U.S. VEHICLE ELECTRIFICATION INFRASTRUCTURE ASSESSMENT

Medium- and Heavy-Duty Truck Charging

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ATLAS PUBLIC POLICY

ABOUT
ATLAS PUBLIC POLICY

DC-based policy tech firm started in 2015

We equip businesses and policymakers to make strategic, informed decisions that serve the public interest

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- **Access:** Collect and disseminate publicly available information.
- **Interpret:** Create dashboards and tools to spur insights and conduct data-driven analyses.
- **Empower:** Strengthen the ability of policymakers, businesses, and non-profits to meet emerging challenges and identify opportunities that serve the public interest.

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OVERVIEW

- High-level MD & HD truck results
- Methodology overview
- Results deep-dive
- Key policy takeaways
- Methodology appendix

Note all dollar values included here are in 2020 dollars, not nominal dollars.

WHY ELECTRIFY TRUCKS?

Climate: ~30% of ground transportation GHG emissions come from medium- & heavy-duty trucks

Health: High air pollutant emissions, linked to asthma, cancer, cardiovascular disease, premature death

- Disproportionately affects low-income communities and communities of color located near freight corridors, ports, depots
- Heavy-duty tractor-trailers are particularly high polluters: 13% of on-road MDHD trucks but ~60% of their GHGs & fuel use

Noise: Reduced noise pollution can benefit drivers, workers and nearby communities

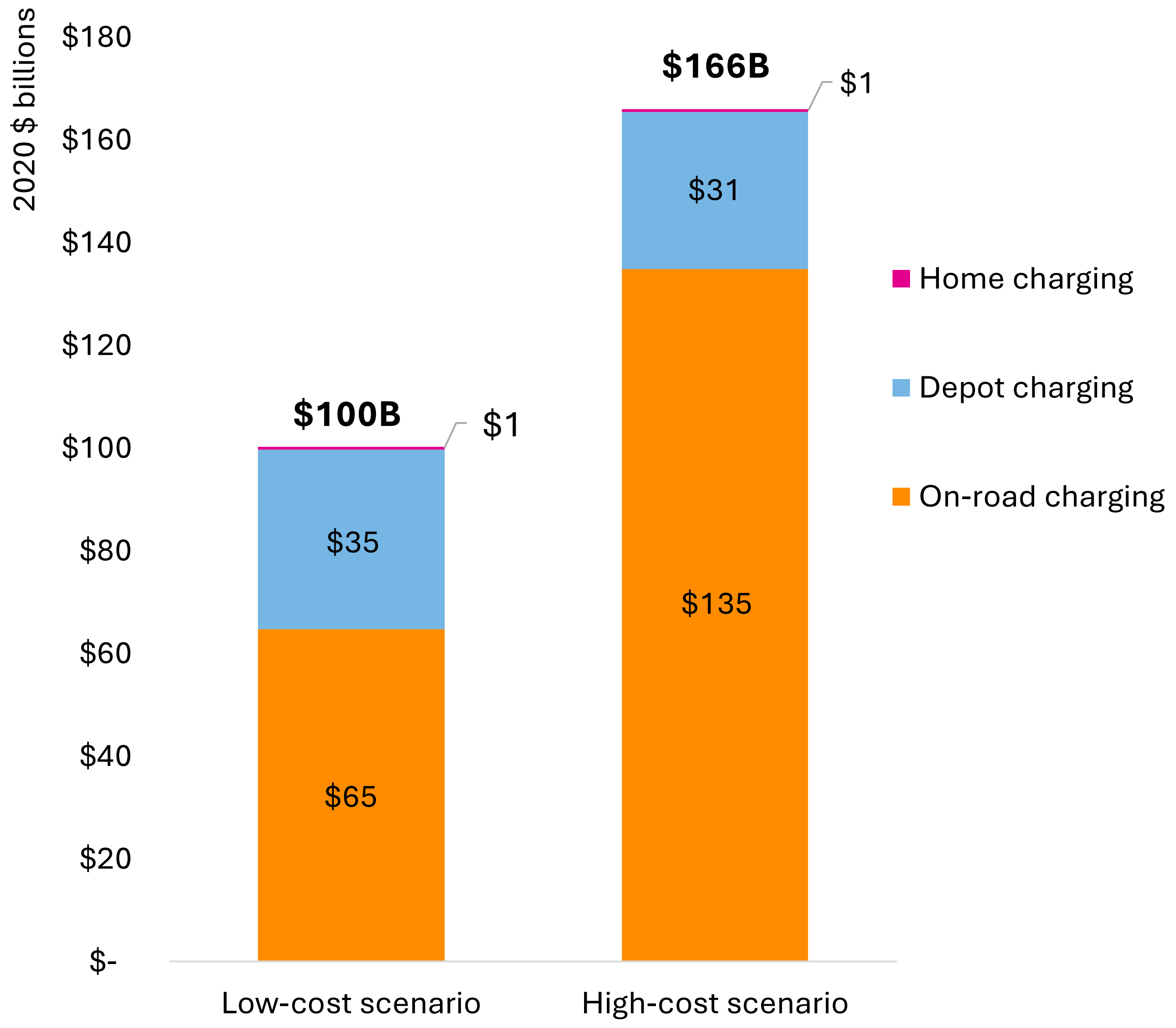
Financial benefits: Studies predict that a number of depot-charging electric truck applications will be cost-competitive with diesel in the near future

STUDY OBJECTIVE

High-level assessment of charging infrastructure and associated investment commitments needed to support full electrification of medium- and heavy-duty trucks

Our analysis includes class 3 – 8 trucks using conductive charging, and does not estimate the *benefits* of electrification

$100B - $166B in charging infrastructure investment commitments are needed this decade to put the U.S. on the path to 100% electric truck sales by 2040



METHODOLOGY OVERVIEW

MODELING APPROACH

1. Calculate **daily energy need** for 37 truck use cases & classes
2. Develop **vehicle-to-charger ratios** for each use case-class-charging location combination, based on energy need & utilization assumptions
3. Model **EV adoption** for each use case-class, by state, using stock rollover
4. Calculate **charging ports needed** in each year, by state
5. Calculate **needed investment commitments** in each year, accounting for project development & utility connection timelines

WE MODEL 37 TRUCK USE CASE-CLASS COMBOS

Truck Charging Location Matrix *(by use case & class)*

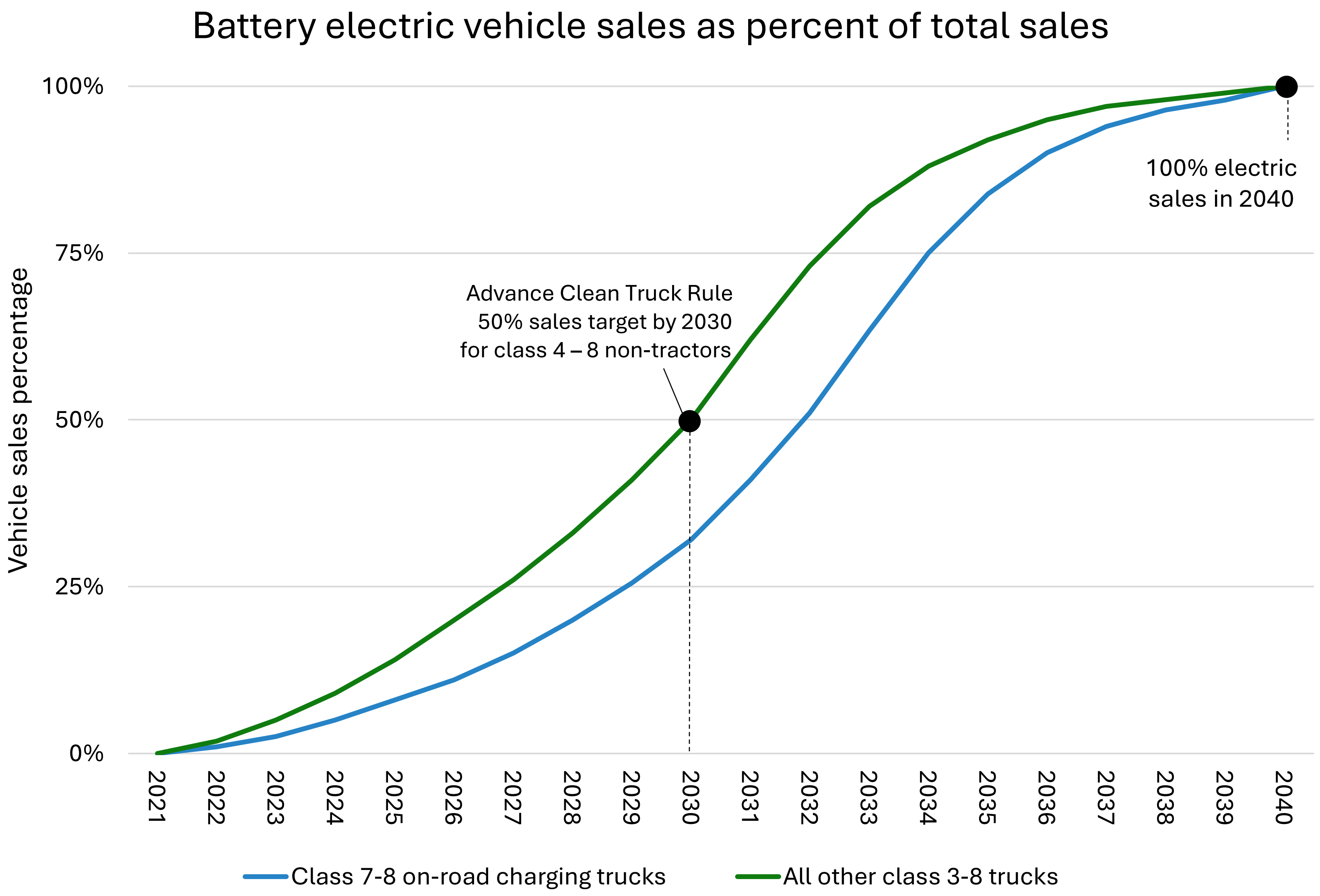
Use Case	Truck Class					
	3	4	5	6	7	8
Construction Truck	Depot, Home	Depot, On-road	Depot, On-road	Depot, On-road	Depot, On-road	Depot, On-road
Regional Truck	Depot, On-road	Depot, On-road	Depot, On-road	Depot, On-road	Depot, On-road	Depot, On-road
Pickup	Depot, Home	Depot, On-road				
Drayage						Depot, On-road
Step Van	Depot, Home	Depot, On-road	Depot, On-road	Depot, On-road	Depot, On-road	
Cargo Van	Depot, Home	Depot, On-road	Depot, On-road			
SUV	Depot, Home					
Terminal Tractor					Depot	Depot
Refuse				Depot	Depot	Depot
Motor Home	On-road	On-road	On-road	On-road	On-road	On-road
Long Haul Truck					On-road	On-road

- Use cases are taken from the West Coast Clean Transit Corridor Initiative ('WCCTCI') report
- Analysis assumes that electric truck technologies continue to improve, enabling an expansion to all truck use cases
- Analysis of construction trucks does not include off-road equipment
- We model all use case-class combinations that exist in IHS' 2019 vehicle stock data, excl. emergency vehicles

AFTER ASSESSING ENERGY NEED, WE ASSIGN EACH VEHICLE TYPE TO 1 OF 10 VEHICLE-CHARGING CATEGORIES

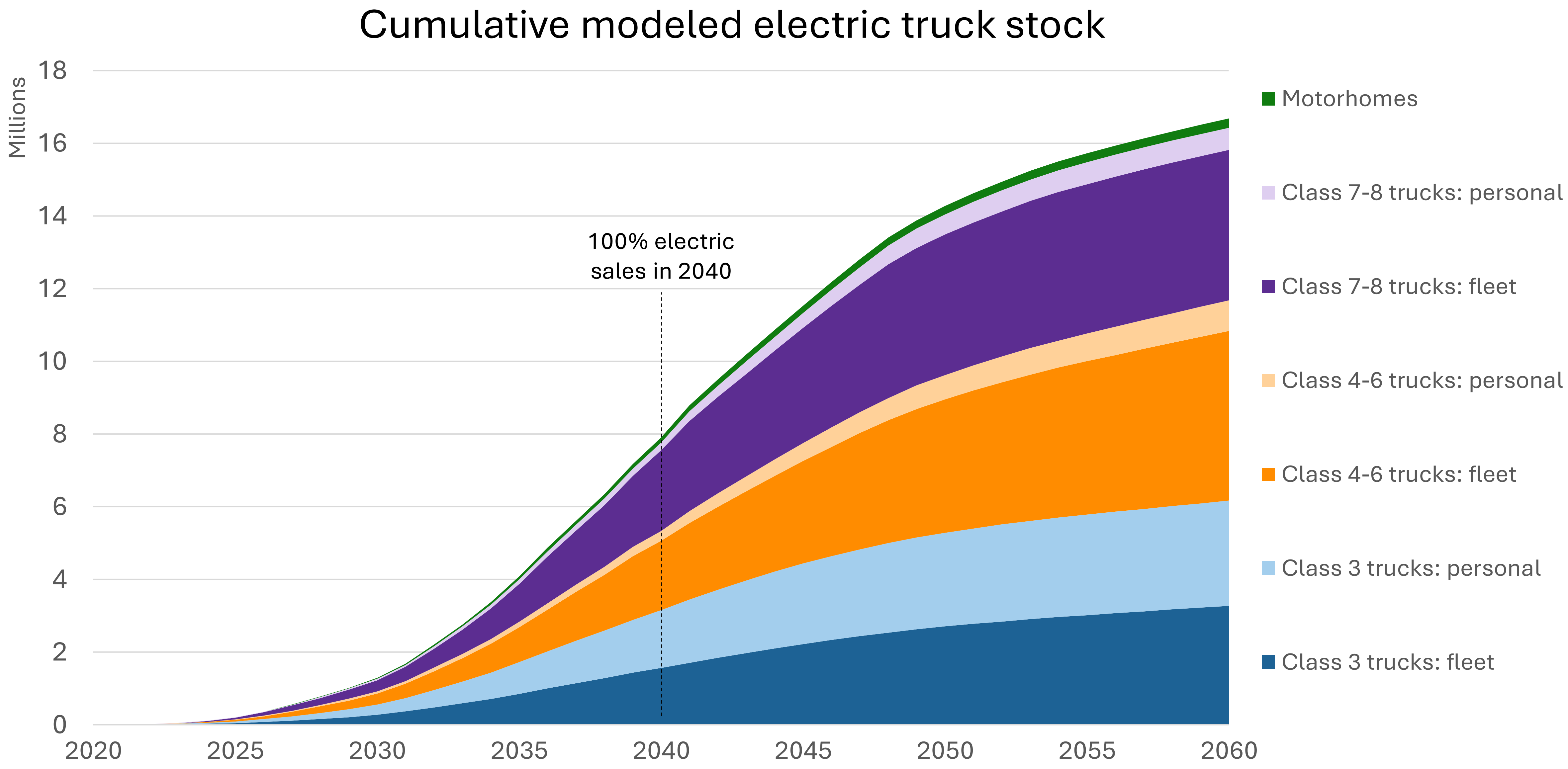
Vehicle Category		Modeled Charging Type
Class 3 trucks		Home Level 2 (11.5kW) Depot Level 2 (10kW)
Class 4 – 6 trucks		Depot Level 2: 10kW & 16.6kW (based on need) Depot 50kW On-road 150kW or 350kW
Class 7 – 8 trucks, excl. long-haul		Depot 50kW Depot 150kW On-road 350kW
Long-haul trucks		On-road 350kW truck parking or 2MW
Motorhomes		On-road 350kW

WE MODEL 100% EV SALES BY END OF 2040



- In line with CA's Proposed Advanced Clean Fleets Regulation, Action Plan from the U.S. House Select Committee on the Climate Crisis, Global Commercial Vehicle Drive to Zero, national Drive Electric Campaign, & goals from Walmart, FedEx
  - Electric sales % could differ if hydrogen vehicles are significantly adopted
- We assume Class 7-8 on-road charging trucks are adopted at a slower initial rate than class 3-6 trucks and class 7-8 trucks that can charge at a depot

→ 17M ELECTRIC TRUCKS BY 2060



WE INCLUDE HARDWARE, LABOR, PROJECT COSTS, & ELECTRICAL UPGRADES NOT COVERED BY UTILITIES

Included in analysis:

- Design
- Charger hardware
- Labor
- Electrical upgrades not expected to be covered by utilities
- Permitting
- Other site construction costs
- Project management

Electrical upgrades included:

- Make-ready (conduit, panel, switchgear)
- DCFC also includes front-of-meter customer transformers, conductor, utility poles (50% - 100% depending on scenario)
- Long-haul truck charging includes utility-side upgrades, incl. substation upgrades or new customer substations

WE DEFINE LOW- AND HIGH-COST SCENARIOS

In both scenarios:

Location

- Personally-owned class 4 – 8 trucks & all long-haul trucks use on-road charging

Costs

- No utility upgrade costs included for Level 2
- 100% utility upgrade costs included for long-haul truck charging

Utilization

- 80% utilization of depot chargers during 9 overnight hours

In low-cost scenario:

Location

- Class 3 personal & class 3 – 8 fleet vehicles (excl. long-haul) charge 90% at depot/home, 10% on road

Costs

- Front-of-meter costs paid 50% by site host for DCFC depot charging
- Smaller truck parking installations

Utilization

- 40% utilization of on-road charging
- 70% utilization of long-haul truck parking chargers

In high-cost scenario:

Location

- Class 3 personal & class 3 – 8 fleet vehicles (excl. long-haul) charge 75% at depot/home, 25% on road

Costs

- Front-of-meter costs paid 100% by site host for DCFC depot charging
- Larger truck parking installations

Utilization

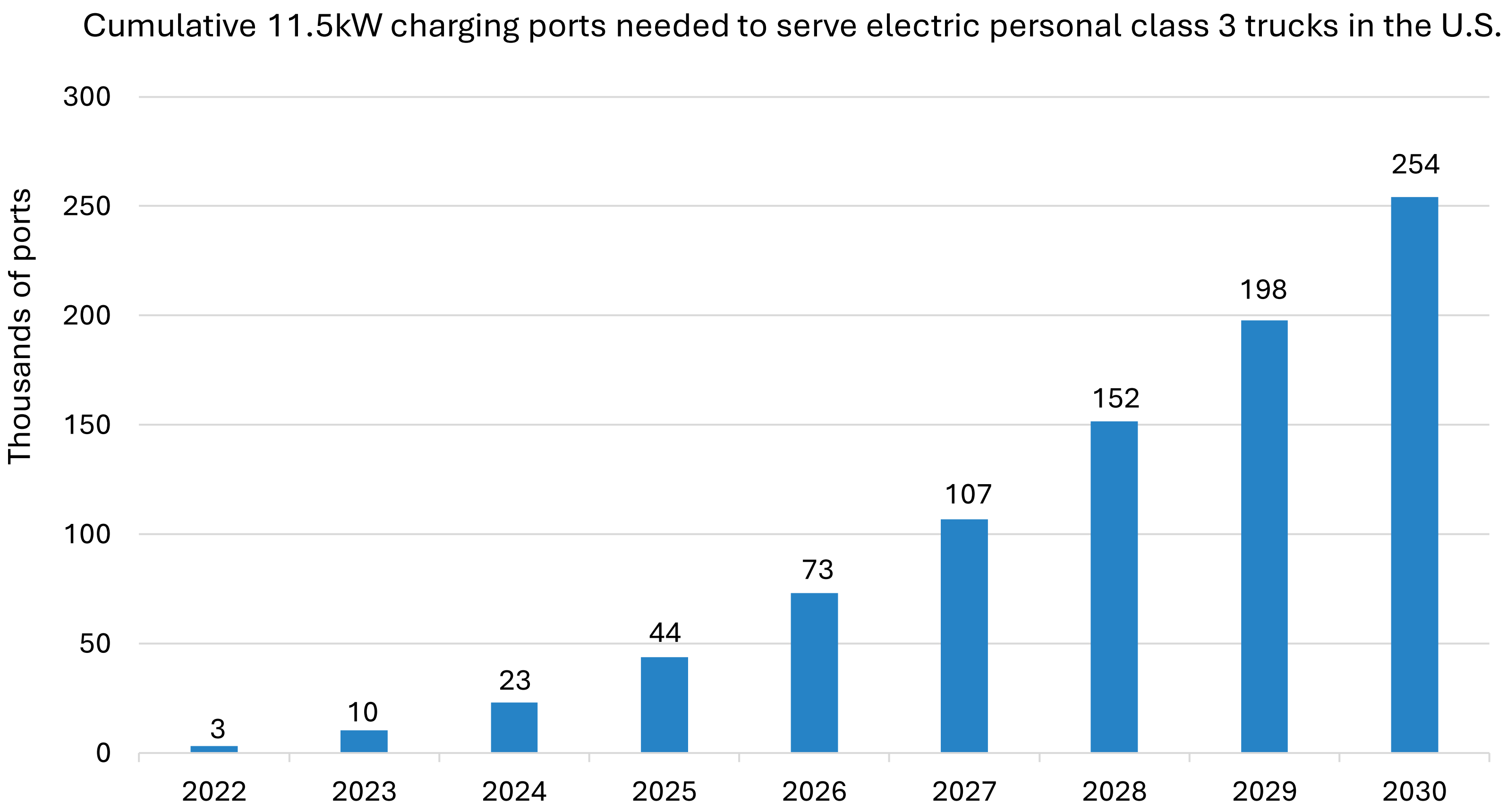
- 20% utilization of on-road charging
- 40% utilization of long-haul truck parking chargers

Biggest differences between low- and high-cost scenario results are due to

- For depot charging: differences in assumed charging location of fleet vehicles
- For on-road charging: differences in assumed utilization

RESULTS DEEP DIVE: HOME CHARGING

$600M NEEDED BY 2030 FOR HOME CHARGING OF ~250K CLASS 3 ELECTRIC TRUCKS



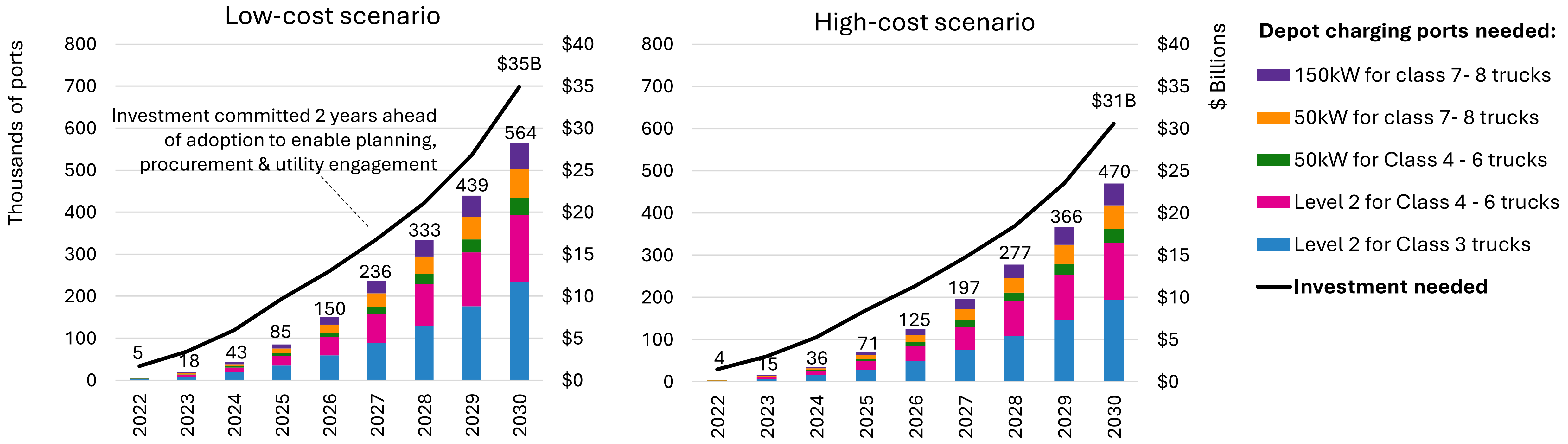
	% of personal class 3 trucks
Pickup	94%
On-road construction truck	4%
Cargo van	1%
Box truck	1%
Step van	<1%

Source: Atlas analysis of 2019 IHS Markit Vehicle Stock data

RESULTS DEEP DIVE: DEPOT CHARGING

MOST CHARGING PORTS ARE NEEDED AT DEPOTS: ~500K PORTS @ $31B – $35B

Cumulative ports & committed investment needed to support electrification of depot-charging trucks:



90% of fleet vehicle charging is at depots; 10% on-road

75% of fleet vehicle charging is at depots; 25% on-road

Low-cost scenario assumes more depot charging, leading to less total investment needed

RESULTS DEEP DIVE: ON-ROAD CHARGING

LONG-HAUL TRUCKS:
ENABLING GEOGRAPHIC COVERAGE OF THE U.S

An illustration of what geographic coverage could look like...

Following the West Coast Clean Transit Corridor Initiative approach:

- Installing 10 x 2MW ports every 100 miles of the Primary Highway Freight System would take 4,151 ports
- Expanding to the full National Highway Freight Network = 5,785 ports

Using WCCTCI costs, doing so would require investment of $7.4 - $10.4B

- This network would not need to be developed at once: it will be most cost-effective to first build out high-trafficked, complete routes that can serve early adoption

Development & timing of electric long-haul trucks & 2MW stations depends on charger/vehicle technology development

LONG-HAUL TRUCKS:
MEETING ENERGY DEMAND

- Long-haul trucks drive an average of 545 miles day (WCCTI report)
- We modeled energy demand for these miles as eventually being met via:

350kW charging

At truck parking spaces during drivers' mandated 10-hour break

Class 8 truck with 2040 efficiency takes 7.4 hrs to charge 545 miles

Assume vehicles charge to full 100%; final 20% takes as long as first 80%

OR

2MW charging

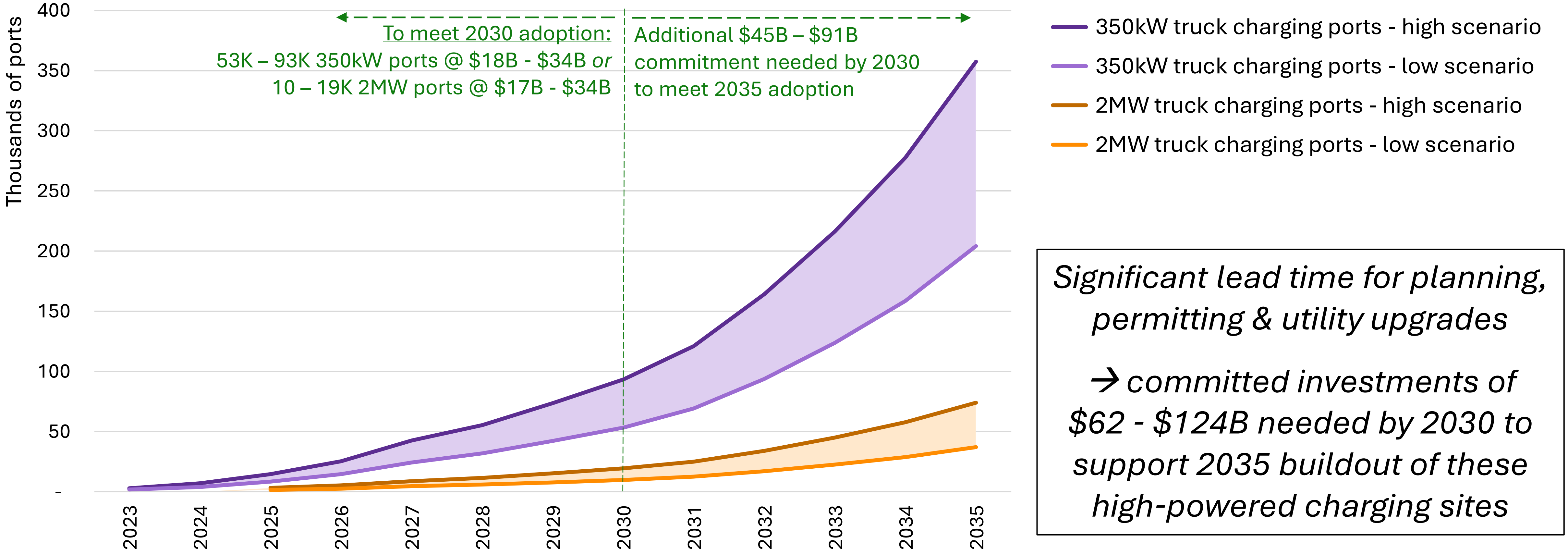
Class 8 truck with 2040 assumed efficiency takes ~50 mins to charge to 545 miles

(Assuming vehicles make multiple daily stops or size battery to fit this mileage within 80% state of charge & avoid last 20% slowdown)

In reality, long-haul trucks will likely be charged by a combination of these or other charging levels; modeling these levels provides bookends

$62B - $124B IN INVESTMENT COMMITMENTS NEEDED BY 2030 TO SUPPORT RAMP IN LONG-HAUL TRUCK CHARGING TO 2035

Cumulative charging ports needed to support electrification of long-haul trucking



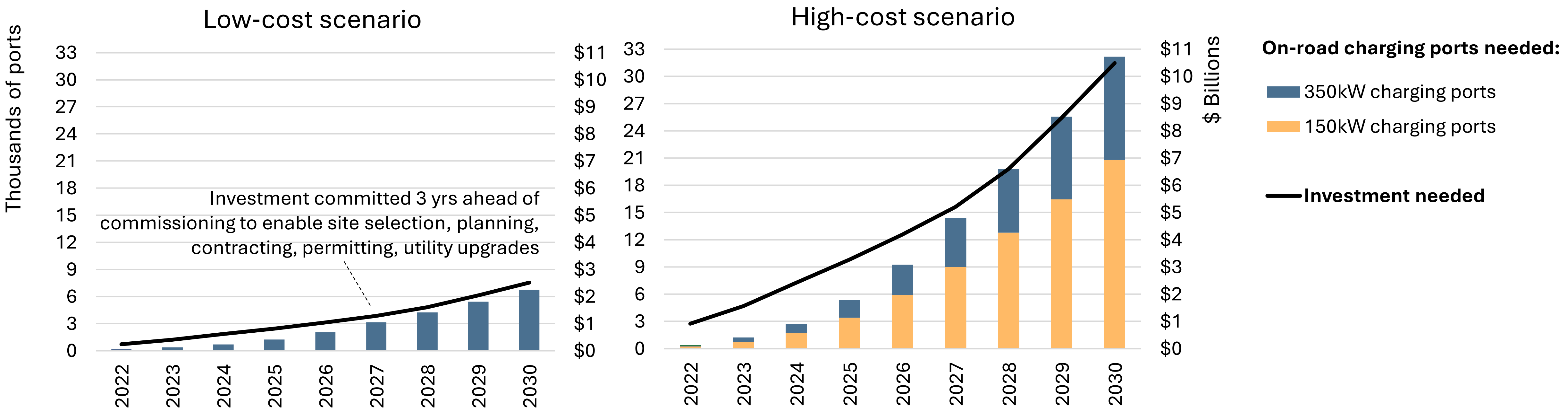
Significant lead time for planning, permitting & utility upgrades

→ committed investments of $62 - $124B needed by 2030 to support 2035 buildout of these high-powered charging sites

Development & timing of long-haul electrification & 2MW stations depends on charger/vehicle technology development.
Charging port & investment ranges due to variation in assumed utilization.

$3B - $10B IN INVESTMENT COMMITMENTS NEEDED BY 2030 FOR ON-ROAD CHARGING OF OTHER TRUCKS

Cumulative ports & investment needed to support on-road charging of electric trucks, excluding long-haul trucks



Both scenarios: All personally-owned class 4 – 8 vehicles charge on-road; Motorhomes & on-road charging class 7-8 trucks use 350kW

<u>Low-cost scenario:</u>

- 10% of fleet vehicle charging is on-road (90% at depots)
- On-road charging class 3 – 6 trucks use 350kW ports
- 40% utilization of chargers

<u>High-cost scenario:</u>

- 25% fleet vehicle charging on-road (75% at depots)
- On-road charging class 3 – 6 trucks use 150kW ports
- 20% utilization of chargers

KEY POLICY TAKEAWAYS

KEY POLICY TAKEAWAYS

1

Reaching 100% electric sales by 2040 requires rapid ramp-up of charging for all vehicle segments

2

Increasing utilization of charging can significantly reduce needed investments

At depots, by using chargers/software that enable sequenced/simultaneous charging, or by moving vehicles

At on-road chargers, by first targeting charging to high-traffic routes, building chargers that can serve multiple vehicle types, & using technology to allow drivers to reserve chargers

3

Policies & incentives that encourage right-sizing of depot equipment can reduce needed investments

KEY POLICY TAKEAWAYS

4

Long-haul trucks will be able to replenish daily energy needs by charging at 350kW chargers during their mandated rest break

But preventing congestion & creating flexibility will require a mix of 350kW parking spaces and ultra-high-powered (1 – 2MW) stations

5

Investment commitments are needed by 2030 to support ramp in electric long-haul trucks through 2035, due to long project & utility lead times needed to build high-powered sites

Pre-planning today and streamlining development timelines where possible can lower needed investments

6

As adoption ramps, ultra-high-powered charging could be similarly cost effective for long-haul truck charging at some sites as electrifying truck parking spaces with 350kW chargers (depends on substation capacity, utilization & install sizes)

Our analysis assumes long-haul charging is installed to most efficiently use substation investments, & under our assumed utilization levels found similar investments needed to support long haul trucks using either kind of charging

METHODOLOGY APPENDIX

INSITE: INVESTMENT NEEDS OF STATE INFRASTRUCTURE FOR TRANSPORTATION ELECTRIFICATION TOOL

Charging investment need = **EV adoption** x **Ports needed per vehicle** x **Cost per port**

Charging investment need

by state, charging type, year

EV adoption

by vehicle type, state, year

Ports needed per vehicle

by charging type, state

Investment in charging is assumed to be needed ***ahead*** *of adoption*

Cost per port

by charging type, state, year

Scale labor costs by state differences;

User can choose to reduce input costs over time

ELECTRIC TRUCK ADOPTION

EV adoption

- We simulate adoption using a simplified stock-flow model that iteratively simulates year-over-year new truck stock due to retirement/replacement and overall stock growth
  - Starting truck stock is derived from 2019 IHS registered truck inventory
    - Class 7 and 8 freight trucks were split into regional and long haul categories using % of vehicles in each of the two categories in CA/WA/OR in the WCCTCI study
  - Stock growth is based on state population projections (for personal Class 3 trucks and motorhomes) or EIA projections of freight growth (for all other vehicles types)
  - Truck scrappage rates are based on NHTSA research of vehicle survivability
  - We assume that trucks are used for substantial revenue service for a maximum of 20 years based on similar assumptions taken by models like the California Air Resources Board's EMFAC mobile source emissions model.

- We then overlay electric truck adoption curves (slide 11) on new truck stock to estimate cumulative EV truck population over time

CHARGING PORTS PER VEHICLE

Ports needed per vehicle

We use:

1. calculated energy demand, and
2. utilization assumptions

to create estimates of charging ports needed per vehicle for all 61 truck use cases

We then collapse these to ratios for each of our our 10 vehicle-charging categories, using the number of vehicles in each of the 61 truck use cases in each state as weights.

CHARGING PORTS PER VEHICLE: 1. WE ESTIMATE AVERAGE DAILY ENERGY NEED FOR EACH USE CASE

(= DAILY VEHICLE MILES * KWH/MILES)

Ports needed per vehicle

Table B-3: US Average Daily VMT per Segment

US Average Annual VMT per Segement						
Segment	Class					
	3	4	5	6	7	8
Construction Truck	48	34	48	38	38	38
Regional Truck	29	48	74	74	74	208
Motor Home	32	64	112	112	112	112
Pickup	77					
Long Haul Truck					545	545
Drayage					32	32
Bus		40	48	112	96	
Step Van	53	53	53	53		
Refuse				75	75	75
School Bus				48	48	48
VAN CARGO	87					
City Bus				112	112	112
Shuttle Bus	48	48	96	112		
Coach						112
Fire Truck						21
SUV	42					
Terminal Tractor						112
Emergency Truck			243	243		

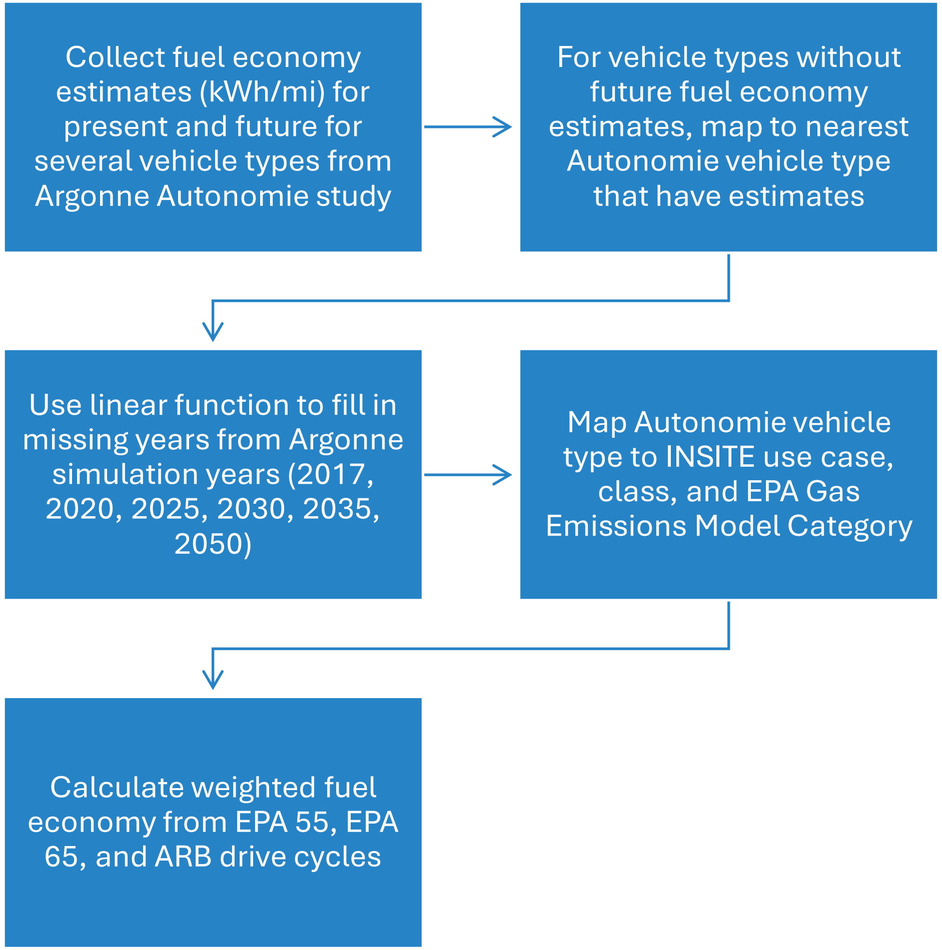
Source: Analysis by HDR, CALSTART, S Curve Strategies, Ross Strategic in West Coast Clean Transit Corridor Initiative (WCCTCI) Report, June 2020

- For motor homes, we instead used 137 miles / day: average distance traveled to camping destination from 2017 Outdoor Foundation American Camper Report
- We were not able to account for state differences in vehicle miles traveled
- Further data and analysis on the *distribution* of trip lengths around these averages could allow for additional precision in the future

CHARGING PORTS PER VEHICLE:
1. WE ESTIMATE AVERAGE DAILY ENERGY NEED FOR EACH USE CASE
(= DAILY VEHICLE MILES * KWH/MILE)

Ports needed per vehicle

Process to estimate fuel economy by INSITE vehicle type



- For on-road charging, we assume 2040 kWh/mile
- For 2030 cost estimates of depot-charging vehicles, we assume kWh/mile in 2030
- We were not able to account for differences in temperature across states
- We assume 10% energy losses for depot charging and on-road charging up to 350kW; 5% losses for 2MW charging

CHARGING PORTS PER VEHICLE: 2. UTILIZATION -- DEPOT CHARGING

Ports needed per vehicle

- We assume depot-charging trucks have 9 hours available to charge overnight (9pm – 6am)
  - Matches assumption used by the California Air Resources Board in Advanced Clean Truck Rule documentation
- Vehicles in depot-charging use cases are assigned to charger power levels (10kW, 16.6kW, 50kW, 150kW) that most efficiently cover their daily energy need
- In the low-cost case, vehicles efficiently share charging ports within the 9pm – 6am charging window
- In the high-cost case, one charging port is installed per vehicle

CHARGING PORTS PER VEHICLE: 2. UTILIZATION -- 350KW TRUCK PARKING

Ports needed per vehicle

We use available data from TX & FL to anchor assumptions:

1) Statewide utilization of TX truck parking spaces = 18%

- However, many sites in TX never fill beyond 30% or 50%
- We assume these sites are unlikely to fully electrify

Therefore, **we model utilization of 40–70% for parking spaces where charging is installed**

- Utilization at highest-utilization public TX rest area: 48%
- Average utilization at lowest-utilization public truck parking district in FL: ~40%
- Average utilization at highest-utilization private truck parking district in FL: > 80%

2) Average utilization in FL ranges from ~40–90% across all hours

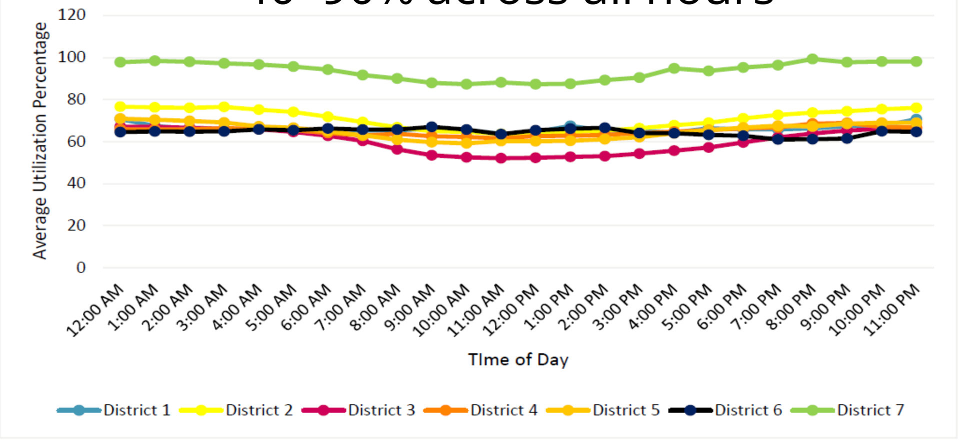


Figure ES 3 | Average Hourly Utilization of Private Truck Parking Locations in the State

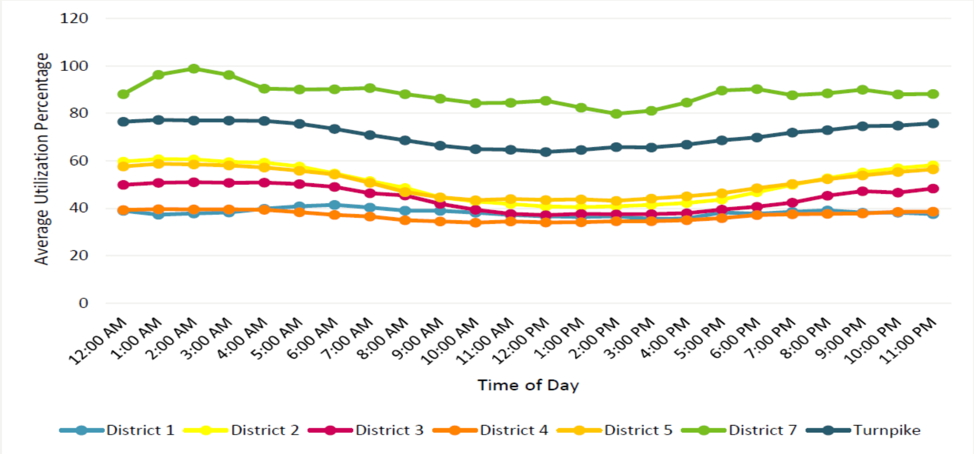


Figure ES 2 | Average Hourly Utilization of Public Truck Parking Locations in the State

Sources: Texas DOT, Feb 2020, "Truck Parking Inventory and Utilization Memo"
Florida DOT, April 2019, "Statewide Truck GPS Data Analysis"

CHARGING PORTS PER VEHICLE:
2. UTILIZATION -- ON-ROAD CHARGING

Ports needed per vehicle

E.g. for 2MW charging of long-haul vehicles:

Class 8 truck w 2040 efficiency takes 46 mins to charge 545 miles
(assuming driver stops multiple times or oversizes battery to meet these miles in first 80% state of charge)

+

Add 10 mins to each session for maneuvering, connect/disconnect, driver being away from vehicle

→

High-cost case:

20% utilization = 5 vehicles per EVSE per day

Low-cost case:

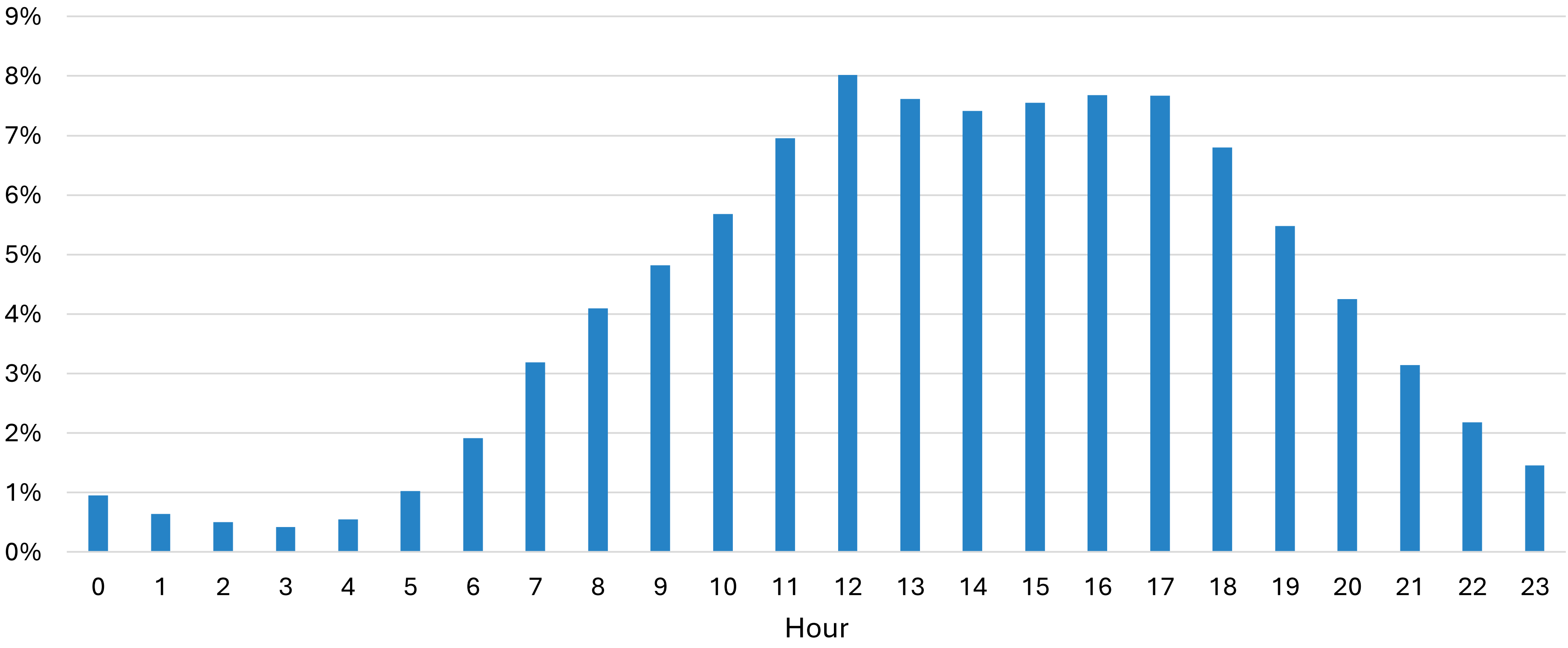
40% utilization = 10 vehicles per EVSE per day,

May require economic incentives for drivers to charge late at night

CHARGING PORTS PER VEHICLE: 2. UTILIZATION -- MOTORHOMES

Ports needed per vehicle

% of foot traffic in each hour at sample of > 100 US gas stations, Q1 2019



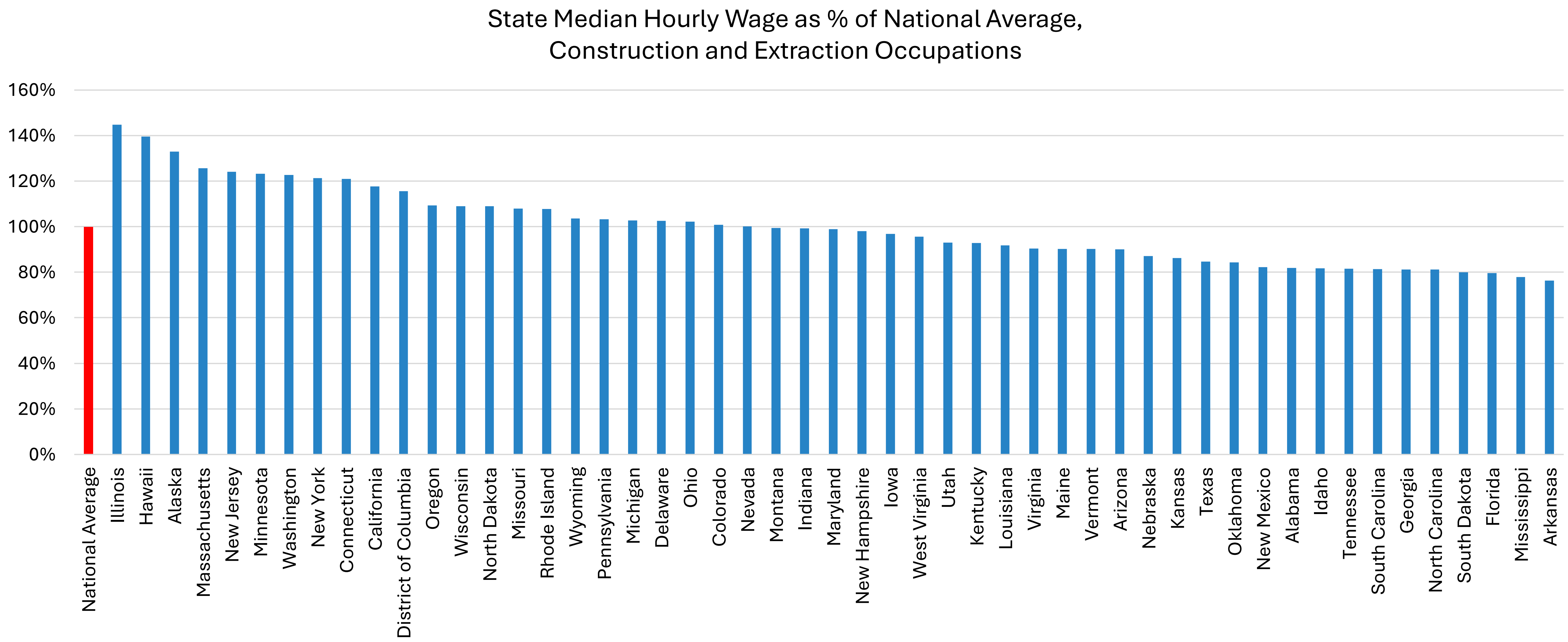
Source: Gas Buddy Foot Traffic Report for the fuel & convenience retailing industry, Q1 2019

- Max 8.02% in a given hour, suggests peak demand is double what it would be if demand was spread evenly over all hours (100%/24 = 4.2%)

→ We assume 50% utilization for motorhomes. This assumes that charging ports for these vehicles are added at existing locations with 350kW LDV and/or truck charging, i.e. geographic charging network coverage for these vehicles is provided by build-out for other vehicle use cases

STATE DIFFERENCES IN LABOR COSTS

Cost per port



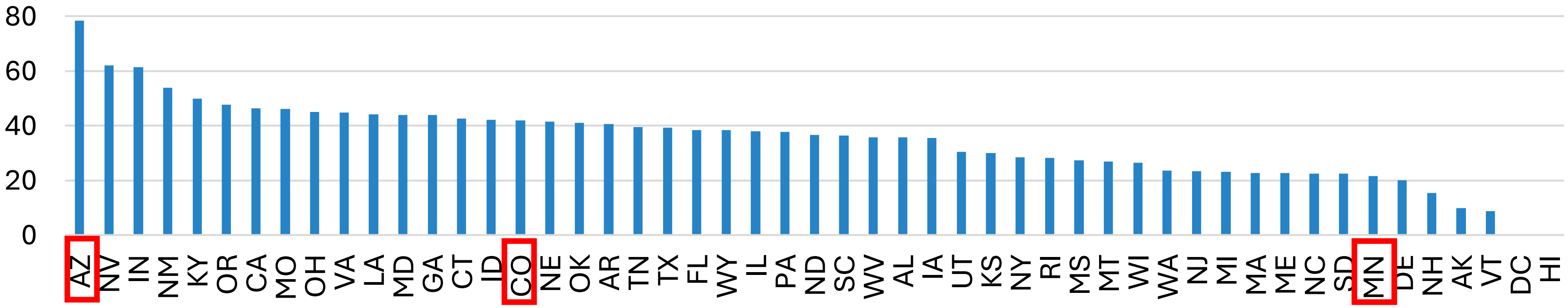
Source: Standard Occupational Classification System Code 47-0000, U.S. Bureau of Labor Statistics Occupational Employment Statistics, May 2019

COST OF 350KW TRUCK CHARGING DEPENDS ON INSTALL SIZE

Cost per port

- Low-cost case: 65% lower-cost and 35% higher-cost electrified parking space sites
  - Small sites electrify 40-100% of their parking spaces – as many as they can until reaching a 10MW threshold for a substation upgrade or 40% [utilization assumption], whichever is higher
  - Assumes national distribution of parking site sizes looks like Minnesota (MN, CO and AZ are only states for which full data could be found)
- High-cost case: 30% lower-cost and 70% higher-cost electrified parking space sites
  - Small sites electrify 70% - 100% of their parking spaces – as many as they can until reaching a 10MW threshold for a substation upgrade or 70% [utilization assumption]
  - Assumes national distribution of parking site sizes looks more like Colorado

Average long-haul truck parking spaces per facility



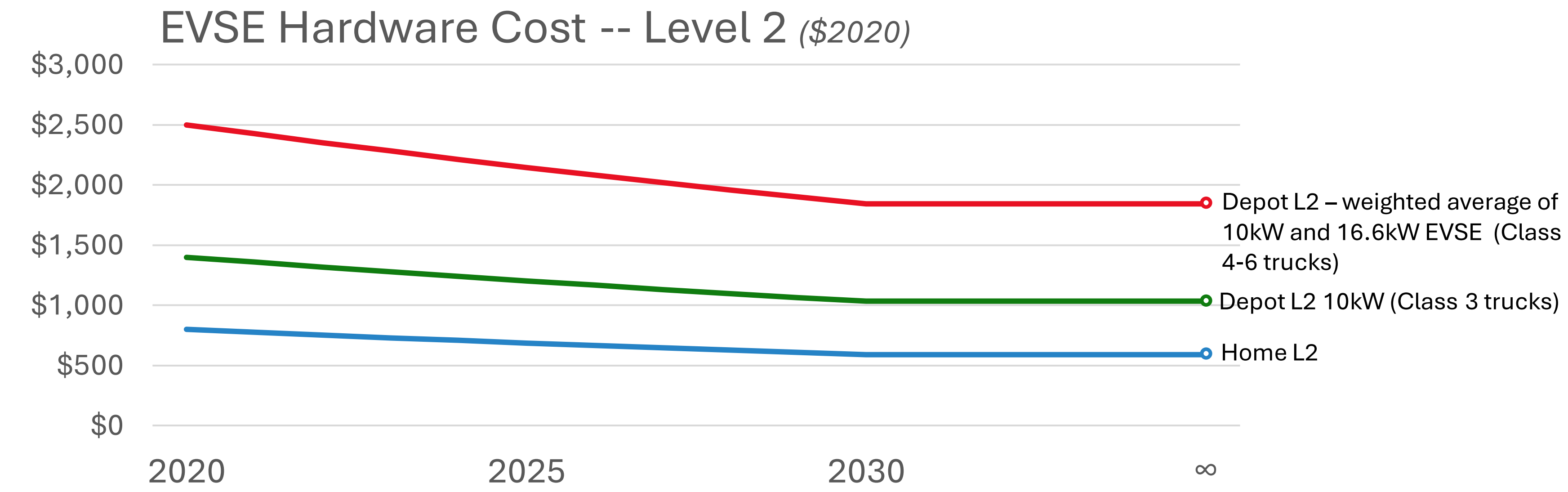
Source: Jason's Law Truck Parking Survey Results and Comparative Analysis, 2015

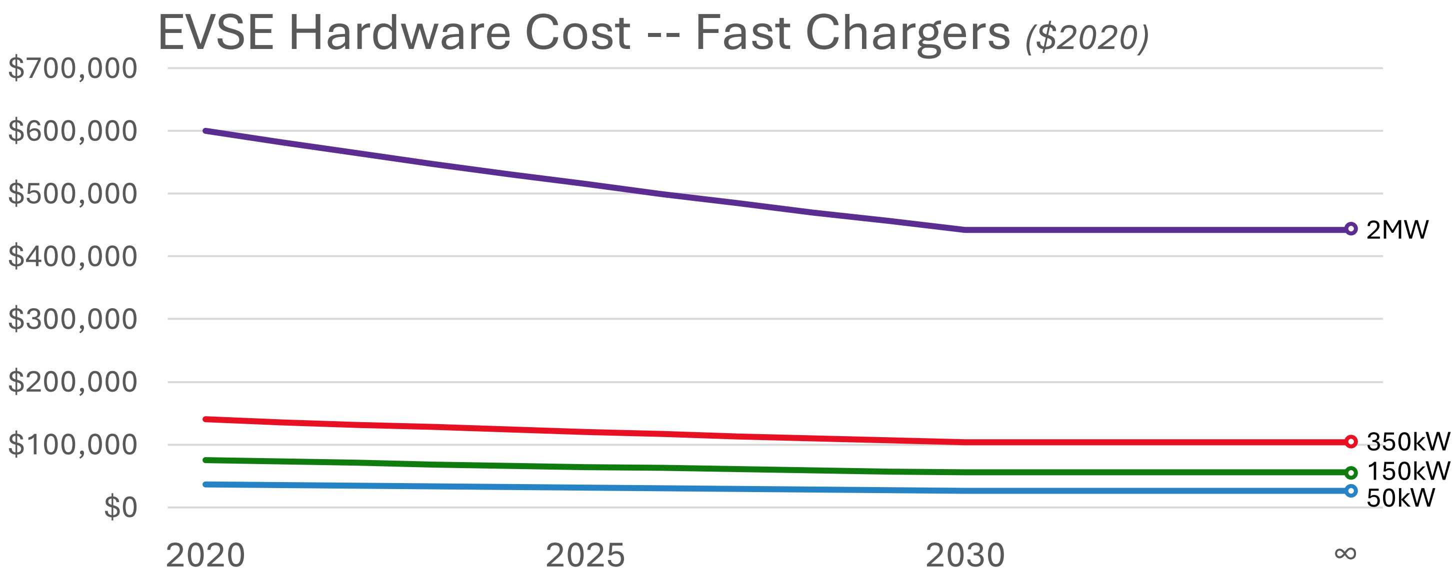
State	% of parking at sites less than 70 spaces	% of parking at sites less than 42 spaces
Minnesota	65%	52%
Colorado	47%	30%
Arizona	48%	35%

* 70 spaces = [28 350kW EVSE that can fit below 10MW substation upgrade] / 40% utilization
* 42 spaces = [28 350kW EVSE that can fit below 10MW substation upgrade] / 70% utilization

EVSE HARDWARE COST REDUCED BY 3% PER YEAR FOR THE NEXT 10 YEARS

Cost per port





- 3% real cost decline is assumption used by the ICCT (2019) for their 2019 – 2025 charging cost analysis
- No further cost declines after 2030
- We do not reduce cost of labor or other materials over time

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