Market Segmentation of Zero-Emission Light-Duty Vehicles

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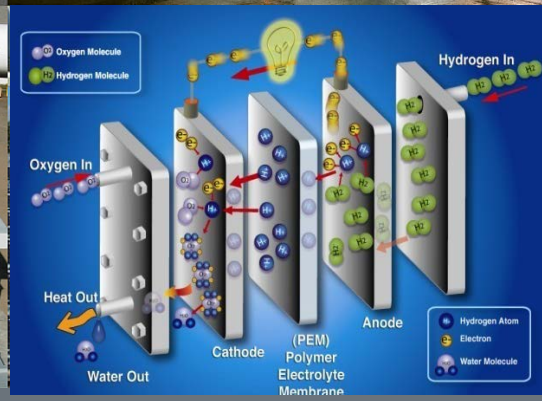

Presentation to HTAC

February 13, 2018

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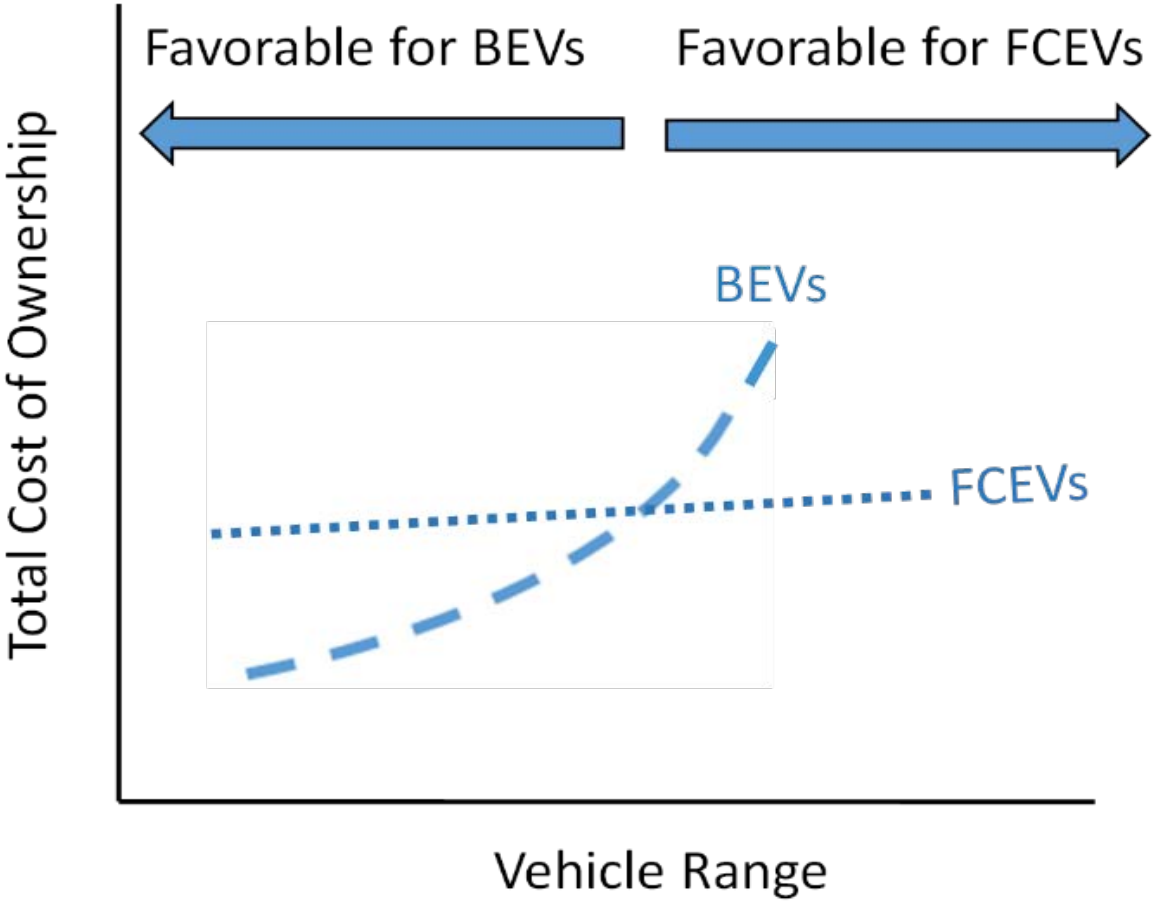
Motivation



Mass Compounding: As BEVs increase range, an increasing fraction of TCO goes to hauling the battery. This effect is less noticeable in FCEVs.

Outline

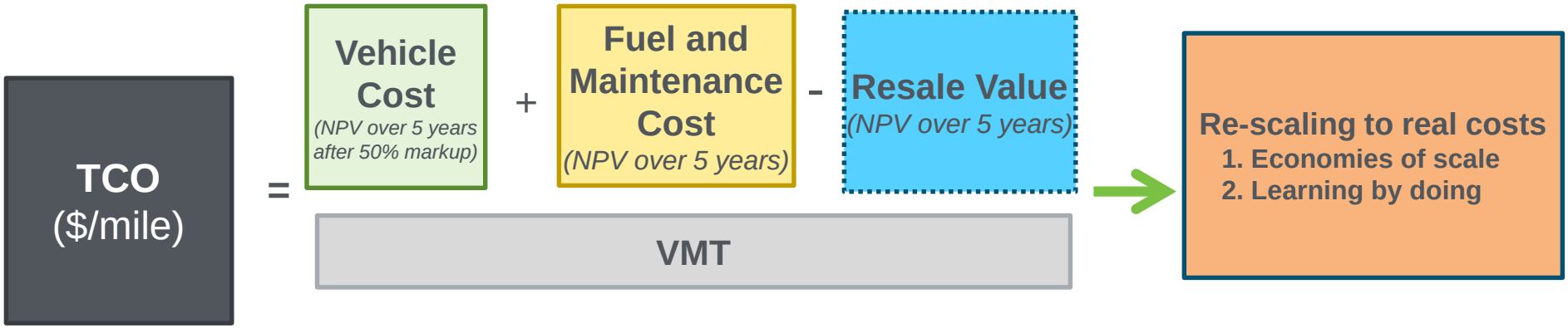
- Part 1:
  - How do costs compare for FCEVs and BEVs across vehicle size classes? Vehicle ranges? Today versus 2040?
- Part 2:
  - How large are the market segments?

Citation

Morrison, Stevens, Joseck (2018) Relative Economic Competitiveness of Light-Duty BEVs and FCEVs. *Transportation Research Part C: Emerging Technologies*. 87, pp. 183-196.

Methodology to Find Total Cost of Ownership

Vehicle-fuel costs are compared using lifecycle cost:



Total Cost of Ownership: Vehicle cost plus fuel cost minus resale value over miles traveled during five years

FCEV Technology Assumptions

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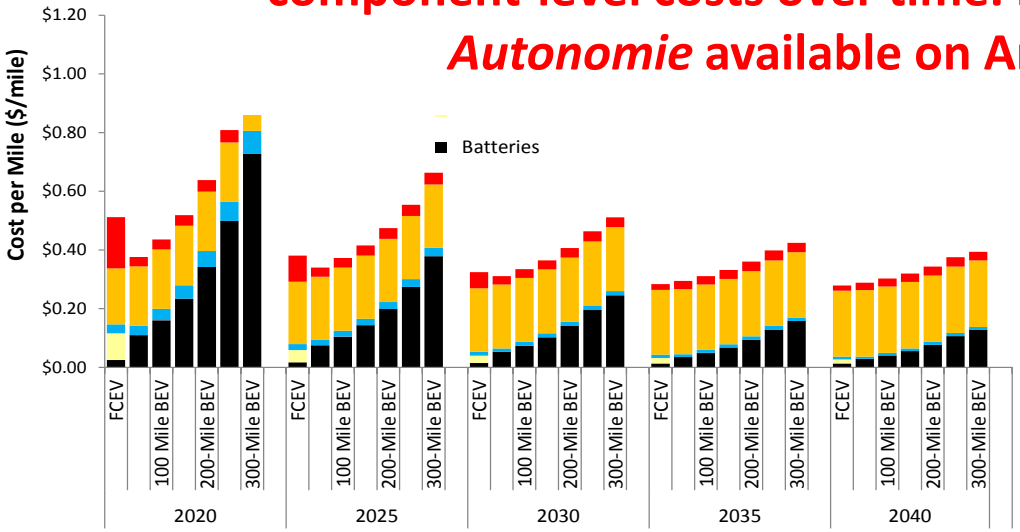
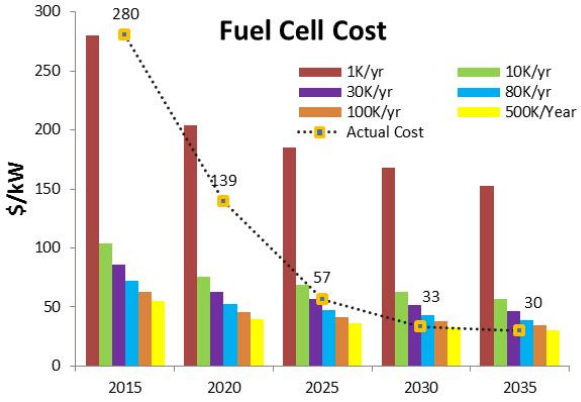
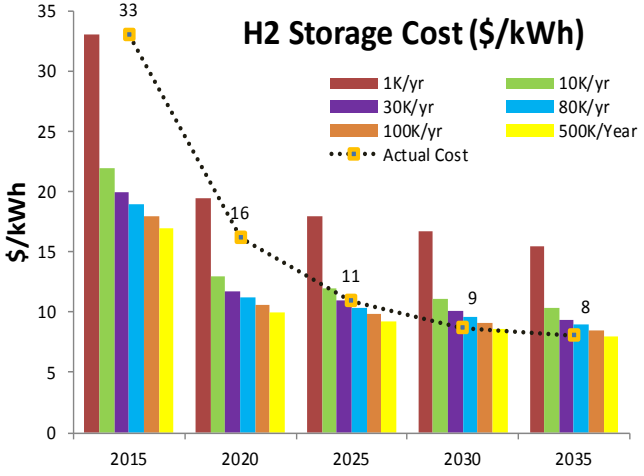
Cost Model: Includes assumptions about change in component-level costs over time. More information about *Autonomie* available on Argonne website.

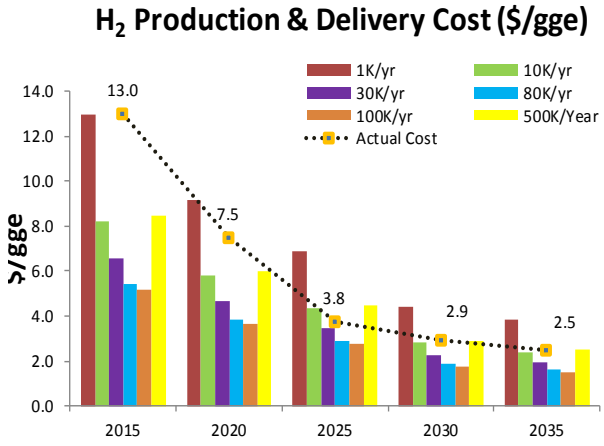


ptions

- **Vehicle Resale:** 25% of original value, before discounting
- **Fuel Cell Durability:** 150,000 miles
- **Hydrogen Production Cost:** $13.00/gge → $2.5/gge
- **H_2 Storage Cost:** $33/kWhr→ $8/kWhr
- **FCEV fuel economy :** between 41 mpgge (pick-up truck in 2015) and 103 mpgge (compact in 2035)
- **Annual miles driven:** 13,028-14,231 / yr (decline with time)







Assumed FCEV sales

Fraction of US LDV Stock (%)

Assumed market adoption of FCEVs LDVs.

Year	Stock of FCEVs	Fraction of LDV market
2020	23,000	0.0%
2025	78,000	0.0%
2030	3,300,000	1.2%
2350	1,220,000	4.5%
2040	28,000,000	10.1%

Vehicle projections: FCEV assumed to grow exponentially to 2040, reaching 10 percent of vehicle stock by 2040. FCEV growth drives cost reductions.

Cost Reduction Drivers

- **Economies of Scale:** Fixed costs (e.g., land, administration) are spread out over a larger number of units.
  - FCTO assumption: scaled elasticity of -0.1
- **Learning by Doing:** Increased output per worker associated with cumulative production
  - FCTO assumption: PR=0.95 (doubling cumulative production reduces costs by 5%)
- **Technological Learning:** R&D pays off in terms of increased efficiency, better equipment, etc. **(DOE Contribution)**
  - FCTO assumptions: Costs reduced by 5%/yr in 2015, R&D $Rate_t$ = 0.05*(0.94)^t and t = yrs after 2015; Implies by 2035 learning rate is 1.5%/yr

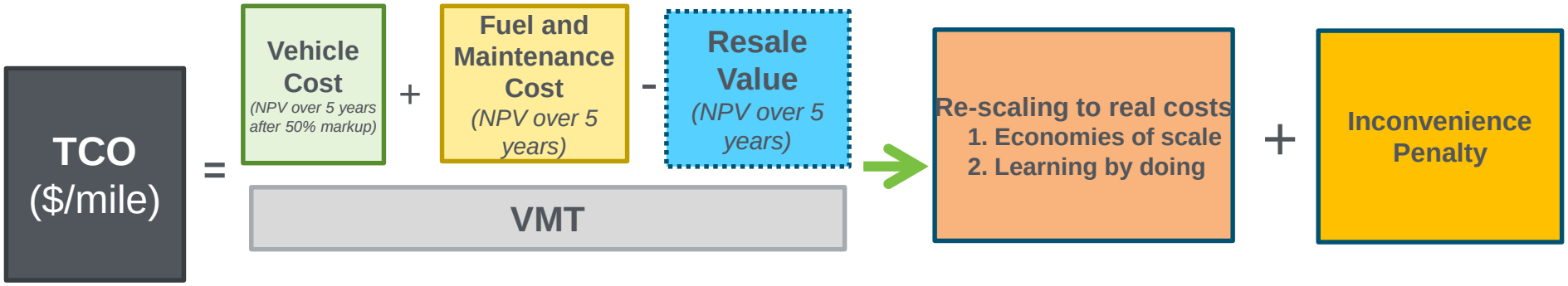
Three cost drivers help reduce FCEV costs over time. BEV costs already at scale so benefit from Learning by Doing and Technological Learning.

Part 2: Travel Behavior

- Use data from National Household Travel Survey (NHTS), and other investigators to estimate daily miles driven curves.
- Estimate “days of inconvenience” corresponding to number of days when a BEV owner cannot reach a desired range (meaning he/she would need a rental car).
- Cost of inconvenience factored into TCO of BEV.

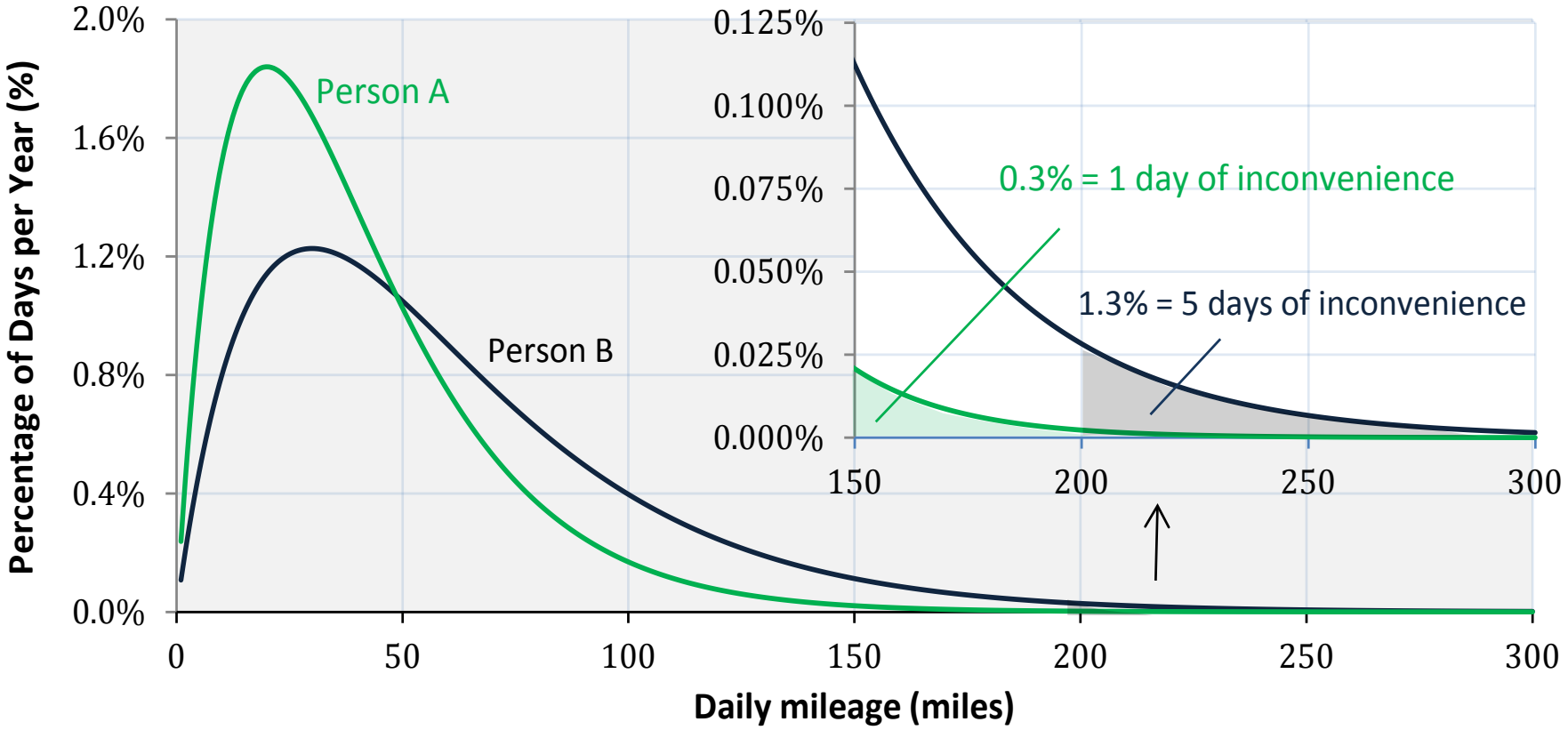
Methodology to Find Total Cost of Ownership

Vehicle-fuel lifecycle costs are compared



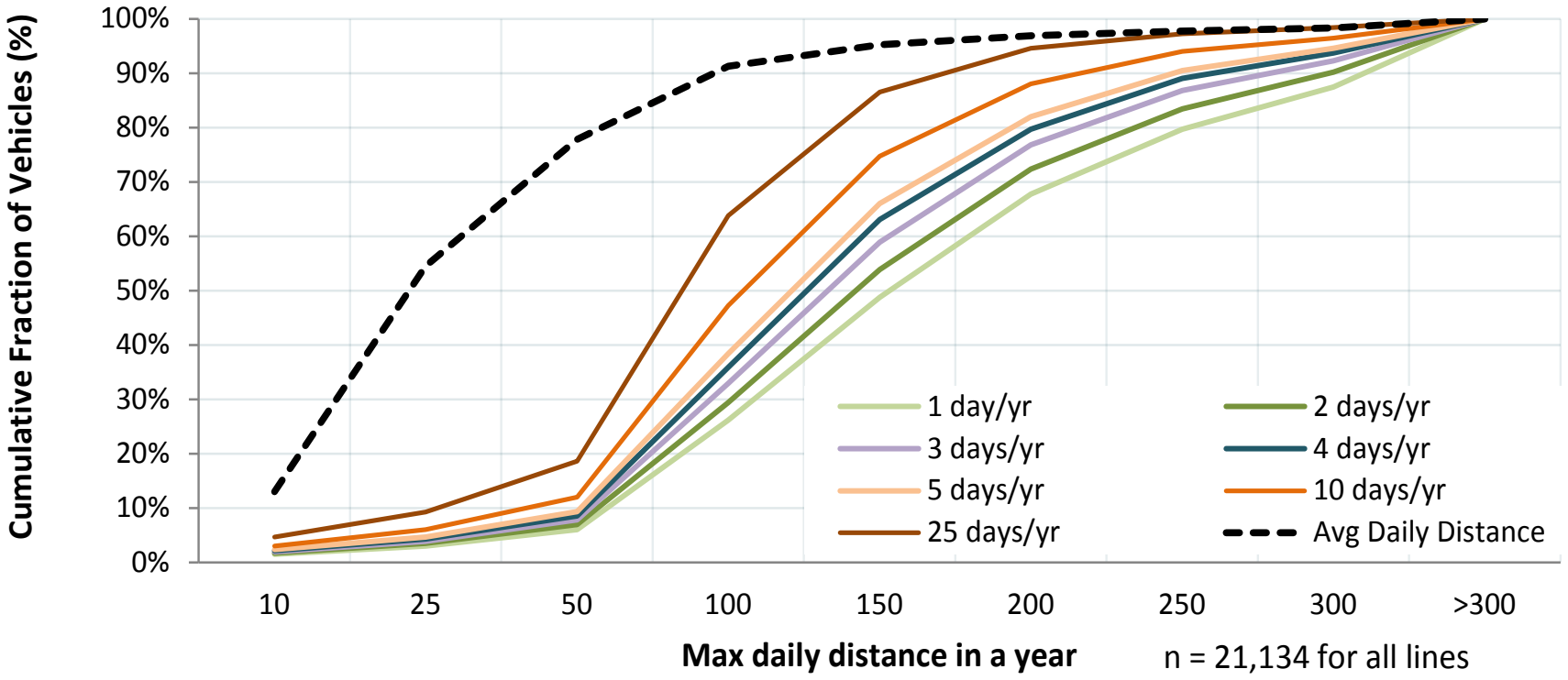
Inconvenience penalty added to the TCO of BEVs and FCEVs

Example of two drivers



A driver's driving profile reveals his/her level of "inconvenience" for a vehicle with a given range

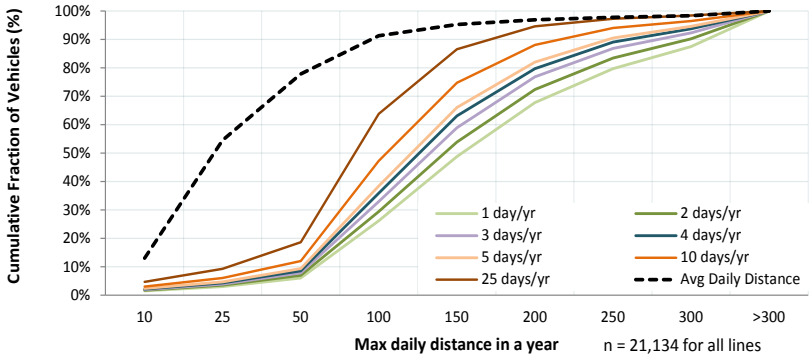
Cumulative Frequency, by number of days of inconvenience



Driving profiles can be aggregated at a national level and show the maximum daily distance for all drivers, assuming a given number of days of inconvenience

Inconvenience Penalty

- BEVs: penalized each day range need is not met
- FCEVs: penalized each day range is more than 150 miles
- Rental cost of $71 per day penalty.



Penalty adds to total cost by $0.02 to $0.57 per mile, based on number of days of inconvenience. Only applied to 1-car households

FCEV cost minus BEV cost

(3 Day of Inconvenience)

Year: 2020

FCEV minus PEV-X Cost

	50 Miles	100 Miles	150 Miles	200 Miles	250 Miles	300 Miles	350 Miles
Two-Seaters	$0.52	$0.39	$0.26	$0.13	$0.00	-$0.13	-$0.27
Minicompacts	$0.74	$0.63	$0.53	$0.42	$0.32	$0.21	$0.11
Subcompacts	$0.69	$0.58	$0.47	$0.37	$0.26	$0.15	$0.04
Compacts	$0.49	$0.38	$0.27	$0.17	$0.06	-$0.04	-$0.15
Midsize Cars	$0.57	$0.45	$0.32	$0.20	$0.08	-$0.05	-$0.17
Large Cars	$0.53	$0.42	$0.31	$0.20	$0.08	-$0.04	-$0.15
Small Station Wagons	$0.59	$0.49	$0.36	$0.23	$0.08	-$0.06	-$0.20
Pass Van	$0.38	$0.23	$0.07	-$0.08	-$0.24	-$0.39	-$0.55
SUV	$0.65	$0.46	$0.27	$0.09	-$0.10	-$0.29	-$0.48
Std Pickup	$0.93	$0.82	$0.70	$0.59	$0.47	$0.36	$0.24
Small Pickup	$0.47	$0.32	$0.17	$0.04	-$0.11	-$0.25	-$0.39

Year: 2025

FCEV minus PEV-X Cost

	50 Miles	100 Miles	150 Miles	200 Miles	250 Miles	300 Miles	350 Miles
Two-Seaters	$0.24	$0.14	$0.05	-$0.04	-$0.13	-$0.23	-$0.32
Minicompacts	$0.34	$0.27	$0.20	$0.12	$0.05	-$0.03	-$0.10
Subcompacts	$0.31	$0.24	$0.16	$0.10	$0.02	-$0.06	-$0.14
Compacts	$0.22	$0.14	$0.06	$0.00	-$0.08	-$0.16	-$0.24
Midsize Cars	$0.26	$0.17	$0.08	$0.00	-$0.09	-$0.18	-$0.27
Large Cars	$0.24	$0.16	$0.08	$0.00	-$0.08	-$0.17	-$0.26
Small Station Wagons	$0.24	$0.19	$0.09	$0.01	-$0.10	-$0.20	-$0.30
Pass Van	$0.18	$0.06	-$0.05	-$0.16	-$0.27	-$0.38	-$0.49
SUV	$0.30	$0.16	$0.03	-$0.10	-$0.24	-$0.37	-$0.51
Std Pickup	$0.48	$0.40	$0.31	$0.23	$0.15	$0.06	-$0.03
Small Pickup	$0.22	$0.11	$0.00	-$0.09	-$0.20	-$0.30	-$0.40

Year: 2030

FCEV minus PEV-X Cost

	50 Miles	100 Miles	150 Miles	200 Miles	250 Miles	300 Miles	350 Miles
Two-Seaters	$0.07	$0.00	-$0.07	-$0.13	-$0.20	-$0.27	-$0.34
Minicompacts	$0.11	$0.05	$0.00	-$0.06	-$0.11	-$0.17	-$0.22
Subcompacts	$0.09	$0.04	-$0.02	-$0.07	-$0.13	-$0.19	-$0.24
Compacts	$0.06	$0.00	-$0.05	-$0.10	-$0.16	-$0.22	-$0.27
Midsize Cars	$0.07	$0.01	-$0.06	-$0.11	-$0.18	-$0.25	-$0.31
Large Cars	$0.06	$0.01	-$0.05	-$0.11	-$0.17	-$0.23	-$0.30
Small Station Wagons	$0.03	$0.01	-$0.06	-$0.12	-$0.20	-$0.27	-$0.35
Pass Van	$0.06	-$0.02	-$0.10	-$0.18	-$0.26	-$0.35	-$0.43
SUV	$0.07	-$0.03	-$0.13	-$0.22	-$0.31	-$0.41	-$0.51
Std Pickup	$0.19	$0.13	$0.07	$0.01	-$0.05	-$0.11	-$0.18
Small Pickup	$0.07	-$0.01	-$0.09	-$0.15	-$0.23	-$0.30	-$0.38

Year: 2035

FCEV minus PEV-X Cost

	50 Miles	100 Miles	150 Miles	200 Miles	250 Miles	300 Miles	350 Miles
Two-Seaters	$0.05	$0.01	-$0.04	-$0.07	-$0.11	-$0.16	-$0.20
Minicompacts	$0.06	$0.02	-$0.02	-$0.07	-$0.11	-$0.15	-$0.19
Subcompacts	$0.05	$0.01	-$0.03	-$0.07	-$0.11	-$0.15	-$0.19
Compacts	$0.04	$0.00	-$0.04	-$0.06	-$0.10	-$0.14	-$0.18
Midsize Cars	$0.04	$0.01	-$0.04	-$0.07	-$0.11	-$0.16	-$0.20
Large Cars	$0.04	$0.00	-$0.03	-$0.07	-$0.11	-$0.15	-$0.19
Small Station Wagons	$0.00	$0.00	-$0.04	-$0.07	-$0.13	-$0.17	-$0.22
Pass Van	$0.06	$0.01	-$0.03	-$0.08	-$0.12	-$0.16	-$0.21
SUV	$0.03	-$0.02	-$0.07	-$0.12	-$0.17	-$0.22	-$0.28
Std Pickup	$0.15	$0.12	$0.09	$0.06	$0.03	$0.00	-$0.03
Small Pickup	$0.06	$0.01	-$0.04	-$0.07	-$0.12	-$0.16	-$0.21

Year: 2040

FCEV minus PEV-X Cost

	50 Miles	100 Miles	150 Miles	200 Miles	250 Miles	300 Miles	350 Miles
Two-Seaters	$0.04	$0.00	-$0.04	-$0.07	-$0.11	-$0.15	-$0.19
Minicompacts	$0.05	$0.02	-$0.01	-$0.04	-$0.07	-$0.10	-$0.13
Subcompacts	$0.04	$0.01	-$0.02	-$0.04	-$0.08	-$0.11	-$0.14
Compacts	$0.03	$0.00	-$0.03	-$0.06	-$0.09	-$0.12	-$0.15
Midsize Cars	$0.03	$0.00	-$0.04	-$0.06	-$0.10	-$0.13	-$0.17
Large Cars	$0.03	$0.00	-$0.03	-$0.06	-$0.09	-$0.12	-$0.16
Small Station Wagons	-$0.01	$0.00	-$0.04	-$0.06	-$0.11	-$0.15	-$0.19
Pass Van	$0.03	-$0.01	-$0.06	-$0.11	-$0.15	-$0.20	-$0.24
SUV	$0.02	-$0.03	-$0.09	-$0.14	-$0.19	-$0.25	-$0.30
Std Pickup	$0.14	$0.10	$0.07	$0.04	$0.01	-$0.03	-$0.06
Small Pickup	$0.06	$0.01	-$0.03	-$0.07	-$0.11	-$0.15	-$0.19

Raw Data – 3 Day of Inconvenience

FCEV cost minus BEV cost

Year: 2020

FCEV minus BEV-X Cost

	50 Miles	100 Miles	150 Miles	200 Miles	250 Miles	300 Miles	350 Miles
Two-Seaters	$0.54	$0.40	$0.27	$0.13	$0.00	-$0.13	-$0.27
Minicompacts	$0.74	$0.63	$0.53	$0.42	$0.32	$0.21	$0.11
Subcompacts	$0.70	$0.59	$0.48	$0.37	$0.26	$0.15	$0.04
Compacts	$0.50	$0.39	$0.28	$0.17	$0.07	-$0.04	-$0.15
Midsize Cars	$0.59	$0.46	$0.33	$0.21	$0.08	-$0.05	-$0.17
Large Cars	$0.55	$0.43	$0.32	$0.20	$0.08	-$0.04	-$0.15
Small Station Wagons	$0.65	$0.51	$0.37	$0.23	$0.08	-$0.06	-$0.20
Pass Van	$0.38	$0.23	$0.07	-$0.08	-$0.24	-$0.39	-$0.55
SUV	$0.66	$0.47	$0.28	$0.09	-$0.10	-$0.29	-$0.48
Std Pickup	$0.94	$0.82	$0.71	$0.59	$0.47	$0.36	$0.24
Small Pickup	$0.47	$0.32	$0.18	$0.04	-$0.11	-$0.25	-$0.39

Strong cost advantage for most BEV size classes in 2020, even with the inconvenience penalty.

FCEV cost minus BEV cost

(3 Day of Inconvenience)

Year: 2020

FCEV minus PEV-X Cost

	50 Miles	100 Miles	150 Miles	200 Miles	250 Miles	300 Miles	350 Miles
Two-Seaters	$0.52	$0.39	$0.26	$0.13	$0.00	-$0.13	-$0.27
Minicompacts	$0.74	$0.63	$0.53	$0.42	$0.32	$0.21	$0.11
Subcompacts	$0.69	$0.58	$0.47	$0.37	$0.26	$0.15	$0.04
Compacts	$0.49	$0.38	$0.27	$0.17	$0.06	-$0.04	-$0.15
Midsize Cars	$0.57	$0.45	$0.32	$0.20	$0.08	-$0.05	-$0.17
Large Cars	$0.53	$0.42	$0.31	$0.20	$0.08	-$0.04	-$0.15
Small Station Wagons	$0.59	$0.49	$0.36	$0.23	$0.08	-$0.06	-$0.20
Pass Van	$0.38	$0.23	$0.07	-$0.08	-$0.24	-$0.39	-$0.55
SUV	$0.65	$0.46	$0.27	$0.09	-$0.10	-$0.29	-$0.48
Std Pickup	$0.93	$0.82	$0.70	$0.59	$0.47	$0.36	$0.24
Small Pickup	$0.47	$0.32	$0.17	$0.04	-$0.11	-$0.25	-$0.39

Year: 2025

FCEV minus PEV-X Cost

	50 Miles	100 Miles	150 Miles	200 Miles	250 Miles	300 Miles	350 Miles
Two-Seaters	$0.24	$0.14	$0.05	-$0.04	-$0.13	-$0.23	-$0.32
Minicompacts	$0.34	$0.27	$0.20	$0.12	$0.05	-$0.03	-$0.10
Subcompacts	$0.31	$0.24	$0.16	$0.10	$0.02	-$0.06	-$0.14
Compacts	$0.22	$0.14	$0.06	$0.00	-$0.08	-$0.16	-$0.24
Midsize Cars	$0.26	$0.17	$0.08	$0.00	-$0.09	-$0.18	-$0.27
Large Cars	$0.24	$0.16	$0.08	$0.00	-$0.08	-$0.17	-$0.26
Small Station Wagons	$0.24	$0.19	$0.09	$0.01	-$0.10	-$0.20	-$0.30
Pass Van	$0.18	$0.06	-$0.05	-$0.16	-$0.27	-$0.38	-$0.49
SUV	$0.30	$0.16	$0.03	-$0.10	-$0.24	-$0.37	-$0.51
Std Pickup	$0.48	$0.40	$0.31	$0.23	$0.15	$0.06	-$0.03
Small Pickup	$0.22	$0.11	$0.00	-$0.09	-$0.20	-$0.30	-$0.40

Year: 2030

FCEV minus PEV-X Cost

	50 Miles	100 Miles	150 Miles	200 Miles	250 Miles	300 Miles	350 Miles
Two-Seaters	$0.07	$0.00	-$0.07	-$0.13	-$0.20	-$0.27	-$0.34
Minicompacts	$0.11	$0.05	$0.00	-$0.06	-$0.11	-$0.17	-$0.22
Subcompacts	$0.09	$0.04	-$0.02	-$0.07	-$0.13	-$0.19	-$0.24
Compacts	$0.06	$0.00	-$0.05	-$0.10	-$0.16	-$0.22	-$0.27
Midsize Cars	$0.07	$0.01	-$0.06	-$0.11	-$0.18	-$0.25	-$0.31
Large Cars	$0.06	$0.01	-$0.05	-$0.11	-$0.17	-$0.23	-$0.30
Small Station Wagons	$0.03	$0.01	-$0.06	-$0.12	-$0.20	-$0.27	-$0.35
Pass Van	$0.06	-$0.02	-$0.10	-$0.18	-$0.26	-$0.35	-$0.43
SUV	$0.07	-$0.03	-$0.13	-$0.22	-$0.31	-$0.41	-$0.51
Std Pickup	$0.19	$0.13	$0.07	$0.01	-$0.05	-$0.11	-$0.18
Small Pickup	$0.07	-$0.01	-$0.09	-$0.15	-$0.23	-$0.30	-$0.38

Year: 2035

FCEV minus PEV-X Cost

	50 Miles	100 Miles	150 Miles	200 Miles	250 Miles	300 Miles	350 Miles
Two-Seaters	$0.05	$0.01	-$0.04	-$0.07	-$0.11	-$0.16	-$0.20
Minicompacts	$0.06	$0.02	-$0.02	-$0.07	-$0.11	-$0.15	-$0.19
Subcompacts	$0.05	$0.01	-$0.03	-$0.07	-$0.11	-$0.15	-$0.19
Compacts	$0.04	$0.00	-$0.04	-$0.06	-$0.10	-$0.14	-$0.18
Midsize Cars	$0.04	$0.01	-$0.04	-$0.07	-$0.11	-$0.16	-$0.20
Large Cars	$0.04	$0.00	-$0.03	-$0.07	-$0.11	-$0.15	-$0.19
Small Station Wagons	$0.00	$0.00	-$0.04	-$0.07	-$0.13	-$0.17	-$0.22
Pass Van	$0.06	$0.01	-$0.03	-$0.08	-$0.12	-$0.16	-$0.21
SUV	$0.03	-$0.02	-$0.07	-$0.12	-$0.17	-$0.22	-$0.28
Std Pickup	$0.15	$0.12	$0.09	$0.06	$0.03	$0.00	-$0.03
Small Pickup	$0.06	$0.01	-$0.04	-$0.07	-$0.12	-$0.16	-$0.21

Year: 2040

FCEV minus PEV-X Cost

	50 Miles	100 Miles	150 Miles	200 Miles	250 Miles	300 Miles	350 Miles
Two-Seaters	$0.04	$0.00	-$0.04	-$0.07	-$0.11	-$0.15	-$0.19
Minicompacts	$0.05	$0.02	-$0.01	-$0.04	-$0.07	-$0.10	-$0.13
Subcompacts	$0.04	$0.01	-$0.02	-$0.04	-$0.08	-$0.11	-$0.14
Compacts	$0.03	$0.00	-$0.03	-$0.06	-$0.09	-$0.12	-$0.15
Midsize Cars	$0.03	$0.00	-$0.04	-$0.06	-$0.10	-$0.13	-$0.17
Large Cars	$0.03	$0.00	-$0.03	-$0.06	-$0.09	-$0.12	-$0.16
Small Station Wagons	-$0.01	$0.00	-$0.04	-$0.06	-$0.11	-$0.15	-$0.19
Pass Van	$0.03	-$0.01	-$0.06	-$0.11	-$0.15	-$0.20	-$0.24
SUV	$0.02	-$0.03	-$0.09	-$0.14	-$0.19	-$0.25	-$0.30
Std Pickup	$0.14	$0.10	$0.07	$0.04	$0.01	-$0.03	-$0.06
Small Pickup	$0.06	$0.01	-$0.03	-$0.07	-$0.11	-$0.15	-$0.19

FCEV cost minus BEV cost

(3 Day of Inconvenience)

Year: 2040

FCEV minus BEV-X Cost

	50 Miles	100 Miles	150 Miles	200 Miles	250 Miles	300 Miles	350 Miles
Two-Seaters	$0.05	$0.01	-$0.03	-$0.07	-$0.11	-$0.15	-$0.19
Minicompacts	$0.05	$0.02	-$0.01	-$0.04	-$0.07	-$0.10	-$0.13
Subcompacts	$0.05	$0.02	-$0.01	-$0.04	-$0.07	-$0.11	-$0.14
Compacts	$0.04	$0.01	-$0.02	-$0.05	-$0.09	-$0.12	-$0.15
Midsize Cars	$0.05	$0.01	-$0.03	-$0.06	-$0.10	-$0.13	-$0.17
Large Cars	$0.04	$0.01	-$0.02	-$0.06	-$0.09	-$0.12	-$0.16
Small Station Wagons	$0.05	$0.01	-$0.03	-$0.07	-$0.11	-$0.15	-$0.19
Pass Van	$0.03	-$0.01	-$0.06	-$0.11	-$0.15	-$0.20	-$0.24
SUV	$0.03	-$0.02	-$0.08	-$0.14	-$0.19	-$0.25	-$0.30
Std Pickup	$0.14	$0.11	$0.07	$0.04	$0.01	-$0.03	-$0.06
Small Pickup	$0.06	$0.02	-$0.02	-$0.07	-$0.11	-$0.15	-$0.19

By 2040, costs shift in favor of FCEVs in most segments. Costs are very favorable in larger size classes and higher range.

Final Results – 3 Days of Inconvenience

2040 Market Size

	0-50 Miles	50-100 Miles	100-150 Miles	150-200 Miles	200-250 Miles	250-300 Miles	300+ Miles	Row Total
Two-Seaters	0.1%	0.2%	0.2%	0.2%	0.1%	0.0%	0.0%	0.7%
Minicompacts	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Subcompacts	0.5%	1.4%	1.3%	0.9%	0.6%	0.2%	0.4%	5.2%
Compacts	1.5%	4.9%	4.5%	3.1%	1.8%	1.1%	1.4%	18.5%
Midsize Cars	1.6%	4.8%	5.0%	3.5%	1.5%	1.0%	1.3%	18.7%
Large Cars	0.8%	2.3%	2.3%	1.6%	1.0%	0.5%	0.8%	9.1%
Small Station Wagons	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Pass Van	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SUV	2.5%	8.2%	9.1%	6.4%	3.7%	2.0%	2.7%	34.5%
Std Pickup	0.8%	3.2%	3.4%	2.1%	1.2%	0.7%	1.1%	12.4%
Small Pickup	0.0%	0.2%	0.1%	0.1%	0.1%	0.0%	0.0%	0.5%
Column Total	7.8%	25.1%	26.0%	17.9%	10.0%	5.5%	7.7%	**100%**

FCEV Favorable

BEV Favorable

82 Percent of LDV market is favorable for FCEVs
Compacts, Midsize and SUVs account for most of the shift

Takeaways

- In 2020, BEV costs are lower than FCEV costs in about 80-100 percent of segments.
- BEV cost advantage strongest in smaller vehicle classes.
- FCEV cost advantage strongest in high mileage segments.
- By 2040, FCEV costs are lower in 75-90 percent of segments.
- Cross over point for many segments happens around 2030 when about 1 million cumulative FCEVs are sold, or when FCEVs are about 1 percent of vehicle stock.
- Need further research in understanding the inconvenience created by lack of BEV and FCEV infrastructure.

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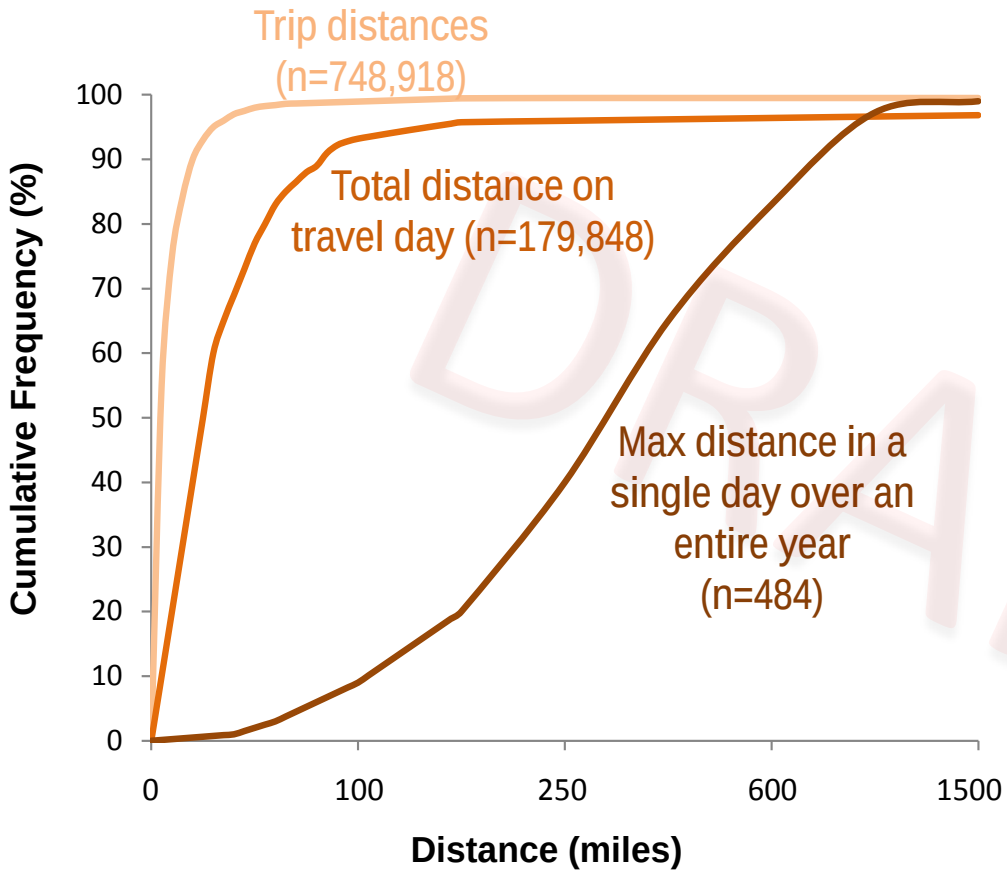
EXTRA SLIDES

Driver range needs



Three ways to consider range needs:

(1) **Trip distance** – how far do we travel for each car trip?

(2) **Total daily distance** – how far we travel each day on average (used in this study)

(3) **Max distance in a single day over an entire year** – the farthest daily driving in an entire year of driving

- *BEV-100 satisfies ~98% of trips, 93% of daily travel, and 9% of max distance in year*
- *Implication: if consumers purchase vehicles based on trip length or daily driving, then short range BEVs will satisfy most of the market. However, if consumers purchase vehicles based on MAX range, then BEV-200+ or FCEV will be needed*

Methodology of Market Segmentation

Market Share by Segment

Max Driver Range

	<50	51-100	101-150	151-200	201-250	251-300	>300	Total
Two-Seaters	0.1%	0.2%	0.2%	0.2%	0.0%	0.0%	0.0%	**1%**
Minicompacts	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	**0%**
Subcompacts	0.5%	1.4%	1.4%	0.8%	0.5%	0.2%	0.3%	**5%**
Compacts	1.6%	5.2%	4.6%	3.2%	1.8%	0.9%	1.2%	**19%**
Midsize Cars	1.8%	5.1%	5.1%	3.4%	1.5%	0.8%	1.2%	**19%**
Large Cars	0.9%	2.4%	2.4%	1.5%	0.8%	0.5%	0.6%	**9%**
Small Station Wagons	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	**0%**
Mid Wagons	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	**0%**
Pass Van	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	**0%**
Cargo Van	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	**0%**
SUV	2.6%	8.7%	9.6%	6.1%	3.6%	1.8%	2.3%	**35%**
Std Pickup	0.8%	3.5%	3.5%	1.9%	1.2%	0.6%	1.0%	**13%**
Small Pickup	0.0%	0.2%	0.1%	0.1%	0.1%	0.0%	0.0%	**1%**
Total	**8%**	**27%**	**27%**	**17%**	**10%**	**5%**	**7%**	**100%**

- Largest segments are SUVs, compacts, and midsize sedans
- 65% of vehicles have range needs over 100 miles

Methodology of Market Segmentation

- Steps:
  1. Break up U.S. LDV market into 77 segments defined by vehicle size class and range requirements
  2. Range = maximum distance drivers travel in all but 4 days per year
  3. Determine segments in which FCEVs have cost advantage over a PEV-X
  4. Account for 30% range degradation of PEV (e.g., PEV-100 travels 70 miles)

Market Share by Segment

Max Driver Range

	<50	51-100	101-150	151-200	201-250	251-300	>300	Total
Two-Seaters	0.1%	0.2%	0.2%	0.2%	0.0%	0.0%	0.0%	1%
Minicompacts	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0%
Subcompacts	0.5%	1.4%	1.4%	0.8%	0.5%	0.2%	0.3%	5%
Compacts	1.6%	5.2%	4.6%	3.2%	1.8%	0.9%	1.2%	19%
Midsize Cars	1.8%	5.1%	5.1%	3.4%	1.5%	0.8%	1.2%	19%
Large Cars	0.9%	2.4%	2.4%	1.5%	0.8%	0.5%	0.6%	9%
Small Station Wagons	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0%
Mid Wagons	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0%
Pass Van	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0%
Cargo Van	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0%
SUV	2.6%	8.7%	9.6%	6.1%	3.6%	1.8%	2.3%	35%
Std Pickup	0.8%	3.5%	3.5%	1.9%	1.2%	0.6%	1.0%	13%
Small Pickup	0.0%	0.2%	0.1%	0.1%	0.1%	0.0%	0.0%	1%
Total	8%	27%	27%	17%	10%	5%	7%	100%

How Numbers are Estimated

- **Survey name**: 2009 NHTS
- **Number of Observations:** ~300K (with survey weights, entire U.S. LDV fleet is captured); this study uses 24K observations
- **Method for converting from daily distance of travel to maximum annual travel:** Gamma distribution as outlined in Lin et al. (2014)

Filtering criteria:

- Respondent recorded a positive distance to work
- Age of vehicle is 5 years old or younger
- Vehicle is a LDV and is not a commercial vehicle
- Driver is a worker and main mode of travel to work is driving

Gamma distribution:

- $\sqrt{(M'_n\,(M'_n - M_d))} = 5$
- $P(x; k, \theta, \rho) = \rho + (1-\rho) * \frac{\gamma(k, \frac{x}{\theta})}{\gamma(k)}$

- Largest segments are SUVs, compacts, and midsize sedans
- 65% of vehicles have range needs over 100 miles