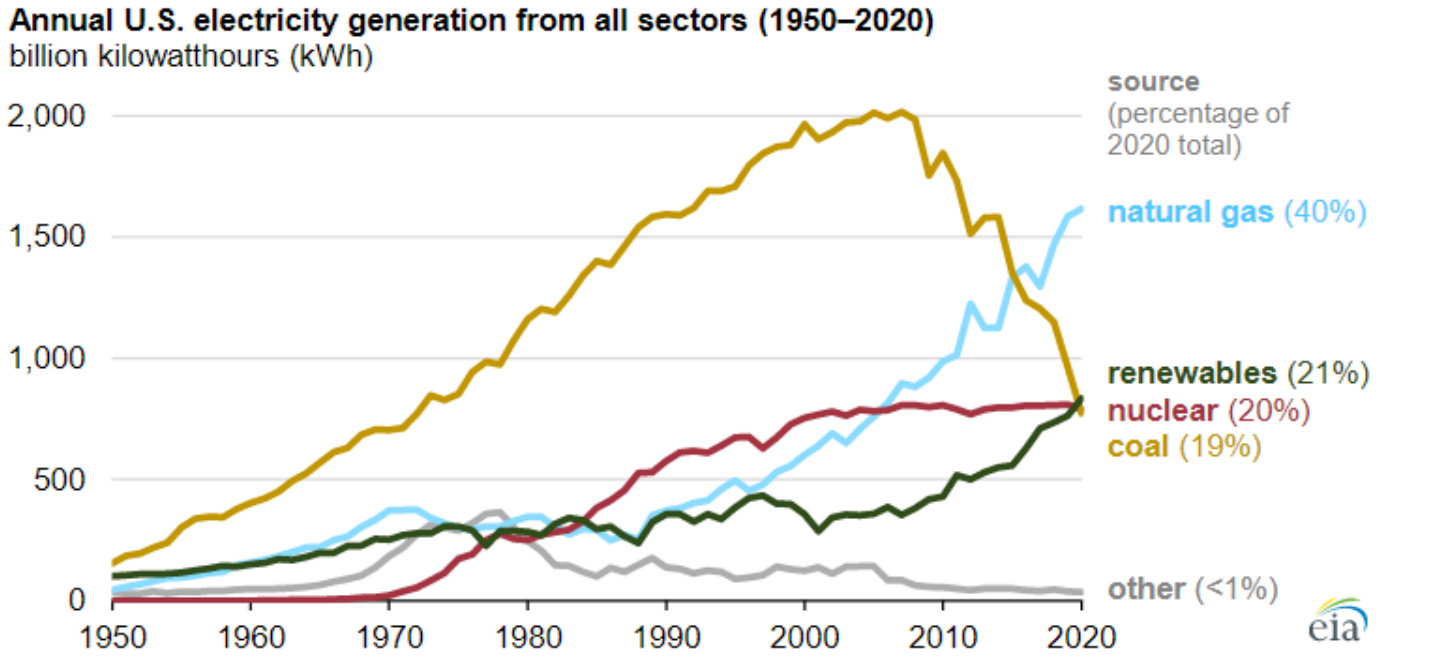
Figure 4. Total Number of EVSE and EV Charging Stations in the Station Locator (2010–2020).[1]

cleantechnica.com

Introduction

Overarching Goals of EVs

- Replacing petroleum
  - In 2018, the transportation sector used 28% of total U.S. energy consumed. By 2020, it was 26%
    - Americans consumed just under one gallon of gasoline per capita per day, down by 14% from the previous year
    - Efficiency of converting liquid fuel to horsepower by combustion is only about 12%-30% for gasoline engines, vs. ~77% for EVs

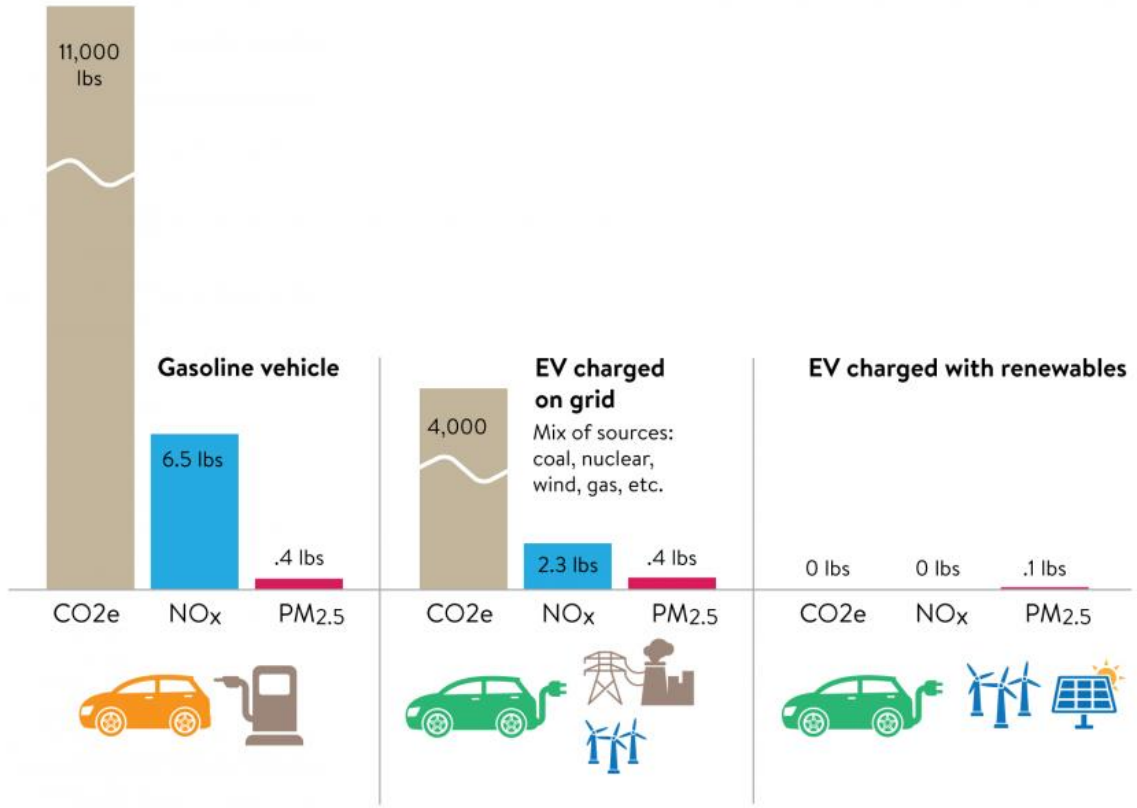


Source: U.S. Energy Information Administration (EIA), *Monthly Energy Review*
Note: This graph shows electricity net generation in all sectors (electric power, industrial, commercial, and residential) and includes both utility-scale and small-scale (customer-sited, less than 1 megawatt) solar.

Introduction

Overarching Goal of EVs

- Improve Air Quality and reduce greenhouse gases and local air pollutants, including particulate matter



https://www.pca.state.mn.us/air/electric-vehicles

Introduction

Electric Cars are Not New!

- William Morrison of Des Moines, Iowa, built a six-passenger wagon in 1891.
- In 1897, the first commercial EV application was taxis
- Of the 4,192 cars produced in the U.S. in 1900, 28% were electric.
- The 1902 Woods Phaeton had a range of 18 miles, a top speed of 14 mph and cost $2,000.
  - In 1916, Woods invented a hybrid car.
- Electric vehicles had disappeared by 1935.
  - Discovery of Texas crude oil
  - Marketing stigmatization
  - Lack of technology improvement
  - Electric starter invented by Charles Kettering
  - Mass production introduced by Henry Ford-affordability
  - Introduction of the highway system

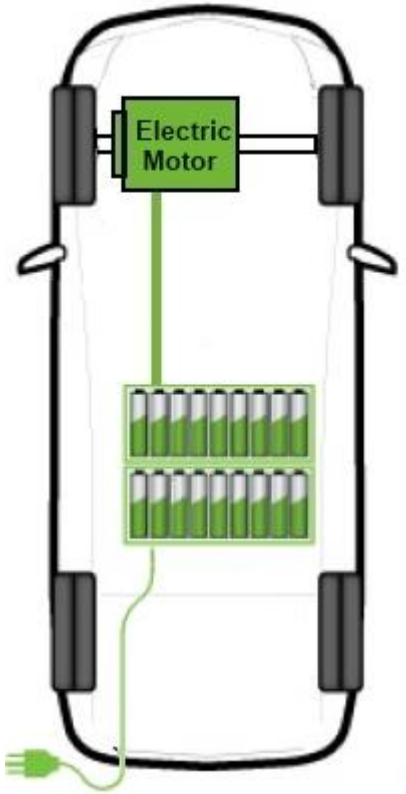
Source: New York Public Library

Vehicle Types

Battery Electric Vehicle (BEV)

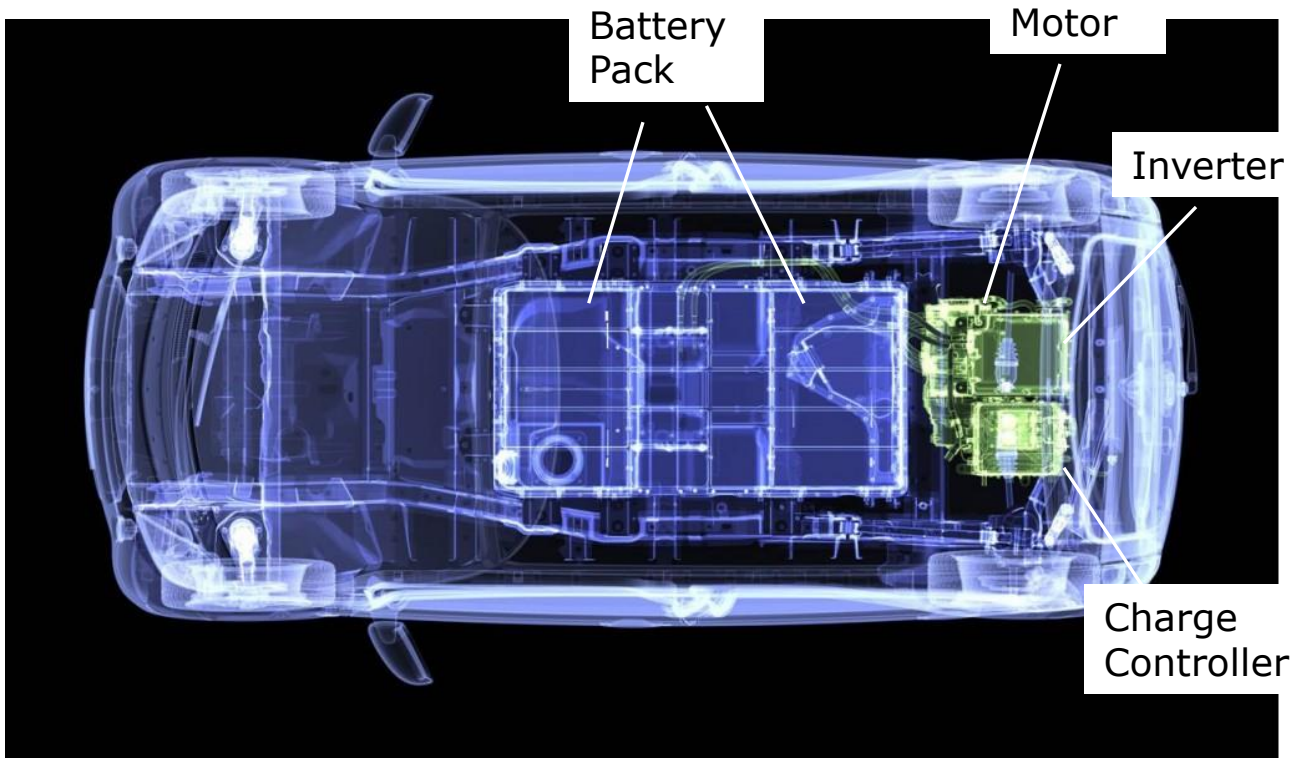
- Electric motor drive only
- Grid power source for battery charge
  - Many sizes with ranges over 500 miles and increasing each year
- BEV examples[1]:
  - Mustang Mach-E
  - Polestar 2
  - VW ID.4
  - Hyundai IONIQ 5
  - Nissan Leaf
  - Porsche. Taycan **Turbo** S

[1]Toms Guide



Vehicle Types

Battery Electric Vehicle (BEV)

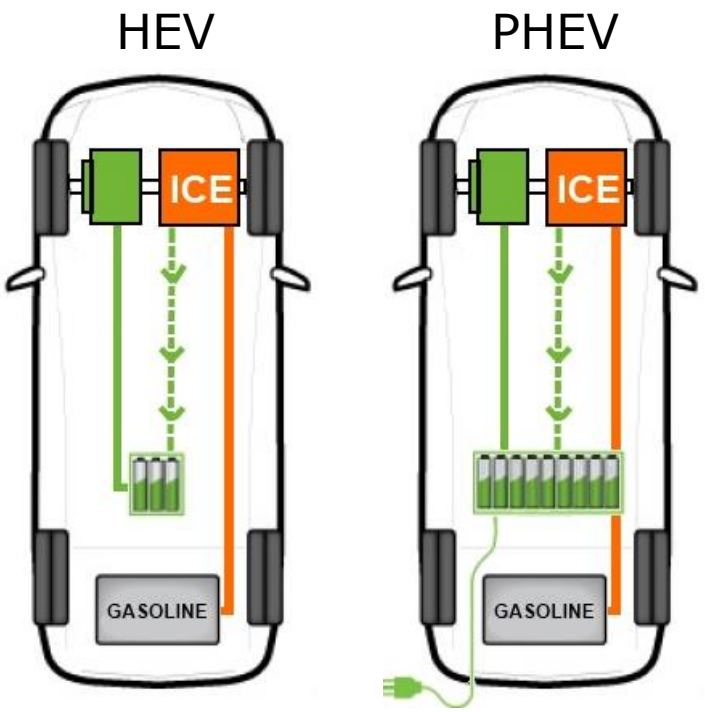


Source: Mitsubishi via All Cars Electric

Vehicle Types

Hybrid Electric Vehicle (HEV/PHEV) - Parallel

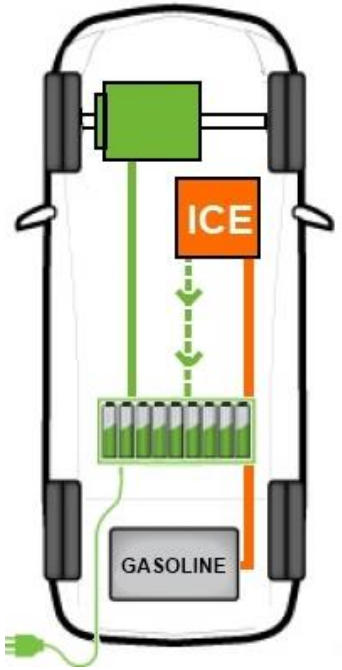
- HEV charges battery by both combustion and regenerative braking
- Either drive source operates or both together
  - Hyundai Ioniq (59 mpg)
  - Toyota Prius Eco (56 mpg)
  - Honda Insight (52 mpg)
  - Toyota Corolla (52 mpg)
- Plug-In Hybrid (PHEV) option also allows for charging battery from the grid
  - Much larger battery, can avoid the use of engine with most daily commuting
  - Toyota Prius Prime (133 mpge)
  - Hyundai Ioniq Plug-In (119 mpge)
  - Ford Escape PHEV (105 mpge)
  - Toyota RAV4 Prime (94 mpge)



Vehicle Types

Hybrid Electric Vehicle (HEV/PHEV) – Series

- Range extending combustion engine (EREV)
  - Combustion engine only charges battery
- Plug-In option also allows for charging battery from the grid
  - 12 to 18 kWh capacity
  - Mitsubishi Outlander
- Recently discontinued
  - Honda Clarity
  - BMW i3 REx
- **Becoming less popular due to the longer range of EVs and Hybrids in general**



Battery Technology

Battery Technology is in flux

- Manufacturers currently looking to improve range and safety through developing different battery types.

Lithium Ion (Cobalt, Mn, Phosphate)

- Lithium sourced from Chile, Argentina, and China
- Tendency to overheat

Nickel-Metal-Hydride

- Typical for hybrids

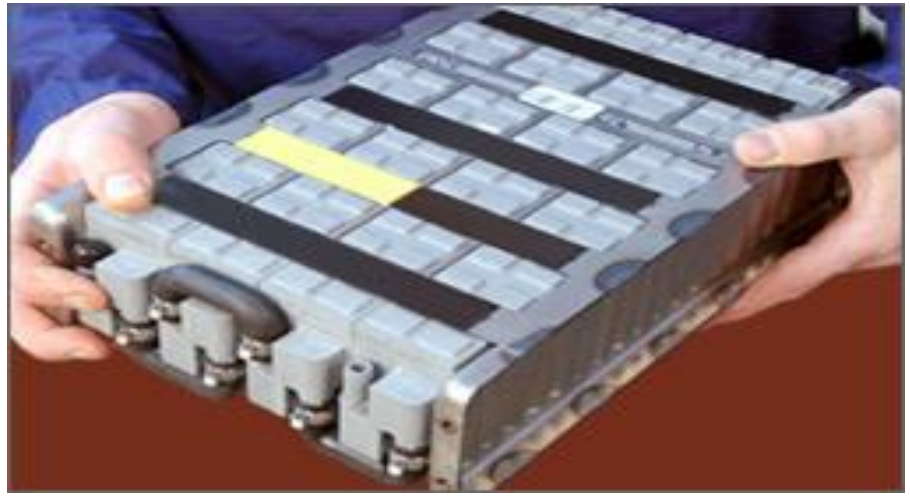
Specification	NiMH	Li-ion		
		Cobalt	Manganese	Phosphate
Specific Energy Density (Wh/kg)	**60-120**	**150-190**	**100-135**	**90-120**
Life Cycle (80% discharge)	300-500	500-1,000	500-1,000	1,000-2,000
Fast-Charge Time	2-4h	2-4h	1h or less	1h or less
Overcharge Tolerance	Low	Low. Cannot tolerate trickle charge		
Self-Discharge/month (room temp)	30%	<10%		
Charge Temperature	0 to 45°C 32 to 113°F	0 to 45°C 32 to 113°F		
Discharge Temperature	-20 to 65°C -4 to 149°F	-20 to 60°C -4 to 140°F		
Maintenance Requirement	60-90 days (discharge)	Not required		
Safety Requirements	Thermally stable, fuse	Protection circuit mandatory		
In Use Since	1990	1991	1996	1999
Toxicity	Low	Low		

epectec.com

Battery Technology

Specifications

- Typically, 1.5 to 100 kWh capacity
  - Battery energy content equal to 1/2 to 1 1/2 gallon of gasoline
  - 60 to 175 kW power
  - 200 to 400 volts
  - 3 to 5 miles/kWh
  - Cost to manufacture battery packs is $132/kWh
    - **89%** reduction since 2010
- Warranties from 36,000 to 100,000 miles
- Requires active cooling and heating
  - Range is reduced in several circumstances.
    - Cold weather
    - Hot weather with A/C



Source: DOE

Battery Technology-Safety

- Flammability-chance of fire
  - Gas vehicles- 1.5%
  - EVs- .03%
  - Hybrids- 3.4%
  - Lithium Ion Batteries- Potential for Thermal Runaway
    - burn hotter, faster and require far more water, can re-ignite hours or even days after the fire is initially controlled
      - Danger to salvage yards, repair shops and others at risk.
    - Prevention using separators

Motor Technology

EV Advantages

- Continuous power for hill climbing and towing due to better and more consistent torque and horsepower
- Higher RPM
- Regenerative braking capabilities
- Better acceleration
- More stability due to a lower center of gravity
- Less maintenance

Fuel Cost Comparison

Payback Analysis

4 miles/kWh vs 24.9 mpg for gasoline engine

- $0.13/kWh vs $4.00 for gallon of gasoline
- 14,000 miles traveled per year
- against a "comparable" gasoline-powered vehicle

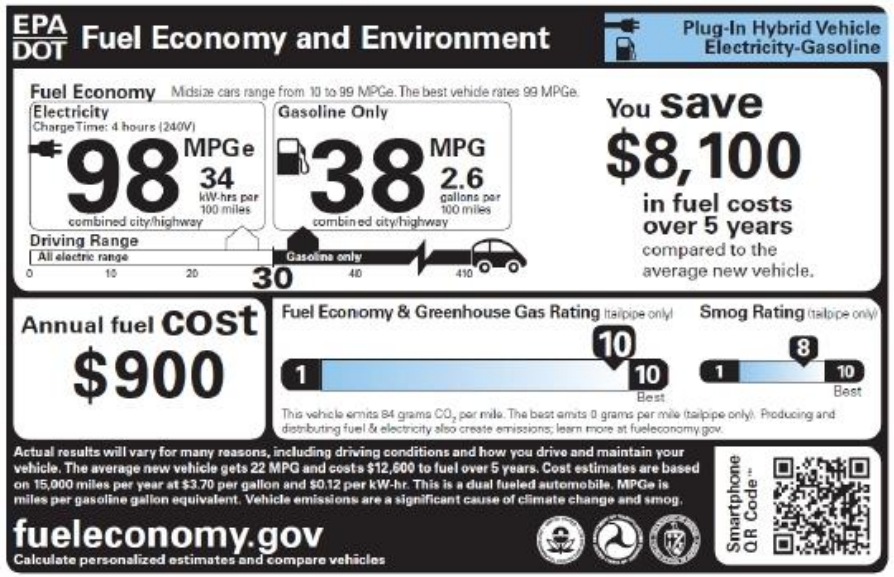
Annual gas fuel cost = (14,000 mi ÷ 24.9 mpg) x $4.00/gal
= $2,248

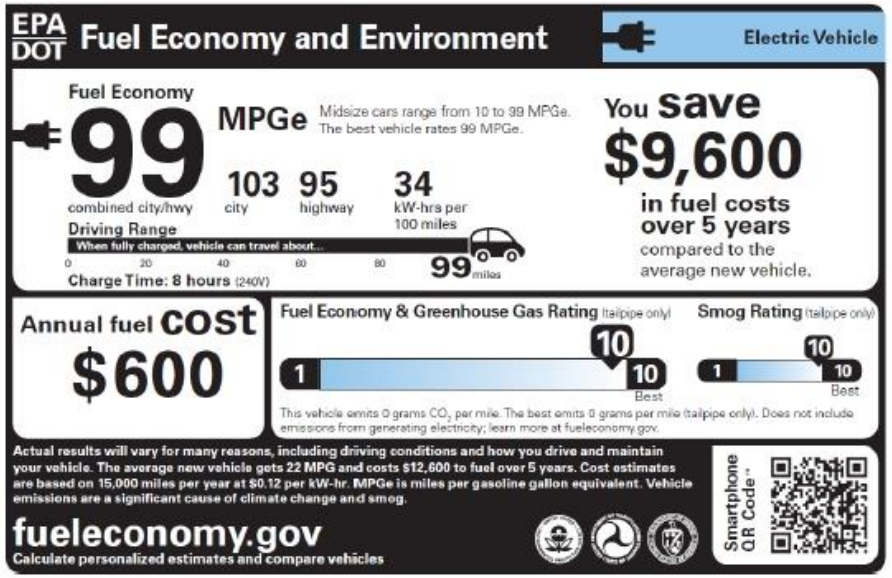
Annual EV fuel cost = (14,000 mi ÷ 4 mi/kWh) x $0.13/kWh
= $ 450

Savings = $1,799

Fuel Cost Comparison

Fuel Economy Labels



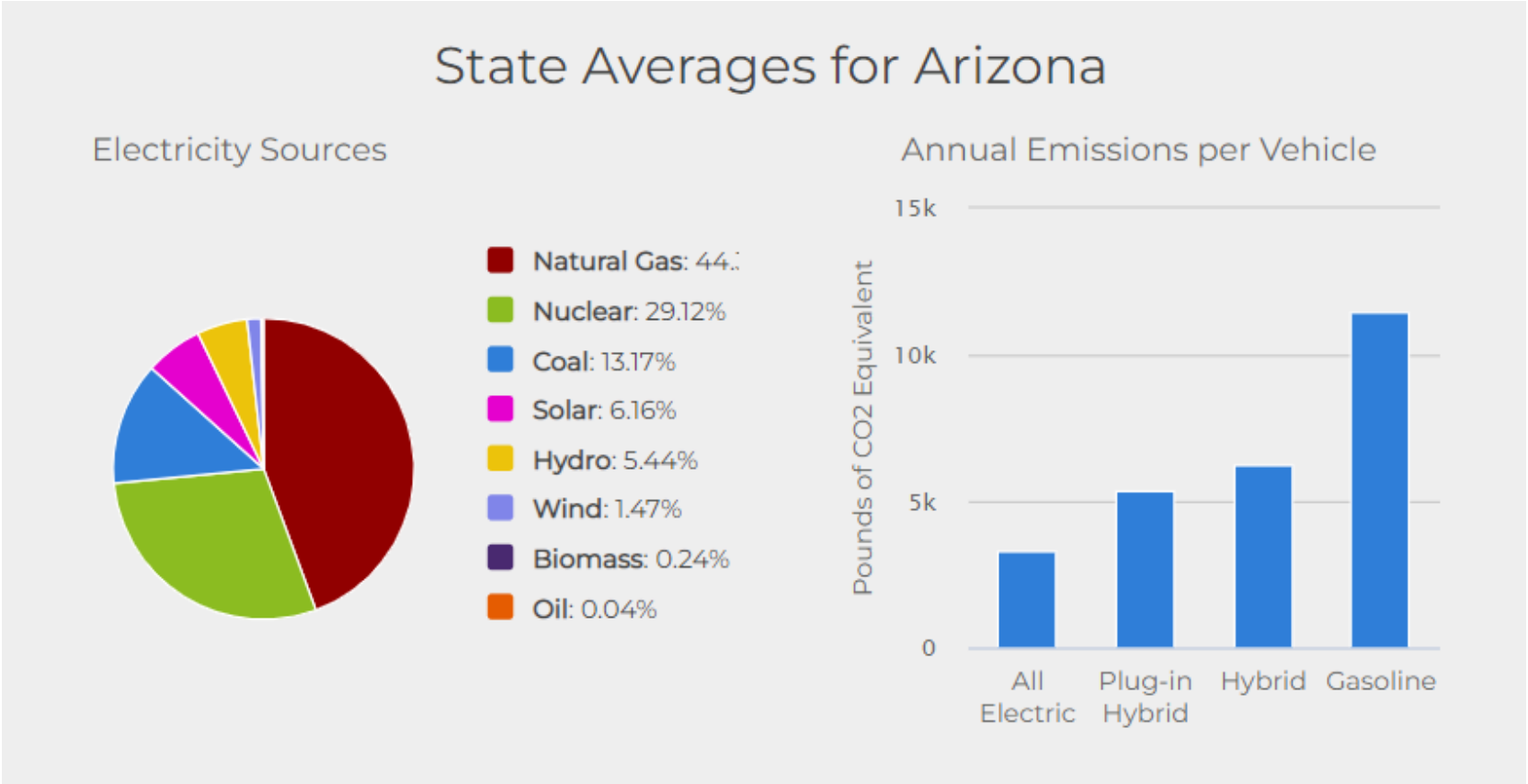


Emissions Comparison

Assumptions and Calculations

- Carbon Dioxide (CO_2) emissions rate for combustion
  - 19.4 lbs (8,800 grams) CO_2 per gallon for gasoline combustion
  - 953.7 lbs/MWh or 432.59 g/kWh for average grid electricity (EIA 2020B, EPA 2021)
- Well-to-wheels energy conversion efficiencies
  - Crude oil to gasoline = 82%
  - Power plant to output shaft electrical efficiency = 0.93 (T&D) x 0.85 (charging) x 0.9 (motor efficiency) = 71%
- Total emissions (20% reduction with zero renewable content)
  - Gasoline = 8,800 g/gal ÷ 24.9 mpg ÷ 0.82
    = **430 g/mile**
  - Electric Vehicle = 432 g/kWh ÷ 4 mi/kWh ÷ 0.71
    = **152.1 g/mile**

How Clean Is My EV???

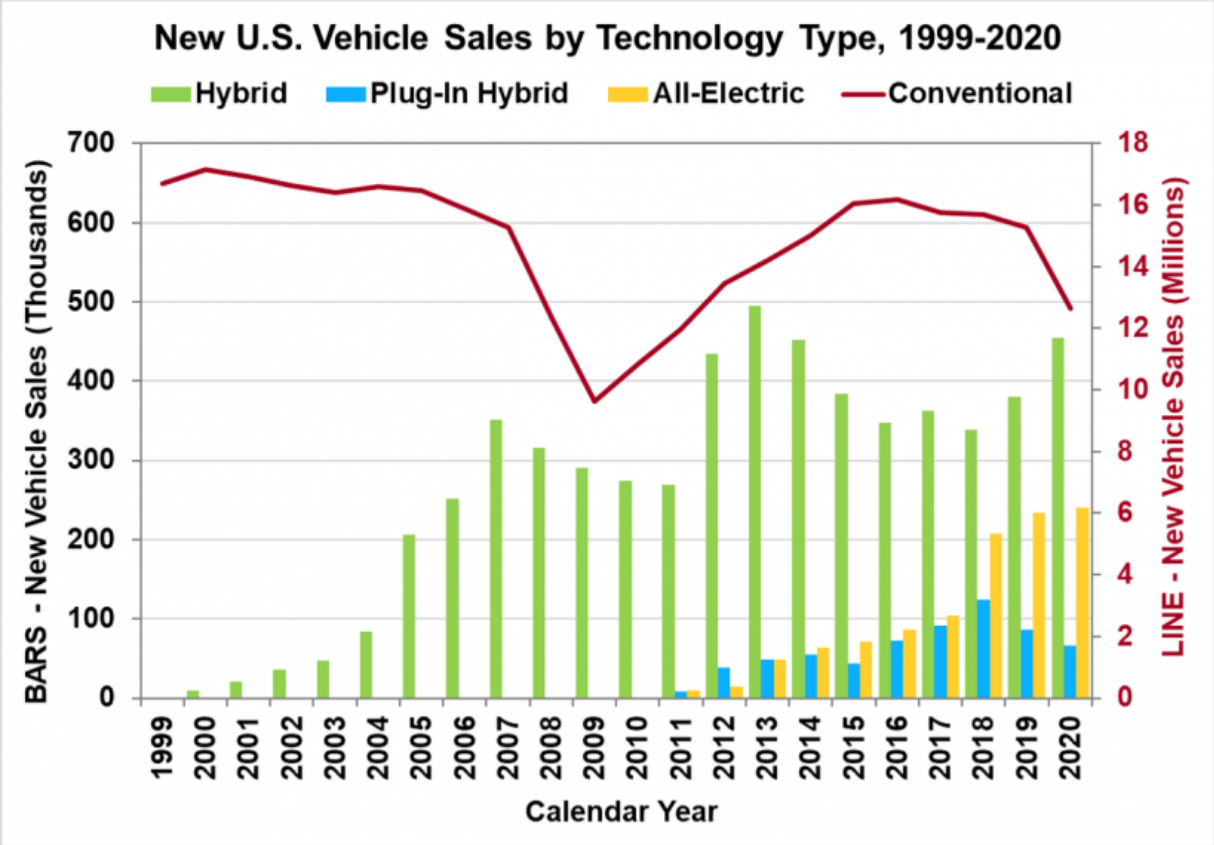


afdc.energy.gov

Market Availability

U.S. Electric Vehicle Sales

- 657,000 pure EVs were sold in 2021 (<4%), but double that of 2020
  - In contrast, there was a 2% increase in the sales of conventional vehicles
- Projected to be about 50% by 2030
- PHEVs and BEVs currently comprise 4.4% of new vehicle sales



energy.gov/eere/vehicles

Market Availability

Plug-In Hybrids

Make	Model	Type	Cost	Range		
				Electric	Gas	Total
Toyota	Prius Prime	PHEV	$28,220	25	615	640
Chrysler	Pacifica	PHEV	$48,478	32	534	566
Kia	Niro	PHEV	$29,590	26	580	606
Mitsubishi	Outlander	PHEV	$36,995	24	296	320
Volvo	XC90, XC60 T8	PHEV	$64,800	18-35	502	520
Porsche	Panamera	PHEV	$114,000	28	452	480

BEVs Growing in Range and Choices

Top BEVs According to Tom's Guide 2022

Make	Model	Cost	Range
Tesla	Model 3	$43,990	300
Hyundai	IONIQ 5	$39,000	300
Ford	Mustang Mach-E	$56,200	300
Nissan	Leaf	$27,400	226
Volkswagen	ID.4	$39,995	260
Polestar	2	$59,900	233
GMC	Hummer EV Edition1	$112,000	350
Lucid	Air Dream Edition	$169,000	517
Porsche	Taycan Turbo S	$185,000	201

Market Availability

A Few Notable Future Market Introductions

Make	Model	Type	Range	Capacity, kWh	Projected Release date
Toyota/Subaru	bZ4X FWD	BEV	311	71.4	Summer/Fall 2022
Audi	Q4 e-tron	BEV	241	77	Fall 2022
Cadillac	Lyriq	BEV	300	100	2023
Tesla	Cyber truck	BEV	Up to 500	200-250	2023
Ford	F-150 Lightning	BEV	230-300	~115-150	2022
Dodge	Ram	BEV	Up to 500	159-200	2024
VW	ID. Buzz	BEV	200?	77	2023

Tesla

VW ID Buzz

EV Superlatives

Model	Type	Range	Notes	In Productiom?
Futuricum Semi Delivery	BEV	683	683 miles in under 24 hours no charging	Limited
Rimac Nevera	BEV	241	258 mph	150 planned at 1 per week
Tesla Roadster	BEV	300	0-60 1.9 seconds, 620-mile range	2020, then 2022, now 2023 after CyberTruck
Mercedes EQV	BEV	213	Van	Yes
Lucid Air Dream Edition	BEV	517	Efficiency	Yes

Rimac Nevera inverse.com

Lucid

Federal/State/Utility Incentives

Federal Incentive

- Qualified Plug-In Electric Drive Motor Vehicle Tax Credit (IRC 30D)
  - $2,500 (5 kWh) up to $7,500 (17 kWh)
  - One-year phase-out after 200,000 vehicles sold- Toyota phasing out by summer, Tesla and GM no longer qualify

State and Utility Incentives can be found at

https://afdc.energy.gov/laws/search

Recharging Stations

Three Levels

- 1st generation electric vehicles not compatible with Level 3 charge
  - Level 3 is direct-to-battery DC
  - Known as “fast charging” or “quick charging”
- Rebates may be available through the APS Marketplace for residential

	Type	Voltage	Miles Range per hour	kW_{Max}	kW_{Typ}	Charge Time
Level 1	AC	120	2-5	2.4	1.4	11 to 24 hours
Level 2	AC	240	20-50	19.2	3.3/6.6	3 to 9 hours
DC Fast Charge (Formerly Level 3)	DC*	Up to 800	Up to 200	400	50-150	< 45 Minutes

*480V 3-phase AC input

Recharging Stations

Opportunities

- CHAdeMO
  - Supported by Nissan, Mitsubishi, Subaru, and Toyota
  - Tesla has adapters for these
  - Being phased out by Japanese to be replaced with CCS
- SAE J-1772 Combined Charging System (CCS)
  - One plug solution; AC & DC
  - Supported by Audi, BMW, Daimler, Ford, General Motors, Porsche and Volkswagen
  - Tesla developing adapter for North America for this
  - HomePlug Green PHY communication protocol
  - DC Level 1; 200-500 VDC, 40 kW, 80 amps
  - DC Level 2; 200-500 VDC, 100 kW, 200 amps
  - DC Fast Charge Ultra-fast; 400-800 VDC, 400 kW, 1,000 amps

Source: Bradley Berman, plugincars.com

Poll Question

There are no tailpipe emissions generated from the use of a battery electric vehicle.

a) True

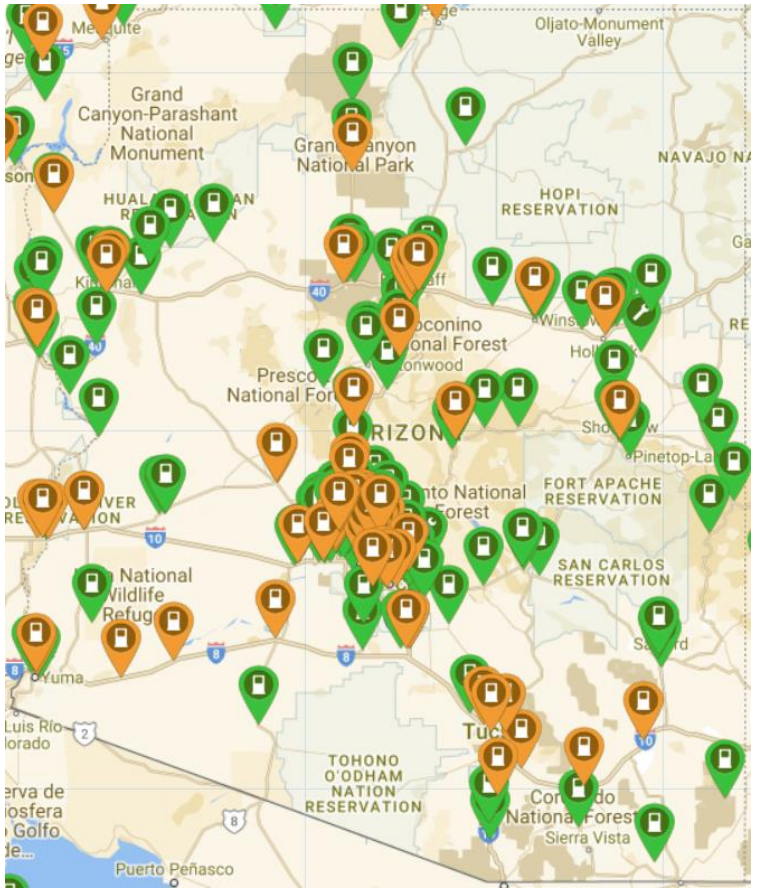
b) False

Source: Energy.gov

Recharging Stations

Locations (End of 2021)

- **APS Service Area: 342 locations/992 plugs**
- **AZ totals 1099 locations/3145 plugs**
- Public charging stations/Charging Outlets in the U.S*
- 2019- 21,257/47,012
- 2021- 46,844/117,028
  - Top five states represent 50% of all stations
    - California (14,496), New York (2,980), Florida (2,668), Texas (2,333), and Washington (1,767)
  - 3 states had <50 in 2019, 0 today (AK with 51)



PlugShare

Recharging Stations

Ownership Modes*

- Privately owned
- Municipally owned and operated for public benefit
- Utility owned and operated for public benefit
- Employer owned and operated as an employee benefit
- Privately owned primarily to enhance an unrelated business—retail shopping, hotels, restaurants, private parking facilities, and so on

*Transportation Electrification, EPRI

Challenges

- Full EV infrastructure roll-out is far in the future
  - 2.4 million stations needed to support 26 million vehicles in 2030[1]
  - Issues with Filling stations
    - Speed of charge
    - First come, first serve vs. reservation
    - Premium paid to skip the line?
  - Gravity, Hydrogen, Heat
  - Thermo- and photovoltaic technology improvements
- Range anxiety is more fiction than fact
  - 50% of Americans travel less than 26 miles per day
  - Will destination chargers really be used?
  - Deadheading still an issue, but rapidly disappearing
- Time to charge for EV batteries is too slow
  - Cross-country travel not practical
- Market reaction to a few bad experiences is unknown
  - Autonomous
  - Fires vs. technology
- Emergency responders must understand and be able to address new safety concerns

[1]International Council on Clean Transportation

Challenges

- Cost premium for EVs is still high and subsidies are phasing out
- Consumer-driven model development
  - SUVs
  - Trucks
  - Crossovers
- Who pays for the electric charge?
  - Work
  - Mall
- Loss of gasoline tax revenues
  - Highway funding
- Competition exists and will grow
  - Diesel-powered cars
  - Stop-start gasoline-powered cars
  - Fuel cell cars??

Questions

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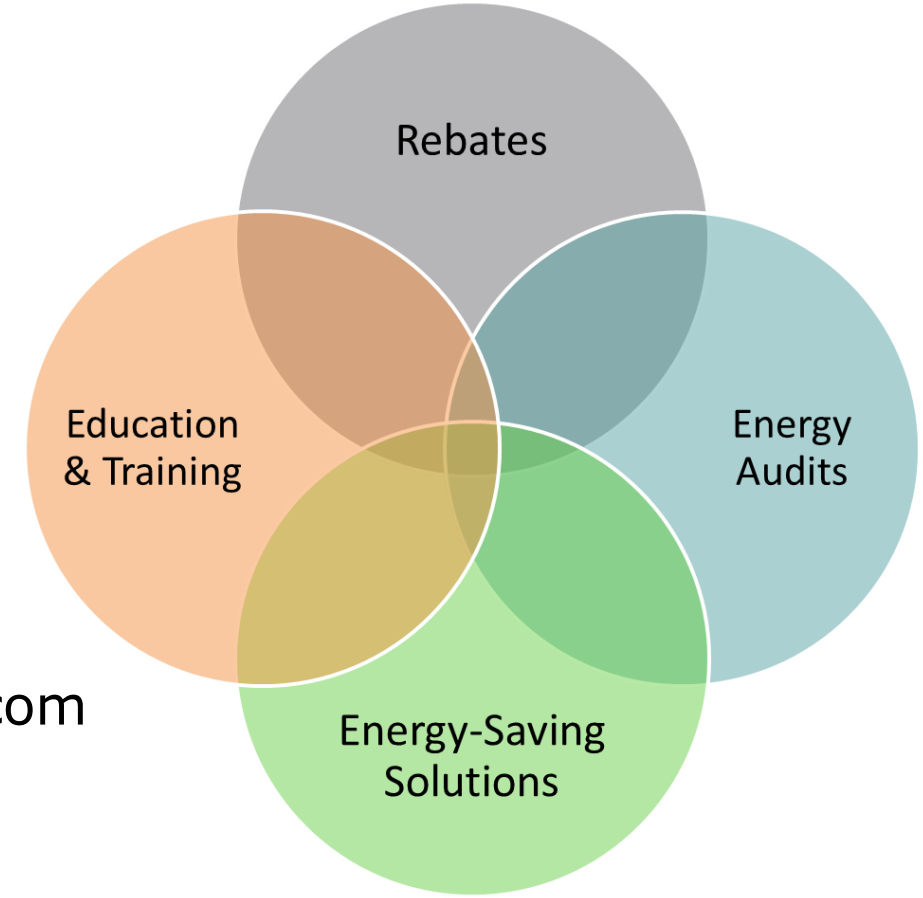
APS Solutions for Business



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SOLUTIONS FOR BUSINESS

A breath of fresh air for customers and employees

What you need to know about HVAC and your business

The energy used by HVAC equipment accounts for 30-50% of all energy costs for Arizona businesses. How does your HVAC system work and how you can make the most of it? Learn more about your system below.

HVAC: Why It Matters

Heating, ventilation, and air conditioning (HVAC) systems all have one goal: creating a great indoor environmental quality (commonly referred to as IEQ) by addressing temperature, humidity and contamination. A good IEQ benefits not only employee and customer comfort, but also their health. There are many contaminants that can be found inside a building. Poor indoor air quality can lead to discomfort and additional sick days. Fortunately, HVAC systems incorporate filters to significantly reduce contaminant levels and maintain a healthy IEQ.

Quick Tips

Keep your HVAC unit operating efficiently

- Routinely inspect and replace air filters
- Remove obstructions from duct vents
- Create a daily schedule on your thermostat
- Setback thermostat after closing
- Use ceiling fans to more evenly distribute air
- Encourage employees to keep windows and doors closed
- Keep heat-producing equipment away from your thermostat
- Insulate any exposed ductwork

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