Environmental Challenges with the Integration of Electric Vehicles in Canada

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This paper aims to identify some of the environmental challenges associated with the mass integration of electric vehicles (EVs) in Canada and propose solutions to address these challenges, with the goal of facilitating policymakers and other key players in making more informed decisions for a sustainable transition to EVs.

The transition from gasoline internal combustion engine vehicles (ICEVs) to EVs is critical to addressing climate change, largely due to EVs not emitting pollution or greenhouse gases (GHG), one of the primary causes of climate change.[1] Along with other benefits such as long-term costs, reliability and efficiency, EVs have the potential to reduce up to 28% of all carbon emissions by targeting the transportation sector.[2] However, ensuring that this transition is sustainable will be challenging. The increasing electricity demand will place considerable pressure on Canada's existing electric grid, and additionally, the manufacturing pollution associated with the production of EVs, and the mining to obtain minerals necessary to make the batteries used in EVs hinders the effectiveness of the EVs' ability to reduce carbon emissions.

To address these challenges, Canada first must establish the necessary national electrical grid framework to ensure the foundation of the adoption of EVs. This will make sure growth is moderate and feasible, while also giving guidelines to the development of Canada. In addition, investing in and using renewable resources will significantly benefit the overall Canadian economy, public health, and the environment by reducing harmful pollution, creating new jobs, and reducing carbon emissions. It is also critical to address the process of producing an EV, reducing mining pollution by prioritizing sustainable mining practices and recycling of current materials. To further reduce emissions on manufacturing, establishing standardized measurement systems and increasing international cooperation will allow for stronger critical analysis that promotes innovation that can improve future batteries for sustainability. Lastly, informed ways of disposing of used EV materials lessen the pollution the discarded battery parts will have on the environment.

Literature Review

To gain a better understanding of current research about EVs and sustainability, we conducted a minor literature review, and have highlighted some sources relevant to the topic of this paper below.

Since one of the main environmental concerns with EVs is the acquisition of materials to build the batteries, we searched the literature for articles that discussed the environmental impacts of mining, as well as solutions to mitigate damage from mining to the environment. Worlanyo & Jiangfeng 2021 in particular discuss reclamation efforts that are important for restoring abandoned mining lands to their natural state, suggesting that poor soil conditions can be tackled using a mix of physical, chemical, and biological methods, such as reshaping the land, adding nutrients, and planting vegetation. They state it is important to plan the future use of reclaimed land whether for conservation, agriculture, or recreation before starting the reclamation process.[3]

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[1] Sanguesa, Julio A., Vicente Torres-Sanz, Piedad Garrido, Francisco J. Martinez, and Johann M. Marquez-Barja. 2021. "A Review on Electric Vehicles: Technologies and Challenges." *Smart Cities* 4 (1): 372–404. https://doi.org/10.3390/smartcities4010022.

[2] Ibid. P.1

[3] Worlanyo, A. S., & Jiangfeng, L. (2021). Evaluating the environmental and economic impact of mining for post-mined land restoration and land-use: A review. *Journal of Environmental Management*, *279*, 111623. https://doi.org/10.1016/j.jenvman.2020.111623

Many studies have also highlighted the importance of recycling as a necessary means to minimize waste from discarded EV batteries. In particular, we identified one article that is an excellent source of recycling strategies targeted for implementation in Canada. The article looks at current research and pilot projects in Canada and focuses on 3 main topics: (i) the key economic and environmental reasons for recycling EV batteries; (ii) the technical and financial challenges of scaling up recycling efforts; and (iii) the main recycling methods being considered. The paper also suggests policies and strategies to overcome these challenges, such as increasing funding for recycling technology innovation, supporting pilot projects that encourage collaboration across the recycling industry, and implementing measures to create a supportive environment for large-scale EV battery recycling.[4]

Finally, a significant portion of the literature on the environmental impacts of the EV transition in advanced economies highlights the need to support this shift through enhancements to the electrical grid. The additional demand EVs will place on the grid, coupled with the already rising consumer demand, is expected to further strain existing infrastructure. In its 2023 statement on the electric grid, Electric Mobility Canada (EMC) emphasized the importance of creating a national sustainable framework to meet the growing electricity demands as EV ownership increases.[5] This framework is intended to guide efforts to ensure the grid is prepared for the anticipated surge in electricity usage, with demand potentially increasing by up to 300% by 2050, translating to a two- to threefold increase in installed capacity.[6] Such growth necessitates comprehensive planning, including modernizing grids and securing reliable electricity sources.

However, the EMC statement could have further emphasized the importance of expanding the grid through renewable energy sources. Aligning grid expansion with climate initiatives would not only attract additional investments but also support the benefits of achieving a net-zero grid. For example, a publication by Binnu Jeyakumar, former Director of Electricity at the Pembina Institute, outlined the affordability, reliability, resilience, and economic advantages of a net-zero grid.[7] These benefits include the net creation of over 80,000 new jobs from 2020 to 2030, stabilized consumer bills as renewable energy costs decline, and enhanced security of the electric grid through a diversified mix of electricity generation sources.[8] While such developments would require substantial investments in the energy sector, the long-term environmental and economic gains make these investments highly worthwhile.

Challenges

We identified four major challenges that may arise when switching to EVs within Canada that we will discuss in this section.

Challenge of Sustainably Obtaining Materials for EVs

As the goal is to bring more EVs to Canada and to increase the percentage of vehicles that are battery-powered, there is a high likelihood that the demand for raw materials that make up EV batteries,

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[4] Beaudet, A., Larouche, F., Amouzegar, K., Bouchard, P., & Zaghib, K. (2020). Key Challenges and Opportunities for Recycling Electric Vehicle Battery Materials. Sustainability, 12(14), Article 14. https://doi.org/10.3390/su12145837

[5] EV Growth: With the Right Support, Canada's Electricity Grid Can Handle It. (2023). *Electric Mobility Canada*. https://emc-mec.ca/publication/ev-growth-with-the-right-support-canadas-electricity-grid-can-handle-it/

[6] Ibid. P.4.

[7] Jeyakumar, B. (July, 2022) *Achieving a Net-Zero Canadian Electricity Grid by 2035*. Pembina Institute. https://www.pembina.org/pub/achieving-net-zero-canadian-electricity-grid-2035

[8] Ibid.

especially Lithium-ion(Li-ion) batteries, which is the current preferred type of EV battery, will greatly increase.[9] A great challenge lies in how those minerals, such as Lithium, Nickel, Cobalt, Graphite, and Manganese can be obtained in ways that minimizes damage and pollution to the environment. Currently, most of these metals must be mined, which, aside from being resource extensive, also causes leaching of harmful products into the air, water, and surrounding land, negatively impacting human health, other species living near the mine.[10] Lithium, cobalt and nickel mines are especially harmful, with lithium mines needing large quantities of water, and cobalt and nickel mines causing the surrounding air to become toxic. A study found even people who lived near mines, despite not working within the mines themselves, ended up having higher than tolerable levels of toxic metals in their system, especially high levels of Cobalt, which through repeated exposure, can cause great damage to organs as well as other serious health problems.[11]

Most of these metals are currently imported from other countries, most notably, Australia and countries in Asia, and are thus difficult for the Ontario or Canadian government to regulate.[12,13] Despite Canada being low on the ranking of countries that are the main source of the minerals, there are a few existing mines for many of the essential metals necessary to make Li-ion batteries in Canada, such as lithium, cobalt and nickel.[10,11] Recently, there has been consideration for opening new mines within Canada to match the demand for minerals that the EV batteries will require.[14] If opened, these new mines will likely have drastic impacts on the environment and surrounding communities. Due to the fact that many of the mines are within indigenous land, and some are close to cities, the potential pollution caused from mining will most likely impact the quality of life of local communities, including vulnerable people who may not have the resources to deal with the problems nearby mining will cause.[15]

It is then important to regulate mining companies to make sure that these resources are being extracted from the mines responsibly and with minimal damage to the environment, and it is even more pertinent to discuss the regulation and environmental damage mitigation strategies of these mines early on, before the EV market becomes larger and it becomes more difficult to implement new policies.

Challenge of Sustainably Disposing of EV Battery Waste

Not only must we consider how to sustainably source EV parts, we must also implement measures to minimize waste from EVs, and to reuse as many materials as possible to reduce the need for

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[9] Canada's ambitious EV targets can't be met without more support for mine supply. (2024, February 14). *MINING.COM*. https://www.mining.com/canadas-ambitious-ev-targets-cant-be-met-without-more-support-for-mine-supply

[10] Banza, C. L. N., Nawrot, T. S., Haufroid, V., Decrée, S., De Putter, T., Smolders, E., Kabyla, B. I., Luboya, O. N., Ilunga, A. N., Mutombo, A. M., & Nemery, B. (2009). High human exposure to cobalt and other metals in Katanga, a mining area of the Democratic Republic of Congo. *Environmental Research*, *109*(6), 745–752. https://doi.org/10.1016/j.envres.2009.04.012

[11] Ibid.

[12] Canada, N. R. (2022, January 18). *Lithium facts*. Natural Resources Canada. https://natural-resources.canada.ca/our-natural-resources/minerals-mining/mining-data-statistics-and-analysis/minerals-metals-facts/lithium-facts/24009

[13] Canada, N. R. (2018, January 23). *Nickel facts*. Natural Resources Canada. https://natural-resources.canada.ca/our-natural-resources/minerals-mining/mining-data-statistics-and-analysis/minerals-metals-facts/nickel-facts/20519

[14] Canada's ambitious EV targets can't be met without more support for mine supply. (2024, February 14). *MINING.COM*. https://www.mining.com/canadas-ambitious-ev-targets-cant-be-met-without-more-support-for-mine-supply

[15] Government of Canada, N. R. C. (2016, September 12). *Natural Resources Canada. The Atlas of Canada. Minerals and Mining in Canada*. Natural Resources Canada. https://atlas.gc.ca/mins/en/index.html

environmentally damaging mining of new materials. Often, used Li-ion batteries from EVs are still viable for second life applications, and therefore, recycling programs are the most sustainable way to handle them.[16] Currently, Canada has the means to recycle up to 95% of used battery materials in private companies within the country, and also by exporting the materials to other countries such as the US to process.[17] The challenges lie elsewhere, notably with building enough infrastructure within Canada to handle the amount of future waste from EVs, and due to owners of EVs being unaware or unwilling to recycle.[18] However, advising the building of infrastructure is beyond the scope of this paper, so we will instead focus on discussing EV owners' incentive and ability to recycle.

A case study in China showed that EV owners tended to use the battery beyond the point where its a recyclable quality, which caused damage to the components, making the materials lower quality and less viable for recycling.[19] The same study found that due to there not being a government program for recycling EVs, people tended to sell them through unauthorized means, such as to companies or organizations that were not regulated by the government. In these cases, the businesses often cut corners and did not prioritize sustainability in their battery recycling process. More notably, it was found that since recycling EVs was often expensive and time consuming, people often did not bother with the process at all, and instead simply threw out the batteries after they no longer worked. If these batteries end up in a landfill, they may cause leaching of heavy metals and electrolytes into the soil, causing harm to the environment.[20]

This means that recycling, and ensuring that as much material that comes from used EVs can be repurposed, is an important aspect of improving EVs' benefit for the environment. With the integration of EVs, it is advisable to plan to not just incentivize owners to purchase EVs over gasoline , but also for them to prioritize recycling, and also to have a robust recycling program in place to allow owners to do so.

Challenges of Electric Grid

One of the major challenges associated with the widespread adoption of electric vehicles (EVs) is the increased strain on the electrical grid. While the grid is capable of managing current demand, given that the transition to EVs is still in its early stages, significant future investments in the electricity sector will be essential to support continued growth.[21] To illustrate, the current annual electricity production stands at approximately 645 TWh, but by 2050, the required production is projected to reach between 972 and 1,359 TWh.[22] This necessitates an annual growth rate of 1.5% to 2.7% to meet these demands.[23]

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[16] Tang, Y., Zhang, Q., Liu, B., Li, Y., Ni, R., & Wang, Y. (2023). What influences residents' intention to participate in the electric vehicle battery recycling? Evidence from China. Energy, 276 (Complete). https://doi.org/10.1016/j.energy.2023.127563

[17] Infographic: China Is the World Leader in Battery Recycling. (2024, April 2). Statista Daily Data. https://www.statista.com/chart/32016/existing-and-planned-lithium-ion-battery-recycling-capacity

[18] Tang, Y., Zhang, Q., Liu, B., Li, Y., Ni, R., & Wang, Y. (2023). What influences residents' intention to participate in the electric vehicle battery recycling? Evidence from China. Energy, 276 (Complete). https://doi.org/10.1016/j.energy.2023.127563

[19] Ibid.

[20] Niu, Y. (2023, September 6). How can China address its EV battery-recycling challenge? *Dialogue Earth*. https://dialogue.earth/en/pollution/how-can-china-address-its-ev-battery-recycling-challenge/

[21] EV Growth: With the Right Support, Canada's Electricity Grid Can Handle It. (2023). *Electric Mobility Canada*. P.5 https://emc-mec.ca/publication/ev-growth-with-the-right-support-canadas-electricity-grid-can-handle-it/

[22] Ibid. P.4.

[23] Ibid. P.4.

Current grid growth rates have proven insufficient, with grid capacity growing by 13% from 2010-2020.[24] More needs to be done to handle future expected demands. Additionally, the energy expansion needs to be through renewable energy. Currently, total energy supply (TES), or all energy produced or imported by Canada is plentiful but is largely fossil fuel-based.[25] With nearly 75% of all produced energy in Canada derived from fossil fuels, relying on these fuel sources will compromise environmental sustainability.[26] Moreover, achieving net-zero emissions by 2050 will require a two to threefold increase in grid capacity, underscoring the need for substantial investments in renewable energy generation, transmission, and distribution infrastructure.

While these investments will strengthen the grid, they must be executed precisely and carefully. Issues such as utility regulatory approvals can delay implementation, making it crucial to anticipate and address potential obstacles.[27] Additionally, current grid strategies need significant improvement, as much of the aging infrastructure is not equipped to support the demands of the coming decades and must be replaced with reliable, modern systems.[28] This also emphasizes the timeliness of taking action now, since replacing grids and ensuring a uniformly modernized system may take anywhere from 5 to 15 years.[29]

Figure 1: 100 Years of Electricity Generation in Canada [18]

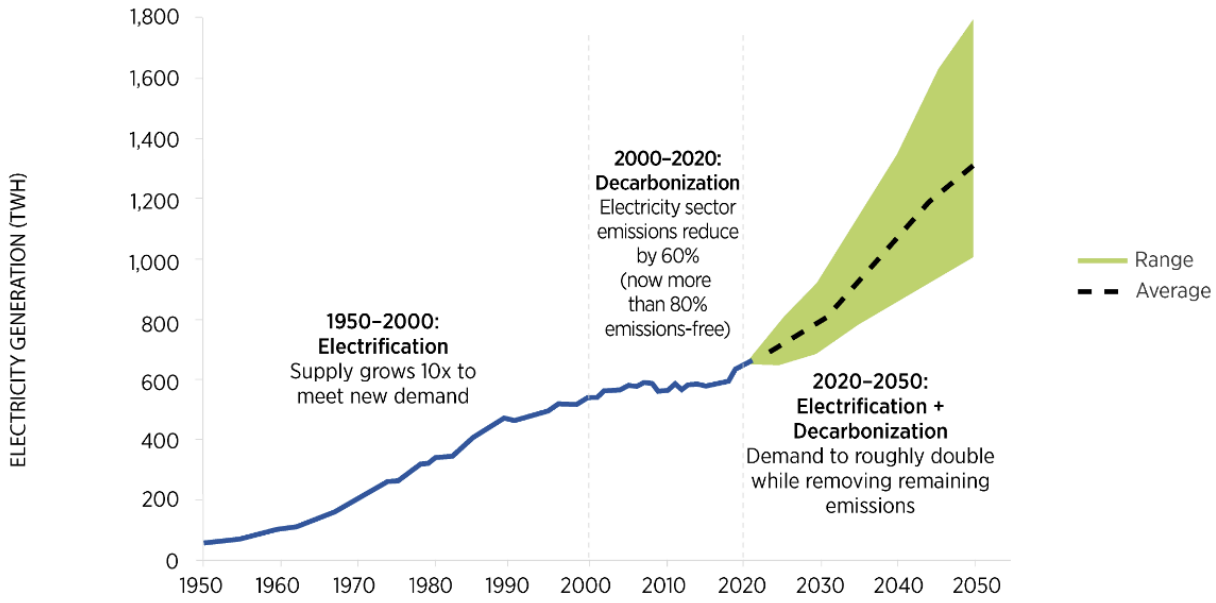

Figure 1

[24] Annesley, J., Campbell, D., Golshan, A., Greenspon, E., (2023). Project of the Century.. *Public Policy Forum*. https://ppforum.ca/publications/net-zero-electricity-canada-capacity/
[25] Ibid.
[26] Ibid.
[27] Ibid. P.5.
[28] Ibid. P.7.
[29] Ibid. P.4.

Figure 1 shows the estimated required energy to sustain Canada in the future in the coming decades.[30] Although these numbers are rough estimates, the overall trending average displays a steep increase in electrical demand. These numbers could range from as low as 1000 Twh in 2050 to 1800 Twh in 2050. This would translate to anywhere from a ~67% increase to a 300% increase in current electricity. Current electrical grids cannot withstand such pressure and are not flexible enough to handle such a steep increase in energy demand. The Conference Board of Canada estimates that approximately $1.7 trillion in investment will be required to decarbonize, expand, and reinforce Canada's electric system by 2050.[31] Though this number may appear daunting, this is what is required to replace old infrastructure, meet future energy demands, and combat climate change. Overall, if Canada can overcome these challenges with the electric grid, this will lay a strong foundation to support future energy demands in addition to EV adoption.

Manufacturing Pollution

Canada faces a significant challenge in the transition to EVs due to the emissions associated with their manufacturing. While EVs are advantageous in reducing carbon emissions and pollution over time, the initial carbon emissions from production are notably high.[32]

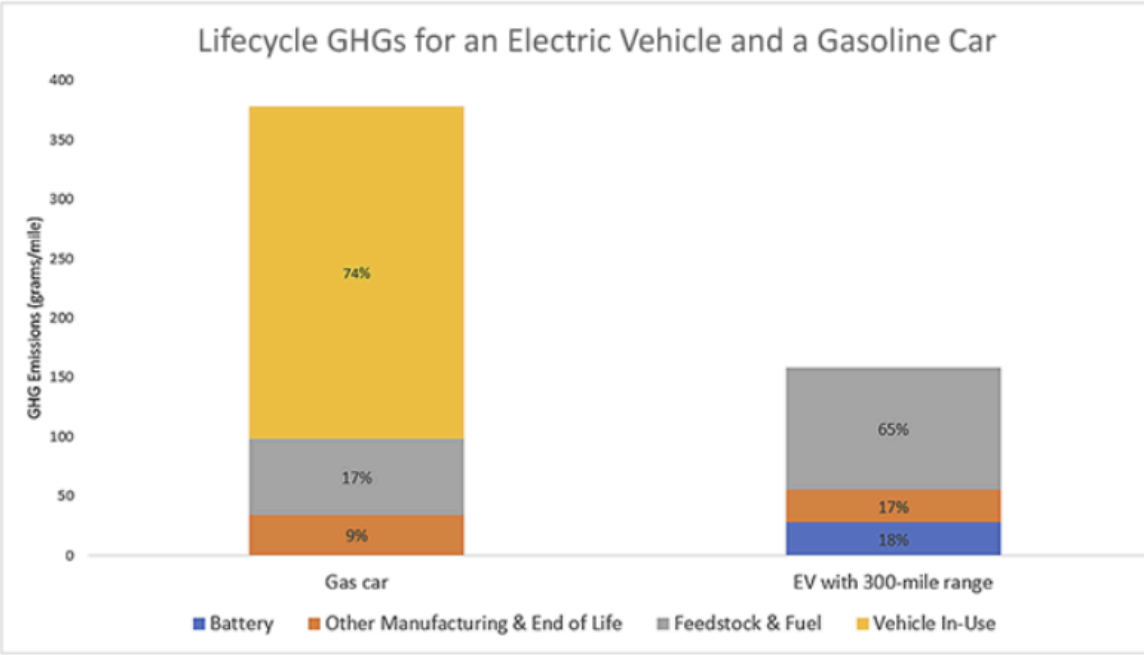

Figure 2

Figure 2 illustrates the greenhouse gas emissions throughout the lifecycle of both gasoline-powered and electric vehicles.[33] The graph shows that gasoline vehicles generally produce significantly higher overall emissions than EVs. However, most emissions from gasoline vehicles arise

[30] Canada, N. R. (2024, May 13). *Powering Canada: A blueprint for success*. Natural Resources Canada. https://natural-resources.canada.ca/our-natural-resources/energy-sources-distribution/electricity-infrastructure/the-canada-electricity-advisory-council/powering-canada-blueprint-for-success/25863
[31] *Accelerated Capital Cost Allowance*. (n.d.). Electricity Canada. https://www.electricity.ca/knowledge-centre/the-grid/regulatory/accelerated-capital-cost-allowance/
[32] US EPA, O. (2021, May 14). *Electric Vehicle Myths* [Other Policies and Guidance]. https://www.epa.gov/greenvehicles/electric-vehicle-myths
[33] Ibid.

from their operation, particularly fuel combustion. In contrast, the most emission-intensive phases for EVs are manufacturing and the production of feedstock and fuel. As a result, the initial emissions of an EV are higher than those of a gasoline vehicle. It is only after several years that EVs begin to offset the emissions that would have been produced by a gasoline car.[34]

Although EVs represent a much better alternative to gasoline-powered cars, it is crucial to further reduce their emissions. Currently, the two-year period required for EVs to offset the emissions of a gasoline car is less than ideal, as it temporarily increases short-term emissions. Minimizing this offset period is essential given the increasingly limited timeframe to prevent global temperatures from rising by 1.5°C.

Solutions

Mining Pollution Solutions

Solution #1: Sustainable Mining Practices

The easiest solution to reduce the environmental impact of the extraction of metals for Li-ion batteries would be for the government to create policies and incentives for mining companies to prioritize sustainability, adopting mining practices that center on reducing damage to the surroundings. This includes the implementation of strict environmental regulations and standards that minimize land degradation, water pollution, and greenhouse gas emissions. For instance, minimizing the use of water and chemicals in mining operations can help reduce the contamination of local water sources. Companies can be incentivized to adopt practices like reforestation and land reclamation after mining activities have concluded.[35] This not only helps restore ecosystems but also mitigates the long-term environmental damage caused by mining. The concept of "green mining," which emphasizes reducing the environmental impact of mining operations through innovative technologies and practices, is gaining traction and could be a significant part of the solution.[36]

However, there are issues with this solution. One may be that if the incentives are not enough to offset the amount the companies lose to implement these sustainable practices, it is less likely for those companies to put it in action. Unfortunately, despite mining being so environmentally damaging as well as being potentially hazardous to human health, it is very profitable for companies to continue doing so and to open up new mines in addition to existing ones as demand for battery materials increase with the increase of EVs in Canada, as well as for them to ignore environmentally beneficial practices in favor of efficiency and product.

Solution #2: Recycling and Circular Economy

A critical solution to reduce the need for more raw materials by mining is the promotion of recycling and the circular economy. The recycling of Li-ion batteries can significantly reduce the demand for new extraction of raw materials by recovering lithium, cobalt, nickel, and other valuable materials from used batteries, thus reducing the environmental burden associated with mining. As was discussed in the challenges section, despite having the resources for recycling, owners of EVs often did not recycle

[34] *Electric Vehicles*. (n.d.) https://evbuyersguide.caa.ca/content/costs
[35] Worlanyo, A. S., & Jiangfeng, L. (2021). Evaluating the environmental and economic impact of mining for post-mined land restoration and land-use: A review. Journal of Environmental Management, 279, 111623. https://doi.org/10.1016/j.jenvman.2020.111623
[36] Ibid.

their used batteries, or not through proper channels.[37] Therefore, it is important to prioritize recycling by implementing policies that encourage manufacturers to design batteries with recyclability in mind and by providing incentives for consumers to return used batteries for recycling purposes.[8] This will be further discussed in the next section.

In an ideal world, there would be no need for mining, and metals would be sourced from sustainable methods. However, as mining is still necessary for essential EV battery components, and as demand for those metals will increase with the integration of EVs in Canada, both these solutions implemented together will be important to, although not nullify, but minimize the damage to the environment.

Battery Waste Management Solutions

Solution #1: Consumer Awareness and Participation

Raising public awareness about the importance of recycling EV batteries is crucial. Many consumers are unaware of how to properly dispose of used batteries or the environmental benefits of recycling. Educational campaigns can inform the public about the recycling options available to them and the positive impact their participation can have on the environment. Additionally, providing consumers with convenient options for returning used batteries, such as drop-off points at retail locations or curbside pickup services, can significantly increase recycling rates. Clear labeling on batteries and vehicles about recycling options can also guide consumers toward making environmentally responsible choices.[38]

Solution #2: Regulatory and Policy Support

Government policies and regulations are also key to driving the growth of EV battery recycling. Regulatory frameworks can mandate that manufacturers take responsibility for the entire lifecycle of their products, including the end-of-life stage.[39] This concept, known as extended producer responsibility (EPR), encourages companies to design batteries that are easier to recycle and to invest in recycling infrastructure.[40] Specific recycling targets and quotas can also be introduced, requiring a certain percentage of batteries to be recycled within a given timeframe. Financial incentives, such as subsidies or tax breaks for companies that engage in recycling, can further stimulate industry investment in this area.[41]

Electrical Grid Solutions

Solution #1: Establish an Aggressive Framework

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[37] Niu, Y. (2023, September 6). How can China address its EV battery-recycling challenge? *Dialogue Earth*. https://dialogue.earth/en/pollution/how-can-china-address-its-ev-battery-recycling-challenge/

[38] Tang, Y., Zhang, Q., Liu, B., Li, Y., Ni, R., & Wang, Y. (2023). What influences residents' intention to participate in the electric vehicle battery recycling? Evidence from China. *Energy*, *276*(Complete). https://doi.org/10.1016/j.energy.2023.127563

[39] Barman, P., Dutta, L., & Azzopardi, B. (2023). Electric Vehicle Battery Supply Chain and Critical Materials: A Brief Survey of State of the Art. *Energies*, *16*(8), Article 8. https://doi.org/10.3390/en16083369

[40] *Extended producer responsibility and economic instruments*. (n.d.). OECD. Retrieved September 6, 2024, from https://www.oecd.org/en/topics/sub-issues/extended-producer-responsibility-and-economic-instruments.html

[41] Beaudet, A., Larouche, F., Amouzegar, K., Bouchard, P., & Zaghib, K. (2020). Key Challenges and Opportunities for Recycling Electric Vehicle Battery Materials. *Sustainability*, *12*(14), Article 14. https://doi.org/10.3390/su12145837

While the existing infrastructure is capable of supporting the current number of vehicles, the anticipated growth in EV ownership will necessitate significant investments in the energy sector. This includes addressing the integrity of aging infrastructure, increasing electricity production, and phasing out fossil fuels. Additionally, Canada must ensure that the energy used to power EVs is sourced from renewable resources, as relying on fossil fuels would undermine the environmental benefits of EV adoption.

To address the challenges facing the electrical grid, a comprehensive framework is needed to support steady growth in the energy sector. To accommodate the expected surge in EVs and achieve net-zero emissions goals, energy capacity must increase by a factor of 2 to 3, translating to an annual growth rate of approximately 1.5% to 2.7%.[42] A robust framework is required to guide this growth and provide a margin for error. One such initiative is the Pan-Canadian Framework, which focuses on four main pillars: pricing carbon pollution; implementing complementary measures to further reduce emissions across the economy; adapting to the impacts of climate change and building resilience; and promoting innovation, clean technology, and job creation.[43] In this initiative, were planned actions to modernize grids, complete coal phase-out, increase renewable energy, etc.[44] However, despite its potential, the framework appears to have lost momentum, with no annual reports published since 2020 and the last update made in 2022.[45] This may have resulted from ineffective results, as Canada did not see a large decrease in carbon emissions since the plan's implementation in 2016.[46] This outdated data limits the accessibility of information for Canadians.[47]

Additionally, energy-specific frameworks, such as Canada's Electric Reliability Framework, primarily assign responsibility for emissions reductions to provincial governments. For example, Ontario's 2024 annual planning report outlines a plan to increase installed capacity through nuclear energy.[48] While nuclear energy has both advantages and disadvantages and remains a topic of debate, the current planning approach appears to lack specificity and detail.

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[42] EV Growth: With the Right Support, Canada's Electricity Grid Can Handle It. (2023). *Electric Mobility Canada*. P.4 https://emc-mec.ca/publication/ev-growth-with-the-right-support-canadas-electricity-grid-can-handle-it/

[43] Canada, E. and C. C. (2017, December 1). Pan-Canadian Framework on Clean Growth and Climate Change. https://www.canada.ca/en/services/environment/weather/climatechange/pan-canadian-framework.html

[44] *Pan-Canadian Framework on Clean Growth and Climate Change – CICS*. (2016) https://scics.ca/en/product-produit/pan-canadian-framework-on-clean-growth-and-climate-change/

[45] Ibid.

[46] Canada, E. and C. C. (2007, January 9). *Greenhouse gas emissions* [Research]. https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/greenhouse-gas-emissions.html

[47] Canada, N. R. (2016, July 14). Canada's Electric Reliability Framework. Natural Resources Canada. https://natural-resources.canada.ca/energy/electricity-infrastructure/electricity-canada/canada-electric-reliability-framework/18792

[48] Annual Planning Outlook. (2024). Independent Electricity System Operator (IESO)

Figure 33 | Summary of Planned Actions

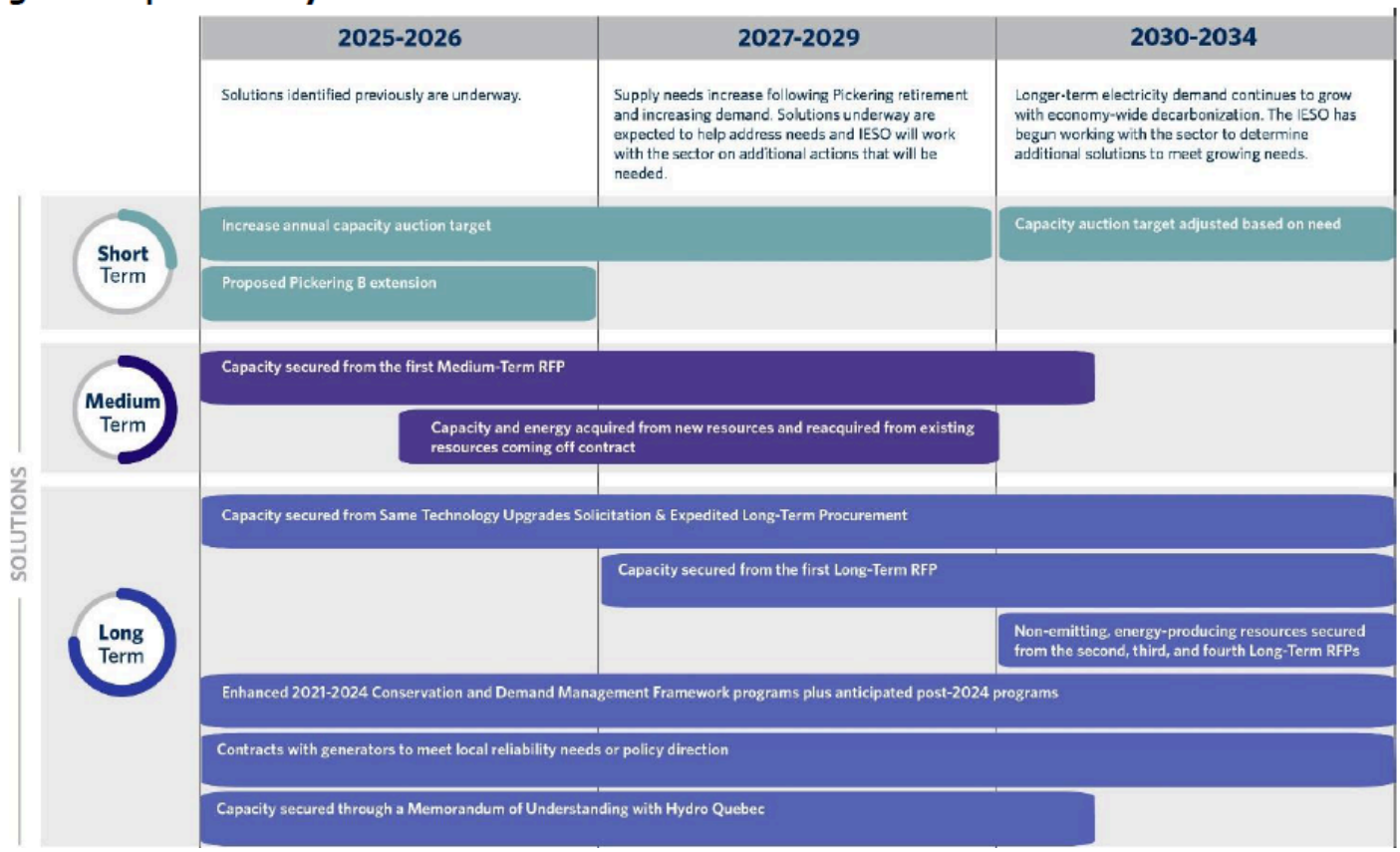

Figure 3

Figure 3 presents the current plan to increase installed capacity and address energy concerns. The plan emphasizes the need to enhance bulk transmission capabilities and achieve targets for increasing installed capacity.[49] However, the data does not provide clear information on the transition to renewable energy sources, leaving significant ambiguity. This is in contrast to Alberta's data, which indicates that the energy sector remains predominantly focused on non-renewable sources. Comparing Alberta and Ontario, the energy sources are vastly different, this necessitates the need to have nationwide cooperation to ensure all provinces are on track to have a clean electric grid. While existing frameworks are effectively addressing many challenges related to energy and EVs, a comprehensive national framework with specific details would help enhance coordination across Canada.

Solution #2: Increasing Renewable Energy Production

Since energy demands are expected to continue rising, Canada needs to generate more electricity to meet the demands. However, the energy needs to be sourced renewably to ensure sustainability.

[49] Annual Planning Outlook, 2024 P. 78

CLEAN TECHNOLOGY PROJECT TRENDS 2018-2023

	2018	2019	2020	2021	2022	2023
Total Clean Technology Projects	**144 projects ($109.5B)**	**151 projects ($99.3B)**	**159 projects ($99.4B)**	**178 projects ($104B)**	**197 projects ($118B)**	**233 projects ($159B)**
Hydro	65 projects ($48.2B)	70 projects ($50.0B)	61 projects ($52.0B)	58 projects ($39.2B)	63 projects ($44.8B)	78 projects ($38.9B)
Wind	27 projects ($9.1B)	31 projects ($9.4B)	36 projects ($8.3B)	41 projects ($14.6B)	35 projects ($13.4B)	31 projects ($12.3B)
Biomass/Biofuels	33 projects ($6.4B)	32 projects ($3.0B)	29 projects ($4.6B)	31 projects ($8.0B)	35 proejcts ($9.4B)	42 projects ($13.8B)
Solar	7 projects ($0.9B)	6 projects ($0.7B)	13 projects ($1.4B)	22 projects ($2.2B)	30 projects ($3.0B)	31 projects ($6.2B)
Nuclear	5 projects ($28.5B)	5 projects ($28.5B)	3 projects ($26.1B)	4 projects ($27.4B)	3 projects ($26.1B)	2 projects ($25.8B)
Carbon Capture and Storage	3 projects ($16.3B)	2 projects ($7.2B)	1 project ($6.0B)	2 projects ($11.3B)	6 projects ($15.5B)	9 projects ($38.3B)
Geothermal	1 project ($0.0B)	2 projects ($0.2B)	3 projects ($0.3B)	5 projects ($0.4B)	4 projects ($0.4B)	4 projects ($0.4B)
Tidal	0 project ($0.0B)	1 project ($0.1B)	6 projects ($0.3B)	6 projects ($0.3B)	7 projects ($0.4B)	7 projects ($0.4B)
Multiple[1]	0 project ($0.0B)	0 project ($0.0B)	0 project ($0.0B)	1 project ($0.03B)	1 project ($0.03B)	1 project ($0.03B)
Other[2]	3 projects ($0.1B)	2 projects ($0.1B)	7 projects ($0.4B)	8 projects ($0.5B)	13 projects ($5.3B)	28 projects ($22.6B)

Figure 4

Figure 4 illustrates the planned projects in Canada, highlighting a significant shift in investment from renewable energy projects to carbon capture, utilization, and storage (CCUS) initiatives. This shift presents concerns, given that CCUS remains a contentious topic.[50] CCUS involves using technology to capture carbon dioxide emissions and redirect them, typically underground.[51] Critics argue that CCUS could serve as a justification for increased oil extraction by mitigating one of the primary drawbacks of fossil fuels, and they also point out the high costs associated with implementing this technology.[52] The controversy surrounding CCUS suggests a potential reduction in investments in renewable energy, with over twice the investment being directed toward CCUS, and less emphasis on fully clean energy sources. This would hinder the momentum towards the integration of renewable energies by solving a long-term problem with a short–term solution.

It is also important to consider the benefits of improving the electrical grid to reduce emissions. Shifting to renewable energy sources for grid power has been shown to decrease well-to-tank emissions

[50] Energy Fact Book, 2023-2024: Investment. (2024, April 24)
https://energy-information.canada.ca/en/energy-facts/investment
[51] Canada's Energy Future 2023: Energy Supply and Demand Projections to 2050. (2023).
Earthjustice. (2023, September 19). Carbon Capture: The Fossil Fuel Industry's False Climate Solution. Earthjustice.
https://earthjustice.org/article/carbon-capture-the-fossil-fuel-industrys-false-climate-solution
[52] Ibid.

by an average of 25-35%.[53] The adaptability of renewable energy allows for the replacement of fossil fuels wherever possible, resulting in significant economic and environmental benefits. For instance, a comprehensive study conducted by the University of California, Berkeley, found that achieving a 90% clean energy electrical grid by 2035 is feasible in the United States.[54] This analysis demonstrated that all energy demands could be met even with a 50% reduction in fossil fuel use and the complete phase-out of coal.[55] While achieving 90% clean energy may seem ambitious, a meta-analysis of 11 studies conducted by Energy Innovation confirms that with appropriate policies, the deployment of solar, wind, and battery technologies would be sufficient to achieve at least 80% clean energy by 2030.[56] Moreover, this transition offers substantial economic and public health benefits. For example, projections indicate that up to 500,000 to 1,000,000 new jobs could be created annually, with investments ranging from billions to trillions of dollars flowing into the energy sector.[57] Additionally, the shift to clean energy would result in reduced pollution, potentially preventing up to 50,000 premature deaths by 2030 and 317,000 by 2050.[58] Although these figures are derived from American circumstances and policies, Canada can achieve these benefits faster and more efficiently.[59] This is because Canadian electricity is already about 80% clean energy (nuclear, hydro, solar, wind, etc.).[60] Thus, achieving net-zero energy by 2035 is feasible by stronger investments in renewable energies and policy.[61] This would also be crucial to meet Paris Climate goals. According to an analysis by the International Energy Agency, to keep global surface temperatures below 1.5 ℃, all developed economies must decarbonize grids by 2035.[62] Overall, clean energy on the electrical grid will significantly benefit the economy, public health, and the environment.

Manufacturing Emissions Solutions

Solution #1: Using Low-Carbon Energies (Renewable)

One of the key environmental advantages of EVs is their lack of reliance on fossil fuels, which results in zero tailpipe emissions. However, the production process of EVs, particularly the manufacturing of batteries, generates more emissions than conventional gasoline vehicles. As a result, EVs only begin to offer net emissions reductions after a few years of operation.

The adoption of low-carbon energy sources, particularly renewables, in the manufacturing and charging of EV batteries can significantly reduce emissions. While the carbon emissions associated with

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[53] Outlook for emissions reductions – Global EV Outlook 2024 – Analysis. (2024). IEA. https://www.iea.org/reports/global-ev-outlook-2024/outlook-for-emissions-reductions

[54] Renewable Energy Is the Key to Building a More Resilient and Reliable Electricity Grid. (2023, November 7). *Center for American Progress*. https://www.americanprogress.org/article/renewable-energy-is-the-key-to-building-a-more-resilient-and-reliable-electricity-grid/

[55] Ibid.

[56] Esposito, D. (2021) *Studies Agree 80 Percent Clean Electricity by 2030 Would Save Lives and Create Jobs at Minimal Cost—Energy Innovation: Policy and Technology*. https://energyinnovation.org/publication/studies-agree-80-percent-clean-electricity-by-2030-would-save-lives-and-create-jobs-at-minimal-cost/

[57] Ibid. P.2.

[58] Ibid. P.2.

[59] Jeyakumar, B. (July, 2022) *Achieving a Net-Zero Canadian Electricity Grid by 2035*. Pembina Institute. https://www.pembina.org/pub/achieving-net-zero-canadian-electricity-grid-2035

[60] *Canada—Countries & Regions*. (n.d.). IEA. https://www.iea.org/countries/canada/electricity

[61] Jeyakumar, B. (July, 2022) *Achieving a Net-Zero Canadian Electricity Grid by 2035*. Pembina Institute. P. https://www.pembina.org/pub/achieving-net-zero-canadian-electricity-grid-2035

[62] Ibid. P.8

producing the vehicle body are comparable between EVs and gasoline cars, the battery manufacturing process is where emissions notably increase.[63]

Figure 5

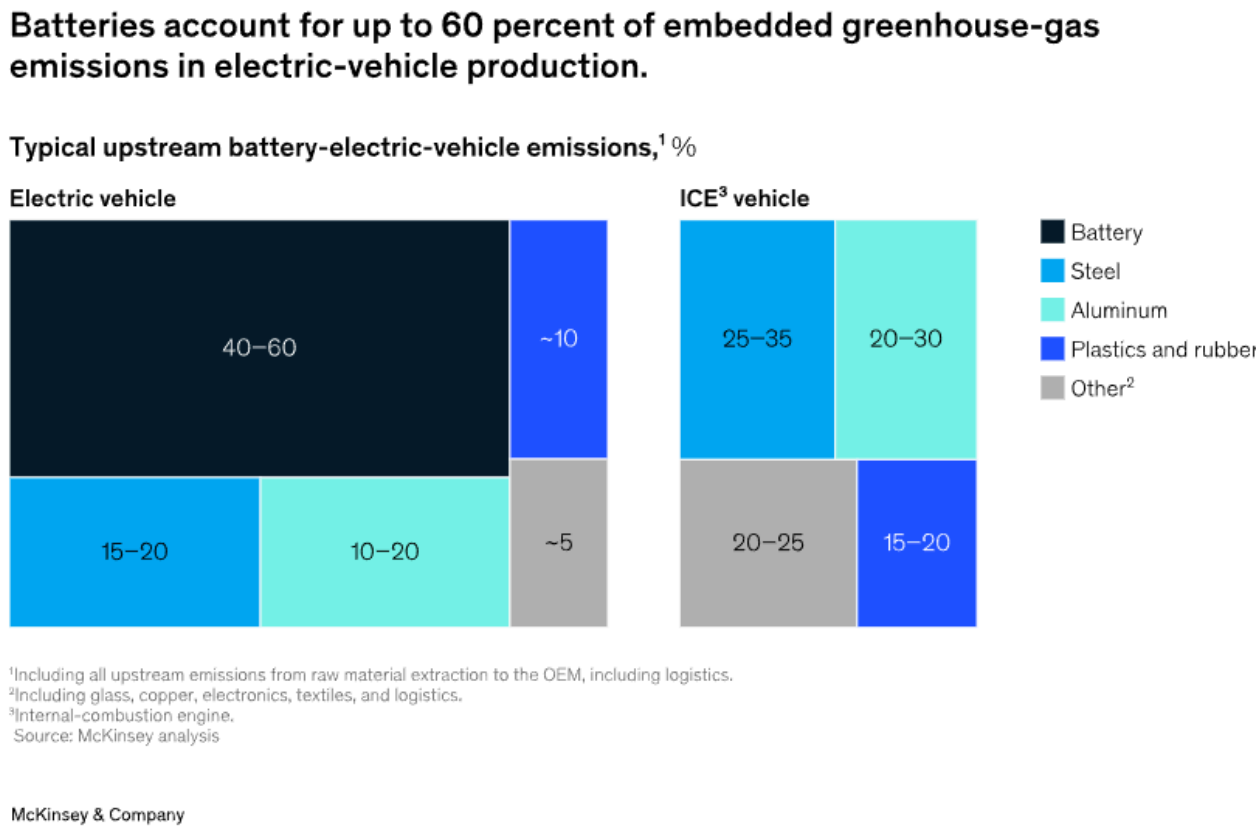

Figure 5 illustrates the sources of emissions for both EVs and gasoline cars. It is evident that, apart from the battery, the emissions profiles of the two vehicle types are quite similar.[64] However, since the battery is accountable for up to 60% of the embedded emissions, the emphasis on reducing manufacturing emissions will be placed on the battery.

Lithium-ion batteries, commonly used in EVs, require substantial energy to produce. Currently, two viable types of lithium-ion batteries are in use: Lithium Iron Phosphate (LFP) and Nickel Manganese Cobalt (NMC) batteries.[65] NMC batteries are preferred for electric vehicles due to their lightweight, compact design and energy density, which makes them ideal for long-distance driving. On the other hand, LFP batteries, while more reliable for safe energy storage in applications like power grids, lack the energy density that EVs typically require.[66] Continued research, however, may enhance the energy density of LFP

[63] Linder, M. et al. (2023).The race to decarbonize electric-vehicle batteries | McKinsey. https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/the-race-to-decarbonize-electric-vehicle-batteries
[64] Ibid. *Exhibit 1*
[65] LFP vs. NMC battery ▹ What's the difference? (n.d.). https://www.aichelin.at/en/products/topics/lfp-vs-nmc-battery
[66] Ibid.

batteries, making them more viable for EVs.[67] Notably, NMC batteries tend to generate higher emissions compared to LFP batteries, emphasizing the importance of improving mining processes to reduce emissions during NMC battery production.[68] Additionally, 20-25% of emissions are associated with the electricity used during the battery production process.[69] Using renewable energies instead of the production process may appear simple, but the benefits could lead to a 25% reduction in battery emissions.

Establishing the consistent use of low-carbon energy in battery manufacturing will be critical in shaping future battery innovations. For instance, Sodium-Ion Batteries (NIBs) stand to benefit significantly from this approach. Although NIBs require further research and development, their materials are more readily available and offer comparable advantages to Lithium-Ion Batteries (LIBs).[70] If challenges related to capacity and stability can be resolved, NIBs could see widespread adoption in the EV market.[71] By integrating low-carbon energy sources from the outset, we can ensure a sustainable supply of batteries for this emerging market.

Solution #2: Cooperation and Assessment

The current approach to measuring the carbon footprint (CF) of batteries is through life cycle assessment (LCA).[72] However, accurately measuring these figures is challenging due to the complexity and lack of compatibility in data, often resulting in outdated, overestimated, or underestimated values.[73] To effectively reduce CF, it is essential to establish a standardized methodology for evaluating each stage of lithium-ion battery (LIB) production. This underscores the importance of international collaboration in developing a standardized approach to measuring the CF of battery electric vehicles (BEVs).

One recommended policy is the European Battery Regulation, recently finalized by the European Commission, which sets market conditions for LIBs based on their CF.[74] This regulation is supported by various organizations, including the Joint Research Centre, the Global Battery Alliance, and the International Electrotechnical Commission, to standardize CF calculations for batteries.[75] If Canada can collaborate with the EU Commission or establish a similar system, this policy would increase transparency regarding the environmental impact of the batteries' LCA. If manufacturers adopt a standardized international system, this promotes innovation and unveils the steps emitting the highest amount of carbon.

While Life Cycle Assessment (LCA) plays a crucial role in evaluating the environmental impact of electric vehicles (EVs), it represents only a small aspect of the broader challenge of integrating EVs into the market. Enhanced collaboration between Canada and the European Union could significantly improve other facets of battery usage, such as increasing battery recovery rates and simplifying the

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[67] Ibid.
[68] Outlook for emissions reductions – Global EV Outlook 2024 – Analysis. (2024). IEA. https://www.iea.org/reports/global-ev-outlook-2024/outlook-for-emissions-reductions
[69] Ibid.
[70] Rodriguez, J. R., Aguirre, S. B., & Pol, V. G. (2019). Role of operando microscopy techniques on the advancement of sustainable sodium-ion battery anodes. *Journal of Power Sources*, *437*, 226851. https://doi.org/10.1016/j.jpowsour.2019.226851
[71] Ibid. P.11
[72] Peiseler, L., Wood, V., & Schmidt, T. S. (2023). Reducing the carbon footprint of lithium-ion batteries, what's next? Next Energy, 1(2), 100017. https://doi.org/10.1016/j.nxener.2023.100017
[73] Ibid. P.2
[74] Ibid. P.2
[75] Ibid. P.2

removal and replacement of batteries by consumers.[76] These measures would not only foster battery reuse but also drive further innovations that enhance the sustainability and convenience of EVs. For instance, the Electric Vehicles Initiative (EVI), a multilateral policy forum launched by the Clean Energy Ministerial (CEM) in 2010, has been instrumental in promoting EV adoption by facilitating knowledge-sharing among governments and supporting policymakers.[77] Under the leadership of Canada, the United States, and China, this initiative has significantly contributed to the global surge in EV ownership. By 2022, over 26 million EVs were on the road, marking a 60% increase from 2021 and a fivefold growth compared to 2018.[78]

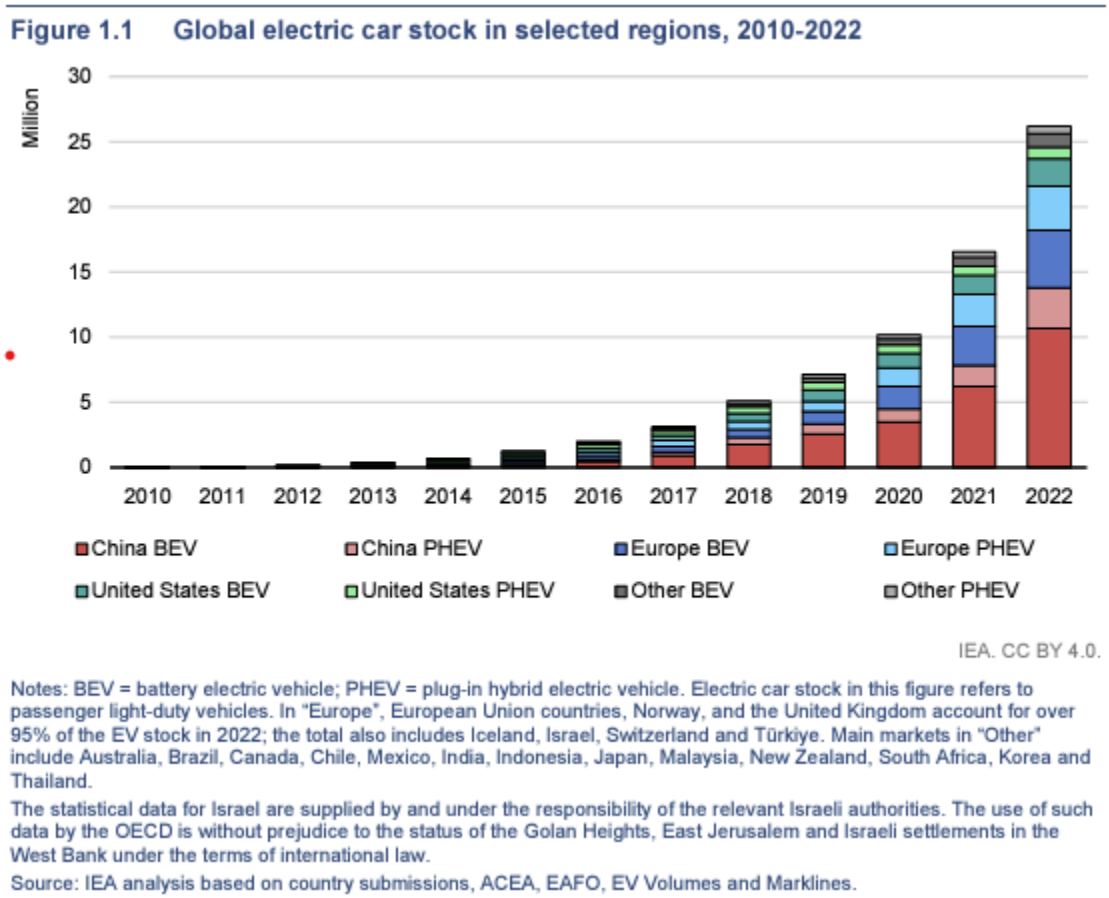

Figure 7

Figure 7 illustrates the exponential growth in EV ownership since the establishment of the EVI in 2010.[79] The data clearly shows a dramatic increase in the adoption of EVs over the past decade. While the EVI may not be the sole driver of this surge, its impact on accelerating EV ownership cannot be overlooked. Ultimately, these efforts underscore the importance of international cooperation in advancing the sustainable adoption of EVs, ensuring the realization of environmental and technological innovations.

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[76] N*ew law on more sustainable, circular and safe batteries enters into force—European Commission*. (2023). https://environment.ec.europa.eu/news/new-law-more-sustainable-circular-and-safe-batteries-enters-force-2023-08-17_en

[77] *Electric Vehicles Initiative – Global EV Outlook 2023 – Analysis*. (2023). IEA. P.13 https://www.iea.org/reports/global-ev-outlook-2023/electric-vehicles-initiative

[78] Ibid. P.14.

[79] Ibid. P.15.

Conclusion

Although the transition to EVs is necessary to reduce overall carbon emissions in efforts to combat climate change, there are many factors to consider that will help reduce the environmental impacts. Considering ways to sustainably source materials, dispose of waste, reduce the pressure placed on the electric grid, and the manufacturing pollution will increase the efficacy of the overall transition to EVs. From the procurement of resources aspect, creating policies and incentives for mining companies to extract resources more environmentally will help lessen the pollution from the mines. Recycling will also further ensure that less pollution reaches the environment, and this can be done by educating and giving the ability to EV owners to dispose of used batteries through the correct means. After the resources are sustainably sourced, focusing on the sustainability of the electric grid and manufacturing pollution will ensue. One of the best ways to combat both solutions is by increasing investments in renewable energy. This will supply energy to the electric grid that can meet demand while also using clean energy in the manufacturing process to further reduce the carbon-intensive process of manufacturing a battery. Additionally, larger investments in renewable energy will greatly improve Canada overall. This is because renewable energy benefits the environment and public health by reducing pollution, Canada's economy through job creation and capital investments, etc.

However, there needs to be a national framework that guides the sustainable development of EVs and electricity. Since energy demand is expected to grow continuously, developing a plan is integral to understanding the actions to take and setting certain expectations to meet targets. This will ensure the smooth transition of EVs with fewer confounding variables. Lastly, since Canada is one of the co-leads of EVI, the international initiative to transition EVs, increased cooperation, and assessment skills will benefit all countries. For instance, the development of a collaboration to set standards for LCA will encourage innovation for future batteries while also significantly reducing carbon emissions within the manufacturing process.

Although these suggested solutions may appear difficult to implement, the benefits of overcoming the challenges mean an international step towards a more sustainable future.

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