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INSTITUTE OF TRANSPORTATION STUDIES

Moving beyond the tailpipe

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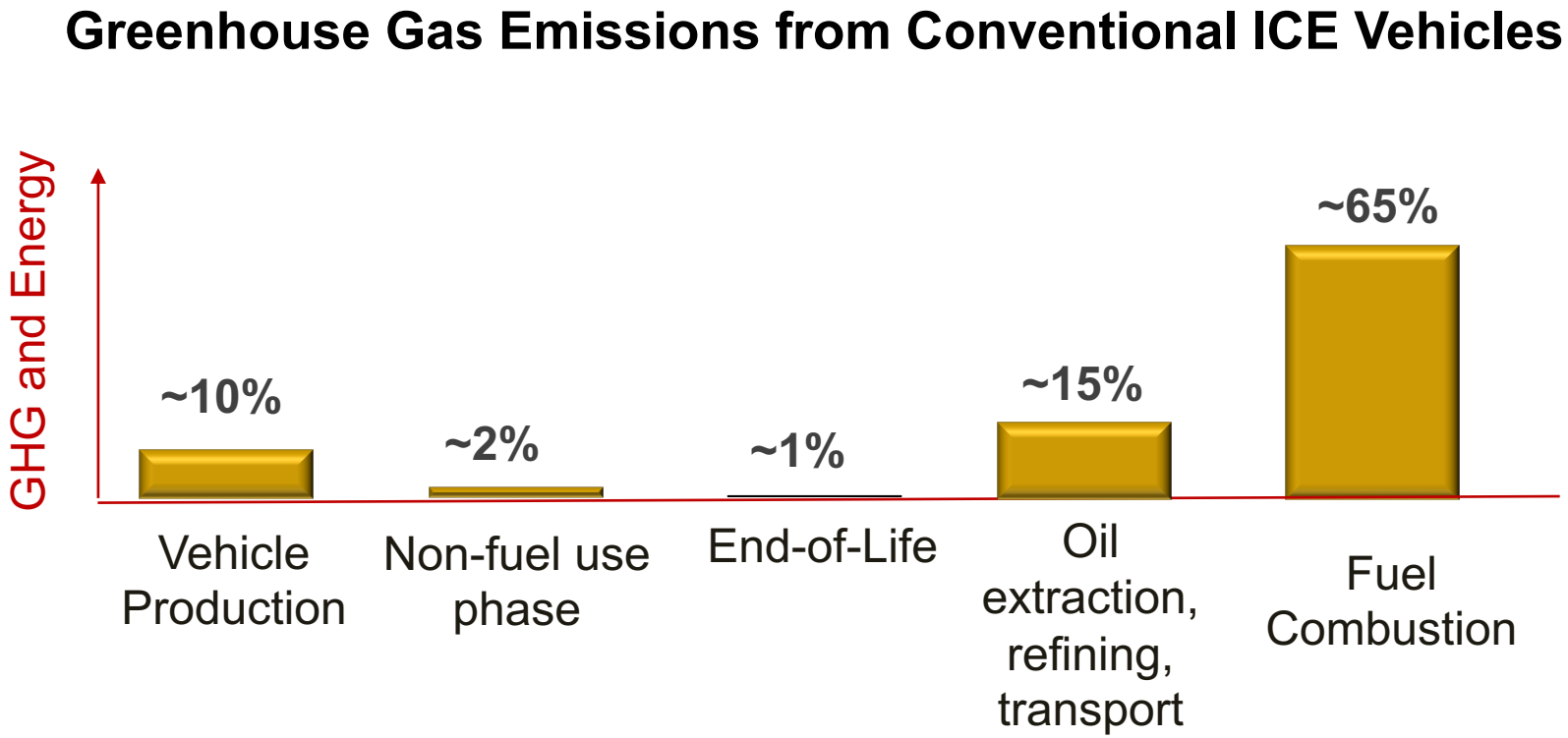
Overview

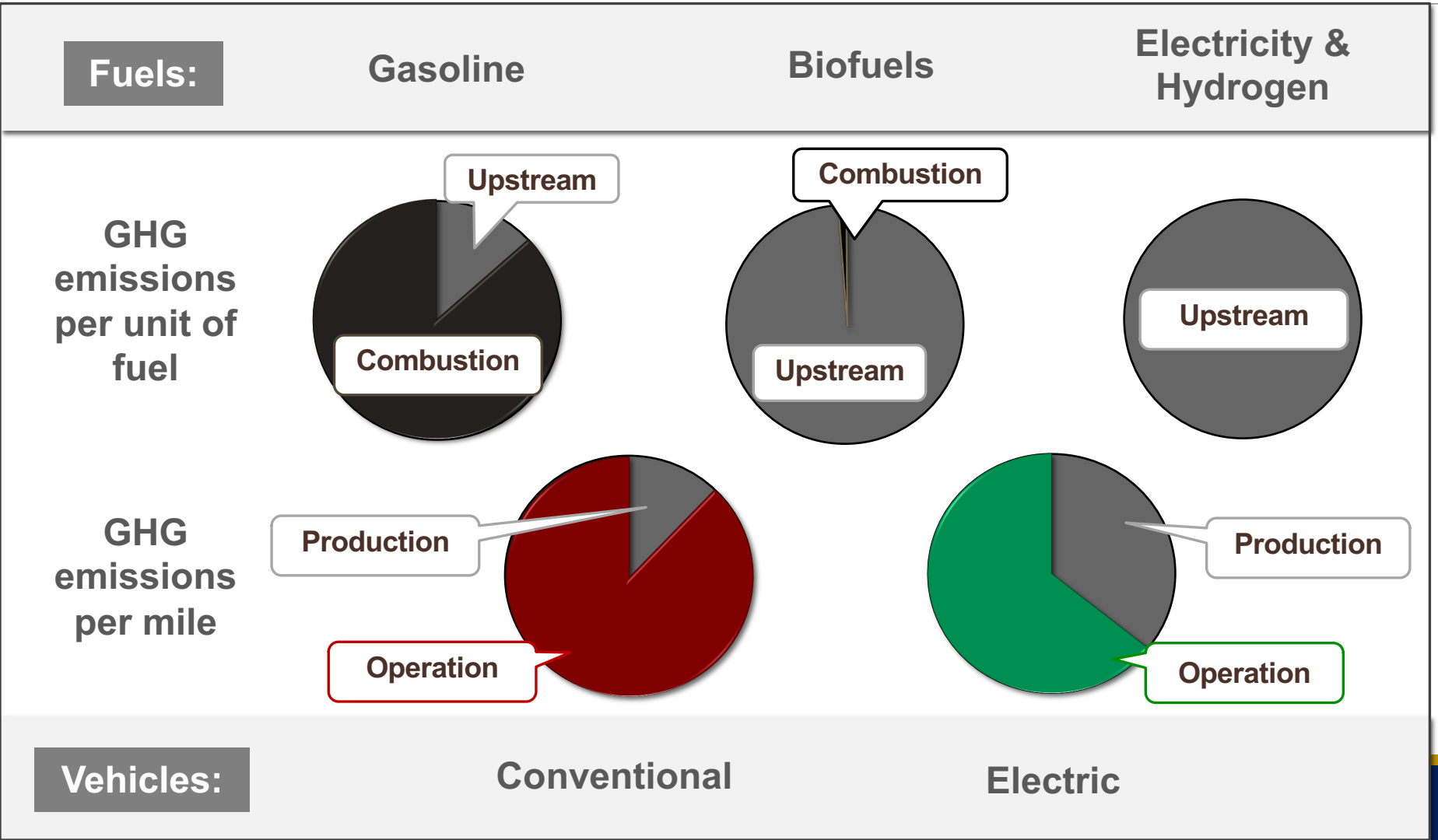
- Motivation
- Reviewing Life Cycle GHG emissions from EVs
- Shared, Automated, Long-Range EVs?
- Results
- Implications/Conclusions

Tailpipes used to be a good proxy

- Most emissions from conventional vehicles occurred during operation
- Most vehicles relied on a single fuel

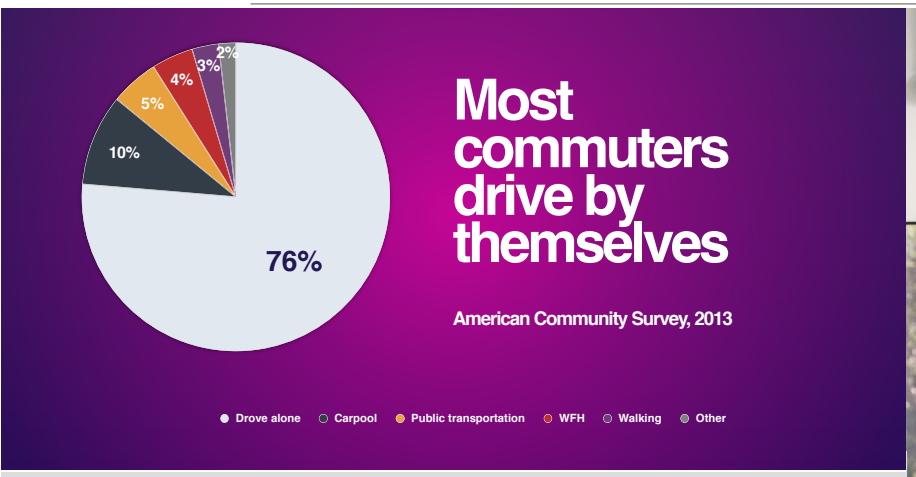


But fuel and vehicle technology are changing



Low-carbon and alternative fuels, as well as vehicle technologies like light weighting and battery storage, shift emissions upstream.

Patterns of vehicle ownership and use could also be changing

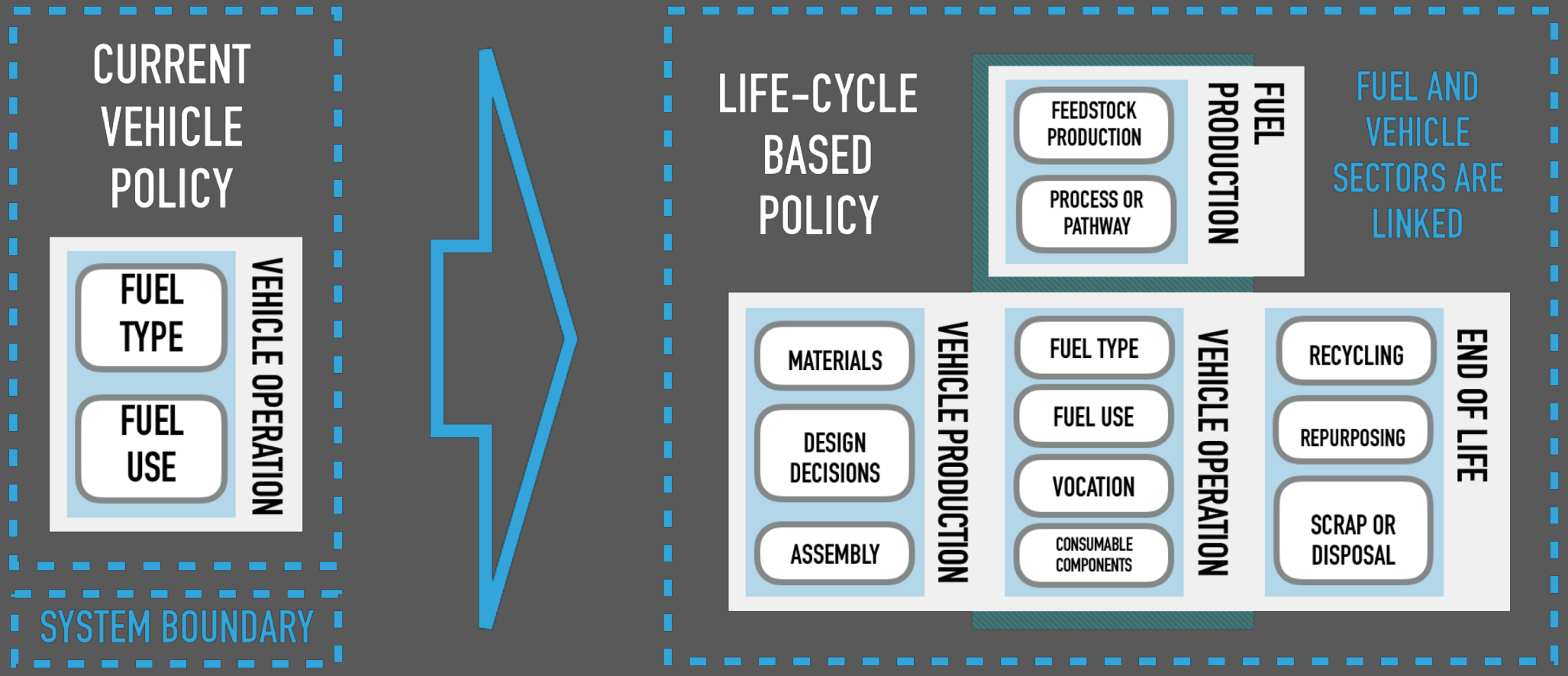


A new option is emerging: Lyft is helping shift from ownership to ridership

Dan Sperling riding an automated shuttle

- On-demand
- Integrated with other modes
- Automated
- Pooled

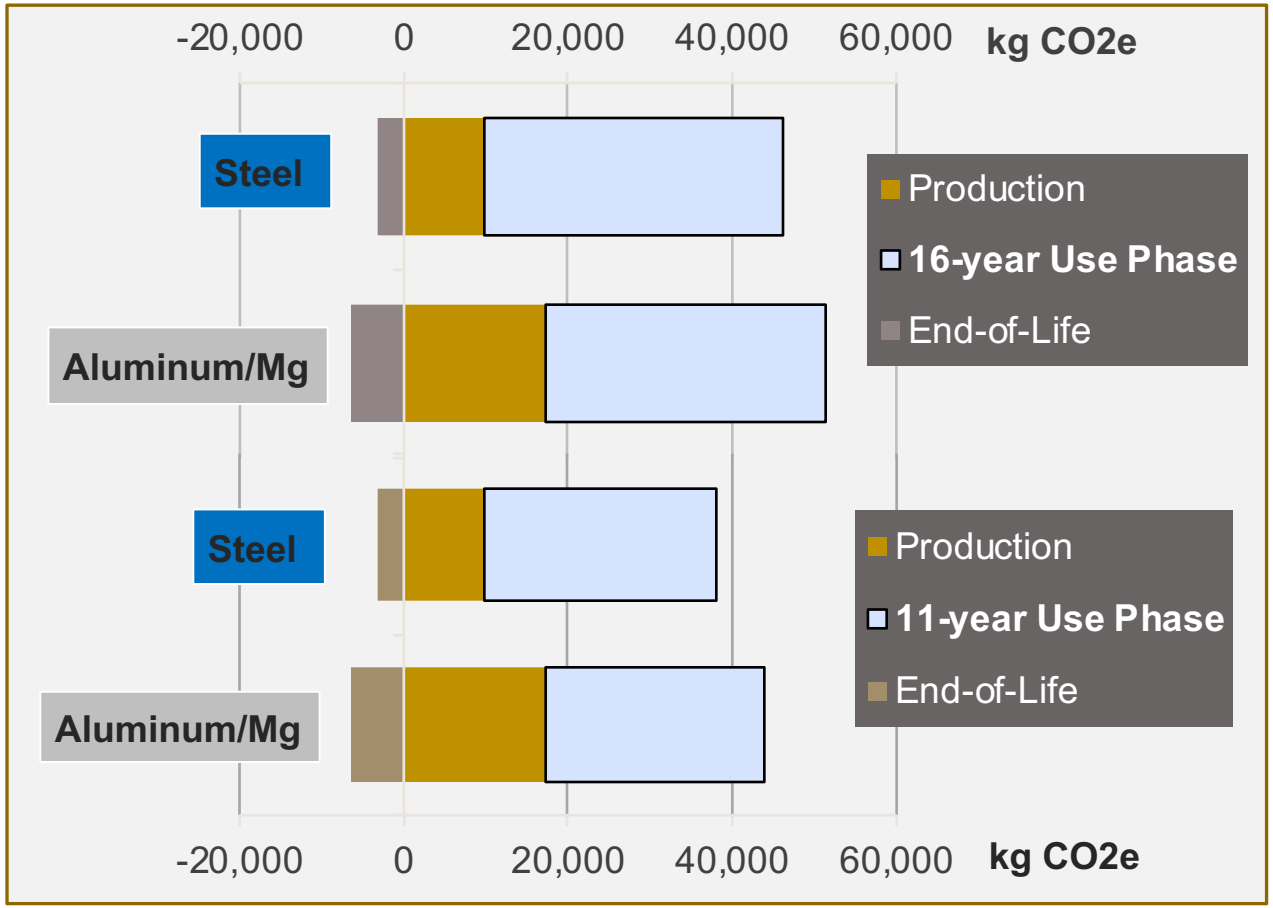
Could LCA be a framework for regulation of vehicles and fuels?



LCA and GHG Mitigation

In this study, for both 16-year and 11-year life, **the heavier vehicle had lower life cycle emissions.**

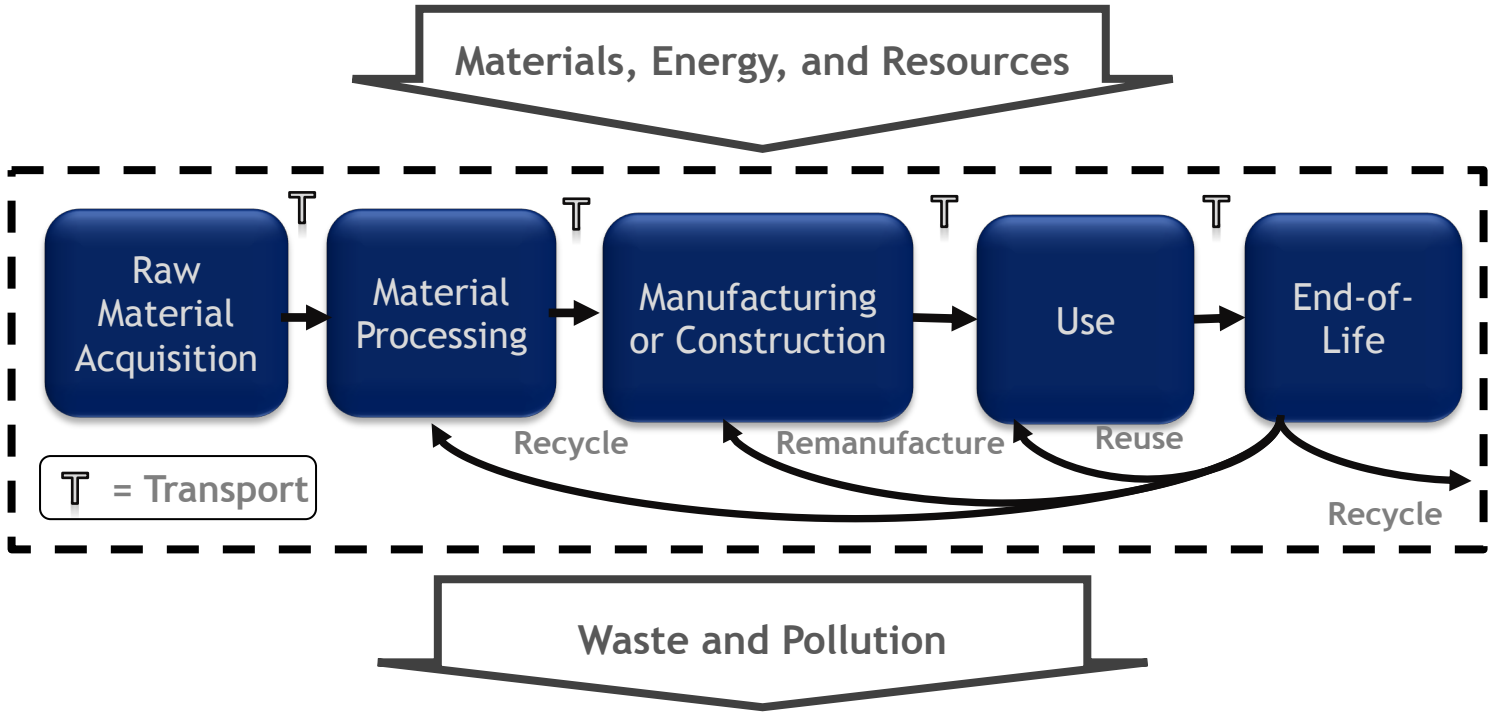
- A life cycle perspective is critical to avoid leakage/unintended consequences
- New technologies can increase efficiency, but not reduce emissions on a life cycle basis



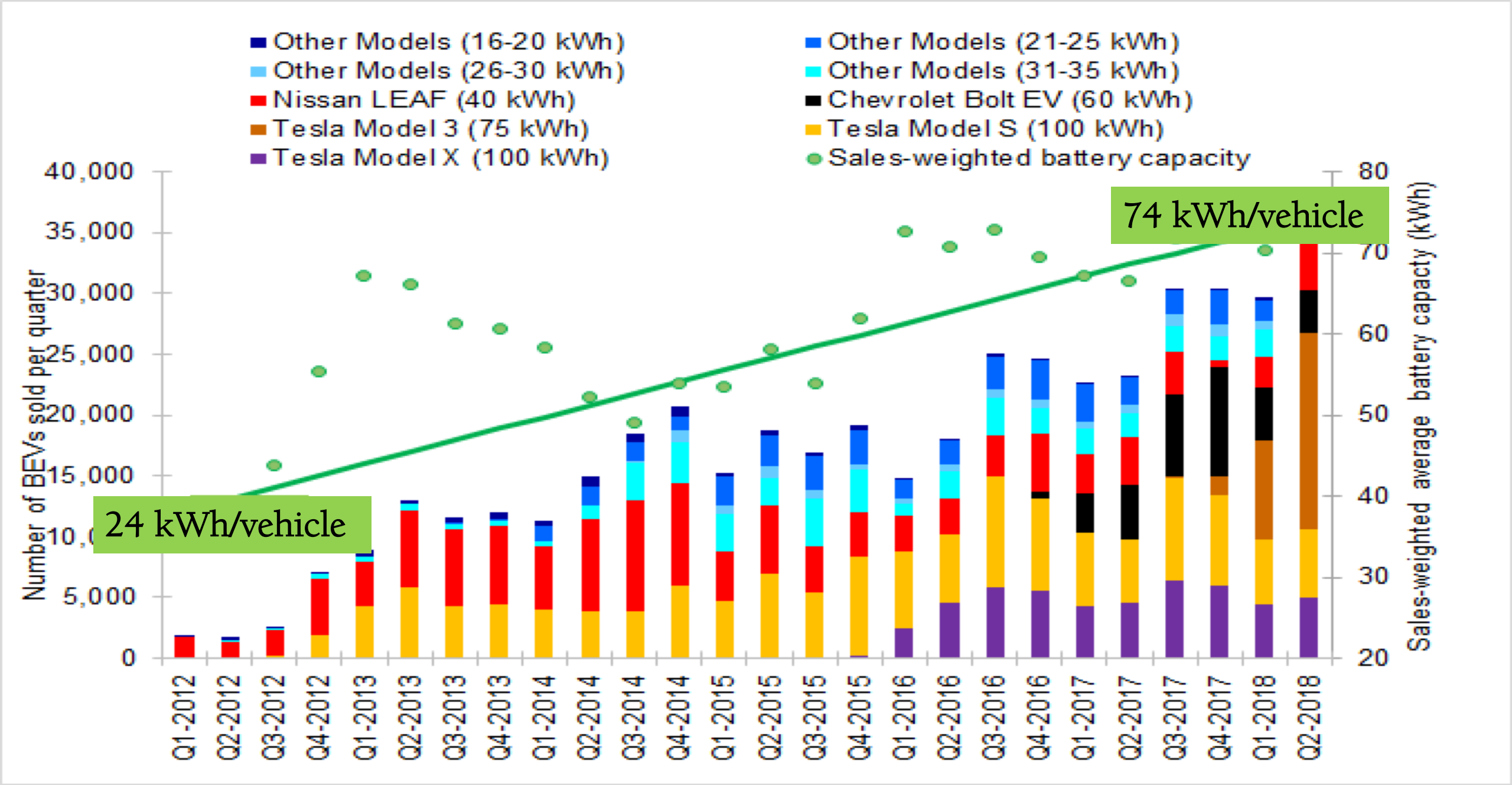
Kendall & Price. "Incorporating time-corrected life cycle greenhouse gas emissions in vehicle regulations." DOI: 10.1021/es203098j

Life Cycle Assessment (LCA)

LCA is a method for characterizing, quantifying, and interpreting environmental flows for a product or service from a "cradle-to-grave" perspective



Study	Vehicle Type	Battery Capacity (kWh)	Vehicle Production (g CO2e/km)	Battery Production (g CO2e/km)	Vehicle Operation (g CO2e/km)
Samaras and Meisterling (2008)	PHEV	20			
Notter et al. (2010)	BEV	34			
Majeau-Bettez et al. (2011)	BEV	24			
Dunn et al. (2012)	BEV	28			
Hawkins et al. (2013)	BEV	24			
Ellingsen et al. (2014)	BEV	27			
Zivin et al. (2014)	BEV	24			
Miotti et al. (2015)	BEV	19 - 60			
Tamayao et al. (2015)	BEV	24			
Kim et al. (2016)	BEV	24			
Archsmith et al. (2016)	BEV	28			
			24 29 34	0 12 24	40 120 200
Average Convetional ICE Vehicle (N=11 Studies)	**ICEV**		**33.2**	-	**191.5**


Other Models (16-20 kWh)
Other Models (21-25 kWh)
Other Models (26-30 kWh)
Other Models (31-35 kWh)
Nissan LEAF (40 kWh)
Chevrolet Bolt EV (60 kWh)
Tesla Model 3 (75 kWh)
Tesla Model S (100 kWh)
Tesla Model X (100 kWh)
Sales-weighted battery capacity
74 kWh/vehicle
24 kWh/vehicle
Number of BEVs sold per quarter
Sales-weighted average battery capacity (kWh)
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
80
70
60
50
40
30
20
Q1-2012
Q2-2012
Q3-2012
Q4-2012
Q1-2013
Q2-2013
Q3-2013
Q4-2013
Q1-2014
Q2-2014
Q3-2014
Q4-2014
Q1-2015
Q2-2015
Q3-2015
Q4-2015
Q1-2016
Q2-2016
Q3-2016
Q4-2016
Q1-2017
Q2-2017
Q3-2017
Q4-2017
Q1-2018
Q2-2018

Use-phase

SAVs with high utilization could realize 800,000 miles over 12 years (~5 x current average mileage for a personal vehicle)

Energy Use and GHGs per Mile for US Passenger Cars and Vans

	MPG	g CO2 per vehicle mile	Avg. Passengers	g CO2 per person mile
1980 Passenger Car	20	485	1.6	**303**
2015 Passenger Car	28	325	1.5	**217**
1980 Passenger Van	14	650	2	**325**
2015 Passenger Van	22	425	2.5	**170**

Use-phase

Fagnant, D. J., Kockelman, K. M., & Bansal, P. (2015). Operations of shared autonomous vehicle fleet for austin, texas, market. *Transportation Research Record: Journal of the Transportation Research Board*, (2536), 98-106.

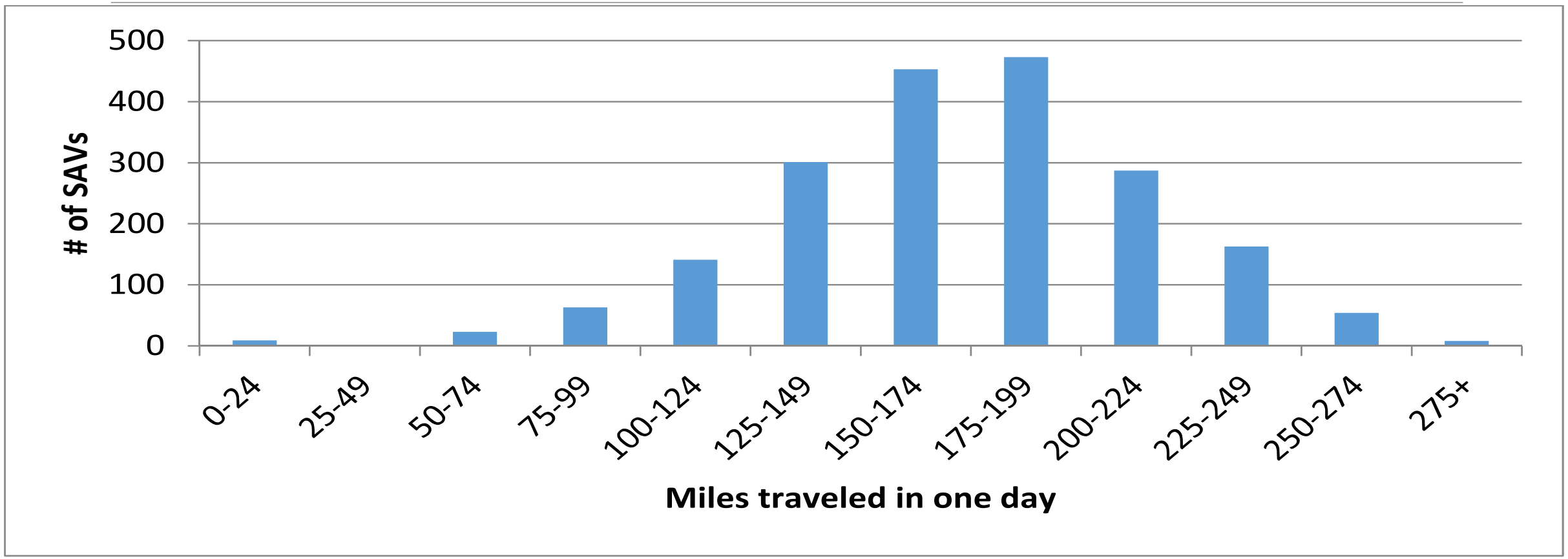


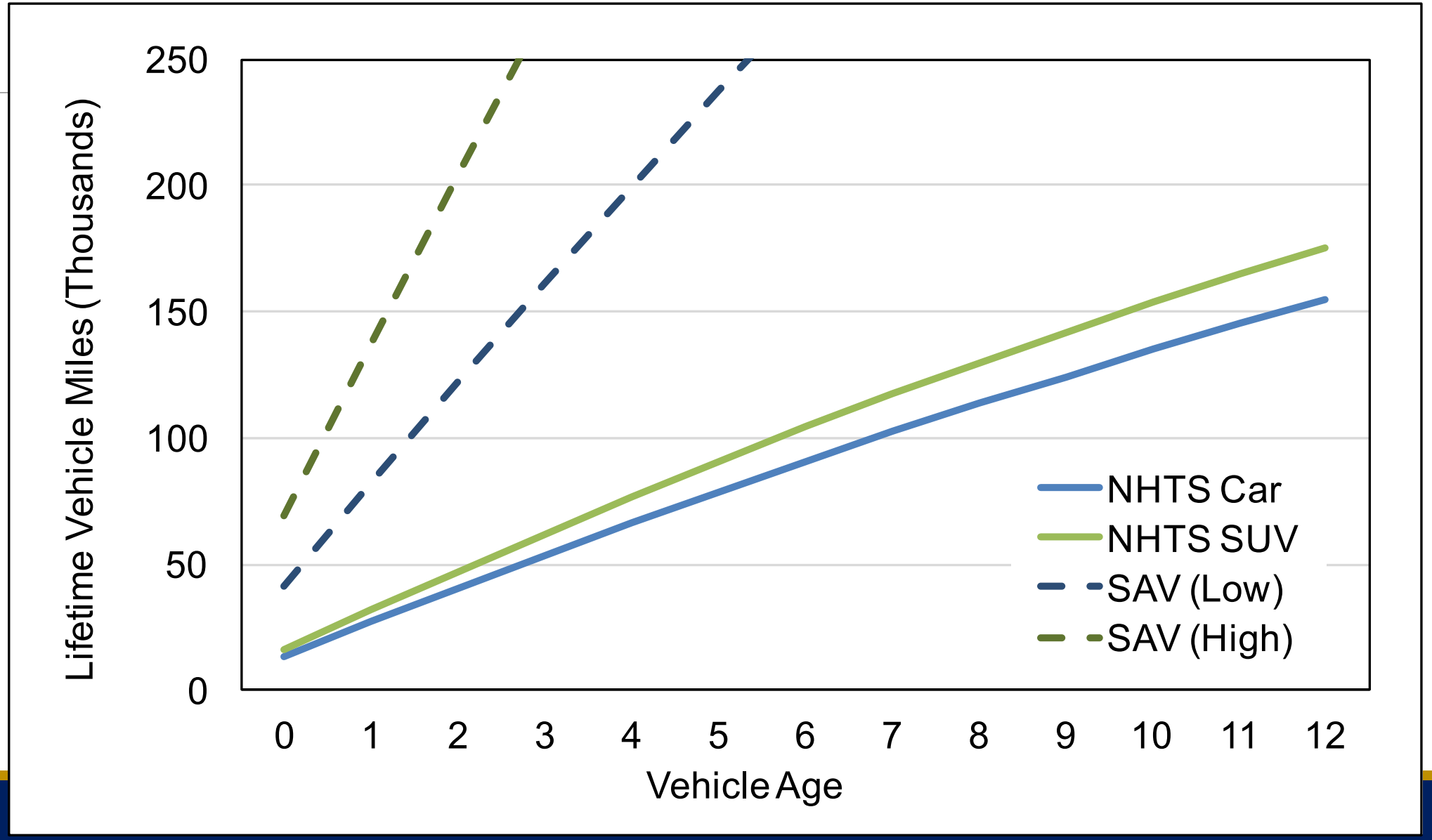
Figure 4: Daily Travel Distance per SAV in Austin Network-Based Setting

Scenarios Considered

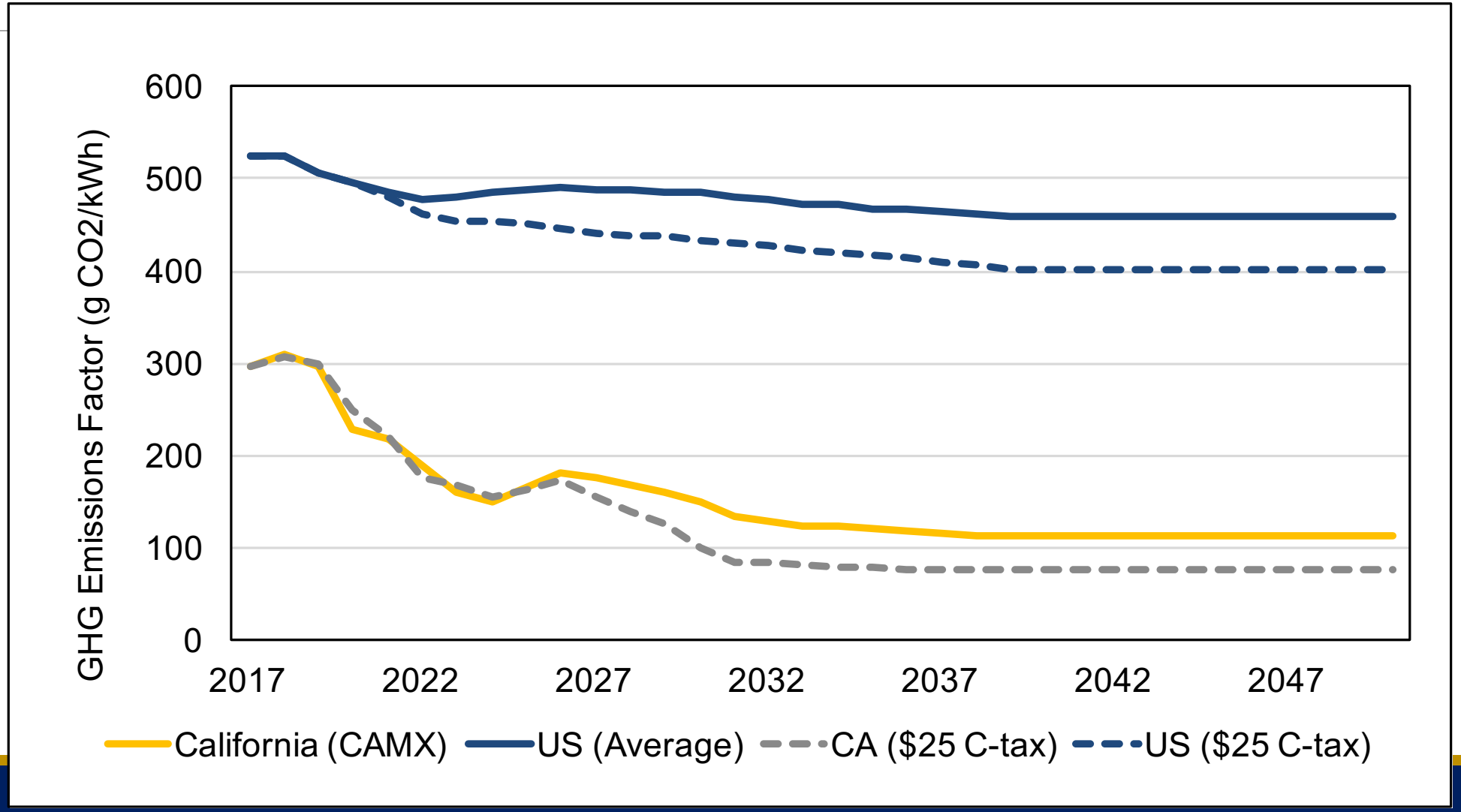



		Leaf (2012)	Compact	Sedan	SUV
2017	Battery (kWh)	24	60	100	100
	Range (miles)	84	209	299	254
2025	Battery (kWh)		60	100	100
	Range (miles)		214	318	282
2025 (Long Range)	Battery (kWh)		100	125	175
	Range (miles)		312	363	443

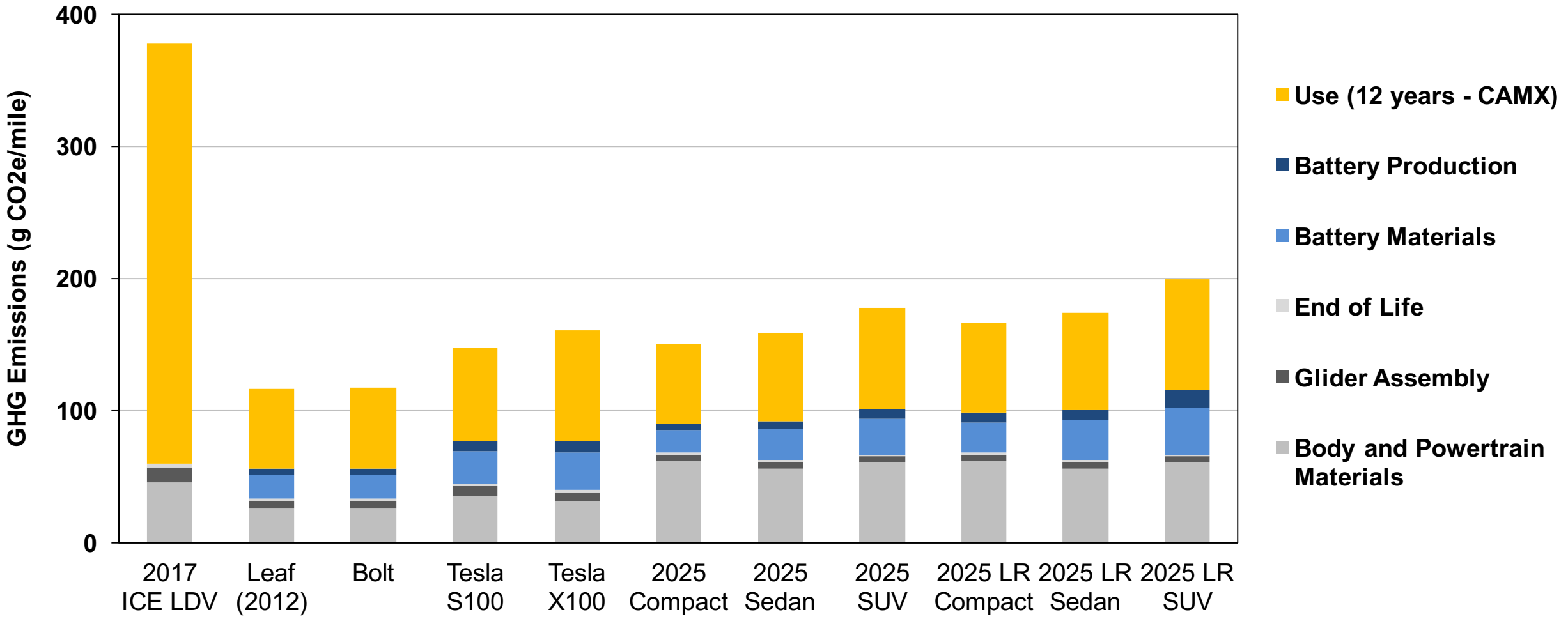
Annual VMT


Lifetime Vehicle Miles (Thousands)
250
200
150
100
50
0
0
1
2
3
4
5
6
7
8
9
10
11
12
Vehicle Age
NHTS Car
NHTS SUV
SAV (Low)
SAV (High)

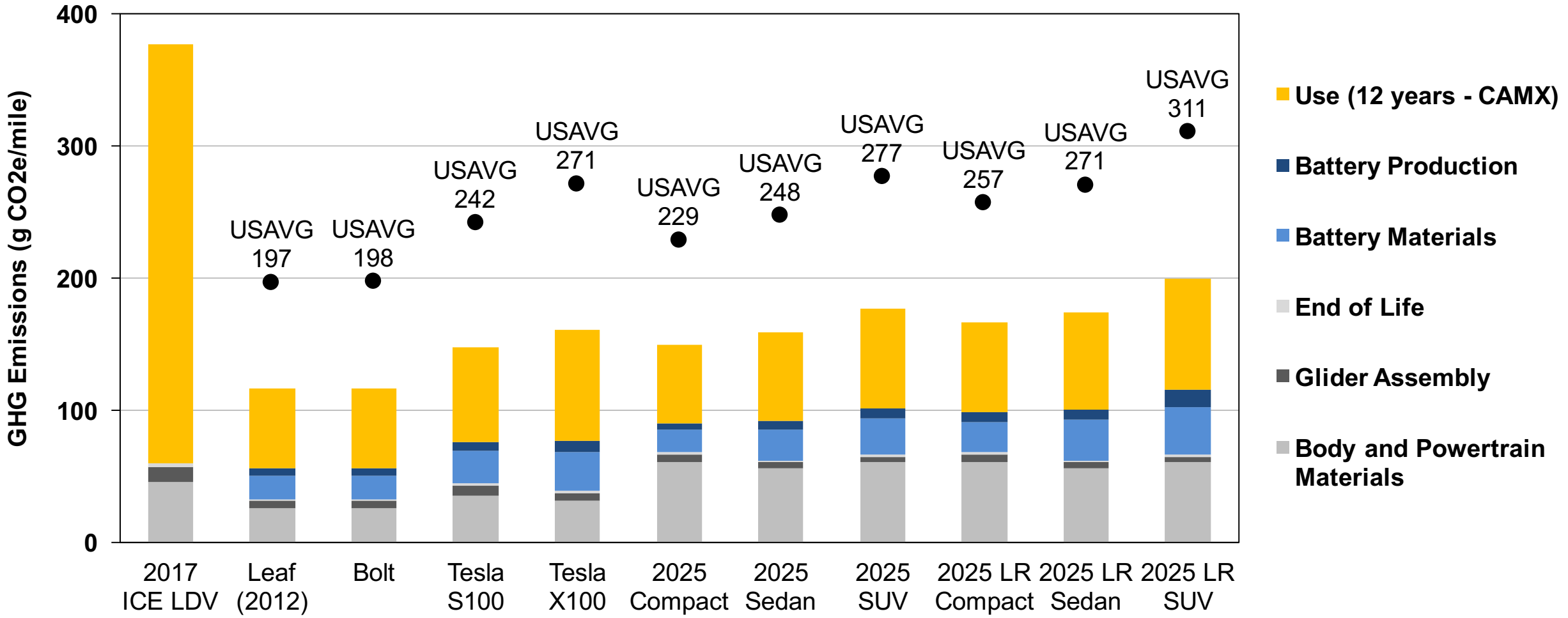
Electricity Emissions

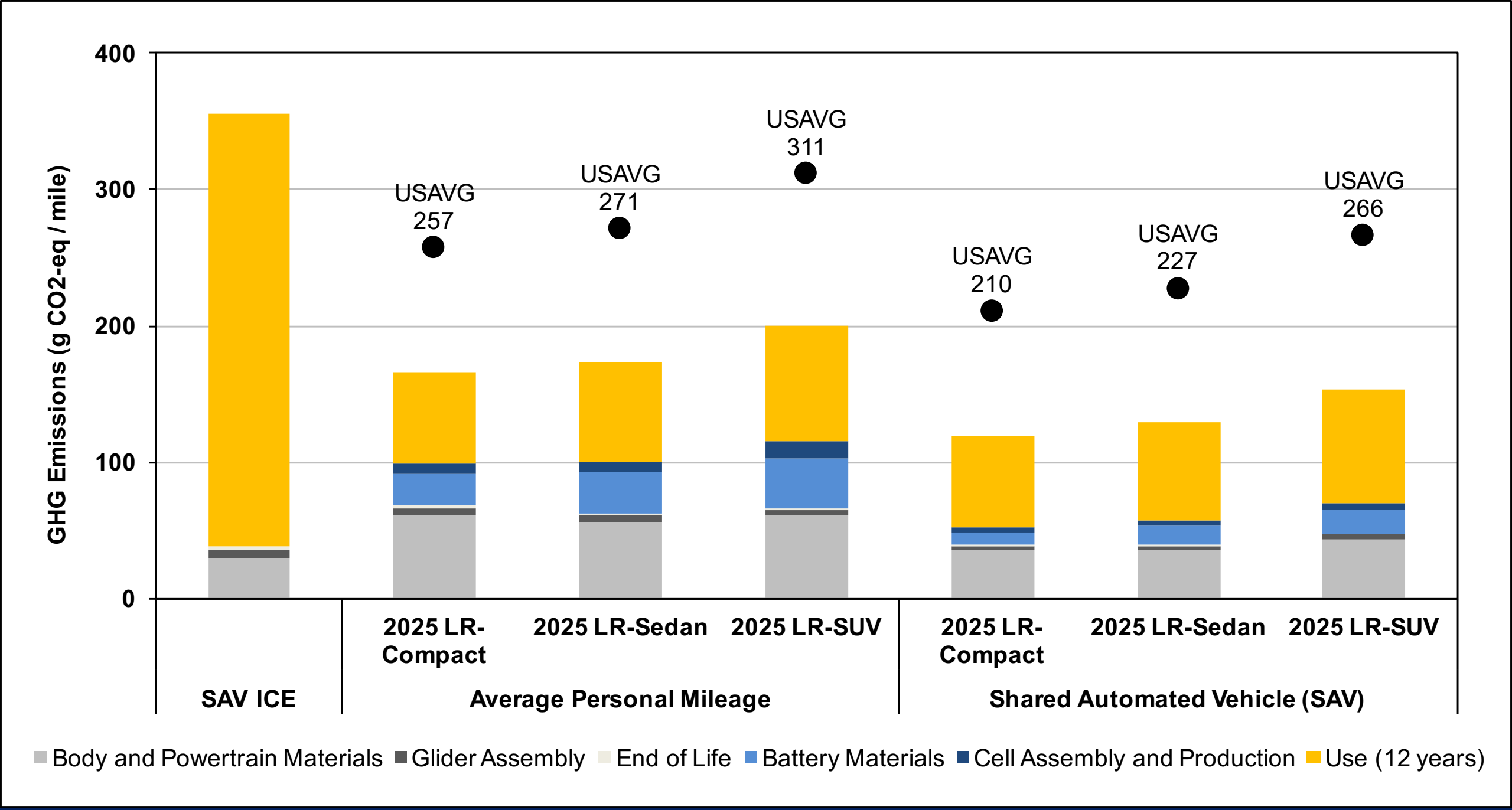


Life-cycle Emissions per Mile

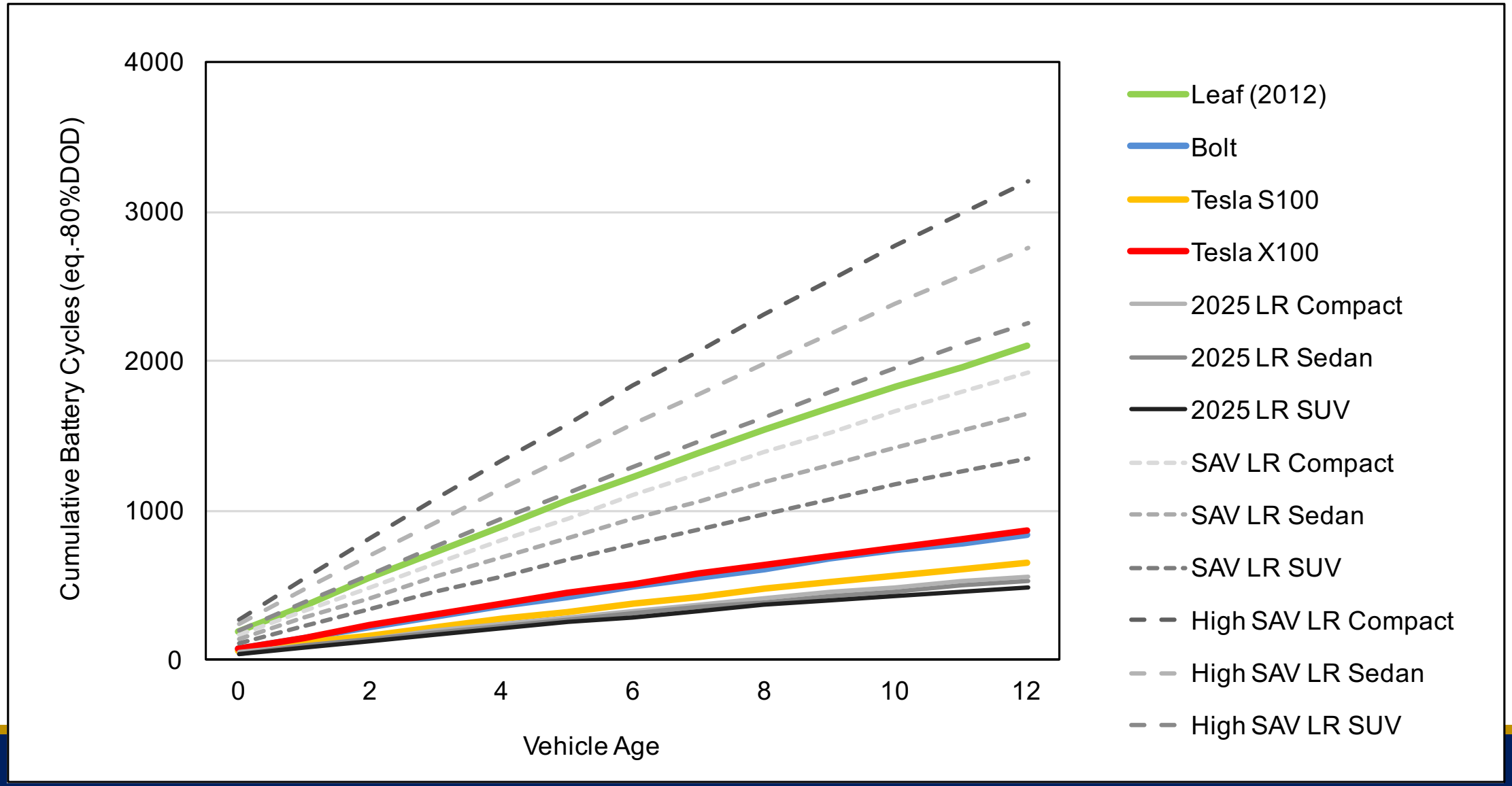


Life-cycle Emissions per Mile




400
300
200
100
0
GHG Emissions (g CO2-eq / mile)
USAVG 257
USAVG 271
USAVG 311
USAVG 210
USAVG 227
USAVG 266
2025 LR-Compact
2025 LR-Sedan
2025 LR-SUV
2025 LR-Compact
2025 LR-Sedan
2025 LR-SUV
SAV ICE
Average Personal Mileage
Shared Automated Vehicle (SAV)
Body and Powertrain Materials
Glider Assembly
End of Life
Battery Materials
Cell Assembly and Production
Use (12 years)

Lifetime Battery Cycles



High-mileage SAVs

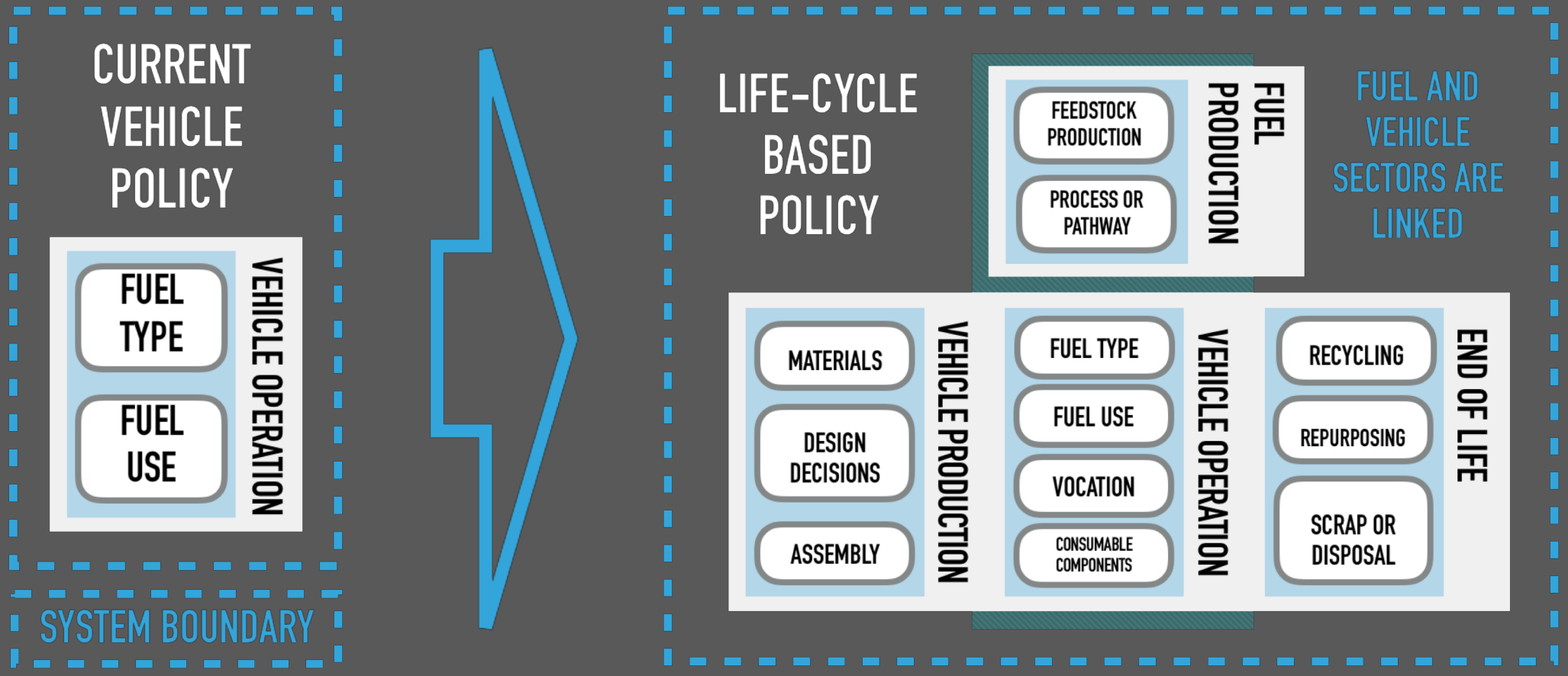
- SAVs with high utilization could realize 800,000 miles over 12 years (~5 x current average mileage for a personal vehicle)
- Battery replacement is a concern

	SAV Low Car	SAV Low SUV	SAV High Car	SAV High SUV
Chassis Replacement	2.0	2.0	3.3	3.3
Battery Replacements (2000 cycles @ 80%DOD)	0.0	0.0	1.4	1.1

Moving Beyond the Tailpipe

- Bigger batteries, more impacts, longer service lifetimes
- Potential for emissions creep from changing vehicle design and model choices
- EVs with long range could meet daily driving required for SAV fleet with single charge event per day

Could LCA be a framework for regulation of vehicles and fuels?



Thank You

https://www.sfchronicle.com/thetake/article/San-Francisco-from-7-2K-6159220.php?t=1e80687d7a0a4808f6