The Hidden Emissions of Electric Vehicles

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Are you anxious about…

…the increase in extreme weather events?

Flooding in Florida (April 2023)

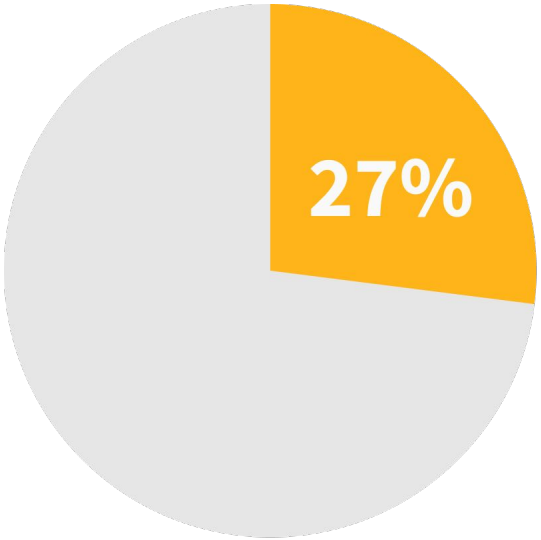
Joe Cavaretta | South Florida Sun-sentinel | Getty Images

Bay Area Bomb Cyclone (January 2023)

CBS SF Bay Area

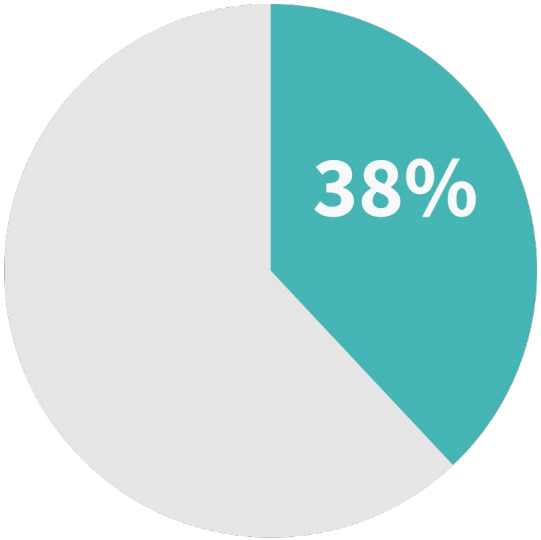
Feeling the effects of climate change

Transportation contributions to greenhouse gas emissions in 2020:



In the U.S.

and



In California

Strategies to Reducing Transportation Emissions

Develop sustainable passenger vehicles

Design walkable cities

Shift from passenger vehicles to public transportation

Strategies to Reducing Transportation Emissions

Develop sustainable passenger vehicles

Design walkable cities

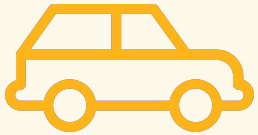
Shift from passenger vehicles to public transportation

California has required that by 2035:

All new passenger vehicles must be ZERO-EMISSION

What are Zero Emission Vehicles?

Zero Tailpipe Emissions



All Battery Electric Vehicle
(BEV)

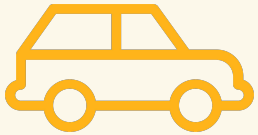
VS

Tailpipe Emissions

Internal Combustion Engine Vehicle
(ICE)

What are Zero Emission Vehicles?

Zero Tailpipe Emissions



All Battery Electric Vehicle
(BEV)

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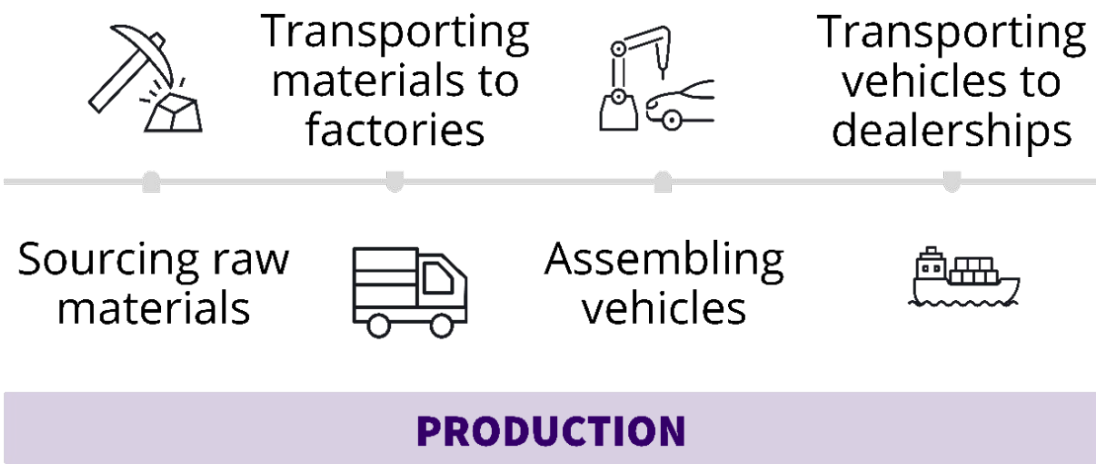
Tailpipe Emissions

Internal Combustion Engine Vehicle
(ICE)

How much do zero-emission vehicles truly emit?

Consider the entire vehicle life cycle.

Emissions over a Vehicle's Lifetime



Emissions over a Vehicle's Lifetime

Sourcing raw materials

Transporting materials to factories

Assembling vehicles

Transporting vehicles to dealerships

Fuel to vehicle

Driving the vehicle

PRODUCTION | **USE**

Emissions over a Vehicle's Lifetime

Sourcing raw materials

Transporting materials to factories

Assembling vehicles

Transporting vehicles to dealerships

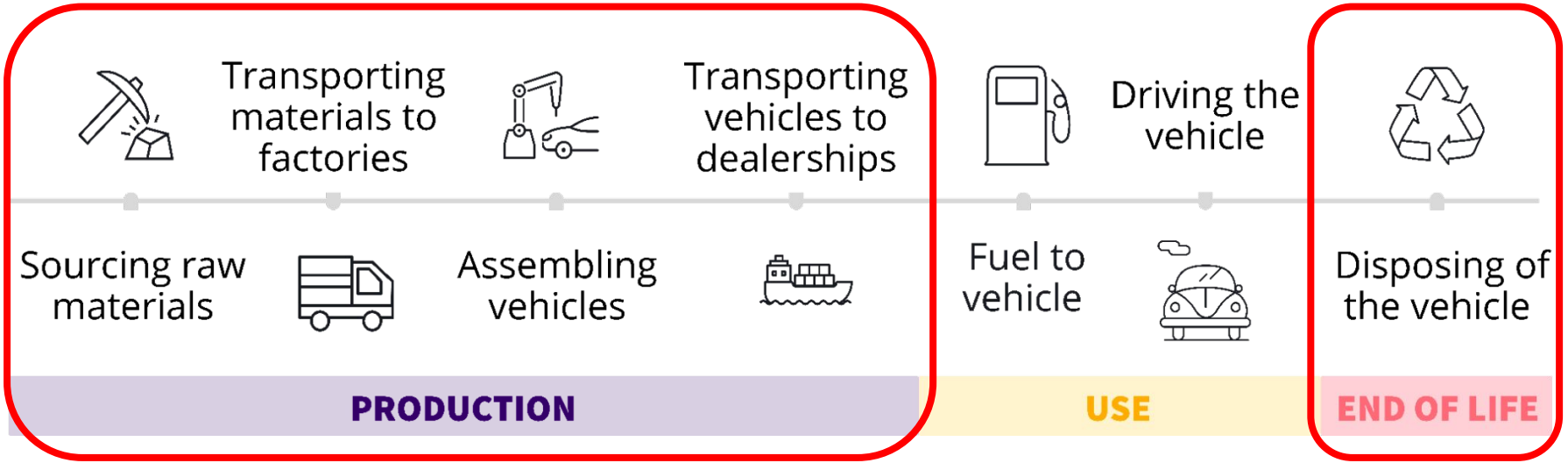
Fuel to vehicle

Driving the vehicle

Disposing of the vehicle

PRODUCTION | **USE** | **END OF LIFE**

Problem #1: Emissions calculations are oversimplified and not comprehensive.



CALIFORNIA
AIR RESOURCES BOARD

U.S. DEPARTMENT OF
ENERGY

Office of
Science

Problem #2: Current models are not accessible.

Our Solution:

Emissions Explorer

Calculates vehicle lifetime emissions

Interactive Website

Storytelling to break down complex emissions issues

Vehicle Emission Calculator Comparison

Emissions Calculators	Vehicle Selection	Location Selection	Use Phase	Production + End of Life
Our Emissions Explorer	✓	✓	✓	✓
Evtool by Union Concerned Scientists	✓	✓	✓	
Driveclean by CARB	✓	✓	✓	
Evolution by Argonne	✓		✓	
Greenercars by ACEEE	✓		✓	✓
Beyond the Tailpipe by Oak Ridge		✓	✓	
Electricity Sources and Emissions by AFDC			✓	

Demo

Try our Emissions Explorer tool!
tinyurl.com/emissions-explorer

How does Emissions Explorer work?

1. User Inputs → **2. Emissions Estimate** → **3. Digestible Outputs**

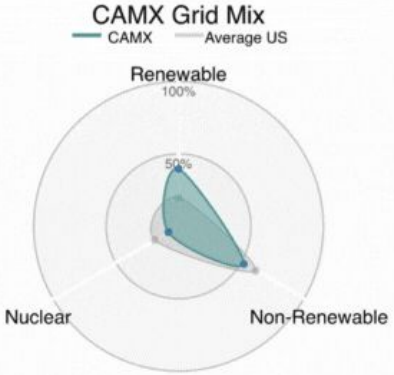
- Location
- Length of Ownership
- Vehicle

Calculation from GREET model

- Quantitative Estimate
- Contextualized Output

1. User Inputs → **2. Emissions Estimate** → **3. Digestible Outputs**

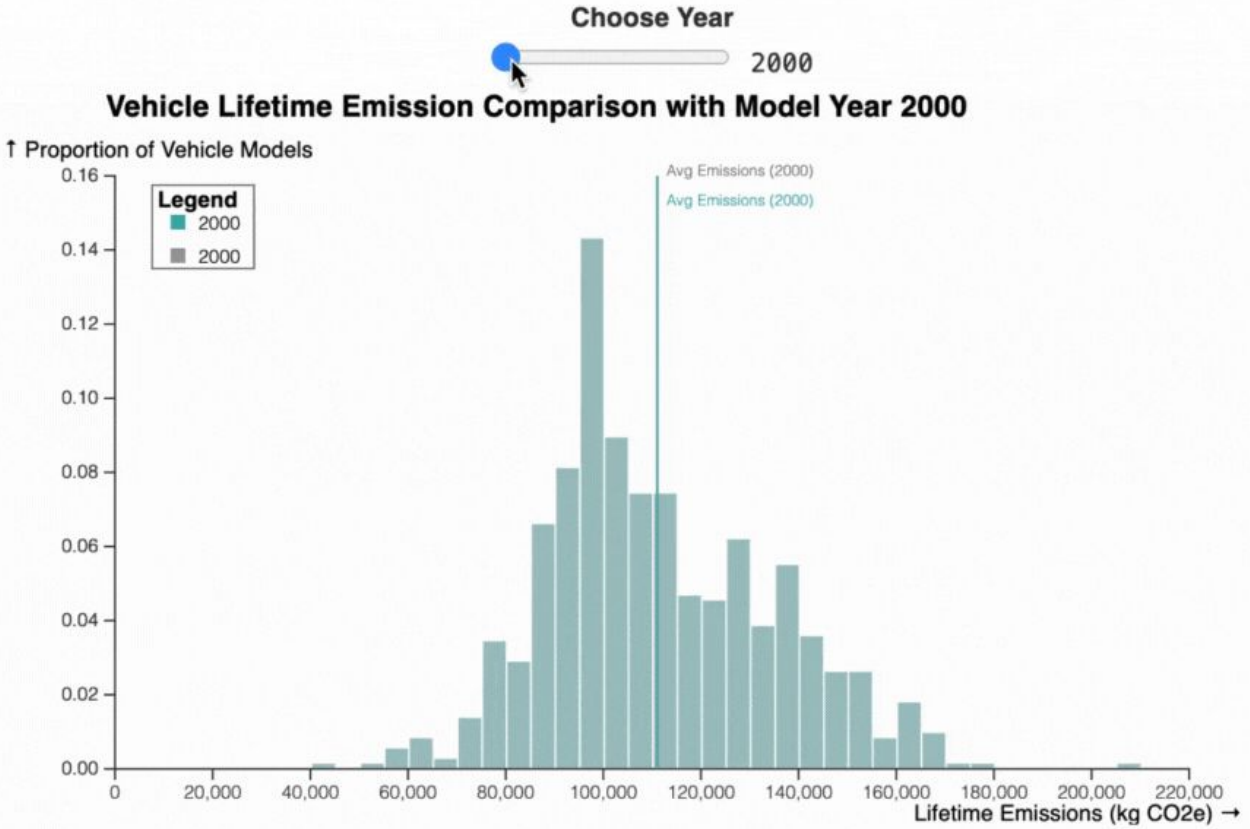
- **Location**
- Length of Ownership
- Vehicle

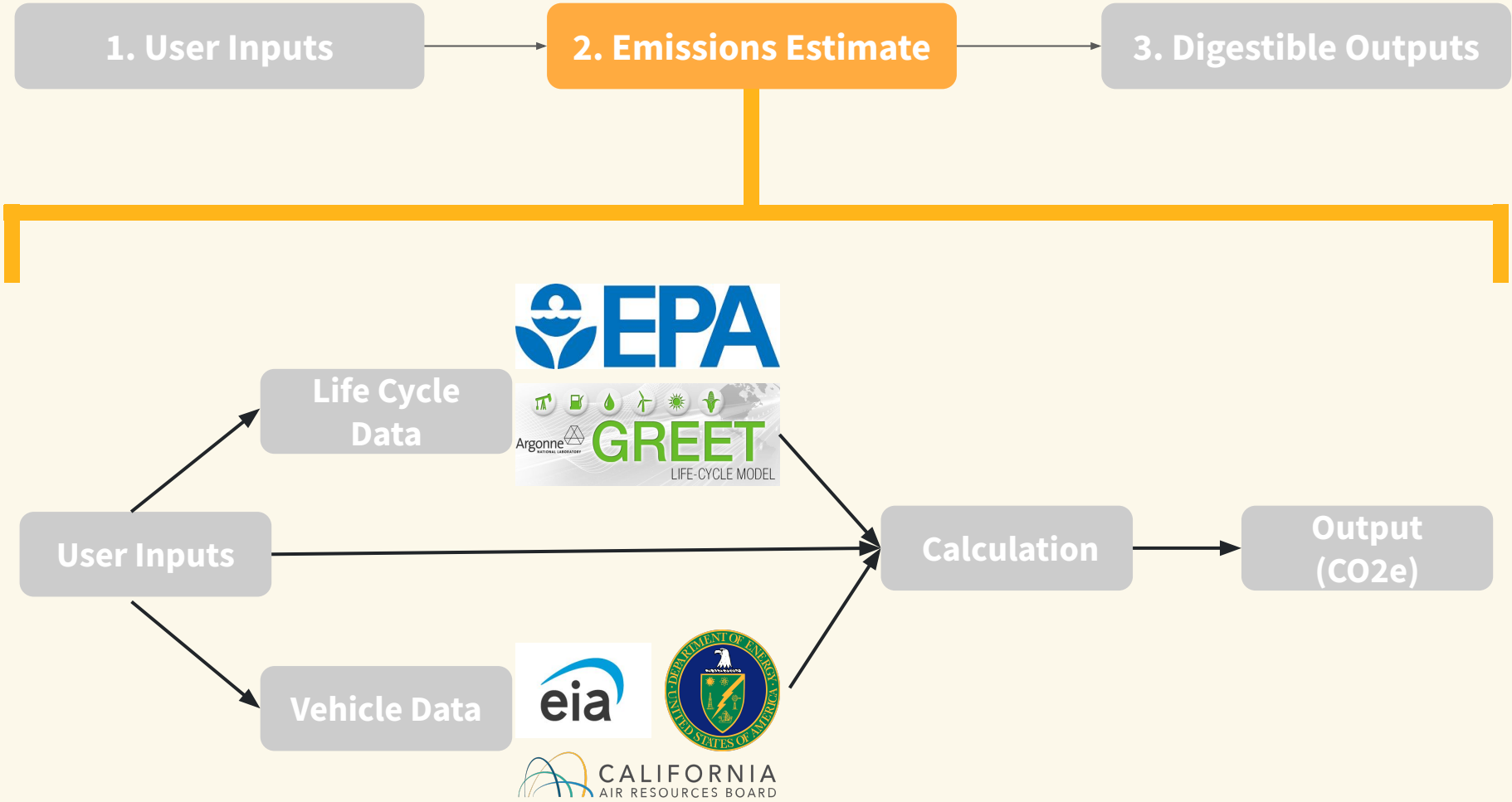


Renewable: 39.7%
Non-Renewable: 52.1%
Nuclear: 8.1%
Other: 0.2%

1. User Inputs → **2. Emissions Estimate** → **3. Digestible Outputs**

- Location
- Length of Ownership
- **Vehicle**




1. User Inputs
2. Emissions Estimate
3. Digestible Outputs
EPA
Life Cycle Data
Argonne NATIONAL LABORATORY
GREET
LIFE-CYCLE MODEL
User Inputs
Calculation
Output (CO2e)
Vehicle Data
eia
DEPARTMENT OF ENERGY
UNITED STATES OF AMERICA
CALIFORNIA
AIR RESOURCES BOARD

Emissions Estimate: Calculations

PRODUCTION | **USE** | **END OF LIFE**

Vehicle

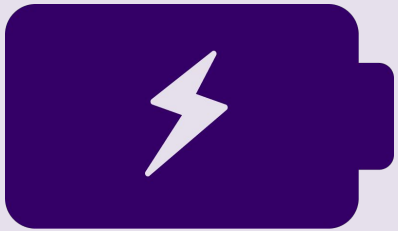
We include:

- Weight
- Composition
  - Steel
  - Aluminum
  - 30+ others

Emissions Estimate: Calculations

PRODUCTION | **USE** | **END OF LIFE**

EV Battery



We include:

- Weight
- Capacity
- Chemistry
  - Li-Ion and NIMH

Emissions Estimate: Calculations

PRODUCTION | USE | END OF LIFE

Combustion Vehicle

- Fuel Efficiency
- Miles Driven

Emissions Estimate: Calculations

PRODUCTION | USE | END OF LIFE

Combustion Vehicle

- Fuel Efficiency
- Miles Driven

Electric Vehicle

- Vehicle efficiency
- Miles driven
- ***Charging location***

Emissions Estimate: Calculations

PRODUCTION | USE | END OF LIFE

Consumables

Fluids

Battery

Tires

Emissions Estimate: Calculations

PRODUCTION | USE | END OF LIFE

Vehicle

We include:

- Recycling method

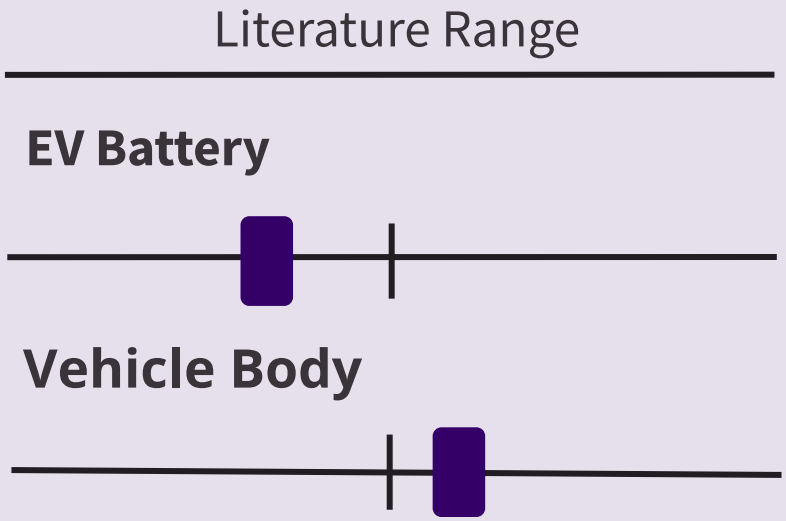
EV Battery

We include:

- Recycling method
- Battery size

Validating our Emissions Estimate

PRODUCTION | **USE** | **END OF LIFE**



Within middle 25%!

Validating our Emissions Estimate

PRODUCTION | USE | END OF LIFE

+35%*

*Compared to EPA estimate

Validating our Emissions Estimate

PRODUCTION | USE | END OF LIFE

+35%*

*Compared to EPA estimate

We assume:

- Fuel Emissions
- EV Emissions

Validating our Emissions Estimate

PRODUCTION | USE | END OF LIFE

- Not many estimates and large uncertainty range
- Overall a small value
  - Less than 5% of total vehicle emissions

1. User Inputs → 2. Emissions Estimate → 3. Digestible Outputs

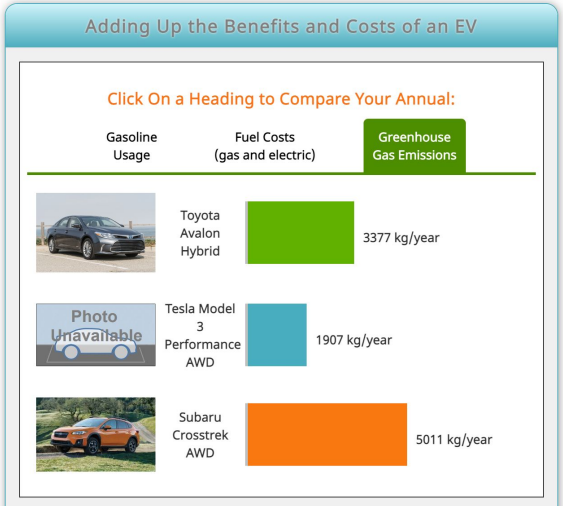
127,095 kg CO2e

1. User Inputs → 2. Emissions Estimate → 3. Digestible Outputs

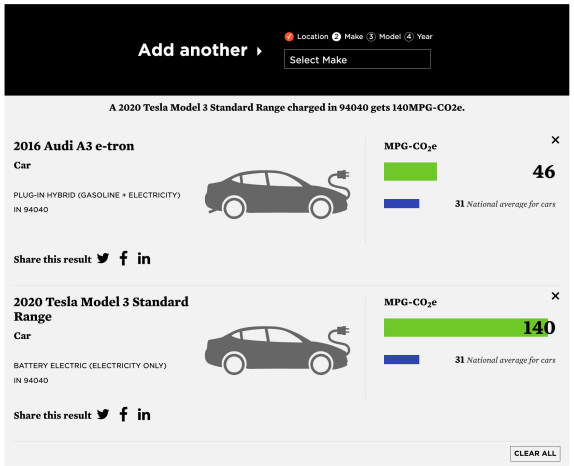
127,095 kg CO2e

But what does this mean?

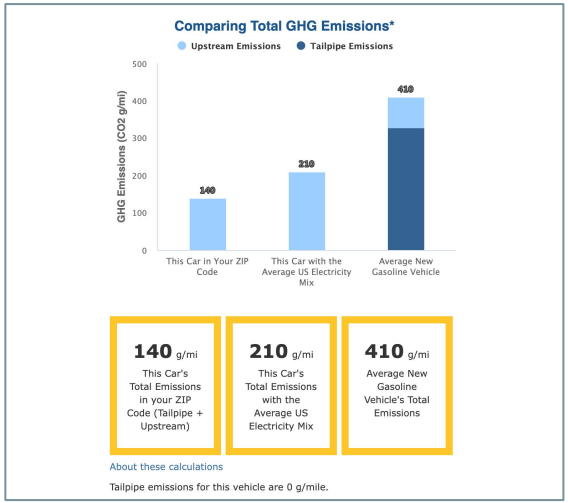
1. User Inputs → 2. Emissions Estimate → 3. Digestible Outputs



Car Webtool "EVOLUTION" by Argonne National Laboratory



How Clean is Your Electric Vehicle by Union of Concerned Scientists

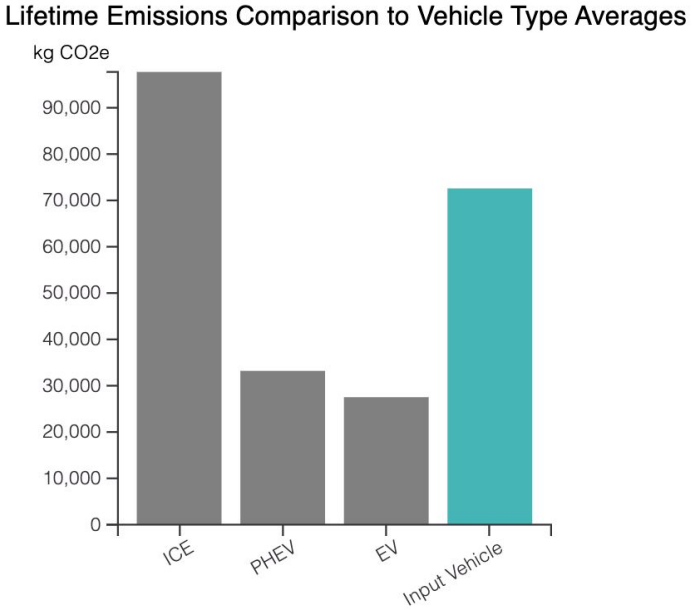


Beyond the Tailpipe Emissions Calculator by Oak Ridge National Laboratory

1. User Inputs → 2. Emissions Estimate → **3. Digestible Outputs**

1. Context

2. Unitization



*Note: Averages shown in bar chart are based on zip code, model year, and planned number of miles for driving from user inputs.

1. User Inputs → 2. Emissions Estimate → 3. Digestible Outputs

1. Context

2. Unitization

Your vehicle lifetime emissions is equal to emissions from

63

Round trip flights from SF to NYC

1. User Inputs → 2. Emissions Estimate → 3. Digestible Outputs

1. Context

2. Unitization

Enter number of miles:

356

Minimum Number of Miles: 1, Maximum: 9999

Estimated Emissions

Estimated Emissions: 145.18 kgCO2e

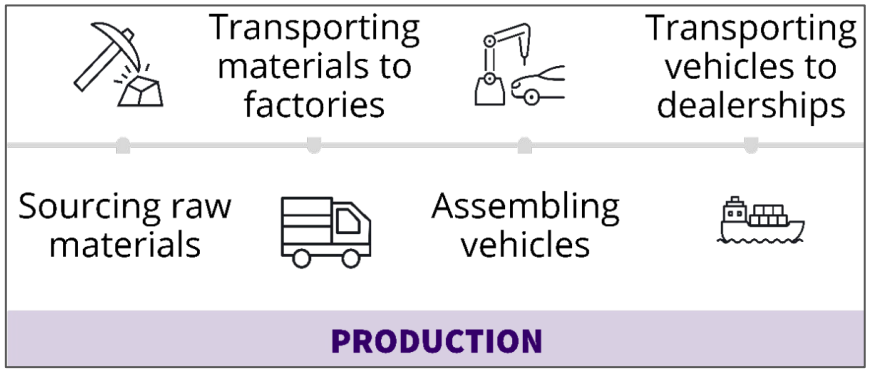
This is equivalent to emissions from an average American household using electricity for:

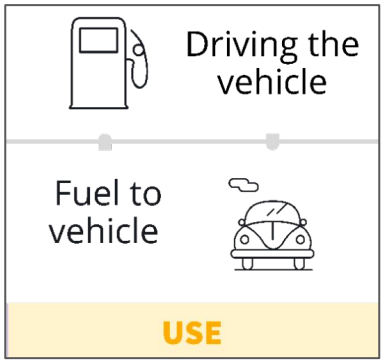
Measuring environmental impact…

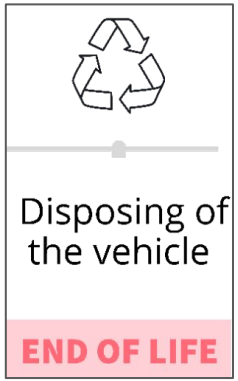
…is more complex than just ‘zero tailpipe emissions.’

Systems Thinking

Rather than focusing on **isolated parts...**

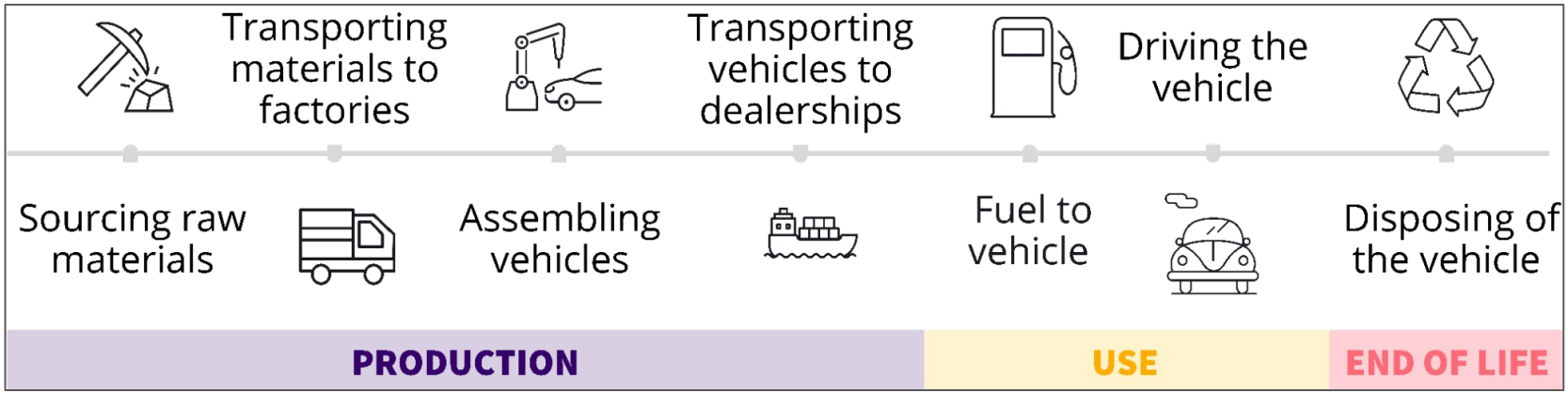




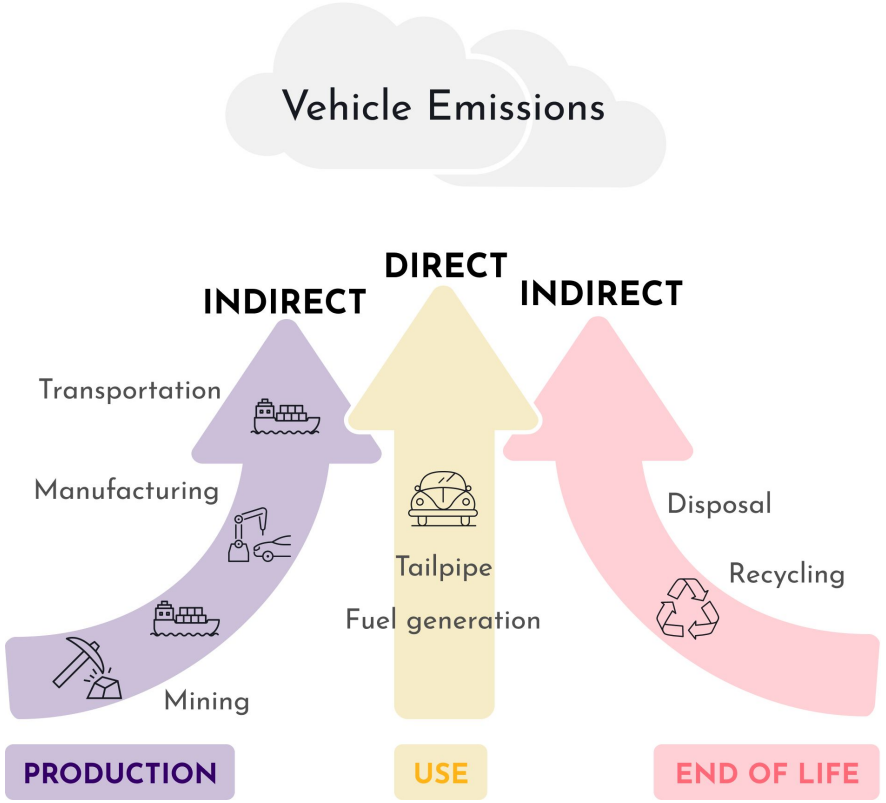


Systems Thinking

...think in terms of **relationships and interactions**



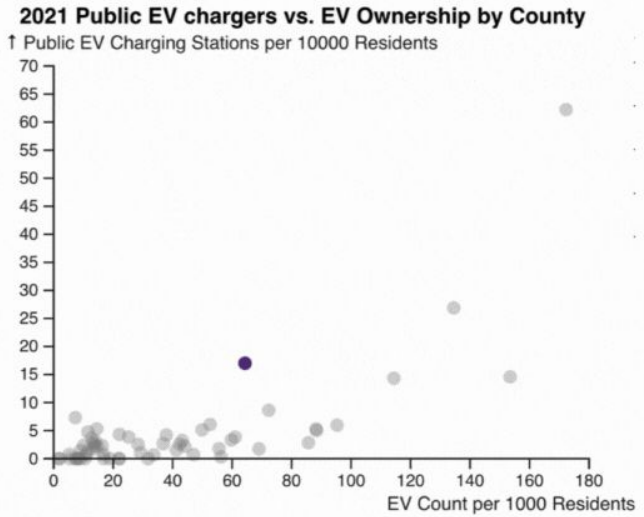
Global Processes
=
Global Emissions



Systems Thinking

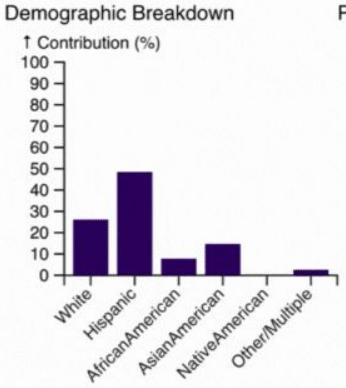
How may communities be affected by transitions to electric vehicles?

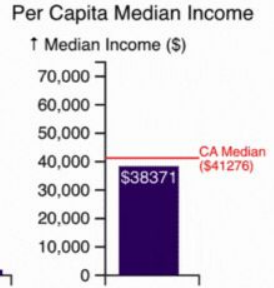
Access to Charging



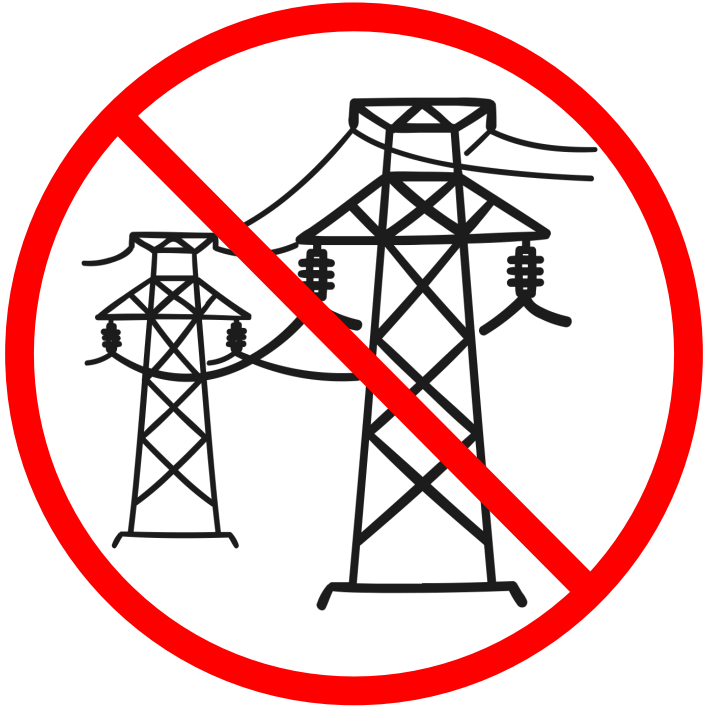
Selected County:
Los Angeles

Est. Population: 9989165
Number of EVs: 642677
Total Public Chargers: 16744

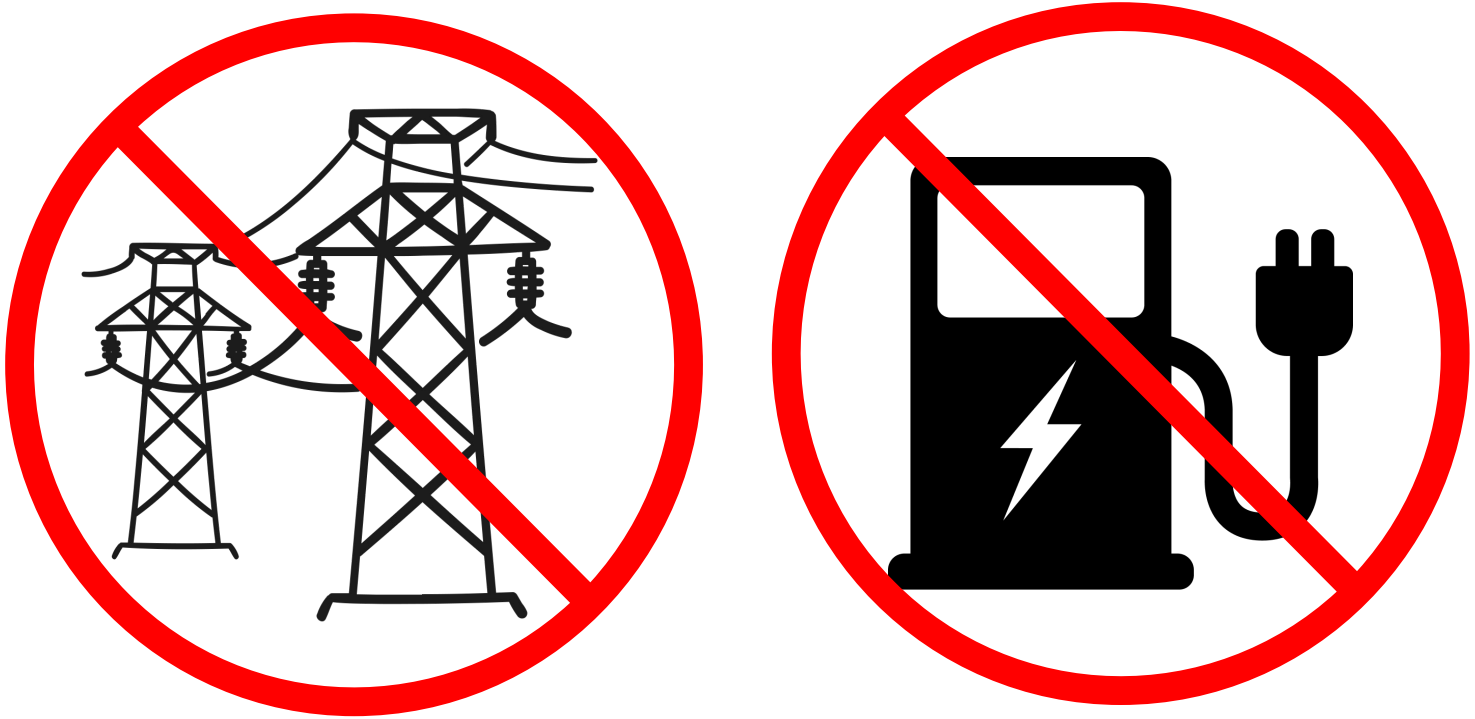




Extreme Weather = No Power



No Power = No Charging



Strategies to Reducing Passenger Vehicle Emissions

Drive an EV

Strategies to Reduce Passenger Vehicle Emissions

Drive an EV

Drive Less

Drive a Smaller Vehicle

Think Bigger:
Impact of electric vehicles on our environment and society

Ongoing Impact

Reproducibility

- Documentation on GitHub
  - Open access data
  - Open source code

Increasing Data Availability

- Conversations with the EPA
  - Realizing the lack of public-facing EV data
  - Plan to offer structured EV data to public

Climate Change and Informatics

- Bridging the gap in communication of complex topics
- Translating scientific information into digestible concepts
- Collaborating across disciplines

Thank you!

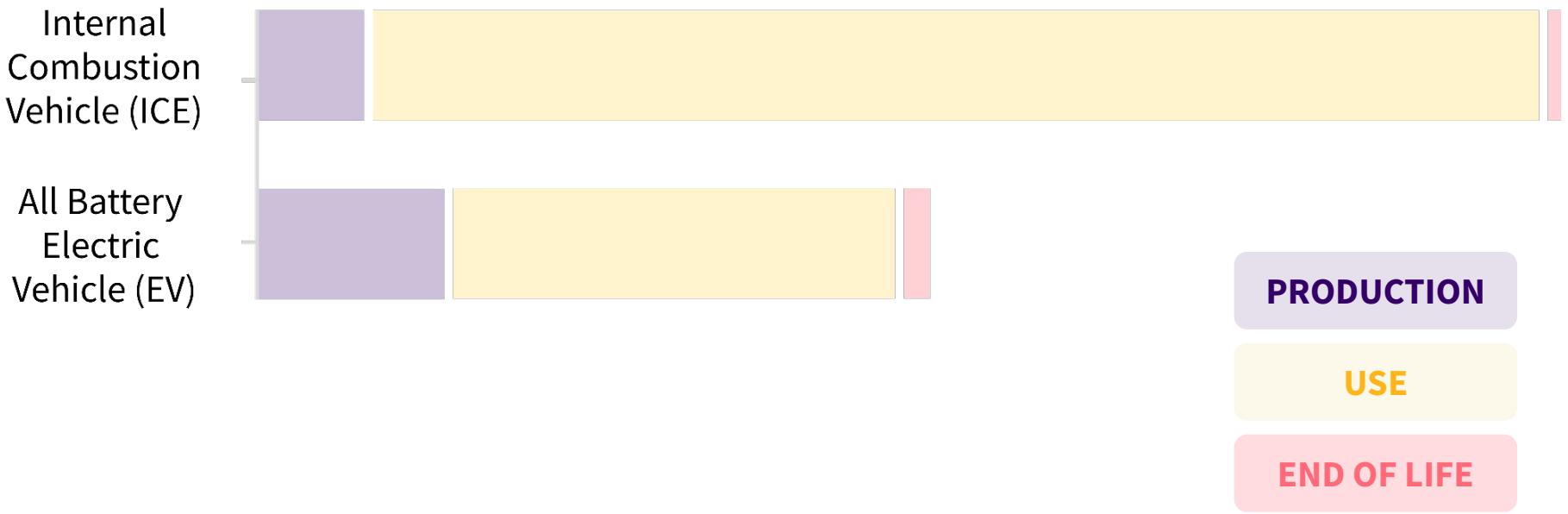
Questions?

We especially thank our advisor, Professor Marti Hearst!

Try our Emissions Explorer tool!
tinyurl.com/emissions-explorer

Appendix

What is difference of Lifetime Emissions between Vehicle Types?



Next Steps

Future Proofing

- Grid mix modeling over time
- Model-specific battery densities

Future Work

- Temperature and humidity effects
  - Integrate with EPA MOVES Deep Learning model
- Integrate EPA-certified battery weights
- Model-specific material compositions

END APPENDIX