Group 6-Transportation Electrification
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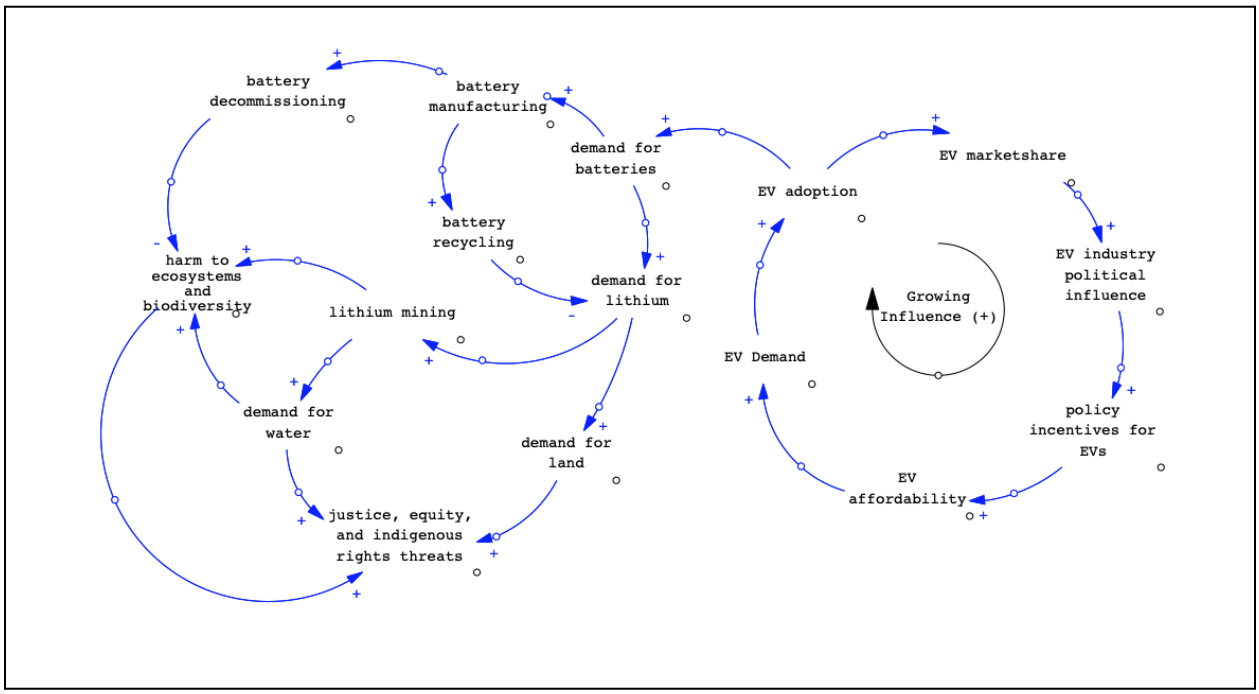
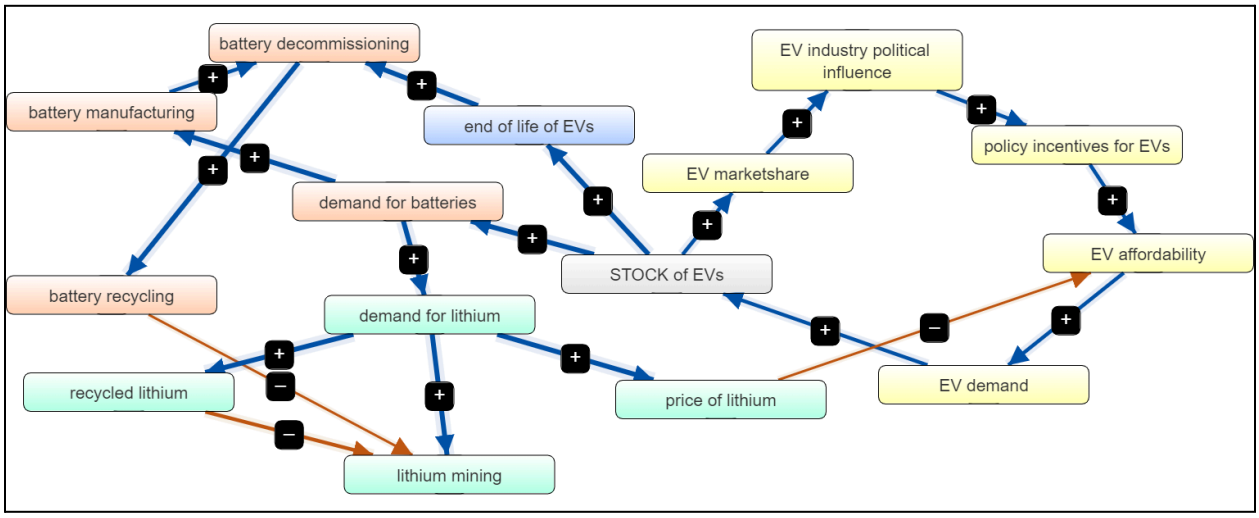
Deliverable #4: Delays

Revised Content

CLD



FCM



We didn't make much revision to the CLD and FCM from our latest deliverable discussing non-linearity since we are identifying a delay coming from the policies. We still focus on the EV market, use of battery, and lithium mining, and limit our scope to the U.S. We are including the

delay from the policy of Inflation Reduction Act (IRA) to the EV marketshare in our Vensim Model and dynamic hypothesis pasted below.

Dynamic hypothesis:

Electric vehicles (EV) are creating a cutting edge in the field of technology and automobiles. Public policy provides direct incentives for the market of EVs to grow, increasing consumer demand for EV products and derivatives, enhancing the needs of lithium in batteries, and boosting industry political influence for advocacy. **In our case, the IRA incentivizes clean energy, electric vehicles, and electric homes by encouraging investments in green technologies, ramping up manufacturing and meeting the new demand. However, the effects of the new policy will not be obvious until at least one year after it is active because it takes time for the corporations and the public to update regulations and lifestyles that align with the new policies. The preparation for the end of the policy, on the contrary, keeps going on during the years of the act, and accommodations will be made right when the act ends. So the impacts on EV cost will start a couple of years after the IRA is launched, and end when it phases out.**
Used battery recycling contributes to environmental sustainability uncertainty, while maintenance and public budgeting draw financial and social sustainability interests. Humanity topics proposed in this dynamic system include justice/equity and indigenous rights which simultaneously push concerns of international sourcing of rare minerals to the table.

Delay Information

- Inflation Reduction Act (IRA) was passed in 2022 but will not impact EV cost until 2023 and will end in 2032
    - Used PULSE function to model this
- Delay was modeled using the SMOOTH function in EV cost
- Assumptions:
    - Average Annual Cost of EV: EV cost has decreased ~0.41 every year from 2016 to 2023. We assume this will hold until 2050.
    - There will not be a policy incentive that will take over after the IRA is done in 2032.
    - We assume it will take EV cost 2 years to form expectations on the IRA.

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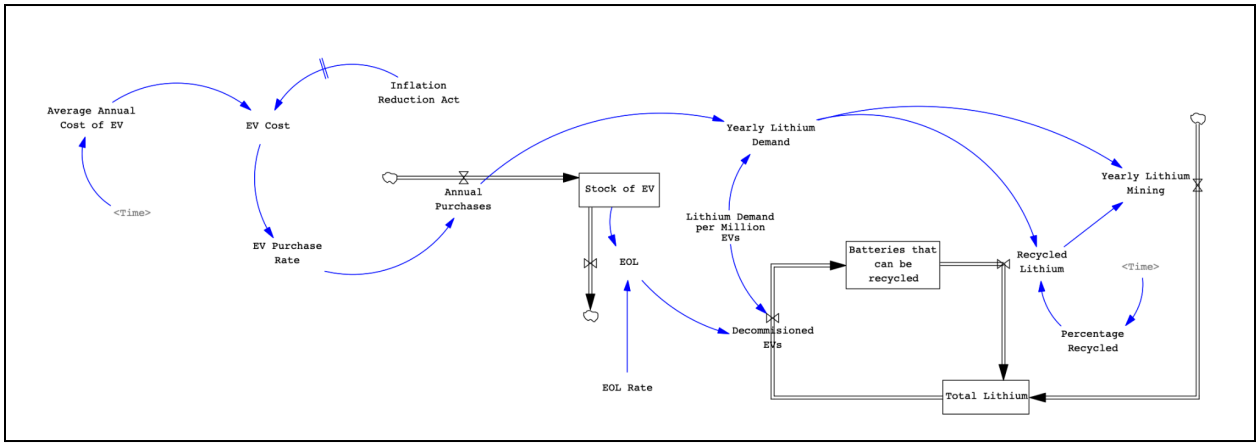
Vensim Model



Equations:

- **Average Annual Cost of EV:** WITH LOOKUP (Time) ([(0,0)-(3000,80)],(2016,70.64),(2020,69),(2024,67.36),(2028,65.72),(2032,64.08),(2036,62.44),(2040,60.8),(2044,59.16),(2048,57.52),(2050,56.7))
    - Source: https://www.statista.com/outlook/mmo/electric-vehicles/united-states#price
- **Inflation Reduction Act:** 7.5*PULSE(2023,9) *Thousand Dollars*
    - Source: https://www.irs.gov/credits-deductions/credits-for-new-clean-vehicles-purchased-in-2023-or-after
- **EV Cost:** Average Annual Cost of EV-SMOOTH3(Inflation Reduction Act,2) *Thousand Dollars*
- **EV Purchase Rate:** WITH LOOKUP (EV Cost) ([(0,0)-(100,4)],(0,3.3),(20,2.5),(48,1.6),(68.59,0.64),(69,0.32),(69.41,0.3),(69.82,0.35),(80,0.01),(100,0))
- **Annual Purchases:** EV Purchase Rate
- **Stock of EV:** Annual Purchases-EOL *Million Cars*
- **EOL:** EOL Rate*Stock of EV
- **EOL Rate:** 0.083
- **Decommissioned EVs:** EOL*Lithium Demand per Million EVs
- **Lithium Demand per Million EVs:** 8.8 *KT*
- **Yearly Lithium Demand:** Annual Purchases*Lithium Demand per Million EVs *KT*
- **Batteries That Can Be Recycled:** Decommissioned EVs-Recycled Lithium *KT*
- **Total Lithium:** Recycled Lithium+Yearly Lithium Mining-Decommisioned EVs *KT*, initial value of 77
- **Yearly Lithium Mining:** Yearly Lithium Demand-Recycled Lithium *KT*

- **Recycled Lithium:** Percentage Recycled*Yearly Lithium Demand
- **Percentage Recycled:** WITH LOOKUP (Time) ([(0,0)-(50,10)],(0,0),(2026,0.06),(2036,0.12),(2046,0.18),(2056,0.24),(2066,0.3))

Data and Sources:

- Assumption that drivers are switching from Internal Combustion Engine Vehicles (ICE) to EV
    - Not purchasing an EV without retiring an ICE
- Stock of fully electric vehicles in the US as of 2021= 1.3 million

Year	New EV Sales (millions)	Stock of EV (millions)
2016	0.15	0.57
2017	0.19	0.76
2018	0.35	1.11
2019	0.30	1.41
2020	0.32	1.73
2021	0.64	2.37
2022	0.77	3.14
2023	0.95	4.09
2024	1.16	5.25
2025	1.42	6.67
2026	1.74	8.41
2027	2.13	10.54

    - Source: https://www.statista.com/outlook/mmo/electric-vehicles/united-states#unit-sales
    - https://www.iea.org/reports/global-ev-outlook-2020
- Stock of ICE light duty vehicles as of 2021= 118.074303 million
    - Source: https://www.eia.gov/opendata/v1/qb.php?category=2118520&sdid=AEO.2016.HIGHMACRO.ECI_STK_TRN_CAR_CNV_NA_NA_MILL.A
- Tax credit =$7,500
    - Source: https://www.irs.gov/credits-deductions/credits-for-new-clean-vehicles-purchased-in-2023-or-after
- Average Cost of EV in 2021

Year	Cost (thousands)	Annual Purchase (millions)
2016	70.64	0.15
2017	70.23	0.19
2018	69.82	0.35
2019	69.41	0.30
2020	69	0.32
2021	68.59	0.64

    - Source: https://www.statista.com/outlook/mmo/electric-vehicles/united-states#price
- Lifespan of EV= 12 years
    - Source: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9171403/

Lithium Demand and EV Demand Non-Linearity

- Lithium Demand

Year	Demand (Thousand Metric Tons)
2019	263
2020	327
2021*	465
2022	559
2023	685
2024	838
2025	1,003
2026	1,169
2027	1,349
2028	1,560
2029	1,831
2030	2,114

    - Source: https://www.statista.com/statistics/452025/projected-total-demand-for-lithium-globally/

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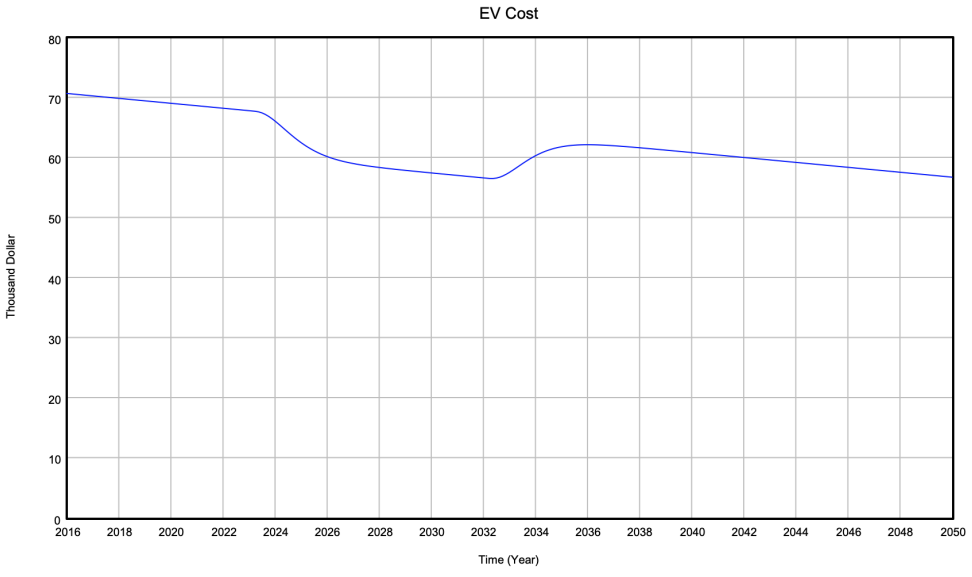
- Unit Sales

Year	EV Sales (millions)
2016	0.15
2017	0.19
2018	0.35
2019	0.30
2020	0.32
2021	0.64
2022	0.77
2023	0.95
2024	1.16
2025	1.42
2026	1.74
2027	2.13

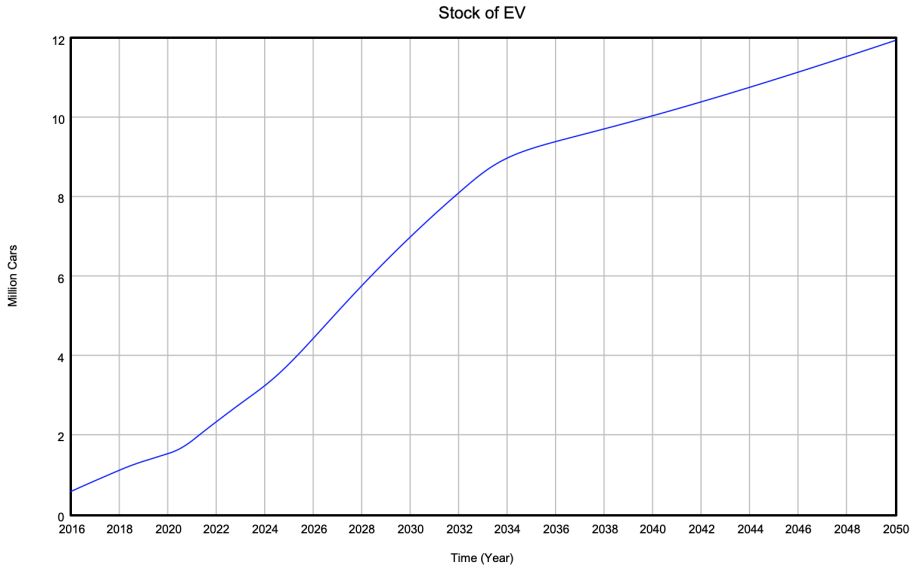
  - Source: https://www.statista.com/outlook/mmo/electric-vehicles/united-states#unit-sales

Graphs of Impacted Variables

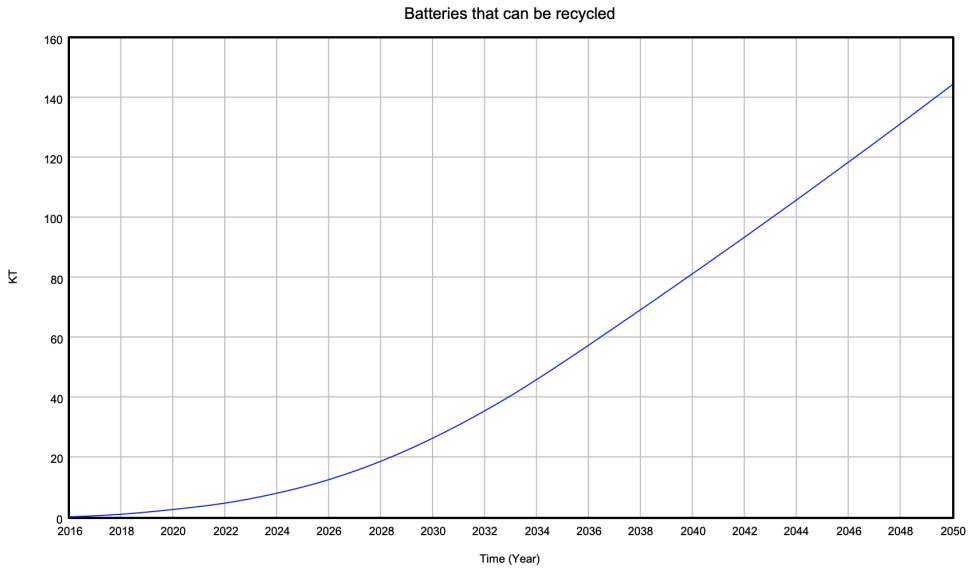


This graph shows the cost of electric vehicles from 2016 to 2050. The general trend is of cost reduction with a sharp decline in 2023 due to the tax credit available for customers from the

Inflation Reduction Act. EV purchases will be subsidized through 2032, after which the cost of EVs increases, but not to the pre-subsidy costs.



The stock of EVs purchased by customers increases from 2016 through 2050. The period of time in which consumers can apply for a EV tax credit (2023-2032) has the sharpest increase in vehicle stock. The increase in stock slows after the tax credit is no longer available and a larger number of EVs begin to reach their end of life and are decommissioned.



Assuming battery recycling technology improves, the kilotons of batteries that can be recycled increases exponentially through 2050. This result is heavily dependent on the assumption that recycling technology will improve and be widely available for all decommissioned EVs.

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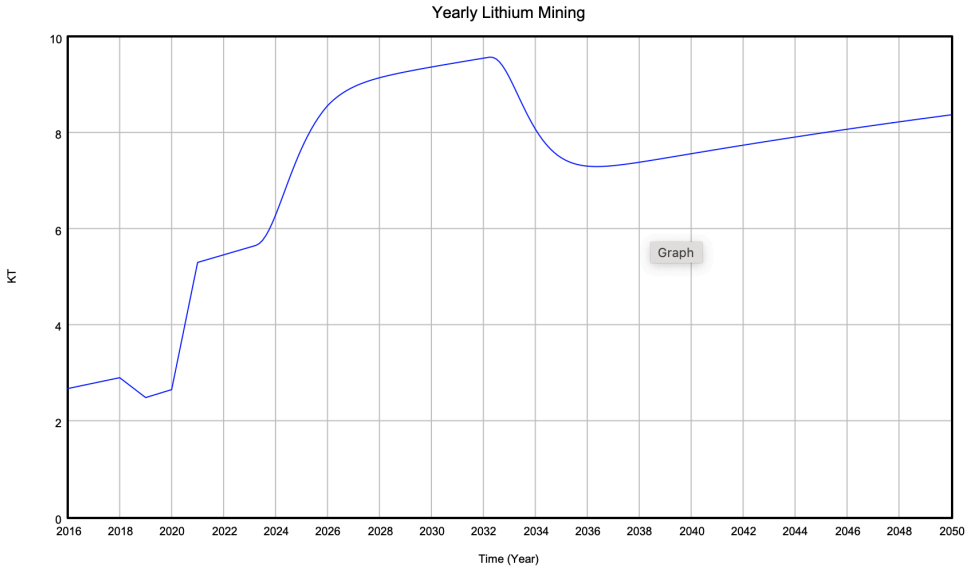

The amount of lithium mined per year is dependent on the amount of EVs sold per year and the ability to recycle lithium batteries from decommissioned EVs. Before battery recycling technology improves, the amount of lithium mined per year increases with the exception of 2018-2019. As the technology for battery recycling improves, there is less demand for lithium mining as seen in the sharp decrease between 2032 and 2036. It is interesting to note that the model predicts that recycled lithium will not be able to meet the total lithium demand and that mining will increase steadily from 2036 to 2050.