Sustainable Inclusive Supply Chain for the Electric Vehicle Industry in Illinois

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February 2023

This work was carried out using a grant from University of Illinois Urbana-Champaign through the Illinois Innovation Network (Sustaining Illinois Supplemental Funding Proposal), given to the Urban Transportation Center at University of Illinois Chicago and Supply Chain Innovation Center and Business Incubator at Governors State University.

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Executive Summary: There has been an extraordinary growth in the electric vehicle (EV) industry in the past fifteen years. It offers a cleaner mode of transportation through the elimination of carbon dioxide and other undesirable emissions and reduces the dependence on fossil fuels thus aiding national energy security. For these reasons, federal and state governments are promoting the adoption of EVs by providing incentives to consumers and manufacturers. This project will review the current status of EVs and EV manufacturing, with emphasis on the state of Illinois. We will present information gathered through literature review, surveys, and interviews.

Introduction

Reliance on petroleum-based fuels for transportation endangers the environment and affects national energy security. A switch to electric vehicles (EVs) is one effective approach to mitigate these problems. The growing EV industry can also create jobs and enhance the economy[1]. With its network of human talent and strategic location, Illinois can be a leader in the development of sustainable and inclusive supply chain solutions for the EV industry[2].

To achieve leadership in EV supply chain, a coordinated effort by the state and local governments, universities and research laboratories, and manufacturers and consumers, is needed. Consumer demand, manufacturing capacity, favorable policies and incentives, research and development, equitable development of the infrastructure, training and implementation – all of these play a vital role in creating a world class EV supply chain within Illinois.

This report will start by providing a brief history of the electric vehicles. Since the battery is the most critical and differentiating component of EVs, that is explored next. Sustainability issues are also considered. Then the charging infrastructure is described, along with capacity issues.

In order for EVs to be widely used, it should be seen to be economical in addition to being environmentally beneficial. Hence the economics of EVs is considered next, followed by incentives and policy frameworks instituted by federal and state governments. Subsequently, the important EV supply chain entities in Illinois are reviewed. Interviews with several of them are described in this section.

Issues regarding equity, workforce, and training are reviewed next, followed by economic impacts in the society through the widespread adoption of EVs. The report ends with survey results from potential consumers, and resources for further investigation.

The EV industry has a dynamic landscape – much has changed in the last ten years, and further developments will continue. Breakthroughs in battery technology, discoveries of new sources for materials, creation and revision of economic incentives, all continue to take place even as this report is being written. It is hoped that this report will be helpful to anyone who wishes to understand and enhance this field.

[1] https://www.epi.org/publication/ev-policy-workers/

[2] https://intersectillinois.org/industries/ev/

Brief History of Electric Vehicles

Although EVs (electric vehicles) were introduced in the nineteenth century[3], the current successful development of EVs began with EV1 by GM in 1996 and Tesla Roadster in 2008. The available EVs now include HEVs (hybrid electric vehicles), PHEVs (plug-in hybrid electric vehicles), BEVs (battery electric vehicles), and PEVs (plug-in electric vehicles, which could be PHEVs or BEVs). Of these, we focus on BEVs (in this report, EVs stand for BEVs) - we exclude HEVs in our discussion since they are not charged from outside the vehicle (they are powered and charged by an internal combustion engine or equivalent), and PHEVs are considered to be a bridge from ICEVs (internal combustion engine vehicles) to BEVs. We also exclude discussions on FCVs (hydrogen fuel cell vehicles) and HCVs (hydrogen combustion engine vehicles) although these technologies could become economically viable in the future.

In 2021, EVs were only 4% of the total new cars sold in US (19% in Europe, and 15% in China)[4]. The leading manufacturers were Tesla, VW, BYD, GM, Ford, Nissan, Stellantis, and Hyundai[5]. As of June 2022, there were 36,520 EV registrations in Illinois[6] (compared to 4.2 million registered automobiles in Illinois, or 563,070 registered EVs in California[7]). Likewise, there were 2,432 EV Supply Equipment (EVSE) ports[8] in Illinois (as of April 2022) compared to 35,877 in California.

Illinois has passed several laws to support the EV industry and committed substantial capital funds[9]. It has the fourth largest auto employment in US, over 800 companies in the auto industry, world class engineering and computer science programs, a large technically qualified work force, … In short, it is well positioned to attract and develop major enterprises in the EV supply chain. Agglomeration economics[10] and economies of scale suggests that the Midwest is ideal for the growing EV industry; the benefits of co-location also suggests that major battery facilities be built near EV assembly facilities.

Data obtained from Illinois Secretary of State[11] website shows the following growth in the registration of EVs in Illinois.

Year	2017	2018	2019	2020	2021	2022
EVs registered	8255	12713	18769	25319	36482	57311
Growth over previous year		54%	48%	35%	44%	57%

[3] https://www.energy.gov/articles/history-electric-car

[4] https://www.canalys.com/newsroom/global-electric-vehicle-market-2021

[5] https://www.forbes.com/sites/mikepatton/2022/03/30/competition-heats-up-for-tesla-in-ev-market/

[6] https://afdc.energy.gov/data/10962

[7] https://www.statista.com/statistics/196010/total-number-of-registered-automobiles-in-the-us-by-state/

[8] https://afdc.energy.gov/data/10366

[9] https://intersectillinois.org/industries/ev/

[10] https://www.chicagofed.org/publications/economic-perspectives/2022/5

[11] https://www.ilsos.gov/departments/vehicles/statistics/electric/2022/electric121522.pdf

If a growth rate of about 43% can be sustained, the goal of 1 million EVs (as envisioned in REV Illinois Act[12]) is feasible (57311 * 1.43^8 = 1,002,135).

[12] https://www.illinois.gov/news/press-release.24143.html

Batteries for Electric Vehicles

Batteries are critical – range and charging times of EVs are mostly based on the battery. Most EVs use Lithium-ion batteries (LIB).

There are many types of LIBs: a comprehensive study is given in Mahmud et. al[13]. All battery cells have a cathode (positive terminal), anode (negative terminal), and an electrolyte between them. An Argonne Lab report[14] lists a variety of cathode chemistries: LCO (Lithium Cobalt Oxide), NMC (Nickel Manganese Cobalt), NCA (Nickel Cobalt Aluminum Oxide), LFP (Lithium Iron Phosphate), and LMO (Lithium Manganese Oxide). Anodes are typically graphite or other compounds of Lithium with Titanium or Silicon. Electrolyte is typically a solid polymer[15].

Thus, in addition to Lithium, other minerals are also needed. As an example, according to data from Argonne National Laboratory, a lithium-ion battery pack for a car of the type NMC532 could contain about 18 pounds of Lithium, 77 pounds of Nickel, 44 pounds of Manganese, and 31 pounds of Cobalt[16].

The EV battery supply chain begins with the mining of the raw materials. They are processed and converted to battery components such as cathodes, anodes, electrolytes, separators, and casings. These are then integrated to create cells. The battery cells are joined together to form modules, which are then assembled into battery packs for use in EVs. Re-use and recycling form the final phase of the supply chain.

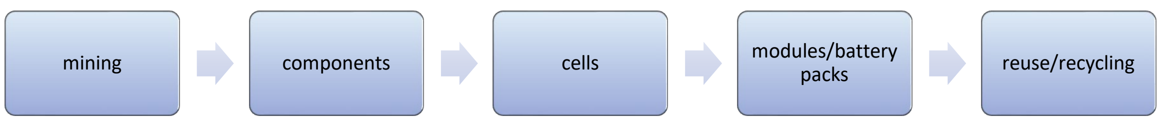

Figure: EV battery supply chain

One important measure in selecting a battery is its price. The price of Lithium-ion batteries has dropped dramatically in the last three decades, from about $7,000 per kWh (kilo watt hour – a unit of energy) in 1991 to nearly $100 per kWh in 2016[17], but prices have started to go up recently and it is about $151 per kWh in 2022[18].

Another measure in selecting a battery is the amount of energy it can provide per kilogram (so as to keep the weight of the battery reasonable). Lithium-ion batteries generally provide 100 to 270 Wh/kg[19]

[13] Saifullah Mahmud, Mostafizur Rahman, Md Kamruzzaman, Md Osman Ali, Md Shariful Alam Emon, Hazera Khatun, Md Ramjan Ali, “Recent advances in lithium-ion battery materials for improved electrochemical performance: A review”, Results in Engineering, Volume 15, 2022, 100472, ISSN 2590-1230, https://doi.org/10.1016/j.rineng.2022.100472.

[14] https://www.epa.gov/sites/default/files/2018-03/documents/spanenberger_epa_webinar_-_3-22-18_-_argonne.pdf

[15] https://www.sciencedirect.com/science/article/pii/S2666523922000253

[16] https://www.nature.com/articles/d41586-021-02222-1

[17] https://pubs.rsc.org/en/content/articlelanding/2021/EE/D0EE02681F

[18] https://about.bnef.com/blog/lithium-ion-battery-pack-prices-rise-for-first-time-to-an-average-of-151-kwh/

[19] https://dragonflyenergy.com/why-does-energy-density-matter-in-batteries/

(Watt-hours per kilogram) compared to 50 to 100 Wh/kg provided by traditional lead-acid batteries. Keep in mind that larger battery packs may not provide the same Wh/kg due to inefficiencies in the packing geometry of the cells. Packing geometry is important since that determines the thermal cooling structure – poorly done, it could lead to 'thermal runaway'[20] leading to fire hazards.

To get an idea of the weight of LIBs, we present a rough calculation here. Numbers used are estimates. Gasoline provides about 12 kWh/kg which is equal to 12,000 Wh/kg[21]. This implies that we need 45 kg of LIB for one kg of gasoline for the same amount of stored energy.

(12000/270 ≈ 45, using the higher value of 270 Wh/kg for the energy per kilogram for the LIB)

However, gasoline engines are very inefficient (like only 12 to 30%[22] of the stored energy is converted to useful mechanical energy) in converting the stored chemical energy into useful work (and electric motors are very efficient), so in effect, we need about 14 kg of LIB for one kg of gasoline for equivalent driving range.

(45 * 0.3 ≈ 14)

Thus weight for weight, LIB weighs about 14 times as much as the needed gasoline for providing the same useful mechanical energy output (driving range). And unlike gasoline, the entire weight remains the same throughout the range of operation.

From a different perspective, to get 300 miles of range, we need about 34 kg (75 lbs) of gasoline (assuming 25 mpg for the gasoline ICEV), or equivalently, 476 kg (1,050 lbs) of LIB. The calculations are

Assumption: fuel efficiency of the ICEV is 25 mpg.

Then 300 miles need 300/25 = 12 gallons of gasoline.

12 gallons of gasoline weigh 12 * 2.8 ≈ 34 kg, or 75 pounds (since one gallon of gasoline weighs about 2.8 kg[23]).

We saw earlier that we need 14 kg of LIB for one kg of gasoline to get the same range.

Hence an equivalent LIB will weigh 34 * 14 ≈ 476 kg, or 1050 pounds.

In terms of fuel cost, 12 gallons of gasoline at $4 a gallon would cost $48; equivalent energy requirement for EV is approximately 110 kWh, which at $0.14 per kWh[24] would cost around $15.40. Calculations are shown below:

12 gallons of gasoline ≈ 12 * 2.8 kg = 34 kg of gasoline

≈ 34 * 14 kg of LIB (since 1 kg of gasoline has about the same useful energy as 14 kg of LIB)

= 408 kg of LIB

[20] https://dragonflyenergy.com/thermal-runaway/
[21] https://hypertextbook.com/facts/2003/ArthurGolnik.shtml
[22] https://www.fueleconomy.gov/feg/atv.shtml
[23] https://coolconversion.com/density-volume-mass/
[24] https://www.energysage.com/local-data/electricity-cost/il/

= 408 * 270 Wh of useful energy

= 1102,160 Wh ≈ 110 kWh

= 110 * 0.14 dollars = $15.4

The Advanced Vehicle Testing site[25] has a chart for the comparison of per mile cost for EVs and ICEVs.

Other measures in selecting a battery would be the rate of charging (kW or kilowatts) and useful life. Battery chemistry plays a large role in this, and we will use average estimates for providing typical values here. A DC fast charger at 200 kW charging rate (see the section on *EV Charging Infrastructure* for a description of charger types) can charge a 60 kWh battery in 18 minutes[26] (60 kWh / 200 kW = 0.3 hours, or 18 minutes). A level 2 charger at 20 kW will take 180 minutes, or 3 hours (60 kWh / 20 kW = 3 hours), to charge the same 60 kWh battery. And a level 1 charger at 2 kW will take 30 hours to fully charge a 60 kWh battery (60 kWh / 2 kW = 30 hours). These are simplified calculations – in reality, the charging rate is not constant, and is slower after the battery is charged to about 80% to 90% of its capacity.

Alternatively, we could compute the range per hour of charge. The US DOE site[27] lists the energy requirement per 100 miles for vehicles. A typical value is 40 kWh per 100 miles, which implies that one kWh allows the vehicle to go 2.5 miles. One hour of charging using a 200 kW DC fast charger gives us a range of 500 miles; using 20 kW level 2 charger gives us 50 miles of range; and using a 2 kW level charger gives us 5 miles of range.

For charging, sometimes a C rate is used[28], with 1 C rate implying that the battery will be charged fully in one hour, a 2 C rate charges in 0.5 hours, etc. A constant power constant voltage (CC-CV) method is commonly used, although alternatives (such as pulse charging) are possible. The battery management system may keep the state of charge (SOC) to be between 5 and 95% (or 20 to 80% or similar schemes depending on the system and the vehicle) to prevent extreme SOCs, in order to enhance the useful life of the battery.

Always charging an EV overnight can reduce the battery lifespan. If SOC is sufficient for the next day, it is better to leave the charging off[29]. The average US commute is about 41 miles[30], so daily charging is often unnecessary. Unless it is required, it is better to stay within 30 to 80% of SOC. It should also be noted that the charging rate is often reduced after an 80% SOC, so it takes longer to charge from 80% to 90% than from 70% to 80%.

EV batteries sold have typically a warranty of over 8 years or 100,000 miles[31]. The US DOE suggests that they may last 12 to 15 years if used in moderate climates. For longer useful life, charging should be limited to 85 or 90% of the capacity. Life of the battery is most when the battery operates between 50 and 86 degrees Fahrenheit – battery management systems try to maintain that temperature. Extreme

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[25] https://avt.inl.gov/sites/default/files/pdf/fsev/costs.pdf
[26] https://www.transportation.gov/rural/ev/toolkit/ev-basics/charging-speeds
[27] https://www.fueleconomy.gov/feg/byfuel/EV2022.shtml
[28] https://medium.com/batterybits/an-introduction-to-fast-charging-and-pulse-charging-21cd21a599ae
[29] https://www.autotrader.com/car-tips/charge-electric-car-every-night
[30] https://www.zippia.com/advice/average-commute-time-statistics/
[31] https://www.caranddriver.com/research/a31875141/electric-car-battery-life/

cold temperatures can severely degrade the batteries – when a Nissan Leaf EV[32] was left out in the cold at negative 18⁰ F, it was difficult to start the motor or even charge it. But newer vehicles are getting better – there is even a plan to drive a Nissan Ariya EV to the North and South Poles[33]. It has been reported[34] that cold weather in Norway is not a problem for Evs.

Batteries determine the range of an EV, an important consideration in the purchase of an EV. The potential range is determined by the type and size of the battery. Driving conditions such as temperature (70⁰ F is optimal), load, speed, terrain, age of battery, and aerodynamics of the vehicle, all have an impact. ICEVs use the excess temperature produced in the engine to heat the vehicle interior, but Evs must use the stored electricity to do that – which also leads to a loss in range.

Batteries suffer from self-discharge[35] – generally 2 to 3 percent of the charge is lost per month if the EV is not in use. As is apparent from popular news articles, the electric batteries also suffer from the possibility of catching fire. But according to an Autoweek article[36], the incidence of fire is much less for Evs compared to ICEVs or hybrids. However, the battery fires are harder to put out, and many fire departments aren't equipped or trained for this hazard. This will change over time.

Suggestion: All fire departments should be trained and equipped to put out battery fires.

An important consideration regarding the batteries is the sustainability of the minerals needed to make them. Some of the Nickel mining practices create environmental problems[37]. A White House report[38] indicates that most of the raw materials (lithium, cobalt, nickel, and graphite) are mined and refined abroad. Cobalt is considered very critical because of concerns about the mining conditions in the Democratic Republic of Congo and the refining conditions in China. Recently, a company named Nth Cycle[39] has plans to extract Nickel in the US as a result of the incentives in the Inflation Reduction Act (see the section on *Federal and State Policies and Incentives*).

Table 1 in the White House report mentioned in the previous paragraph suggests that the global reserves of lithium is 17 million tonnes (mostly in Chile, Australia, Argentina, and China – a recent discovery in India[40] seems promising), and if Evs make up 100% of all vehicle sales, we need 188,700 tonnes a year – which implies that the known lithium reserves will last us only about 90 years. Hence recycling becomes very important. Once the primary use of a battery is over because of the degradation of its charging capacity, it is suggested[41] that they may be used in vehicles that need lesser capacity, and after that, as stationary storage devices. And after that, the batteries can be recycled by reclaiming the

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[32] https://www.autoevolution.com/news/cold-soaking-your-old-nissan-leaf-at-18f-and-expecting-it-to-charge-is-a-pipe-dream-207558.html
[33] https://insideevs.com/news/631310/nissan-ariya-pole-to-pole-expedition-video/
[34] https://www.greencarstocks.com/norway-proves-cold-weather-isnt-deterrent-to-electric-vehicles/
[35] https://evcentral.com.au/will-my-battery-go-flat-if-i-leave-my-ev-parked-for-too-long/
[36] https://www.autoweek.com/news/a38225037/how-much-you-should-worry-about-ev-fires/
[37] https://www.brookings.edu/blog/up-front/2022/09/21/indonesias-electric-vehicle-batteries-dream-has-a-dirty-nickel-problem/
[38] https://s.wsj.net/public/resources/documents/100-day-supply-chain-review-report.pdf
[39] https://interestingengineering.com/innovation/nickel-product-in-the-us-first-time
[40] https://finance.yahoo.com/news/india-found-major-deposit-lithium-220559248.html
[41] https://lionsmart.com/en/life-cycle-of-lithium-ion-electric-vehicle-batteries/

materials. In this context, it is worth noting that some studies show that existing reserves of petroleum at current rate of consumption will be exhausted in about 50 years[42].

Through ongoing research in battery technology[43], it is possible that safe, cheap, and fast charging batteries will be developed in future. Solid state batteries (which replace the liquid electrolyte with ceramics), sodium-ion batteries, and improved recycling are exciting possibilities in the near future. Argonne National Laboratory[44] in Lemont, Illinois, is one of the leading research centers for EV batteries. Current research[45] offers possibilities of higher density batteries such as lithium-air batteries. There is even a possibility of a 'forever battery'[46] which will end the worries about sustainability.

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[42] https://www.discovermagazine.com/planet-earth/is-the-world-running-out-of-oil
[43] https://www.technologyreview.com/2023/01/04/1066141/whats-next-for-batteries/
[44] https://www.anl.gov/topic/batteries
[45] https://www.dailykos.com/stories/2023/2/4/2150996/-Practical-lithium-air-battery-shows-3x-the-energy-density-of-today-s-best-electric-vehicle-batteries
[46] https://investorplace.com/hypergrowthinvesting/2023/02/the-forever-battery-changing-the-ev-industry/

EV Charging Infrastructure

Evs have rechargeable batteries as discussed in the previous section. Charging needs an EVSE (electric vehicle supply equipment) port and a connector. There are generally three types of chargers: level 1 (based on 120-volt AC power supply, which can easily be accommodated in home garages), level 2 (based on a 240-volt AC power supply, which may need a new circuit to be installed at home garages, also commonly available at public charging stations), and DC Fast Charging (typically for public charging stations). If the power supply is AC, then the onboard charger in the vehicle must first convert it to DC. From the US DOE site[47], we have the following:

Level	Power Supply	Connector	Typical Charging Rate	Typical miles per one Hour of Charging	Typical Hours needed for Full Charge (for 50 kWh battery)
1	120 VAC	J1772	2 kW	5	25
2	240 VAC	J1772, Tesla	7 to 20 kW	25	2.5 to 7
DC Fast Charge	400 VAC or more	CCS, Tesla, CHAdeMO	50 to 350 kW	200+	0.15 to 1

Tesla has the most number of DC Fast Chargers (Tesla calls them SuperChargers[48]) in the US, but until 2022, their connector standard was proprietary (limited to Tesla vehicles). Hence other manufacturers created a common standard, the CCS (Combined Charging System), through a global association called CharIn[49]. The Bipartisan Infrastructure Law (BIL) established a National Electric Vehicle Infrastructure Formula Program (NEVI)[50] for providing incentives to install new chargers, but it will only support "non-proprietary connectors that meet applicable industry safety standards"[51]. So in 2022, Tesla announced that its SuperChargers would be open to all automobiles, and called them "North American Charging Standard" or NACS[52]. As yet they do not qualify for the incentives under BIL, only CCS chargers qualify. But adapters can be used to connect an EV to any equivalent charging plugs.

Charging technology is evolving. Battery swapping has been tried but has not commercially succeeded[53] yet. Automobile manufacturer Nio seems to have a battery pack that can be swapped in three minutes, while Toyota is researching swappable cartridges for commercial Evs, and BMW believes it is not

[47] https://afdc.energy.gov/fuels/electricity_infrastructure.html
[48] https://www.tesla.com/en_eu/supercharger
[49] https://www.charin.global/
[50] https://www.fhwa.dot.gov/bipartisan-infrastructure-law/nevi_formula_program.cfm
[51] https://cleantechnica.com/2023/01/19/one-more-big-reason-its-too-late-to-switch-all-manufacturers-to-teslas-nacs-plugs/
[52] https://www.tesla.com/blog/opening-north-american-charging-standard
[53] https://www.autoevolution.com/news/what-if-we-are-wrong-about-electric-cars-part-1-an-economic-discussion-206571.html

viable[54]. Ample[55], a California based company, currently offers battery swapping technology for fleets that partner with them.

Extreme fast chargers (XFC) are being deployed for fleets and electric buses[56]. Another option is inductive charging: it allows for cable-free charging, and may even be done as the vehicle is traveling over tracks made for that using charging coils under the road[57]. If Evs can be charged while being driven over specific stretches of roads, there are many advantages: 1. A smaller battery could be used, making the EV more affordable and lighter; 2. Range anxiety is reduced; and 3. The peak charging power needed in DC chargers is avoided, and utilities can expect a more even load.

The tool EVI-ProLite[58] helps to calculate the needed charging infrastructure for a given number of Evs registered. For example, for Illinois to support one million Evs, EVI-ProLite suggests that 21,649 workplace level 2 chargers, 13,298 public level 2 chargers, and 1,716 public DC Fast Chargers are needed. A screen shot of the output page is given below.

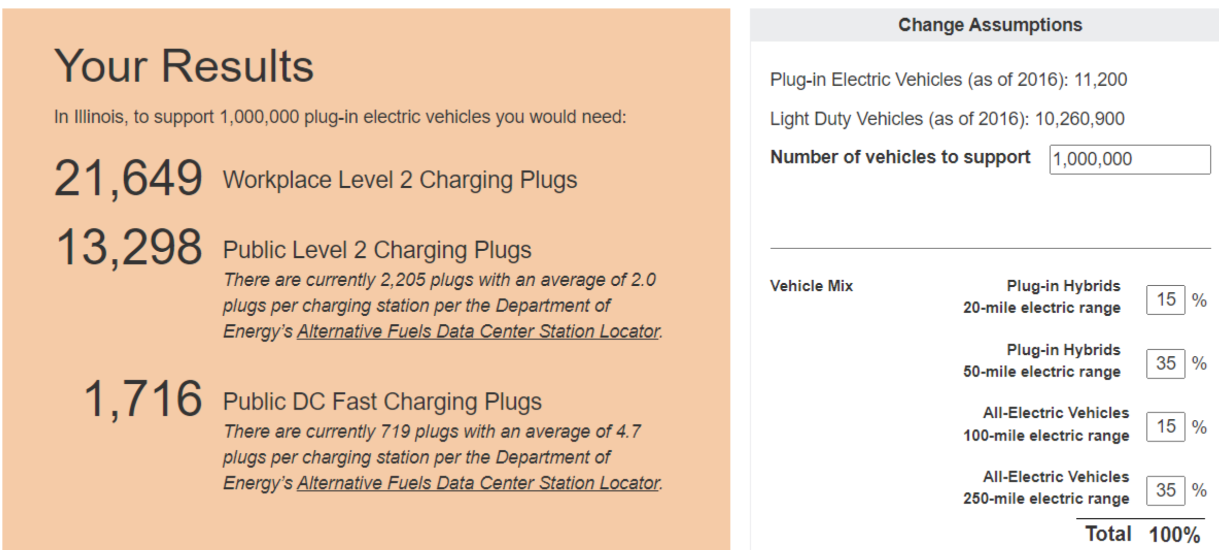

Figure: charging ports needed for 1 million EVs in Illinois, obtained from EVI-ProLite

While generally the charging infrastructure works to send energy from the grid to the vehicle, it is also possible to have V2V (vehicle to vehicle)[59] and V2G (vehicle to grid) or V2H (vehicle to home)[60] charging (GM calls it V2X or vehicle to everything). There is also the simpler V2L, or vehicle to load, which allows the EV to power appliances. V2V is helpful in charging vehicles that are stranded on a road due to lack of charge. It has been used even for charging an electric plane[61]. V2G and V2H have many benefits: 1.

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[54] https://carbuzz.com/news/toyotas-cartridge-batteries-are-the-answer-to-long-charge-times
[55] https://ample.com/
[56] https://www.energy.gov/eere/articles/pump-charge-extreme-fast-charging
[57] https://www.msn.com/en-us/autos/news/electrified-roadways-coils-hidden-in-streets-could-charge-your-electric-vehicle-while-you-drive/ar-AA15iS8H
[58] https://afdc.energy.gov/evi-pro-lite
[59] https://cleantechnica.com/2022/05/24/electric-silverado-could-get-dual-ccs-ports-v2v-charging/
[60] https://techcrunch.com/2022/04/28/are-bidirectional-ev-chargers-ready-for-the-home-market/
[61] https://electrek.co/2022/11/04/ford-lightning-powers-first-ev-recharged-electric-plane-flight/

When power is down, the EV can be used as a power source (when hurricanes hit Florida, some used their Ford F-150 Lightning as a power source[62]); 2. EVs can be charged during off-peak hours, and used as a power source during peak hours, thus supporting the grid to have an even load; and 3. Solar or wind power generators can use EVs for storing power. Because EVs typically charge during off-peak hours (taking advantage of TOU – Time of Use rates, which allows for lower rates during off-peak hours)), it has been suggested that electric utilities have been able to work more efficiently and pass on their profit to consumers (even non-EV owners) in California and Nevada[63] [64]. These studies show that EVs have increased utility revenues more than the incurred cost, thus creating a downward pressure on electric rates for EV and non-EV users. There are also reports on people being able to make money by charging during off-peak hours, and selling electricity back to the utility during peak hours[65].

Suggestion: If IDOT (Illinois Department of Transportation) deploys highly noticeable service trucks with V2V charging capability on Illinois highways, range anxiety felt by EV users can be reduced. A unique phone number, similar to 411, can be assigned to seek assistance.

Traditionally only electric utilities were allowed to sell electricity to the public, so some of the charging stations are forced to sell electricity by the number of minutes of charging (as a service) rather than by the kWh although recently many states have started allowing EV charging businesses to sell electricity directly to the public[66]. Again, some utilities have 'demand charges', which is based on the peak usage. This can distort the cost significantly and may even prevent charging businesses to offer fast charging services (because the peak use is very high) – which is why convenience stores may be reluctant to invest in fast chargers[67]. Demand charges could be as much as 90% of a charging station's electricity costs[68]. If a large number of customers use the fast charger throughout the day, demand charges may not be a significant issue. Some best practices[69] call for the elimination of demand charges. Another way to mitigate demand charges would be for the charging stations to have a large capacity battery which is being charged at an even rate throughout the day, and allowing EV fast charging from this battery so that the charging station will not have to draw large amounts of electricity from the grid in a short interval. Furthermore, solar panels[70] or wind turbines can be added to the facility to reduce the dependence on the grid.

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[62] https://newsletter.businessinsider.com/view/6276b41db929a3bebc05868dhh4gf.c2v/382f4c07
[63] https://www.msn.com/en-us/money/news/this-is-how-electric-cars-may-have-lowered-energy-bills-in-california/ar-AA15wn9E
[64] https://www.synapse-energy.com/sites/default/files/EV-Impacts-June-2019-18-122.pdf
[65] https://www.msn.com/en-us/autos/news/soon-you-ll-be-able-to-make-money-owning-an-electric-car/ar-AA15usOv
[66] https://www.politico.com/news/magazine/2022/10/28/electric-vehicles-fueling-station-gas-utilities-infrastructure-00063398
[67] https://www.cnn.com/2022/10/18/business/ev-chargers-convenience-store
[68] https://rockymnt.wpenginepowered.com/wp-content/uploads/2017/04/eLab_EVgo_Fleet_and_Tariff_Analysis_2017.pdf
[69] https://rmi.org/rate-design-best-practices-public-electric-vehicle-chargers/
[70] https://beamforall.com/product/ev-arc-2020/

There is a concern that the power needs of EVs would be a severe burden on Illinois state electricity supply. A preliminary assessment shown below allays the concern.

Currently there are 4.5 million automobiles registered in Illinois[71]. Say that they are all EVs (which is decades in future). Assuming that each is driven 10,000 miles a year, and that EVs get 3 miles per kWh[72], we need an additional 15 billion kWh (= 4.5 million times 10,000 / 3) to power the vehicles (as a side note, we also save 1.8 billion gallons of fuel annually, assuming a fuel efficiency of 25 mpg). In 2021, Illinois produced 181.5 billion kWh[73]. So, the new requirement is only 8.3% of the existing electricity production. There is already a push to increase the electricity production through solar and wind power generation by as much as 25% by 2025[74]. Of course, the intent is to reduce electricity production using fossil fuels, but the numbers indicate that there is no impossible barrier in this regard. And keep in mind that the current goal is only 1 million EVs by 2030.

Another argument about the non-sustainability of EVs is that although EVs do not use fossil fuels, the electricity supplied is generated from fossil fuels. Here it should be noted that current electricity production in Illinois is 60% from nuclear power plants, 18% from coal, 14% from natural gas, and 9% from renewable sources (solar and wind)[75]. The growth in energy from renewable sources is rapid, especially because of the incentives through CEJA (Climate and Equitable Jobs Act)[76]. So while this concern is partially valid, progress is being made in greening the electricity sources.

Finally, there are safety and security concerns with respect to charging stations. These operate on high voltage, and proper design and maintenance is vital. And potential security flaws[77] in the charger station management systems can lead to exploitation and disruption of service.

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[71] https://www.statista.com/statistics/196036/number-of-registered-automobiles-in-illinois/

[72] https://www.selectcarleasing.co.uk/hybrid-electric-cars/guides/miles-per-kwh

[73] https://www.eia.gov/electricity/state/illinois/

[74] https://www.sj-r.com/story/news/2018/04/28/solar-farms-set-to-sprout/12368625007/

[75] https://www.eia.gov/beta/states/states/il/overview

[76] https://www.seia.org/news/illinois-renewable-energy-growth-surges-months-after-climate-and-equitable-jobs-act-signed

[77] https://thehackernews.com/2023/02/is-your-ev-charging-station-safe-new.html

Economics of EVs

To achieve wide adoption, EVs must appeal as a reasonably cost-effective alternative to ICEVs. Given the higher initial cost of EVs, this requires a careful analysis. While ICEVs have been refined over a hundred years, serious development of EVs have occurred only in the last two or three decades, hence it must be kept in mind that further developments will occur in favor of EVs in the near future.

For rough comparisons, we can use the miles per gallon equivalent (MPGe) for EVs. As we saw earlier, one gallon of gasoline weighs 2.8 kg, and each kilogram of gasoline has about 12 kWh of useful energy, hence one gallon of gasoline has about 33.6 kWh of energy. An average EV can go 3 miles per one kWh of energy, so with 33.6 kWh, it can go about 100 miles. Hence, we say that the average EV gets 100 MPGe. For specific vehicles, the US DOE site[78] lists the official values of their MPGe.

In the section on batteries, we saw that an approximate cost of gasoline for a range of 300 miles in an ICEV was about $48, while the cost of electricity for the same range in an EV is about $16. More realistically, we should include the cost of initial purchase, and many other costs such as insurance costs, battery replacement costs, and cost of tires (and reduced maintenance costs). To illustrate the comparison of the true cost of an EV versus that of an ICEV, a rough estimation is given below.

In 2022, the average price of EVs was about $66,000 while that of ICEVs was $46,000[79]. But many of the EVs are of the luxury type, so this is not a fair comparison. We can compare the total cost of ownership of specific vehicles using the Vehicle Cost Calculator[80] provided by the US Department of Energy. For example, assuming that 2022 Chevrolet Bolt EV and 2022 Chevrolet Trax ICEV (base models) are comparable, we make the following assumptions:

	Bolt EV	Trax ICEV
Purchase price	31000	21400

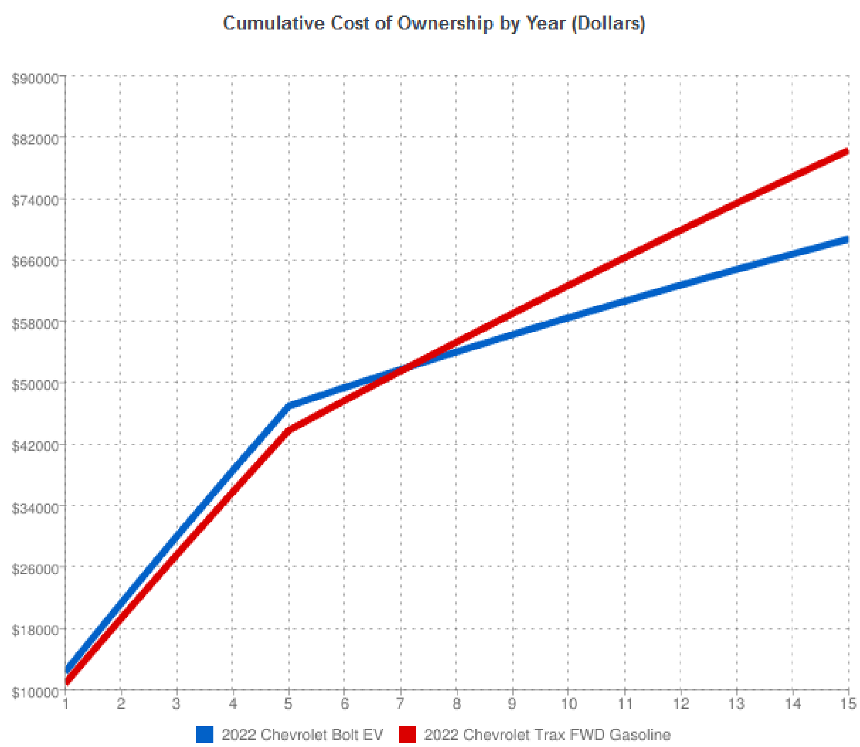
Assumptions	
Gasoline price per gallon	$3.50
Average daily commute miles	40
Days driven per week	5
Weeks driven per year	50
Daily miles on highways: percentage	30%
Annual mileage for non-commute trips	4000
Trips miles on highways: percentage	80%
State	Illinois

78 https://www.fueleconomy.gov/feg/byfuel/EV2022.shtml
79 https://www.forbes.com/sites/jimgorzelany/2022/09/09/buying-an-electric-car-by-the-numbers/
80 https://afdc.energy.gov/calc/

With the above assumptions, we get the following results from the Vehicle Cost Calculator:

Results:			
Vehicles	Annual Operating Cost	Cost per Mile	Annual Emissions (lbs CO2)
2022 Chevrolet Bolt EV	$2,708	$0.19	2,899
2022 Chevrolet Trax FWD	$4,185	$0.30	12,450

The table of results given above does not include the cost of the vehicle in the 'Annual Operating Cost' column. That is included in the chart below.



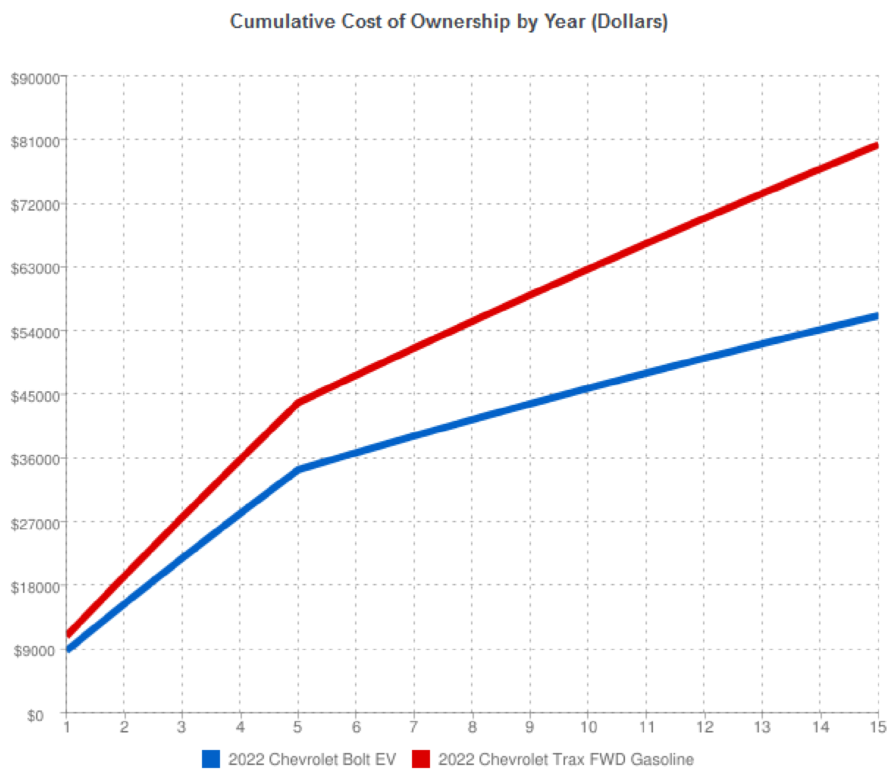
(chart obtained from the Vehicle Cost Calculator provided by US Department of Energy)

In addition to the explicit assumptions which are changeable by the user, the calculator makes additional assumptions and estimates. Gasoline price, electricity rate, financing and interest rates, maintenance costs, cost of tires (higher for EVs), insurance, license, registration, etc. are estimated from the best available sources. In particular, a five-year loan with 10% down payment is assumed, which explains the change of slope at year five in the chart. As we can see, past year seven, the total cost of ownership of the EV is below that of the ICEV. Also note that in 'Annual Emissions' column, emission due to both production and operations are included (EVs have zero emissions during operations).

The above calculations do not take into account the federal and state incentives provided. Assuming that the maximum incentive is available ($7,500 federal, and $4,000 by Illinois), the purchase price of 2022 Chevrolet Bolt goes down, and we have the following:

	Bolt EV	Trax ICEV
Purchase price	19500	21400

Using the same assumptions as earlier, and we will get the same annual operating cost and cost per mile; however, the total cost of ownership changes as shown below:



(chart obtained from the Vehicle Cost Calculator provided by US Department of Energy)

In this case, clearly the total cost of ownership of the EV is less than that of the ICEV throughout the time interval. But keep in mind that not all government incentives may be available since they are conditional, based on both the buyer as well as the vehicle (location of the final assembly as well as the locations where minerals are mined for the battery).

In some aspects, EVs do cost more. Initial cost is typically higher than that of a comparable ICEV. Insurance costs may be high because repairs cost more[81]. Tires for EVs cost more since EVs are heavier and allows faster acceleration leading to more wear and tear[82]. Battery replacements are expensive, and hence resale value of an EV is negatively affected. Repairs can be expensive. There is also the cost of installing a charger. On the other hand, the operating costs (fuel) and maintenance costs are less for an

[81] https://www.forbes.com/advisor/car-insurance/electric-vehicle/
[82] https://arstechnica.com/cars/2022/12/heres-why-electric-vehicles-need-ev-specific-tires/

EV, and if charged at home, it makes refueling trips unnecessary. Overall, the total cost of ownership of an EV is seen to be less[83] than that of a comparable ICEV.

There are many studies[84] [85] that show that EVs are less expensive in the long run. Some hold that while EVs are expensive now[86], lower cost EVs are going to be built in the future. It is worth noting that there are also studies[87] that show EVs are more expensive than ICEVs on a per mile of range (especially if one never uses home charging). Additionally there are misinformation campaigns[88] about costs as well.

Suggestion: Illinois charges an extra $100 for the annual license plate renewal fee for EVs (ICEVs and PHEVs pay $151, EVs pay $251). This fee goes to road maintenance, which is currently supported by a tax on gasoline sales. But given the desire to promote EVs and the benefit of the elimination of pollution, it seems counterintuitive to add a fee for EVs. The state should find a different means for highway maintenance, and remove the increased fee for EV license plate renewal.

[83] https://advocacy.consumerreports.org/wp-content/uploads/2020/10/EV-Ownership-Cost-Final-Report-1.pdf
[84] https://www.businessinsider.com/electric-car-vs-gas-cost-charging-loan-maintenance-study-2022-5
[85] https://electrek.co/2023/02/06/police-chief-explains-tesla-model-y-patrol-car-will-save/
[86] https://jalopnik.com/electric-vehicles-cost-too-damn-much-1848805009
[87] https://www.businessinsider.com/electric-vehicles-cost-more-per-mile-range-than-gas-cars-2022-2
[88] https://jalopnik.com/that-meme-about-the-cost-of-charging-an-electric-car-is-1849327989

Federal and State Policies and Incentives

Because of the need to reduce environmental pollution and also reduce the dependence on fossil fuels, federal and state governments have passed several bills to promote the EV industry. Some of the major bills are described below.

Build Back Better Agenda[89]: This is a framework proposed by the Federal Government in 2021 to rebuild the US economy. This has many aspects – with respect to EVs, it has plans to install a national network of EV charging stations; to offer point of sale incentives to consumers; to promote clean technologies; to expand domestic EV supply chains; and to advance environmental justice through Justice40[90] initiative (**Justice40 Initiative** is a program to ensure that at least 40% of benefits of federal investments in certain areas like climate change and clean transit reach disadvantaged communities. It was enacted as an executive order in January 2021).

The Build Back Better agenda is brought into action through the American Rescue Plan (enacted on March 11, 2021), Infrastructure Investment and Jobs Act (enacted on November 5, 2021), and the Inflation Reduction Act (enacted on August 16, 2022).

American Rescue Plan[91]: This was enacted on March 11, 2021, to secure the health and economic well being of Americans who were adversely affected by the COVID pandemic.

Infrastructure Investment and Jobs Act (IIJA)[92] [93](or **Bipartisan Infrastructure Law**, BIL): This was signed into law on November 15, 2021. This act provides over $1 trillion to fix US infrastructure, such as roads, bridges, dams, levees, sewage pipes etc. About $15 billion of that is for expanding the national EV charging network, deploying chargers along highway corridors, and reducing emissions.

Inflation Reduction Act (IRA)[94]: This was signed into law on August 16, 2022. The main thrust of this act is to reduce inflation, health care costs, and the deficit, and tackle climate change. The act promotes clean energy, with many incentives such as a $7,500 tax credit for individuals when they buy an EV assembled in North America.

A more detailed breakdown of the incentives to individuals:

> From August 16, 2022, only cars that had their final assembly in North America would qualify, and previous sales caps for manufacturers still hold through December 31, 2022 (so Tesla and GM cars, though assembled in North America, would not qualify since they have already exceeded the sales cap). https://afdc.energy.gov/laws/electric-vehicles-for-tax-credit has a list of vehicles that qualify.

[89] https://www.whitehouse.gov/build-back-better/
[90] https://www.thejustice40.com/
[91] https://www.whitehouse.gov/american-rescue-plan/
[92] https://en.wikipedia.org/wiki/Infrastructure_Investment_and_Jobs_Act
[93] https://www.cbh.com/guide/articles/infrastructure-bill-2021-breakdown-analysis/
[94] https://www.whitehouse.gov/briefing-room/statements-releases/2022/08/15/by-the-numbers-the-inflation-reduction-act/

From January 1, 2023, all vehicles (cars under $55,000 and SUVs/trucks under $80,000) assembled in North America will qualify (including Tesla and GM vehicles, regardless of the previous sales cap), but additionally, restrictions are placed on the sourcing of critical minerals and battery components used in EVs to be limited to countries with free trade agreements with the US. These restrictions increase over time - for example, in 2024, 50% of the minerals used and 60% of the battery components must be from countries with free trade agreements with the US.

The above incentives are given only as a rebate on the individual's tax (so if the tax liability is $6,000, the rebate would only be at most $6,000) - and there is a limit on income too: adjusted gross income should be below $150,000 for single tax filers or below $300,000 for married couples filing jointly.

There is also a rebate of up to $4,000 for the purchase of used EVs. These rebates will be available through 2032.

Some of the rules for the rebate are still being fine-tuned, and it is best to consult an official website such as the IRS site[95] for this.

The promotion of EVs and clean energy (such as heat pumps, wind turbines, and solar panels) is estimated[96] to create millions of jobs, reduce greenhouse gas emissions by one gigaton and help avoid up to 3900 premature deaths and 100,000 asthma attacks annually by 2030.

Build America, Buy America Act (BABA)[97]: This was signed into law on November 15, 2021, as part of IIJA. It aims to strengthen the US industrial base, and protect national security. One of the requirements is that when federal funds are used for a project, all iron, steel, manufactured parts, and construction material must be sourced from the US for that project.

IIJA, IRA, and the CHIPS and Science Act (CHIPS: Creating Helpful Incentives to Produce Semiconductors; signed into law on August 9, 2022) together allocates about $135 billion toward EV manufacturing[98]. A goal is to have half of all new cars made to be EV by 2030.

Following the Build Back Better Agenda and the Bipartisan Infrastructure Deal, President Biden has signed an executive order[99] that sets a target of 50% of sales of vehicles to be zero-emissions (mostly EV, but includes PHEV and fuel cell electric vehicles) by 2030.

DOE and DOT will create a Joint Office of Energy and Transportation to promote EV chargers along highways as well as in rural, disadvantaged, and hard-to-reach locations. $5 billion is for funding states for building a national charging network; $2.5 billion for promoting rural charging and charging access in disadvantaged communities.

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[95] https://www.irs.gov/credits-deductions/credits-for-new-clean-vehicles-purchased-in-2023-or-after

[96] https://www.whitehouse.gov/briefing-room/statements-releases/2022/08/15/by-the-numbers-the-inflation-reduction-act/

[97] https://www.epa.gov/cwsrf/build-america-buy-america-baba

[98] https://www.cnbc.com/2022/10/19/biden-administration-awards-2point8-billion-in-grants-for-electric-vehicle-battery-manufacturing.html

[99] https://www.whitehouse.gov/briefing-room/statements-releases/2021/12/13/fact-sheet-the-biden-harris-electric-vehicle-charging-action-plan/

California Framework Agreement[100]: In 2020, when the then US administration was rolling back the pollution reduction requirements on automobiles, California worked with some automobile manufacturers (BMW, Honda, VW, Ford, Volvo) to voluntarily reduce pollution. The framework was developed by the California Air Resources Board (CARB) within the California EPA. A few other states also support this framework (New York, Massachusetts, Vermont, Maine, Pennsylvania, Connecticut, Rhode Island, Washington, Oregon, New Jersey, Maryland, Delaware, Colorado, Minnesota, Nevada, Virginia, New Mexico).

Suggestion: Illinois should review this framework and consider whether to support it.

EPA's **Clean School Bus Program**[101]: Using funding from the Infrastructure Investment and Jobs Act, this program will provide $5 billion to replace existing school buses with zero-emission and low-emission buses in the 2022-26 time frame.

Many states have created their own programs for Electric School Buses (ESB)[102] [103] :

New York, April 2022: requires all new purchases from 2027 to be zero emission; to be all zero-emission by 2035 (approximately 47,000 buses)

Connecticut, May 2022: electrification by 2030 for buses in "environmental justice communities"

Maryland, March 2022: all new purchases from 2025 to be electric

Colorado, June 2022: school bus electrification grant program with equity-first, considering metrics such as income level, racial makeup, health impacts and air pollution burdens

West Virginia, March 2022: to support the new electric school bus manufacturing facility by GreenPower Motor in Charleston

Indiana, March 2022: approved utility pilot programs for ESBs

Suggestion: Illinois could develop similar programs to support ESBs. Currently Lion Electric in Joliet is going to manufacture ESBs; also Midwest Transit Equipment Company is retrofitting existing gas and diesel school buses with electric drive trains. This is both a health issue as well as an environmental justice issue (typically poorer school districts have less to spend on clean transport). The state should continue to support these initiatives.

Since 2010, battery pack costs have dropped by 85%[104], EV range has increased, and available EV models in the US has expanded to over 40. Building on that, the Whitehouse has set a target of 50% EV sales share in 2030.

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[100] https://ww2.arb.ca.gov/our-work/programs/zero-emission-vehicle-program
[101] https://www.epa.gov/cleanschoolbus
[102] https://www.wri.org/insights/electric-school-buses-us-legislative-victories
[103] https://www.ncsl.org/research/energy/state-electric-vehicle-incentives-state-chart.aspx
[104] https://www.whitehouse.gov/briefing-room/statements-releases/2021/08/05/fact-sheet-president-biden-announces-steps-to-drive-american-leadership-forward-on-clean-cars-and-trucks/

The Climate and Equitable Jobs Act (CEJA)[105] in Illinois: This was enacted on September 15, 2021. Its focus is on clean energy and decarbonization, with a requirement that Illinois convert to 100% renewable energy by 2050 (in 2021, only 11% of the state's electricity generation is from renewable sources). It has a variety of workforce training programs that will support workforce development in EV industry, and aims to support environmental justice (EJ) and economically disadvantaged communities by directing 40% of the transportation benefits to these areas. The act will create a centralized mechanism for policy development for EVs in Illinois, and has a goal of having one million EVs on the road by 2030. Another aspect of the act is in modernizing the Illinois electric grid.

As part of CEJA, the following rebate program has been created for EVs purchased in Illinois: $4,000 for the purchase of an all electric vehicle, and $1,500 for the purchase of an all electric motorcycle. The rebate is available through January 31, 2023. Future rebates are set at $2,000 from July 2026, and $1,500 from July 2028; however these rebates are available only while funding lasts. News articles[106] suggest that currently the number of applications have exceeded the amount of available funding.

The **Reimagining Electric Vehicles Act**[107], Illinois, was enacted in November, 2011. The goal is to encourage businesses in the EV industry to invest in facilities in Illinois. It is an enhanced version of the EDGE[108] (Economic Development for a Growing Economy) tax credit. For large companies like an EV manufacturer that can invest at least $1.5 billion and create 500 new jobs over a five-year period, the REV Act offers tax credits for up to 15 years, as well exemptions from taxes on utilities and telecommunications. Smaller manufacturers must invest at least $20 million and create 50 new jobs over a four-year period to receive the REV Act incentives.

Suggestion: These state incentives are limited and are not means tested like the federal program. They should be sustained for at least a decade for EVs to be widely adopted; and means testing or limiting the incentive to one time per individual may be adopted to conserve funds.

In addition to the incentives listed above, several states and countries have proposed a phase-out[109] of fossil fuel vehicles. Some of the states phasing out the sale of new ICEVs (light vehicles) are

State	By Year
California	2035
Connecticut	2035
Hawaii	2035
Massachusetts	2035
New Jersey	2040
New Mexico	2026

105 https://www.bomachicago.org/assets/pdf/CEJA+2021+Summary+and+Overview/
https://dceo.illinois.gov/climateandequitablejobs.html
https://www.ilga.gov/legislation/publicacts/102/102-0662.htm

106 https://www.illinoistimes.com/springfield/demand-exceeds-supply-for-illinois-evs/Content?oid=16335418

107 https://pantagraph.com/news/state-and-regional/govt-and-politics/eight-months-in-illinois-electric-vehicle-incentives-still-on-the-assembly-line/article_dee871a8-0f66-11ed-bd4d-632286bb5431.html

108 https://rsmus.com/insights/tax-alerts/2022/illinois-edge-credit-extended-five-years.html

109 https://en.wikipedia.org/wiki/Phase-out_of_fossil_fuel_vehicles

New York	2035
North Carolina	2035
Oregon	2030
Rhode Island	2035
Vermont	2035
Washington	2030

(data taken from https://en.wikipedia.org/wiki/Phase-out_of_fossil_fuel_vehicles)

And some of the major countries proposing a phase-out of sale of new ICEVs (light vehicles) are

Country	By Year
Canada	New sales by 2035; all ICEVs phased out by 2050
People's Republic of China	2035
Egypt	2040
Finland	2040
Germany	2030
India	2040
Indonesia	2050
Italy	2035
Japan	2035
Republic of Korea	2035
Mexico	2040
New Zealand	2040
Norway	2025
Poland	2040
Spain	2040
Sweden	2030
Turkey	2040
UK	2030
USA	New sales by 2035; all ICEVs phased out by 2050

(data taken from https://en.wikipedia.org/wiki/Phase-out_of_fossil_fuel_vehicles)

Conversely, Wyoming is considering phasing out EVs[110] by 2035!

[110] https://www.teslarati.com/wyoming-phase-out-evs-2035/

The EV Supply Chain in Illinois

The EV supply chain includes the extraction of raw materials, manufacture of component parts (battery, motor, motor controllers, regenerative braking, drive systems), assembly, and distribution. Also included are the activities of the infrastructure installation and maintenance, and the overall research and development.

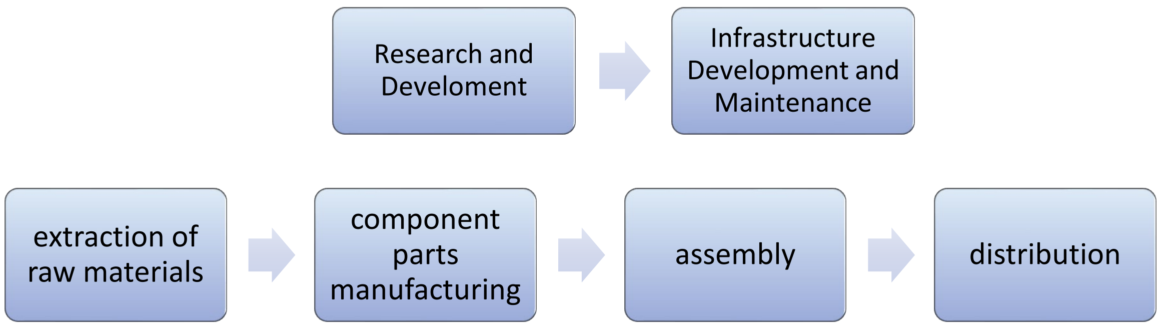

Figure: EV Supply Chain

Listed below are descriptions of some of the major companies in Illinois that are part of the EV supply chain.

Rivian Automotive LLC, located in Normal, Illinois, makes R1T pickup trucks and R1S SUVs (as well as EDV - electric delivery vans, primarily for Amazon). It has a capacity of 150,000 vehicles annually; however, the company is still in its startup phase, and delivered only 2,553 vehicles in the first quarter of 2022[111]. It employs about 5,200 workers (as of June 2022)[112].

Lion Electric Company located in Joliet, Illinois, is slated to make electric medium and heavy-duty vehicles (school buses). Production is to begin in the second half of 2022, and the plant has a capacity of making 20,000 units annually[113]. It will employ about 1400 workers. Merkur is a manufacturing performance and product-development firm that guided the development of the Lion Electric facility, and has an office in Downers Grove.

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111 https://insideevs.com/news/578177/rivian-built-2553-vehicles-q1-2022-delivered-1227/

112 https://energynews.us/2022/06/06/a-decade-after-evtown-rivian-is-making-an-illinois-citys-electric-vehicle-vision-a-reality/

113 https://rejournals.com/clarius-partners-lion-electric-manufacturing-facility-a-once-in-a-lifetime-project-in-joliet/

Midwest Transit Equipment in Kankakee, Illinois, in partnership with SEA Electric, will convert (retrofit) gasoline or diesel powered school buses to electric[114]. Likewise Illinois Energy Consortium is partnering with Highland Electric Fleets to electrify school buses[115].

AllCellTech Batteries, Broadview, Illinois, recently acquired by Beam Global, makes Lithium-ion batteries for electric vehicles[116]. They have developed a thermal management system that prevents thermal runaway propagation, making their batteries safer.

T/CCI Manufacturing in Decatur will be manufacturing compressors for electric vehicles using incentives from CEJA and REV Illinois Acts[117]. Kay Manufacturing[118] in Calumet City makes drivetrain components. Molex, a company in Monee, makes busbars used in EVs and chargers. EVBox in Libertyville manufactures EV chargers. EMS in Richmond makes electric busbars.

Several public EV charging companies operate in Illinois. Some of them are Tesla SuperCharger, BP Pulse, ChargePoint, EVgo, EVConnect, XCharge, Electrify America, Elite Charging Systems, SemaConnect, EVPassport, Volta, Blink, and Rivian Waypoints. Companies that will install an EV charger (public chargers or home chargers) are ABB E-Mobility, QMerit, PowerCharge, Smart Charge America, Ameren (LaSalle, IL), Klees EV (Buffalo Grove, IL), EvoCharge, Pro Air HCE (Downers Grove, IL), Kapital Electric (Bensenville, IL) and 167 others listed at the Illinois Commerce Commission site[119].

Additionally, other manufacturers and suppliers are also located in Illinois and neighboring states. Stellantis is expected to begin produce EVs in its Belvedere plant in 2024[120]. Navistar (Lisle, IL), Meritor Inc., BorgWarner Inc. (Bellwood, IL), Eaton Corporation Inc. (Lincoln, IL), OrangeEV and many others are part of the EV industry supply chain in Illinois. Also noteworthy are the major universities in Illinois that are engaged in research, and particularly noteworthy is the Argonne National Laboratory in Lemont which is at the forefront of research electric vehicle batteries.

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[114] https://www.prnewswire.com/news-releases/midwest-transit-equipment--sea-electric-to-power-10-000-electric-school-buses-301437670.html

[115] https://www.prnewswire.com/news-releases/illinois-energy-consortium-powered-by-future-green-partners-with-highland-electric-fleets-to-bring-fleet-electrification-as-a-service-to-illinois-school-districts-301681603.html

[116] https://www.allcelltech.com/

[117] https://www.richland.edu/tcci/

[118] https://kaymfg.com/capabilities/

[119] https://www.icc.illinois.gov/emdb/ucdb/search

[120] https://www.gmtoday.com/autos/as-rivian-struggles-to-meet-early-demand-illinois-looks-to-become-manufacturing-hub-in-coming/article_e3821340-6336-11ec-9b20-e74a2aa0ec9f.html

Interviews with Illinois EV Supply Chain Contributors

As part of this project, we have conducted interviews (either in-person or online) with several companies that are part of the EV supply chain in Illinois. A brief report of the interviews are given below. The companies are grouped into battery manufacturing, charging infrastructure, EV manufacturing and assembly, and those in mass transit operations.

EV Battery Manufacturing

Beam Global

AllCell Technologies, LLC[121], was established in 2001 with a focus on manufacturing batteries for electrically powered mobile vehicles. Initially the company was making batteries for telecoms, electric scooters, autonomous vehicles, forklifts, eBikes, and delivery drones. It now has a manufacturing facility in Broadview, Illinois. Their technology allows better management of the heat load of a battery pack with industry leading results including improved power and energy density, increased life, and top safety certifications. They offer unique technologies in heat management of battery packs. Customers are mainly in North America, along with a few global customers.

In 2022, AllCell was acquired by Beam Global, a California company with several product lines including EV Charging equipment. With this change there is a potential to expand their manufacturing facilities. Main procurement item is lithium cells, supplied by mostly LG, but also Samsung and Panasonic. One of the challenges in supply management is the long lead time for lithium cells. Other material purchased include graphite and wax. Companies seeking opportunities to do business with AllCell should contact Panos Prezas, VP for Business Development. In addition to raw materials, the company is also looking for new equipment to automate production processes.

The state of Illinois incentives for supporting EV requires smaller companies to invest at least $20 million and create 50 new jobs over a four-year period[122] – this is a high hurdle for companies like AllCell. Hence the company will use the regular EDGE incentives as they expand their production. They are currently hiring managers, and entry level workers with basic manufacturing skills.

[121] https://www.allcelltech.com/

[122] https://pantagraph.com/news/state-and-regional/govt-and-politics/eight-months-in-illinois-electric-vehicle-incentives-still-on-the-assembly-line/article_dee871a8-0f66-11ed-bd4d-632286bb5431.html

EV Charging Infrastructure

Konnectronix

The company[123] was established in 1989 as Telefonix, Inc., and is located in Waukegan, Illinois, along with a secondary manufacturing facility in Gurnee, Illinois. In 2017 it changed its name to Konnectronix, Inc., with a new focus on EVSEs among other products.

Konnectronix believes that their products can replace gas stations and similar infrastructure. They build low-power EV chargers under the Konnectronix and PowerPost EVSE brands, as well as in partnership with market leaders. Their Level 2 chargers are priced under $2,000, and Level 3 chargers at around $10,000. They reach their customers through direct marketing and have partnerships with parking garages. Their sales are limited to US, though they do have sales partners who sell their products abroad. The company focuses on low power EV chargers that can be installed in homes.

They obtain their raw materials from abroad and make their own cables and reels. Companies seeking opportunities to do business with Konnnectronix should contact Sean Burke, Chief Operating Officer.

Most of the training of workers is done internally, and currently they are not planning to expand. Many facility managers reach out to them for installing EVSEs, and the challenge is to provide the right information and education to make them aware of the many obstacles involved in setting up EVSEs. As of now they do not envisage make use of the incentives provided through the REV Act.

Francis Energy

Francis Energy[124] was established in 2015 in Tulsa, Oklahoma, and offers a network of EV chargers. Currently there are none operated by them in Illinois – it is available in Missouri, and they may expand to Illinois in the future. For each project they hire local contractors supervised by a satellite team. They are also investing in battery storage in order to optimize the charging infrastructure.

Currently they purchase hardware from SL Power Electronics. Companies seeking opportunities to do business with Francis Energy should contact Jason Pitcock, SVP, Government Relations. They are planning to install 2500 EVSEs within two years. Generally they hire qualified electricians, and an EPA certification would be welcomed.

Noodoe EV

Noodoe EV[125] offers cloud based operating systems for EV charger management. They also install Level 2 and Level 3 charging stations (up to 360 kW), but they do not manufacture the

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123 https://www.konnectronix.com/about-us.html
124 https://francisenergy.com/
125 https://www.noodoe.com/noodoe-ev-about/

hardware. The company was established in 2018, and is headquartered in Denver, Colorado. Their charging stations are located in US, Asia, and Australia. They can be installed in hotels, workplaces, shopping centers, or apartment complexes.

Noodoe uses an Open Charge Point Protocol which makes it easier to integrate with the charging hardware of EVSE systems. They believe their more modern software has advantages over the proprietary - but industry leading - software used by ChargePoint. They use a direct sales force to reach their potential customers. Main customers are fleet operators, local charging network providers, and other site hosts.

Their business is growing despite the increased competition. Government incentives and regulatory standardization help in the growth of this industry. They hire mainly software engineers.

Volta Charging

Volta Charging[126] was established in 2010 and is headquartered in in San Francisco, California. At their core, they are an EV charging infrastructure company. They provide a network of Level 2 and Level 3 charging stations across 26 states, several of which (over 275) are in the greater Chicago area.

The charging facilities are provided with 55 inch screen which in addition to assisting the user for charging the vehicle, also allows the company to advertise and promote events and public messaging. The revenue created through this is used to subsidize the costs of the charging station. The company also offers an artificial intelligence based EV tool (PredictEV[127]) which is useful in predicting the EV adoption in the near future and the required charging stations to support that. It allows for identifying ideal and equitable charging locations and charging mix, and upholds the federal government's Justice40 goals.

They have a manufacturing facility in Aurora, Illinois, and use local manufacturers depending on the components purchased. Final assembly of the chargers are done in house. Companies seeking opportunities to do business with Voltas Charging should contact Andrew O'Donnell, general manager in the Midwest area.

WindFree Solar

WindFree Solar[128] was established in 2009, and is headquartered in Chicago, Illinois. It installs solar PV (photovoltaic) systems for commercial, public sector and residential sites, and is also a leading battery storage and EV charging station installer. WindFree Solar is a certified Minority Owned Business (MBE: Minority Business Enterprise) and an Equity Eligible Contractor (EEC). The Inflation Reduction Act (IRA) provides federal investment tax credit for solar, battery

[126] https://voltacharging.com/
[127] https://voltacharging.com/predictev
[128] https://www.windfree.us/about

storage, and EV charger projects., and WindFree Solar is ideally equipped to help customers to avail of these credits.

The company mostly designs and installs the systems, and manufacturing is outsourced. Some of their customers are Tesla, Uber, the State of Illinois, and the Chicago Public Schools.

WindFree Solar has a growing business, and train their technicians through apprenticeship. They are also hiring maintenance personnel, licensed electricians, and EV engineers. Companies seeking opportunities to do business with Windfree Solar should contact Jack Johannesson, the Sales Director.

EV Manufacture and Assembly

Lion Electric

The Lion Electric Company[129] in Joliet, Illinois, is a subsidiary of Lion Electric, Canada. The Joliet facility manufactures zero-emission heavy duty vehicles. They design and manufacture all-electric school buses, minibuses for special needs or urban transit, as well as urban trucks. In future they will also manufacture electric ambulances and utility vehicles.

Major customers include Amazon, IKEA, Student Transportation of America (STA[130]), and First Student[131]. Educating the customers about the infrastructure requirements for electric buses is a challenge – often they need to appeal to School Superintendents to get the orders from school districts. Though Lion Electric mostly buys batteries from outside sources, they have a battery manufacturing company in Mirabel, Canada, which has recently started production. The electric drive systems (motors, inverters, controllers, axles, and driveshafts) are supplied by Dana Inc. (based in Maumee, Ohio).

Lion Electric in Joliet has approximately 1,300 employees, of which over 300 are in its Engineering and R&D departments. They are planning to hire more personnel to keep up with their growing operations.

Lion Electric works closely with the state of Illinois to make use of the state incentives for EV manufacturing and employment growth.

Midwest Transit Equipment (MTE)

MTE[132] is one of the largest bus dealers in the US. They sell and service new and used buses throughout the US and around the world. They are headquartered in Kankakee, Illinois.

[129] https://thelionelectric.com/en
[130] https://ridesta.com/about/
[131] https://firststudentinc.com/about-us/
[132] https://www.midwesttransit.com/

Steve Gardner, VP for Electric Buses in MTE, discussed how MTE is retrofitting existing school buses with SEA Electric[133] drive train. These vehicles are cleaner than the existing diesel buses, and since only the drive train is being changed, will not cost as much as a new electric bus.

SEA Electric was founded in Australia in 2012, and is currently headquartered in California, USA. They developed the technology to retrofit diesel buses with electric drive trains. The electric bus takes about 4 to 8 hours to charge, and has a typical range of 185 miles. These are ideally suited for school buses which have limited travel distances and plenty of down time for recharging. They require much less maintenance and hence is economical in the long run. Zero emissions ensure that the school children are shielded from toxic conditions that are detrimental to their growth.

One of the challenges that MTE faced was ramping up the production capacity of retrofitting the buses. MTE has invested in multiple locations in the state to enhance this needed capacity. Their goal is to retrofit 10,000 buses in ten years.

Mass Transit

Chicago Transit Authority

The Chicago Transit Authority[134] (CTA) is the operator of public mass transit in Chicago and some of its surrounding suburbs. It is an independent governmental agency. They operate bus routes and a rail system ("The 'L'"). On an average weekday, about 1.6 million rides are taken on CTA. They operate about 129 bus routes (1536 route miles) and 8 rail lines (224 miles of track).

CTA first introduced an electric bus in 2014, in collaboration with the state government. During the first year, CTA struggled with the charging and battery technology. At that time there was no charging infrastructure. CTA later collaborated with New Flyer[135], which provides electric buses as well as other zero or low emission vehicles using fuel cells or compressed natural gas. In collaboration with Heliox[136], a Dutch company that specializes in rapid charging technology and solutions for electric vehicles, CTA installed 450 kW (fast charging) and 180 kW (slow charging) batteries with a fleet of 40 electric buses, making CTA the first independent government agency to adopt electrification of transit buses. In 2019, the Chicago City Council passed a resolution[137] to electrify all buses by 2040.

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[133] https://www.sea-electric.com/
[134] https://www.transitchicago.com/about/
[135] https://www.newflyer.com/
[136] https://www.heliox-energy.com/us/home
[137] https://www.transitchicago.com/electricbus/

CTA is not currently hiring personnel related to electric buses. The contract CTA has with both the bus manufacturer and the installer of charging infrastructure include training in areas such as charger maintenance and bus operation. Subsequently these CTA employees who have been trained by bus and charger contractors will train a larger pool of other CTA employees.

Equity Issues, Workforce Issues, and Training

Growth in EVs and the development of the EV infrastructure should be equitable to all sections of the society. According to the State Senator Celina Villanueva, "Historically, Black and Brown people have fought tremendous battles against climate change while hazardous wastes are disproportionately poured into their communities"[138]**.** Access to EV is also an environmental justice issue[139]. Projects need to be developed with appropriate labor agreements and equitable wages. And there is evidence[140] that EVs promote a healthier community.

The move to EVs will cause a drop in employment in the businesses that service the internal combustion engine vehicles. These include service stations and gas stations. In California, it is projected[141] that about half of the 60,910 jobs of auto service technicians and mechanics could be lost in the next two decades. The Climate and Equitable Jobs Act, Illinois[142], seeks to provide state support for transitioning employees. Automobile dealerships[143] will also be affected because they depend on the service income which may decrease with EVs.

Another equity issue is how the incentives are structured. Many of the early buyers of EVs are the wealthy who have resources to buy them even without incentives. By the time EVs have become commonplace and the average people who are often more dependent on transportation are about to buy an EV, the incentives may no longer there. Perhaps Illinois can look at the steps California has taken to refocus incentives to low-income people, particularly the "gasoline superusers"[144]. Similarly, the charging infrastructure must meet the needs of those who live in multistory buildings or rent their apartments - especially those who park on the street. Some cities like Los Angeles are installing EV chargers on existing street electric poles[145] (since they already wired!). Behavioral economics may also be applied to increase the acceptance of EVs - if it is difficult for people to reach charging stations, then bring the charging stations to them: such as places of work and places where they spend time (malls, hotels). State

[138] https://www.illinois.gov/news/press-release.23893.html

[139] https://www.scientificamerican.com/article/access-to-electric-vehicles-is-an-environmental-justice-issue/

[140] https://keck.usc.edu/study-links-adoption-of-electric-vehicles-with-less-air-pollution-and-improved-health/

[141] https://www.msn.com/en-us/autos/buying/as-california-switches-to-electric-cars-thousands-of-mechanics-will-lose-jobs/ar-AAXRjFu

[142] https://www.illinois.gov/news/press-release.23893.html

[143] https://www.theatlantic.com/technology/archive/2022/01/climate-electric-vehicle-car-dealership-power/621330/

[144] https://www.greencarreports.com/news/1135650_california-considers-refocusing-ev-incentives-toward-low-income-gasoline-superusers

[145] https://www.npr.org/2022/10/25/1131369881/electric-vehicles-home-apartment-renters-charging-evs

governments[146] are beginning to establish rules that would require residential construction to include solar panels and EV charging stations.

Suggestion: Illinois should consider creating requiring new constructions to include EV charging stations, and investigate options for adding charging stations to existing buildings.

US Bureau of Labor Statistics (BLS) suggests that the projected employment growth from 2020 to 2030 in the areas of wind turbine service technicians is about 68%, and that of solar installers is about 52%[147]. BLS has no separate category for EV technicians yet. US DOE reports that EV jobs increased 26.2% in 2021[148], but fossil fuel jobs decreased by 3.1%[149].

It is imperative that the workforce for the production and servicing of EVs, as well as manufacture, installation, and maintenance of EVSEs be trained. There are many news articles[150] about EV public charging stations being out of order. One study[151] showed that only 72.5% of the EVSE's in the San Francisco Bay Area were functional. Private companies like ChargerHelp[152] and EVITP[153] are training technicians for servicing EVSEs. Heartland Community College[154] in Normal, Illinois, offers certificate courses in Electric Vehicle Service Advisor, Electric Vehicle Energy Storage, and Electric Vehicle Maintenance and Light Repair, and Associates in Applied Science degree program in Electric Vehicle Technology. With investment from State of Illinois, Heartland has also created a new Electric Vehicle Energy Storge[155] training program. The State of Illinois is also funding a manufacturing training academy at Southwestern Illinois College[156].

The Careers in Electric Vehicles[157] site by the Bureau of Labor Statistics identifies many areas of occupations needed for EVs and the requisite skills. They include scientists and engineers (chemists, material scientists, electrical engineers, mechanical engineers, chemical engineers, software developers) as well as manufacturing technicians (assemblers, machine tool operators, machinists, production managers) and infrastructure personnel (urban and regional

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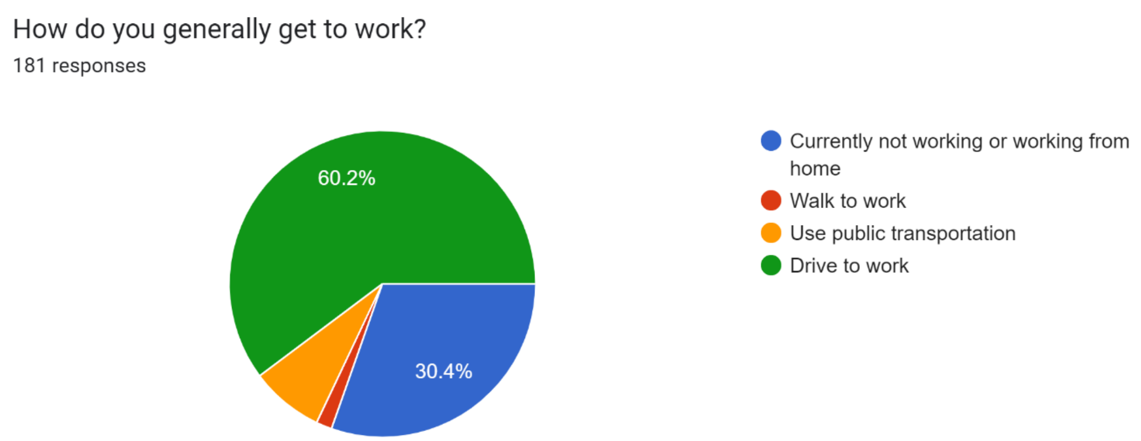
[146] https://www.krqe.com/news/politics-government/legislature/bill-would-require-new-homes-to-include-solar-panels-charging-stations/
[147] https://www.bls.gov/opub/mlr/2021/article/projections-overview-and-highlights-2020-30.htm
[148] https://www.energy.gov/articles/doe-report-finds-energy-jobs-grew-faster-overall-us-employment-2021
[149] https://www.energy.gov/sites/default/files/2022-06/USEER%202022%20Fact%20Sheet.pdf
[150] https://www.msn.com/en-us/money/other/out-of-order-the-ev-charging-industry-has-a-maintenance-problem/ar-AAZsyAk
[151] https://arxiv.org/ftp/arxiv/papers/2203/2203.16372.pdf
[152] https://www.axios.com/2022/10/27/ev-electric-car-charger-mechanics-technicians
[153] https://evitp.org/about-us/
[154] https://www.heartland.edu/degrees/index.html
[155] https://www.illinois.gov/news/press-release.24034.html
[156] https://www.swic.edu/about/news/gov-pritzker-announces-15m-investment-to-create-two-state-of-the-art-manufacturing-training-academies-downstate/
[157] https://www.bls.gov/green/electric_vehicles/electric_vehicles.pdf

planners, electric powerline installers and repairers, charging station installers and repairers, retail sales persons, customer service representatives).

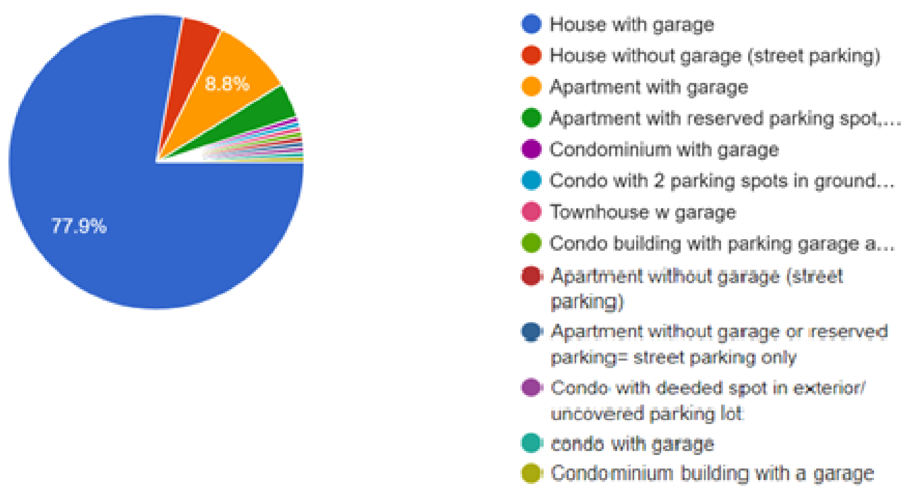
Consumer Perceptions of EV

If Illinois should reach one million EVs by 2030 as envisaged in the REV Illinois program, the demand for EVs has to rise and the right incentives be devised by policy makers. As noted in the section on federal and state incentives, many incentives are available, and it is important to see how consumers are persuaded by them, or even aware of them. For this reason, a survey was sent to a mailing list of the Chicago Southland Economic Development Corporation, and about 180 responses were obtained. While this is not a random sample of Illinois residents, the Chicago Southland is comprised of a diversity of people and the number of respondents are large enough to draw meaningful results. We have also included results from other available survey results to gain a better understanding.

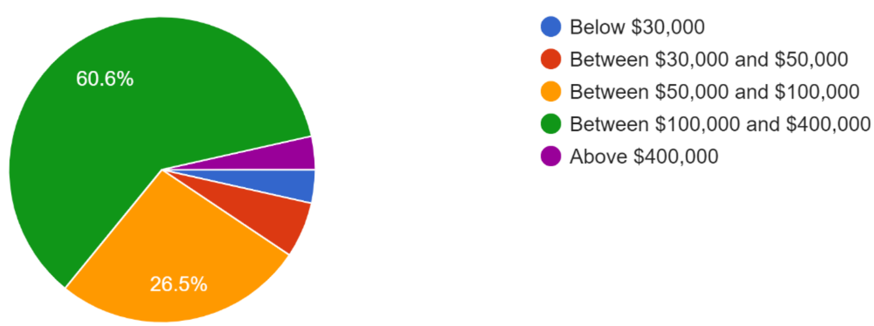
The survey results are given below.



How would you best describe your current place of living:
181 responses

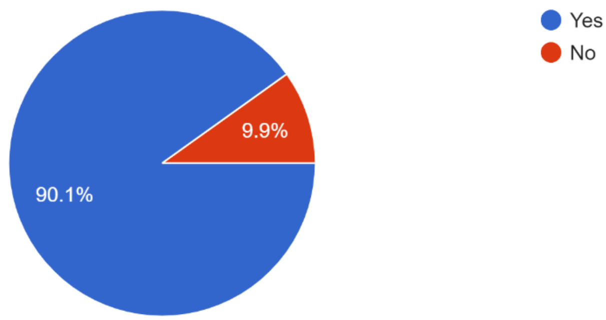


What is your annual household income:
170 responses



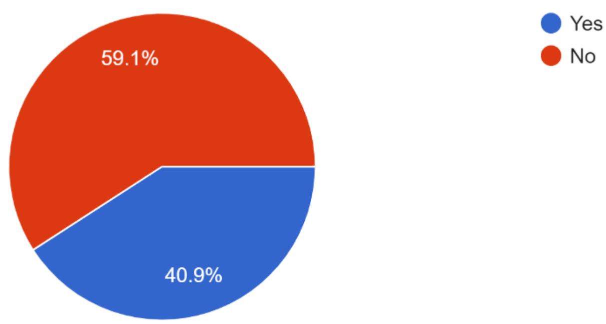
Do you (or anyone in your family) currently own or lease a vehicle or vehicles that run on gasoline or diesel?

182 responses



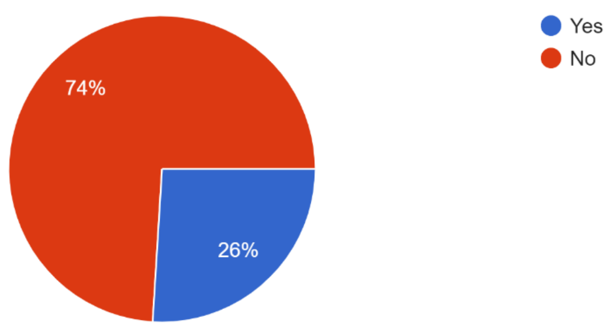
Have you ever driven an electric vehicle?

181 responses

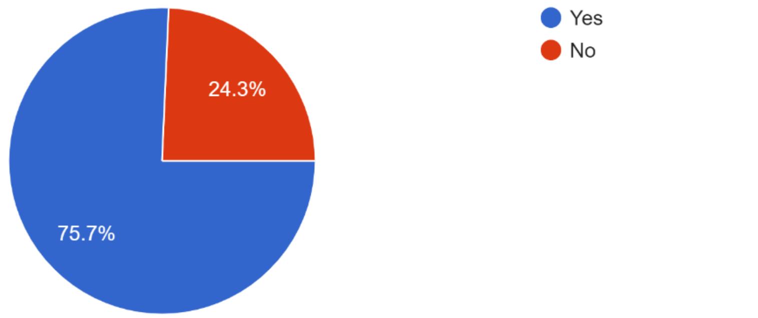


Do you (or anyone in your family) currently own an electric vehicle?

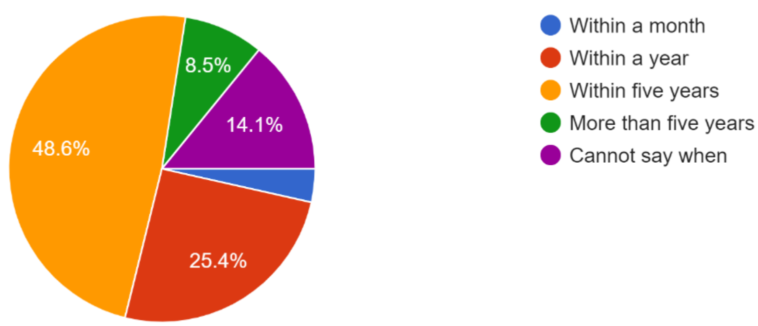
181 responses



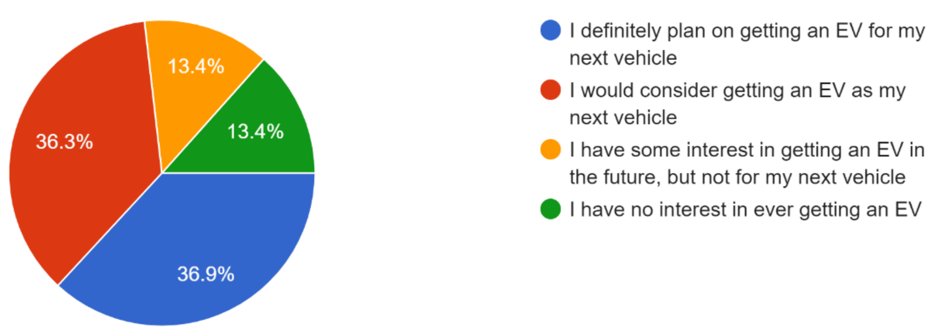
Are you considering purchasing an electric vehicle in the future?
181 responses



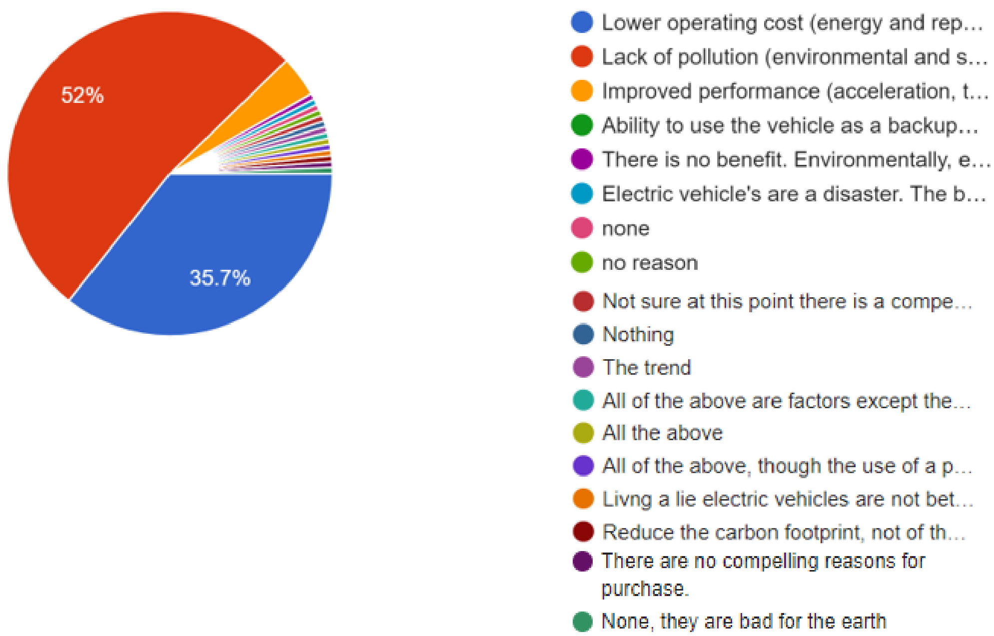
If you answered 'Yes' to the previous question, in approximately what time horizon?
142 responses



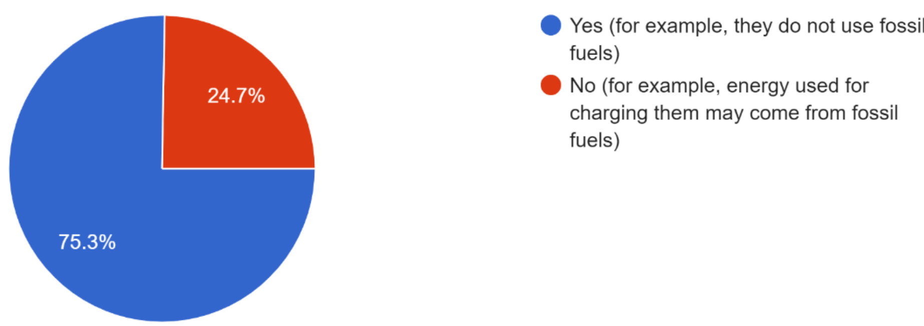
Which of the following statements most accurately describes your feelings about purchasing an electric vehicle?
179 responses



In your opinion, what is the most compelling reason for buying an electric vehicle?
171 responses

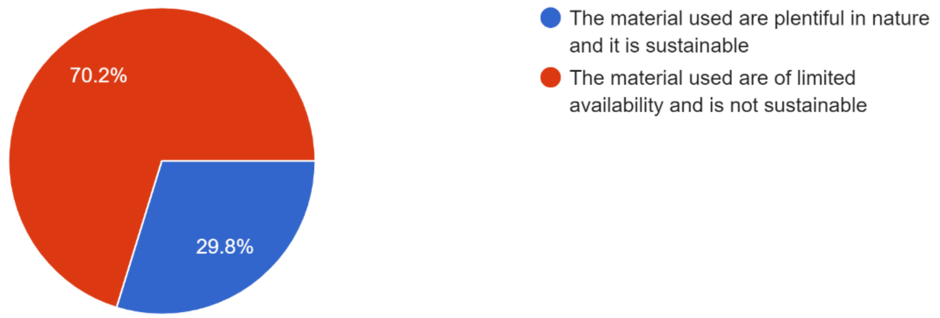


In your opinion, do electric vehicles promote environmental sustainability?
178 responses



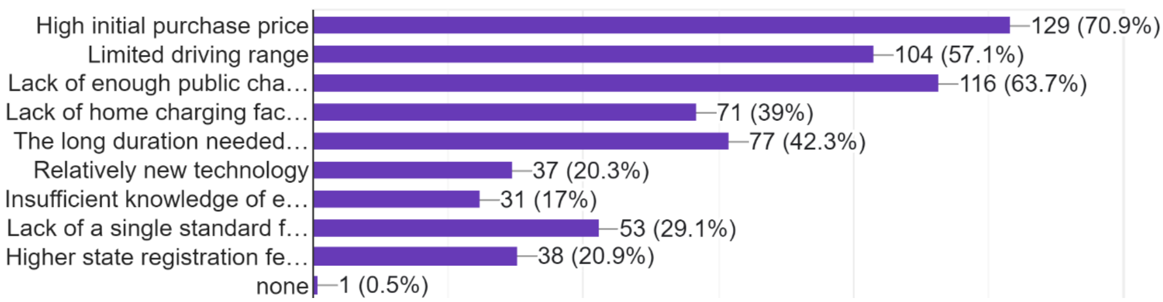
In your opinion, which of the statements below describe best the prevailing battery technology?

178 responses



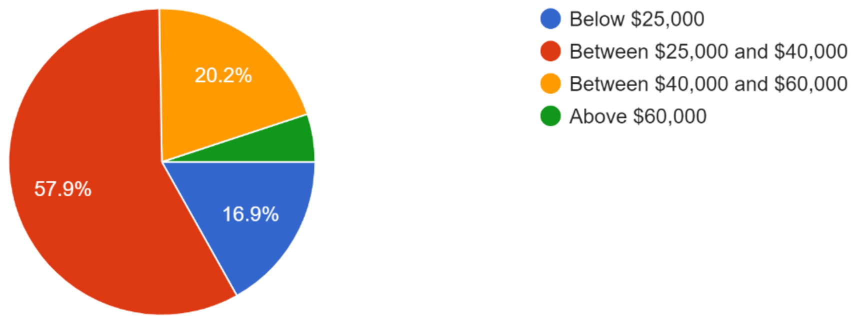
In your opinion, what is the most important obstacle in purchasing an electric vehicle? (Choose all that apply)

182 responses

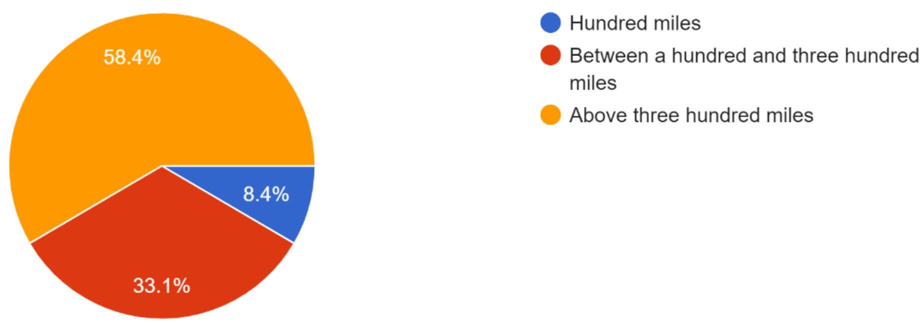


If you were to buy a new electric vehicle, what do you think is a reasonable price for it?

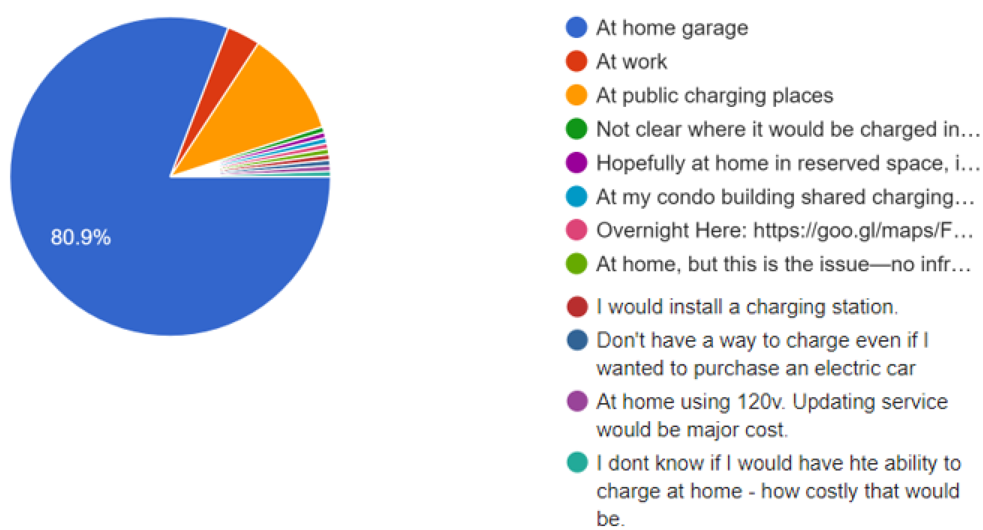
178 responses



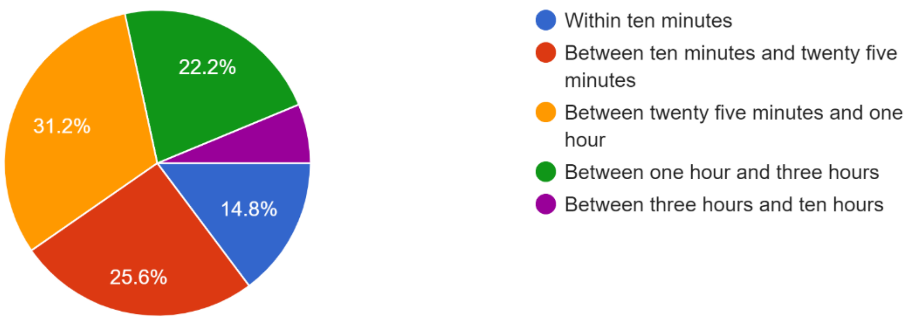
If you were to buy an electric vehicle, what range (on a single charge) would be acceptable to you?
178 responses



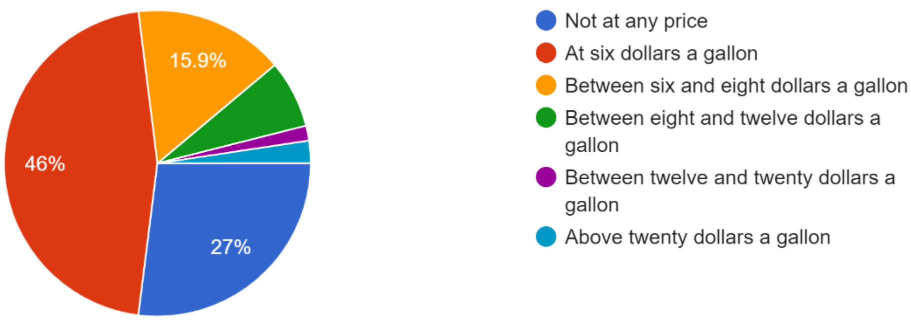
If you were to buy an electric vehicle, where would you (ordinarily) charge it?
178 responses



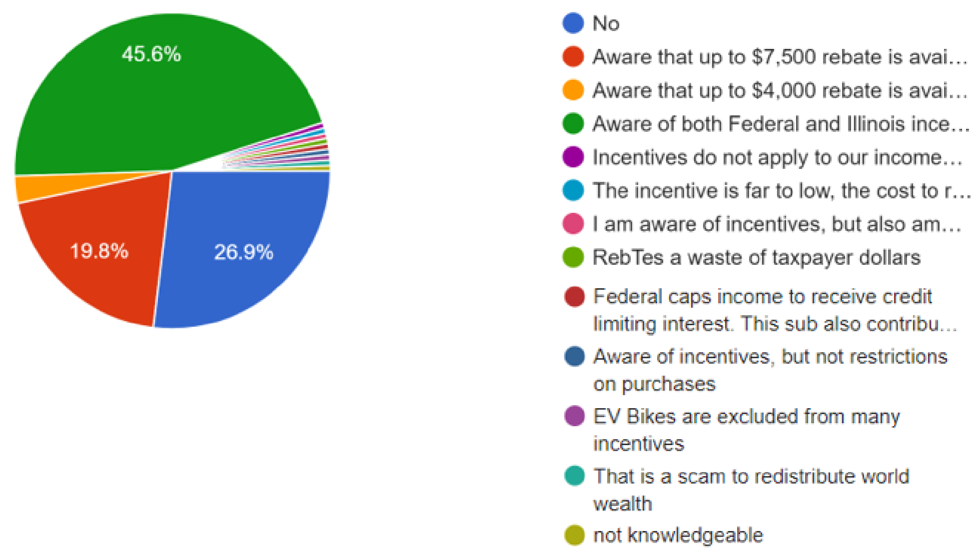
If you were to buy an electric vehicle, in your opinion, how fast should the battery charge from low charge to approximately full charge?
176 responses



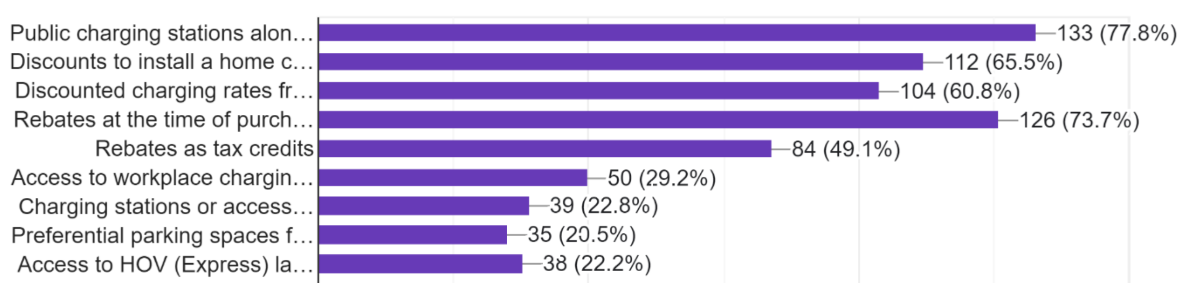
If you were not planning to buy an electric vehicle, at what price of gasoline will you consider buying one?
126 responses



Are you aware of the incentives offered by the Federal and Illinois State governments for consumers to buy electric vehicles?
182 responses



Which of the following state or federal policies, if implemented, would most likely increase your desire to buy or lease a plug-in electric vehicle? (Select all that apply)
171 responses



To summarize, in the preceding pages we have provided some demographic information about the respondents, and information regarding their perceptions. Majority of them drive to work, and about half drive between 5 and 20 miles to work (one way). About 78% live in houses with garage, which indicates that it would be relatively easy for them to install a level 1 or level 2 charger. 90% own ICEVs, but only 41% have ever driven an EV, with 74% not owning (themselves or family members) an EV. Since familiarity is needed prior to the adoption of any new technology, this suggests that offering opportunities to test drive EVs may encourage more consumers to consider EVs. A Consumer Reports survey[158] agrees with this suggestion.

[158] https://www.cnn.com/2022/07/08/business/consumer-reports-electric-car-survey/index.html

In terms of consumer perceptions and decision making, about 75% of the respondents are considering purchasing an EV in future. About 30% may buy within a year, and another 48% may buy an EV within five years. About 37% are definitely planning on buying an EV as their next vehicle, with an additional 36% considering an EV for their next purchase.

Regarding the main reason for buying an EV, elimination of emission pollutants (52%) and lower operating costs (36%) were the top two. About 75% believe that EVs are good for environmental sustainability, while others disagree, because of the source of energy for charging (and perhaps the carbon footprint in the manufacture of EVs). There is anxiety about the manufacturing process – 70% felt that the materials used in current battery production are of limited availability and not sustainable.

The five most important reasons that stood as obstacles in purchasing an EV are:

1. High initial purchase price
2. Lack of enough public charging places
3. Limited driving range
4. The long duration needed for charging
5. Lack of home charging facilities

Many other surveys also point to price, range anxiety, and charging time as the top concerns in buying an EV. A survey[159] of SlashGear readers identified range as the top concern (followed by cost of battery replacement, skepticism of the capacity of the electric grid, and charging time). Those with individual garages can install chargers and charge overnight, but those who use street parking will need help. Several cities are beginning to provide chargers at street light fixtures[160]. A New York Times survey[161] identified the price as the main concern. A multinational study[162] identified lack of charging stations and range anxiety as the top concerns. Another multinational study by Deloitte[163] found that the biggest hurdle to buying an EV is its cost (range and charging time were the next), and 70% do not want to spend more than $50,000 for an EV.

Getting back to our survey, we found that most people (81%) plan to charge from home, from the power grid. When using chargers, 40% wanted an approximate full charge within 25 minutes, and another 31% were willing to wait up to one hour. In terms of the price of vehicles, 58% felt that a reasonable price would be between $25,000 and $40,000. It should be noted that many of the models are of the higher end luxury type which may deter a large part of the population from buying them. 58% feel that the range should be above 300 miles per charge. Earlier we saw that about half the respondents drive between 5 and 20 miles to work, so this may be an unreasonable expectation, and consumer education

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[159] https://www.msn.com/en-us/autos/news/31-of-people-said-they-wouldn-t-get-an-electric-car-for-this-reason-slashgear-survey/ar-AA15km8f

[160] https://thecityfix.com/blog/how-utility-poles-and-streetlights-can-improve-equitable-access-to-ev-charging-in-u-s-cities/

[161] Ewing, Jack, and Peter Eavis. "Mainstream Car Buyers Turn Toward Electrics." *New York Times*, 14 Nov. 2022, p. B1(L). *Gale In Context: Opposing Viewpoints*, link.gale.com/apps/doc/A726444495/OVIC?u=governors&sid=bookmark-OVIC&xid=c066e81f. Accessed 21 Nov. 2022

[162] https://assets.ey.com/content/dam/ey-sites/ey-com/en_gl/topics/automotive-and-transportation/automotive-transportation-pdfs/ey-mobility-consumer-index-2022-study.pdf

[163] https://www.businessinsider.com/us-electric-vehicle-buyers-cars-too-expensive-2023-1

may be useful in changing perceptions. Often people depend on one car for daily commute as well as the occasional long distance drive. If it can be demonstrated that there are sufficient fast charging stations along highways, and that the charging time is low, many can be persuaded to buy EVs with range less than 300 miles. They should also be made aware of the possibility of renting a vehicle for the occasional long trips.

In the survey, 81% had stated they would ordinarily charge their vehicles at their home garage. Since many in Illinois lack this option, it is imperative that alternative solutions are in place. In terms of charging time, though 15% of the respondents would like to have an approximately full charge in ten minutes, about 72% are content with a charging time under one hour. And it appears that that if gasoline prices go up beyond six dollars to a gallon, 46% of the respondents will consider buying an EV.

Only 46% of the respondents are aware of the federal and state incentives available for buying an EV. This shows that even though these incentives are in place, the public has not yet fully understood them, and there is a need for educating the public about these incentives.

Finally, in terms of incentives that would encourage them to buy an EV, the top six were

1. Public charging stations along highways
2. Rebates at the time of purchase or lease
3. Discounts to install a home charging station
4. Discounted charging rates from electric utility provider
5. Rebates as tax credits
6. Access to workplace charging stations

Suggestion: EV Charging Trucks should be readily available to be summoned if an EV runs out of charge. This can reduce range anxiety substantially.

Suggestion: Overnight charging at home is the most inexpensive and convenient means of charging, and sufficient for most commuting needs. For those with home charging facilities, public chargers are only needed for occasional (typically) long distance travel. However, vehicles are purchased with the mindset of covering all needs, leading to a requirement of longer ranges. If EV owners can be shown that it is economical to buy a low range EV for regular commute and rent another vehicle for the occasional long trip, there will be more willingness to buy a lower range EV, which is beneficial in many ways: smaller batteries can be used, EVs can be inexpensive, the load on the grid would be at off-peak hours, and the public chargers would be left for the true long distance travel.

Suggestion: This survey and others indicate that those who have driven an EV are more likely to buy an EV. Similar to auto dealers allowing customers to test drive a car, facilities to allow the public to test drive EVs could promote interest in buying EVs.

Economic Impacts

Ford CEO Jim Farley says that EV manufacturing needs 40% less labor - leading to possible reduction in labor and layoffs[164]. This is because EVs need fewer parts to assemble – electric motors are less complex than an internal combustion engine, and the transmission does not require multiple gears since the electric motor has sufficient torque even at low speeds. EVs also do not need mufflers, radiators, and exhaust systems. United Auto Workers Union believes that out of their 400,000 members, about 35,000 may lose work. A report from Germany suggests that they could lose 400,000 jobs. However, on the plus side, Ford sees more work such as battery production being done in house to retain all their employees.

As EVs become more popular, we can expect gas stations to lose their customers. US has about 120,000 gas stations[165], and Illinois has about 3,800[166]. Illinois also has a substantial crude oil refining industry, ranking fourth in the nation (after Texas, Louisiana, and California, with nearly one million barrels per day capacity), and a sizeable ethanol (1.5 billion gallons annually) and biodiesel (134 billion gallons annually) industries. These industries also would be affected with a higher adoption of EVs.

ICEV mechanics and regular auto service centers (for example, the ones that do oil change) will also see their demand diminish. The current auto mechanics industry in Illinois employs 29,300 people [167], with annual mean wage of $49,870.

Equity programs are needed in both EVs and the EV charging infrastructure. Low and moderate income individuals need assistance in buying EVs, and underserved and low income communities need access to public chargers. Organizations such as Greenlining[168] are active in promoting equity programs.

An article[169] by the Economic Policy Institute suggests that the shift to EVs is a transformational change that must be carefully managed. The authors use IMPLAN, a software using economic input output modeling, incorporating interindustry relationships and demands for intermediate goods. They find that with a proper incentive plan which incentivizes appropriate labor standards and boosts investment in the domestic capacity of assembly and manufacture of auto parts, employment and job quality can be improved.

The IMPLAN model described above takes into account a 30% reduction in assembly labor required when moving from ICEV assembly to EV assembly. Some of the key findings are based on specific scenarios. Assume that EVs will become 50% of the sale of all automobiles in US (say by 2030). If there is no policy implementation of incentives to boost domestic assembly or parts manufacture, the study finds that about 33,000 jobs will be lost in auto assembly, and 41,000 jobs will be lost in parts manufacturing. On the other hand, if through policy implementation of proper incentives causes domestic share of EV assembly to go up from the current level of 50% (as is currently in the case of

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[164] https://www.ft.com/content/8df00b42-4e3f-4a45-b665-2726720105e0
[165] https://www.politico.com/news/magazine/2022/10/28/electric-vehicles-fueling-station-gas-utilities-infrastructure-00063398
[166] https://www.eia.gov/state/print.php?sid=IL
[167] https://www.bls.gov/oes/current/oes493023.htm
[168] https://greenlining.org/work/climate-equity/transportation-and-mobility-equity/
[169] https://www.epi.org/publication/ev-policy-workers/

ICEVs) to 60%, and the powertrain component manufacture goes from current level of 45% to 75%, then employment will go up 3000 in auto assembly, and 149,000 in parts manufacturing. In addition, these improvements would benefit blacks and non-degree holders more since they have a higher representation in the auto industry compared to the overall economy.

The JOBS EVSE 2.0[170] model by Argonne National Laboratory provides an estimate of the economic impact of developing and operating the EVSE infrastructure in different states or regions in US. The hardware for EVSE includes the supply (often the grid), transformers, panels, and chargers. The supply chain includes equipment makers, facility builders and installers, energy suppliers, facility managers, maintenance and administration, etc. In addition to the revenue generated through charging, additional revenues may be had from other retail activities (convenience stores visited while charging) as well as advertisements and access fees. The JOBS EVSE model also includes induced economic activity through the use of appropriate multipliers based on RIMS 2 (Regional Input-output Modeling System) created by US Department of Commerce.

The JOBS EVSE 2.0 model uses a number of user changeable variables such as the choice of station types, number of stations in each year of operation, average monthly electricity sales, cost of electricity, maintenance costs, etc. To illustrate the use of this model, recall that in the section "EV Charging Infrastructure", the tool EVI-ProLite[171] was used to estimate the needed charging infrastructure for Illinois to support one million EVs. It was estimated that 21,649 workplace level 2 chargers, 13,298 public level 2 chargers, and 1,716 public DC Fast Chargers are needed. To keep it simple, here we will only consider the impact due to the requirement of the public DC Fast Chargers. So we need to develop and operate about 1,700 public DC Fast Chargers, say over a ten year period. Thus our question is: What would be the economic impact of adding 170 public DC Fast Chargers (here we will take it to be 150 kW public chargers among the several options given in JOBS EVSE 2.0 model) in each year for the next ten years starting in 2023?

We use default values for all costs as given in the JOBS model except for the number of chargers per station. Default number of chargers per station is 4, which we will set here to one (a more economic alternative is to leave the default value, and reduce the number of stations to one fourth of 170 – but this is only an illustration). Some of the other default values are shown below:

Charger Type	Total Number of Chargers per station	Total Number of Ports per station	Average Usage - Sessions/Month	Average Usage - kWh/Session	Potential annual sales per station (kWh/station-month)	Charger Power (kW)
DCFC 150: Public	*1*	*4*	*152*	*25.2*	**3,825**	**150**

For the chosen values of input, the model will compute the economic impact which is the sum of direct impact (jobs, income, revenue), indirect impact (inputs by supporting industries), and induced impacts (spending by those who receive the earnings). The results are given in terms of employment, earnings

[170] https://www.anl.gov/esia/jobs-evse
[171] https://afdc.energy.gov/evi-pro-lite

(wages, salaries, and proprietor's income), and output (total value of sales including intermediate goods).

The JOBS model tells us that expected expenditure (pre-construction development, construction, installation, equipment, and shipping expenses) is about $962,821 per station, or $160 million in each of the ten years, about half of which is in-region (all values are given in 2020 dollars). An estimate of the annual energy sold is about 30 million kWh by year 2032. The employment generated through station development is roughly 950 per year through 2031; that due to station operations rise from zero to 835 over the ten years. The operations employment come from electricity sector, retail sector, advertising, data and networking sector, and warranty, maintenance, and access fees sectors. The combined total earnings (development and operations) is $839 million.

The purpose of this illustration is only to show that if we have a plan for developing additional EV charging stations, the JOBS model can predict the economic impact in a detailed way. Additional information from the JOBS model is shown in the Appendix.

Conclusion

For those who witnessed the rapid transition from film photography to digital photography, it is not difficult to accept that technological revolutions can be swift. However, even though EVs are gaining ground, it appears that the transition will be over several decades. On average, vehicles last twelve years[172], but since there is a wide variance of how long a vehicle lasts, we can expect some of them to last over twenty years. Hence even if the last ICEV is sold in a future year, it would be another twenty years before all vehicles would be EVs. Those concerned with climate change would like the change to be faster, while those in the fossil fuel and ICEV industries would prefer a slower transition.

Given that many countries are proposing a phase-out of the ICEVs, change seems inevitable. This gives US and Illinois an opportunity to establish leadership in the emerging EV industry and create new jobs. Additionally, care must be taken to transition those who would be adversely affected by this through retraining. As was stated in the introduction, to achieve leadership in EV supply chain, a coordinated effort by the state and local governments, universities and research laboratories, and manufacturers and consumers, is needed. We hope that the material presented in this report leads to a better understanding of the EV landscape and promote the EV supply chain activities in Illinois.

[172] https://www.caranddriver.com/research/a32758625/how-many-miles-does-a-car-last/

Resources

EV Toolkit[173] by Federal Energy Management Program helps plan fleet electrification, lists training opportunities, provides an EVSE planning form, offers an EV Utility Finder (including incentives) at any zip code, etc.

EV Toolkit[174] by Greening the Grid organization provides information on key areas of vehicle electrification.

EV Toolkit[175] by Xcel Energy provides help to communities to create and implement electrification goals.

EV Smart[176] by ComEd offers information and tips about rebates, rate plans, location of charging stations, etc.

EV Readiness Program[177] by the Metropolitan Mayors Caucus allows communities to plan for the growth in EVs and the necessary infrastructure. It offers a detailed spreadsheet to assess the goals and readiness. There is also an EV Readiness Decision Guide for Local Governments[178] as well as an EV Readiness Checklist[179].

JOBS EVSE[180] by Argonne National Laboratory provides a spreadsheet model that estimates the economic impact of constructing and operating EVSEs.

Vehicle Cost Calculator[181] by US DOE Alternative Fuels Data Center calculates the total cost of ownership (and emissions) based on the vehicle chosen and assumptions chosen by the user. Multiple vehicles can be chosen for comparison among them.

An **interactive map of EV Charging Station Locations**[182] identifies the available charging stations by different types (level 2, DC fast charging) as well as connector types (J1772, CCS, CHAdeMO, Tesla). It also allows for route planning.

Range of EVs is listed in the **Electric Vehicle Database**[183] which has data on about 284 EVs.

Alternative Fuels Data Center website[184] provides available federal incentives based on the VIN (vehicle identification number) of the vehicle. This is helpful because the Inflation Reduction Act has requirements of final assembly in North America in order to obtain the Clean Vehicle Credit (and these

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[173] https://www.energy.gov/eere/femp/electric-vehicles-toolkit
[174] https://greeningthegrid.org/electric-vehicle-toolkit
[175] https://xcelenergycommunities.com/evtoolkit
[176] https://www.comed.com/SmartEnergy/InnovationTechnology/Pages/ElectricVehicles.aspx
[177] https://mayorscaucus.org/initiatives/environment/becoming-ev-ready/
[178] http://greenways2go.com/product/ev-readiness-decision-guide-for-local-governments/
[179] https://mayorscaucus.org/wp-content/uploads/2020/08/EV-Readiness-CHECKLIST-01Jun2020_final.pdf
[180] https://www.anl.gov/esia/jobs-evse
[181] https://afdc.energy.gov/calc/
[182] https://afdc.energy.gov/fuels/electricity_locations.html#/find/nearest?fuel=ELEC
[183] https://ev-database.org/cheatsheet/range-electric-car
[184] https://afdc.energy.gov/laws/electric-vehicles-for-tax-credit

requirements become more stringent over time). Similarly, the **IRS site**[185] for qualified vehicles lists the manufacturers and their makes (models) that qualify for the federal rebate.

The **Electric Vehicle Database**[186] lists the range, energy consumption, top speed, and other variables for about 280 EVs.

The **Electric Vehicle Infrastructure Projection Tool (EVI-Pro) Lite**[187] by the US Department of Energy Alternative Fuels Data Center helps to calculate the EV Charging infrastructure needed by states or city/urban areas.

Electrification Transition Impacts on the Illinois Automotive Industry[188] is a report by the Center for Automotive Research providing a detailed analysis and risk assessment of the automotive electrification trends in Illinois. It identifies Illinois among top ten states for motor vehicles and parts manufacturing and lists over a thousand establishments in the automotive and related industries in Illinois (in areas such as metal working, assembly, electrical and electronics, body, axle, and brakes). Business involving internal combustion engines, fuel systems, and exhaust systems are in danger of being eliminated, and those in EV batteries, electricals, electronics and telematics will see growth. Recommendations include assisting the distressed businesses to transition, diversifying battery related production, and establishing building codes and utility regulations to encourage EV infrastructure adoption.

Electric Vehicle Adoption in Illinois[189] is a 2020 report by Argonne National Laboratory, done at the request of ComEd. It considers successful EV adoption policies, and creates projections of EV utilization and charging patterns, and estimates of changes in energy demand, greenhouse gas emissions, and charging load. It argues for significant and long-term incentives for consumers, and the need for governments (local, state, and federal), automakers, dealerships, and non-profit organizations to work together.

Building an Electric Transportation Supply Chain in the United States[190] is a 2021 report which looks at the current number of jobs and businesses involved in the electric transportation (ET) supply chain in the US, their historical growth rate, and projected growth rate for near-term future. The ET supply chain includes manufacturing, distribution, installation, research and development, and maintenance of vehicles and equipment, component parts (battery, motor controller, motor, regenerative braking, drive systems), and infrastructure.

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[185] https://www.irs.gov/credits-deductions/manufacturers-and-models-for-new-qualified-clean-vehicles-purchased-in-2023-or-after

[186] https://ev-database.org/cheatsheet/range-electric-car

[187] https://afdc.energy.gov/evi-pro-lite

[188] https://www.imec.org/wp-content/uploads/reports/Impacts%20of%20Electrification%20Transition%20on%20Illinois%E2%80%99%20Automotive.pdf

[189] https://publications.anl.gov/anlpubs/2020/09/161819.pdf

[190] https://info.aee.net/hubfs/AEE%20National%20ET%20Report.pdf

Appendix: The JOBS EVSE 2.0 Model Inputs and Results – an Illustration

For the given assumptions, the model calculates the impact (employment, earnings, and output). The details given below are only to illustrate the complexity of the model in terms of inputs and results. For a specific scenario, the reader is advised to make use of the model themselves. It is available for download at https://www.anl.gov/esia/jobs-evse. A brief summary of the results are given in the section on *Economic Impacts*.

Assumptions (user changeable):

EV Station Type and Capacity

Charger Type	**Total Number of Chargers per station**	**Total Number of Ports per station**	**Average Usage - Sessions/ Month**	**Average Usage - kWh/Session**	**Potential annual sales per station (kWh/station-month)**	**Charger Power (kW)**
DCFC 150: Public	*1*	*4*	*152*	*25.2*	3,825	150

Number of New Stations Completed Each Year

Station Type	**2023**	**2024**	**2025**	**2026**	**2027**
DCFC 150: Public	170	170	170	170	170

2028	**2029**	**2030**	**2031**	**2032**
170	170	170	170	170

Equipment Expense ($ / unit)

Station Type	**Cable Cooling**	**Charger**	**Conduit and Cables**	**Trenching & Boring**	**On-site Electrical Storage**
DCFC 150: Public	*$500*	*$87,800*	*$25*	*$80*	*$332,800*

Safety & Traffic Control	**Load Center/Panels**	**Transformers**	**Meters**	**Misc. (mounting hardware, etc.)**
$3,000	*$40*	*$37,865*	*$2,000*	*$2,000*

Equipment Quantity Table (units / station)

Station Type	Cable Cooling	Charger	Total Trenching/Boring Distance (ft)	On-site Electrical Storage	Safety & Traffic Control
DCFC 150: Public	4	1	75	1	1

Load Center/Panels	Transformers	Meters	Misc. (mounting hardware, etc.)
4	1	4	1

Total Station Equipment Expense Table ($)

Station Type	Cable Cooling	Charger	Conduit and Cables	Trenching & Boring	On-site Electrical Storage
DCFC 150: Public	*$2,000*	*$87,800*	*$1,875*	*$6,000*	*$332,800*

Safety & Traffic Control	Load Center/Panels	Transformers	Meters	Misc. (mounting hardware, etc.)	Station Equipment Expenses
$3,000	*$160*	*$37,865*	*$8,000*	*$2,000*	**$481,500**

Total Station Shipping Expense Table ($)

Station Type	Cable Cooling	Charger	Conduit and cables	On-site Electrical Storage	Safety & Traffic Control	Load Center/Panels	Transformers	Meters	Misc. (mounting hardware, etc.)	Station Shipping Expenses
DCFC 150: Public	*$60*	*$2,634*	*$56*	*$9,984*	*$90*	*$5*	*$1,136*	*$240*	*$60*	**$14,265**

Station Development Costs Table (non-land)

Station Type	Equipment Installation	Site Prep & Construction	Electrical Infrastructure & Make Ready	Engineering & Design	Permitting	Contingencies	Station Development, Construction, and Installation Expense
DCFC 150: Public	*$144,450*	*$45,743*	*$144,450*	*$93,893*	*$14,445*	*$24,075*	**$467,055**

What percentage of the equipment is manufactured in-region?

Station Type	Cable Cooling	Charger	Conduit and Cables	On-site Electrical Storage	Safety & Traffic Control	Load Center/Panels	Transformers	Meters	Misc. (mounting hardware, etc.)
DCFC 150: Public	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*

What percentage of the equipment is purchased from in-region wholesalers?

Station Type	Cable Cooling	Charger	Conduit and Cables	On-site Electrical Storage	Safety & Traffic Control
DCFC 150: Public	0%	0%	0%	0%	0%

Load Center/Panels	Transformers	Meters	Misc. (mounting hardware, etc.)
0%	0%	0%	0%

Equipment Category Table (Local share %)

Station Type	Cable Cooling Shipping	Charger Shipping	Conduit and Cables Shipping	On-site Electrical Storage Shipping	Safety & Traffic Control Shipping
DCFC 150: Public	0%	0%	0%	0%	0%

Load Center/Panels Shipping	Transformers Shipping	Meters Shipping	Misc. (mounting hardware, etc.) Shipping
0%	0%	0%	0%

Station Development, Construction, and Installation Expense - Local Share Percentages

Station Type	Equipment Installation	Site Prep & Construction	Electrical Infrastructure & Make Ready	Engineering & Design	Permitting	Contingencies
DCFC 150: Public	100%	100%	100%	100%	100%	100%

Total per Station Development Expense	
(Including pre-construction development, construction, installation, equipment, and shipping expenses in 2020$)	
DCFC 150: Public	**$962,821**

Average Monthly Sales: Electricity (kWh) (per station)					
Station Type	**2023**	**2024**	**2025**	**2026**	**2027**
DCFC 150: Public	*3,825*	*3,825*	*3,825*	*3,825*	*3,825*
	2028	**2029**	**2030**	**2031**	**2032**
	3,825	*3,825*	*3,825*	*3,825*	*3,825*

Monthly Retail Revenue ($) (per station)					
Station Type	**2023**	**2024**	**2025**	**2026**	**2027**
DCFC 150: Public	*$1,520*	*$1,520*	*$1,520*	*$1,520*	*$1,520*
	2028	**2029**	**2030**	**2031**	**2032**
	$1,520	*$1,520*	*$1,520*	*$1,520*	*$1,520*

Monthly Ad Revenue ($) (per station)					
Station Type	**2023**	**2024**	**2025**	**2026**	**2027**
DCFC 150: Public	*$1,400*	*$1,400*	*$1,400*	*$1,400*	*$1,400*
	2028	**2029**	**2030**	**2031**	**2032**
	$1,400	*$1,400*	*$1,400*	*$1,400*	*$1,400*

Access Fee	
Station Type	**Access Fee to Use Charger**
DCFC 150: Public	*$0.00*

Summary of Average Monthly Sales per station				
Station Type	**Average kWh/month**	**Retail Revenue ($/kWh)**	**Ad Revenue ($/kWh)**	**Access Fees ($/kWh)**
DCFC 150: Public	**3,825**	**$0.40**	**$0.37**	**$0.00**

EVSE Energy and Operational Costs (Monthly)					
Station Type	**Electricity Cost to Station ($/kWh)**	**Administrative Expense ($/month)**	**Maintenance Expense ($/month)**	**Warranty ($/month)**	**Data and Networking Fees ($/month)**
DCFC 150: Public	*$0.09*	*$10.00*	*$5.00*	*$10.00*	*$60.00*

Calculated Price at Charging Stations						
Station Type	**Electricity cost to station ($/kWh)**	**Administrative expense ($/kWh)**	**Maintenance expense ($/kWh)**	**Warranty ($/kWh)**	**Data and networking fees ($/kWh)**	**[Average] Total Price at Station ($/kW)**
DCFC 150: Public	**$0.09**	**$0.00**	**$0.00**	**$0.00**	**$0.02**	**$0.11**

Station Operations: Local Share Percentages								
Station Type	**Electricity cost to station**	**Induced Purchases**	**Ad Revenues**	**Access Fees**	**Administrative Expense**	**Maintenance Expense**	**Warranty Expense**	**Data and Networking Fees**
DCFC 150: Public	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*

Total Expenditure per Year in-Region (Thousands, 2020$)					
Station Type	**2023**	**2024**	**2025**	**2026**	**2027**
DCFC 150: Public	$81,453	$81,453	$81,453	$81,453	$81,453
	2028	**2029**	**2030**	**2031**	**2032**
	$81,453	$81,453	$81,453	$81,453	$81,453

Cumulative Expenditures (Thousands, 2020$)					
Station Type	**2023**	**2024**	**2025**	**2026**	**2027**
DCFC 150: Public	$159,587	$319,173	$478,760	$638,347	$797,934
	2028	**2029**	**2030**	**2031**	**2032**
	$957,520	$1,117,107	$1,276,694	$1,436,281	$1,595,867

Cumulative Expenditures In-Region (Thousands, 2020$)					
Station Type	**2023**	**2024**	**2025**	**2026**	**2027**
DCFC 150: Public	$81,453	$162,906	$244,359	$325,812	$407,265
	2028	**2029**	**2030**	**2031**	**2032**
	$488,718	$570,171	$651,624	$733,077	$814,530

EV Stations in Operation					
Station Type	**2023**	**2024**	**2025**	**2026**	**2027**
DCFC 150: Public	170	340	510	680	850
	2028	**2029**	**2030**	**2031**	**2032**
	1,020	1,190	1,360	1,530	1,700

Electricity Sales (kWh)					
Station Type	**2023**	**2024**	**2025**	**2026**	**2027**
DCFC 150: Public	3,100,800	6,201,600	9,302,400	12,403,200	15,504,000

2028	**2029**	**2030**	**2031**	**2032**
18,604,800	21,705,600	24,806,400	27,907,200	31,008,000

Results

Economic Impacts - EMPLOYMENT

Total Station Development & Station Operations (Supply Chain+Induced) Employment						
	2023	**2024**	**2025**	**2026**	**2027**	**2028**
Station Development	948	948	948	948	948	948
Station Operations	-	83	167	250	334	417
Total	948	1,031	1,115	1,198	1,282	1,365

2029	**2030**	**2031**	**2032**	**2033**	**Total**
948	948	948	-	-	8,532
501	584	668	751	835	4,591
1,449	1,532	1,616	751	835	13,123

Combined Station Development and Station Operation Employment						
	2023	**2024**	**2025**	**2026**	**2027**	**2028**
Supply Chain	581	642	702	763	823	884
Induced	367	390	413	436	459	482
Total	948	1,031	1,115	1,198	1,282	1,365

2029	2030	2031	2032	2033	Total
944	1,004	1,065	544	604	8,556
505	528	551	207	230	4,566
1,449	1,532	1,616	751	835	13,123

Station Development Employment						
	2023	**2024**	**2025**	**2026**	**2027**	**2028**
Supply Chain	581	581	581	581	581	581
Induced	367	367	367	367	367	367
Total	948	948	948	948	948	948

2029	2030	2031	2032	2033	Total
581	581	581	-	-	5,232
367	367	367	-	-	3,300
948	948	948	-	-	8,532

Station Operations Employment						
	2023	**2024**	**2025**	**2026**	**2027**	**2028**
Supply Chain	-	60	121	181	242	302
Induced	-	23	46	69	92	115
Total	-	83	167	250	334	417

2029	2030	2031	2032	2033	Total
363	423	484	544	604	3,324
138	161	184	207	230	1,267
501	584	668	751	835	4,591

Electricity Sector Employment	2023	2024	2025	2026	2027	2028
Supply Chain	-	2	4	5	7	9
Induced	-	1	3	4	6	7
Total	-	3	6	10	13	16

	2029	2030	2031	2032	2033	Total
Supply Chain	11	12	14	16	18	97
Induced	9	10	11	13	14	78
Total	19	22	26	29	32	176

Retail Sector Employment	2023	2024	2025	2026	2027	2028
Supply Chain	-	42	85	127	170	212
Induced	-	12	24	36	48	60
Total	-	54	109	163	218	272

	2029	2030	2031	2032	2033	Total
Supply Chain	255	297	340	382	424	2,335
Induced	72	84	96	108	120	661
Total	327	381	436	490	545	2,996

Advertising Sector Employment

	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	Total
Supply Chain	-	15	31	46	61	76	92	107	122	138	153	841
Induced	-	9	18	27	36	45	54	63	72	81	90	496
Total	-	24	49	73	97	122	146	170	195	219	243	1,337

Data and Networking Sector Employment

	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	Total
Supply Chain	-	1	1	2	2	3	4	4	5	5	6	33
Induced	-	0	1	1	1	2	2	2	3	3	4	19
Total	-	1	2	3	4	5	6	7	8	9	10	52

Warranty, Maintenance, Administrative Costs, & Access Fees Sector Employment

	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	Total
Supply Chain	-	0	1	1	1	2	2	2	3	3	3	18
Induced	-	0	0	1	1	1	1	2	2	2	2	12
Total	-	1	1	2	2	3	3	4	4	5	5	30

Economic Impacts - EARNINGS

Total Station Development and Station Operations (Supply Chain + Induced) Earnings (Thousands, 2020$)

	2023	2024	2025	2026	2027	2028
Station Development	67,359	67,359	67,359	67,359	67,359	67,359
Station Operations	-	4,231	8,462	12,693	16,924	21,155
Total	67,359	71,590	75,821	80,052	84,284	88,515

	2029	2030	2031	2032	2033	Total
Station Development	67,359	67,359	67,359	-	-	606,234
Station Operations	25,386	29,617	33,848	38,079	42,311	232,708
Total	92,746	96,977	101,208	38,079	42,311	838,941

Combined Station Development and Station Operations Earnings (Thousands, 2020$)

	2023	2024	2025	2026	2027	2028
Supply Chain	47,642	50,635	53,627	56,620	59,613	62,606
Induced	19,717	20,956	22,194	23,432	24,671	25,909
Total	67,359	71,590	75,821	80,052	84,284	88,515

	2029	2030	2031	2032	2033	Total
Supply Chain	65,598	68,591	71,584	26,935	29,928	593,379
Induced	27,147	28,385	29,624	11,145	12,383	245,563
Total	92,746	96,977	101,208	38,079	42,311	838,941

(Operations Earnings include Electricity, Retail, Advertising, Data and Networking, Warranty, Maintenance, Administrative Costs, and Access Fees Earnings)