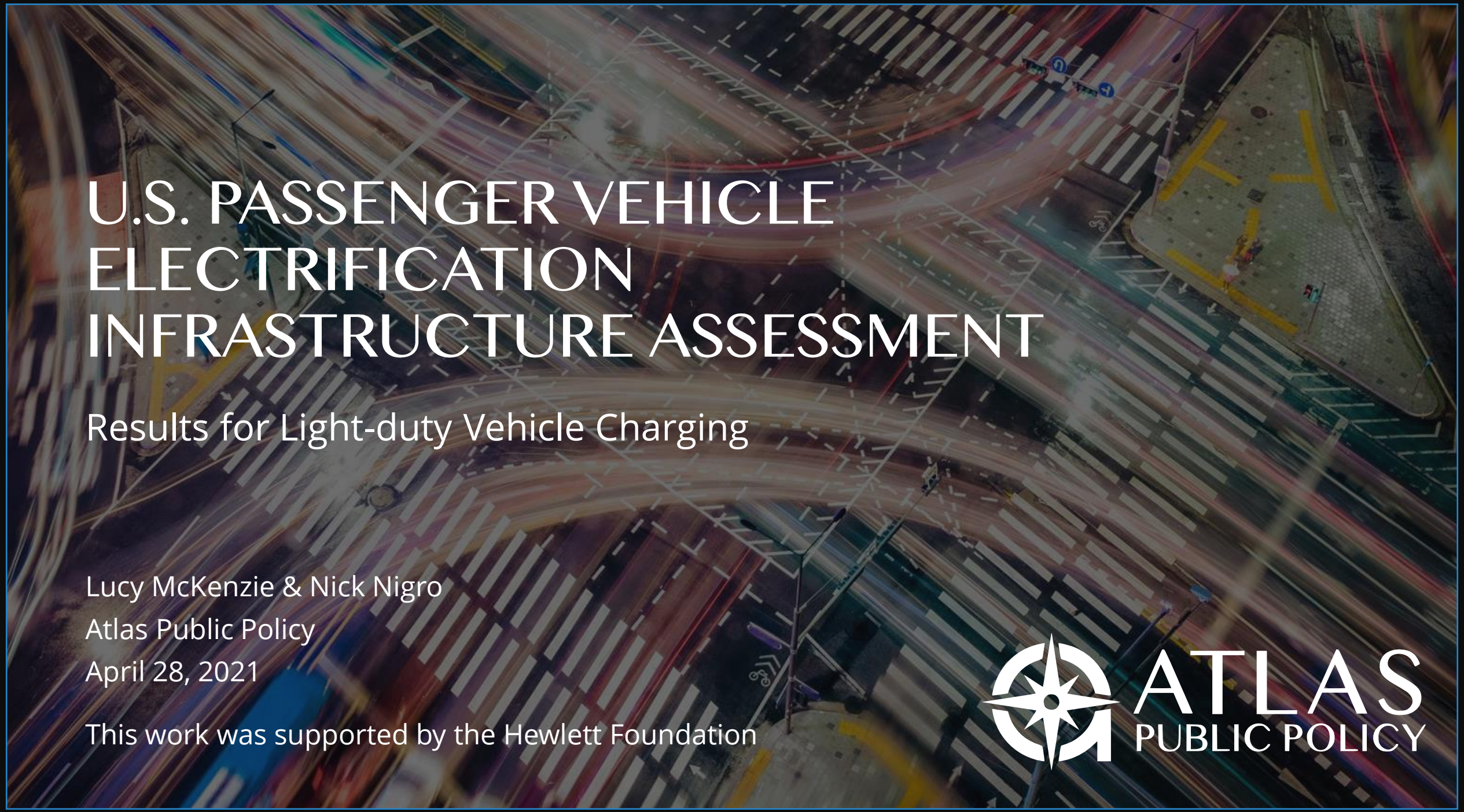

U.S. PASSENGER VEHICLE ELECTRIFICATION INFRASTRUCTURE ASSESSMENT

Results for Light-duty Vehicle Charging

Lucy McKenzie & Nick Nigro
Atlas Public Policy
April 28, 2021

This work was supported by the Hewlett Foundation

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

Our Key Focus Areas

- **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.

THANK YOU!

Atlas would like to thank the following individuals and organizations who generously provided their expertise and data in support of this work:

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- Greg Hintler, Mobility House
- Daniel Haake, HDR
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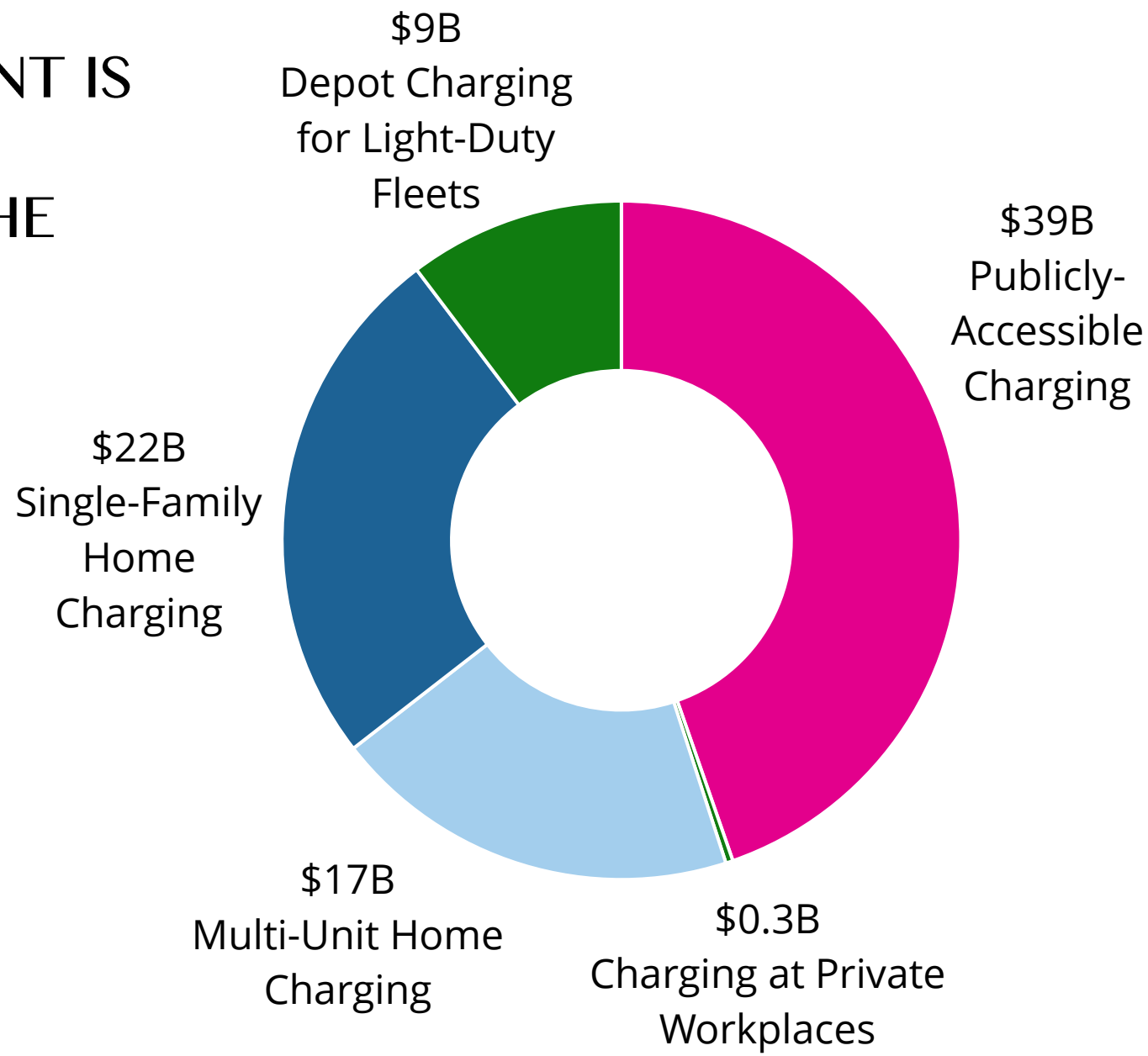
- Ken Kresyman, Ameren
- Britt Reichborn-Kjennerud and Jared Trumpetto, ConEdison
- Lincoln Wood, Southern Company

OVERVIEW

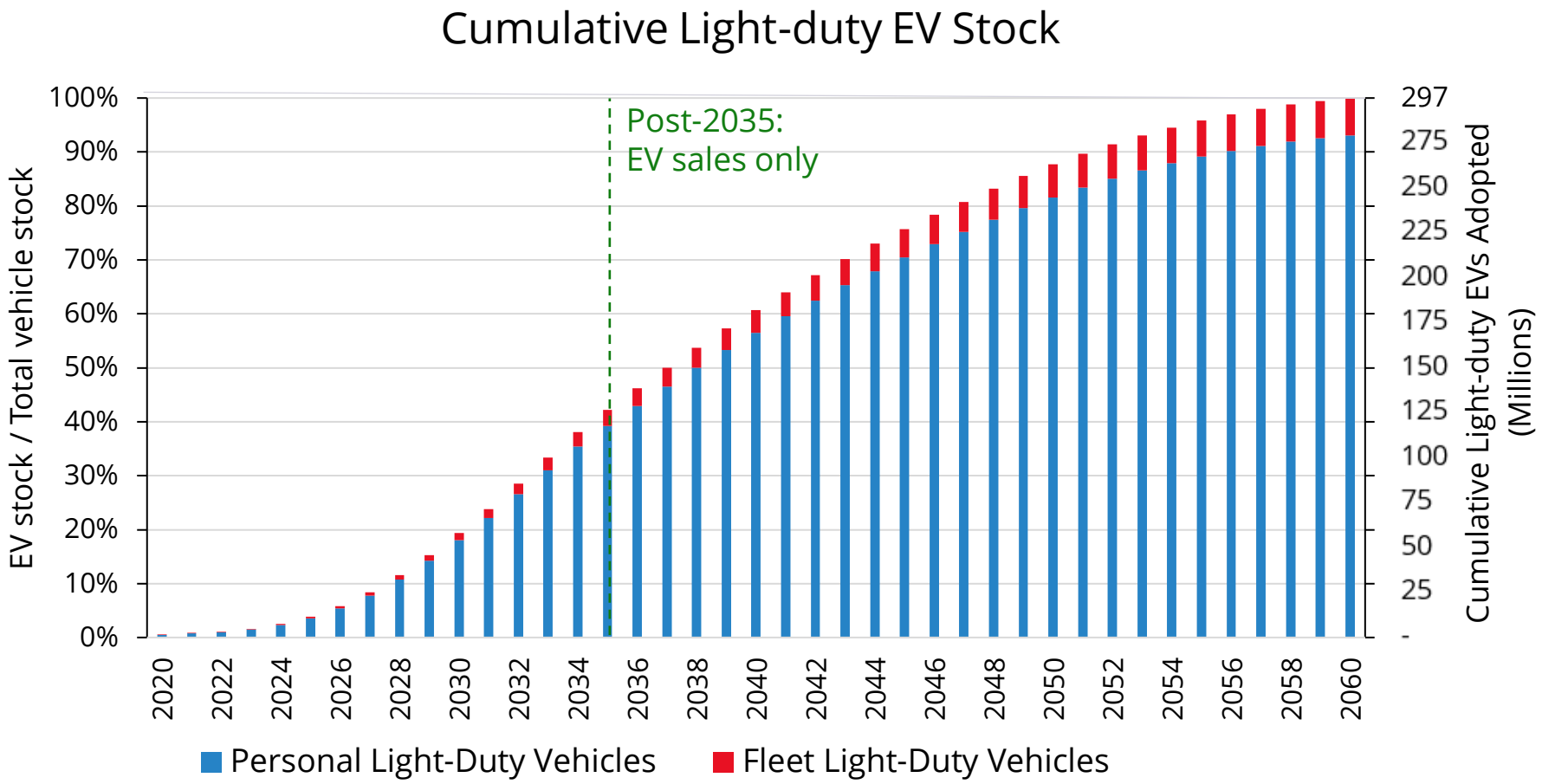
- Charging infrastructure need for light-duty vehicles
- Methodology overview
- Next steps

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

$87B OF CHARGING INFRASTRUCTURE INVESTMENT IS NEEDED OVER THE NEXT 10 YEARS TO PUT THE U.S. ON THE PATH TO FULL LIGHT-DUTY VEHICLE ELECTRIFICATION



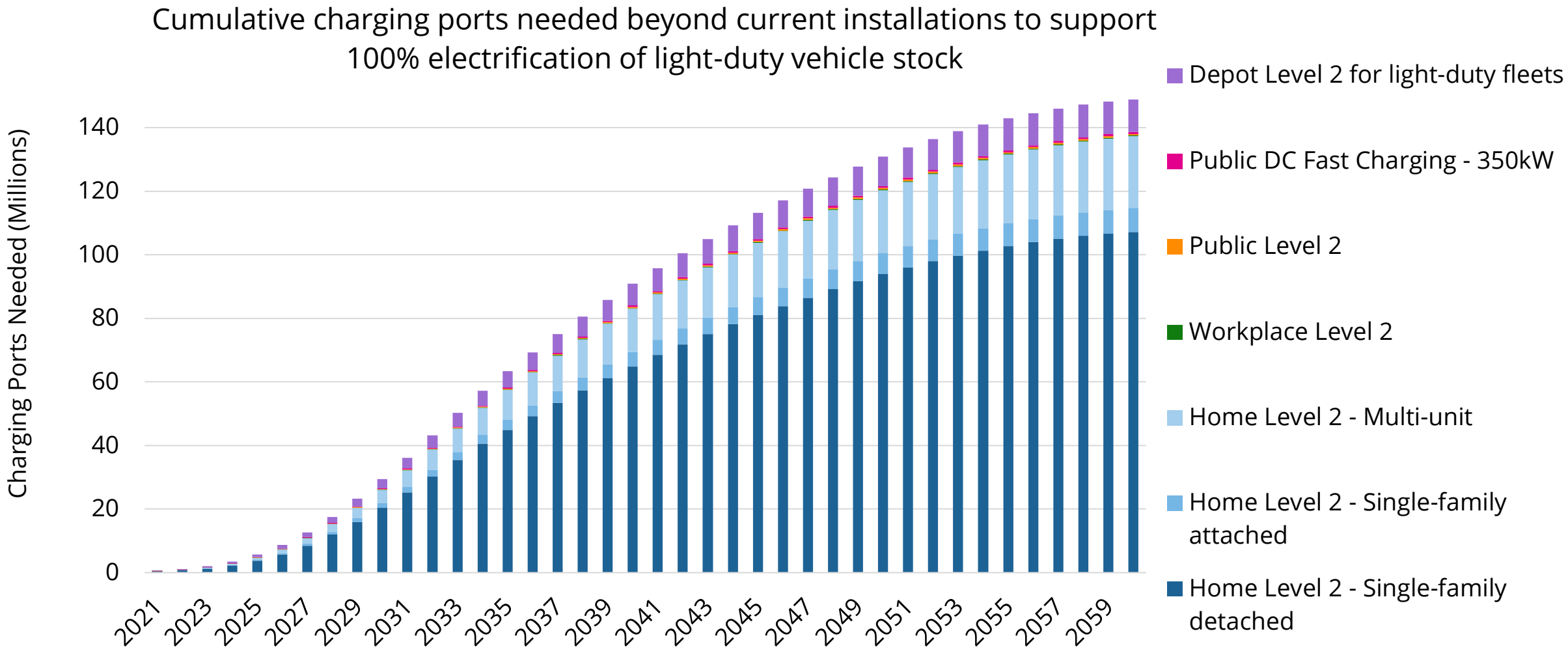
WE MODEL100% EV SALES BY 2035



- National ZEV-only sales mandate from 2035; S-curve sales 2021-2034
- Same EV % across all states and across Personal/Fleet LDVs
- Vehicle stock increases at U.S. EIA projected rates
- Transportation network company vehicles (Lyft, Uber) not separately modeled; included in Personal LDVs

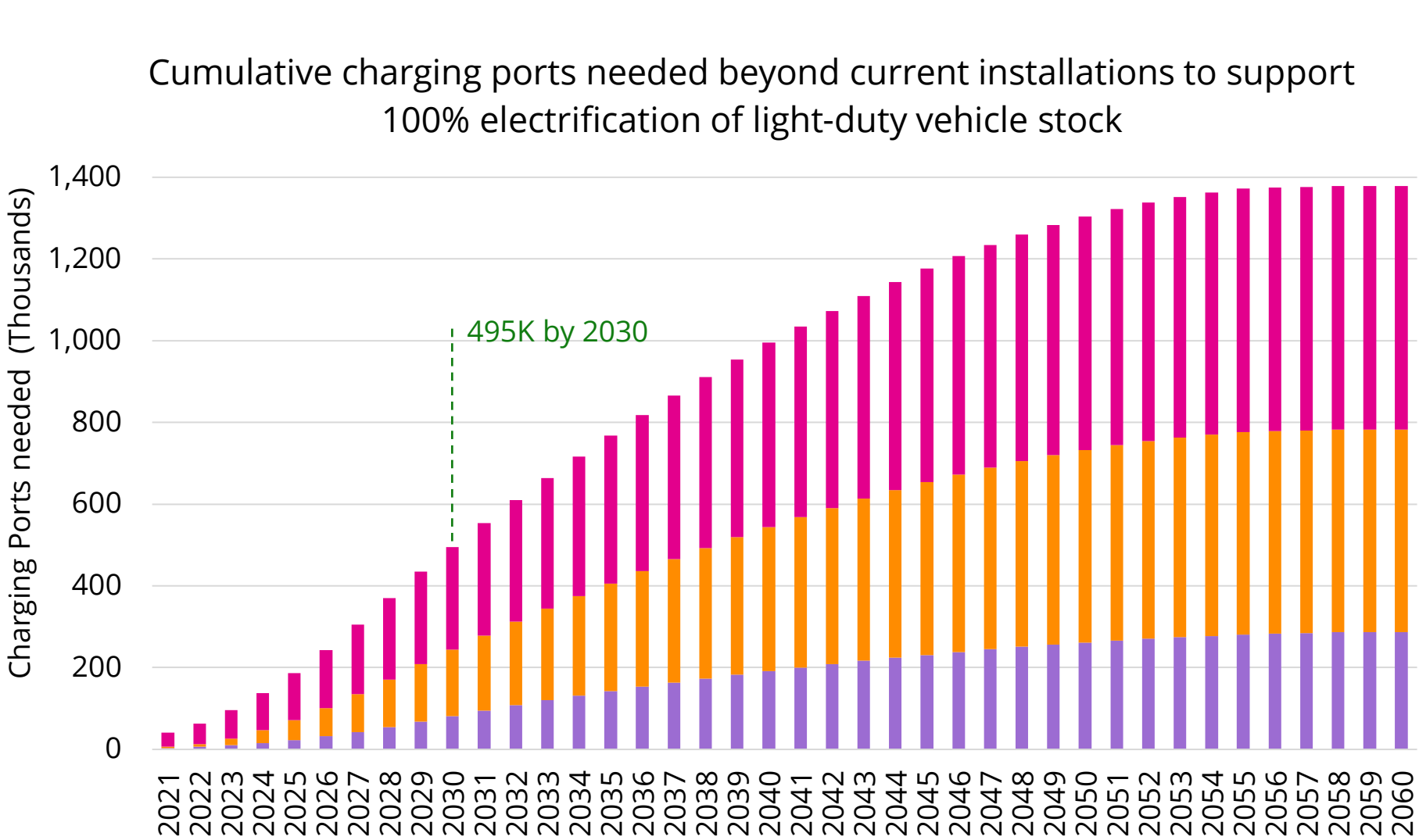
VAST MAJORITY OF CHARGING PORTS WILL BE AT HOME

(DESPITE ONLY AN ESTIMATED 50% OF VEHICLES HAVING HOME CHARGING ACCESS)



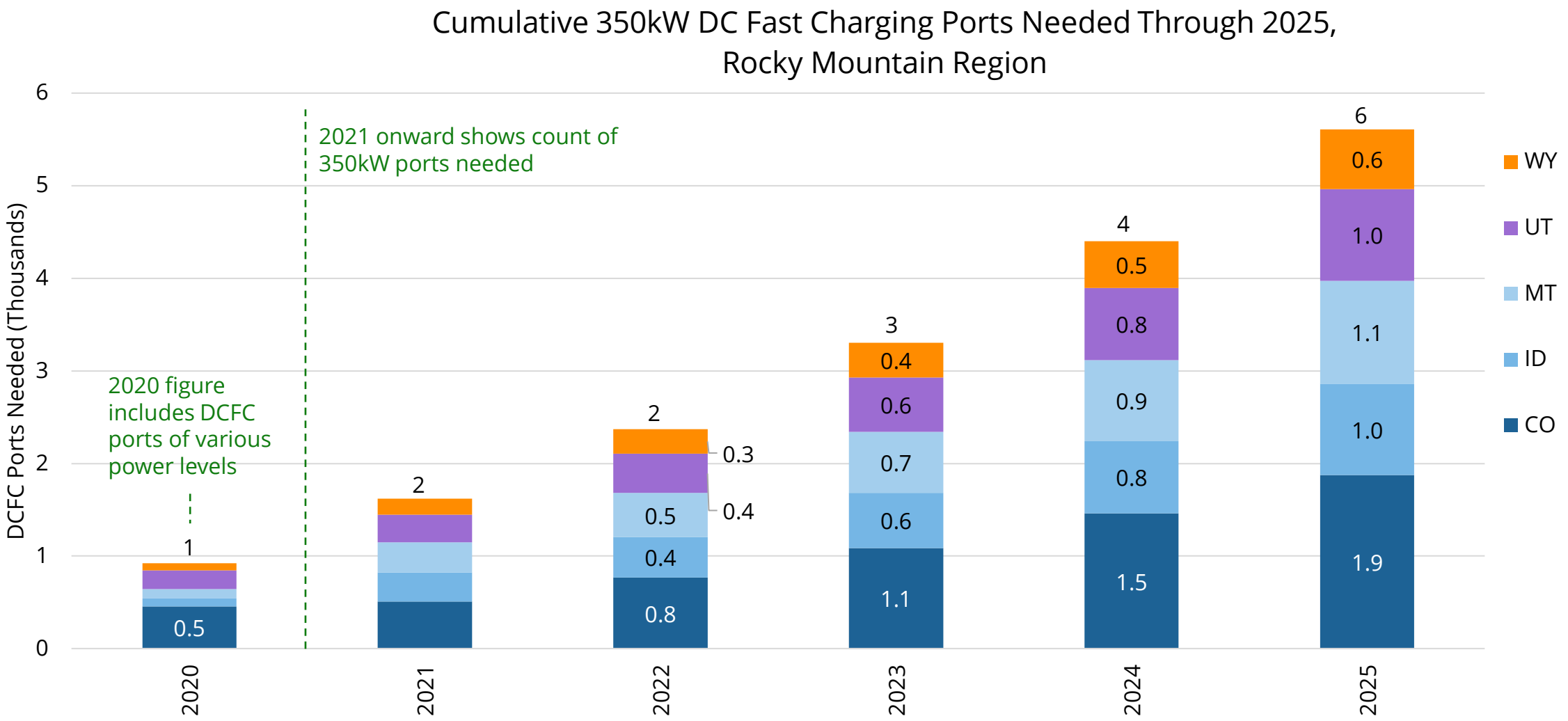
Source for home charging access assumption: Ge and Wood “There's No Place Like Home: Residential Parking, Electrical Access, and Implications for the Future of Electric Vehicle Charging” NREL Technical Report (forthcoming).

A ROBUST NETWORK OF NEW PUBLIC & WORKPLACE CHARGING IS ALSO NEEDED

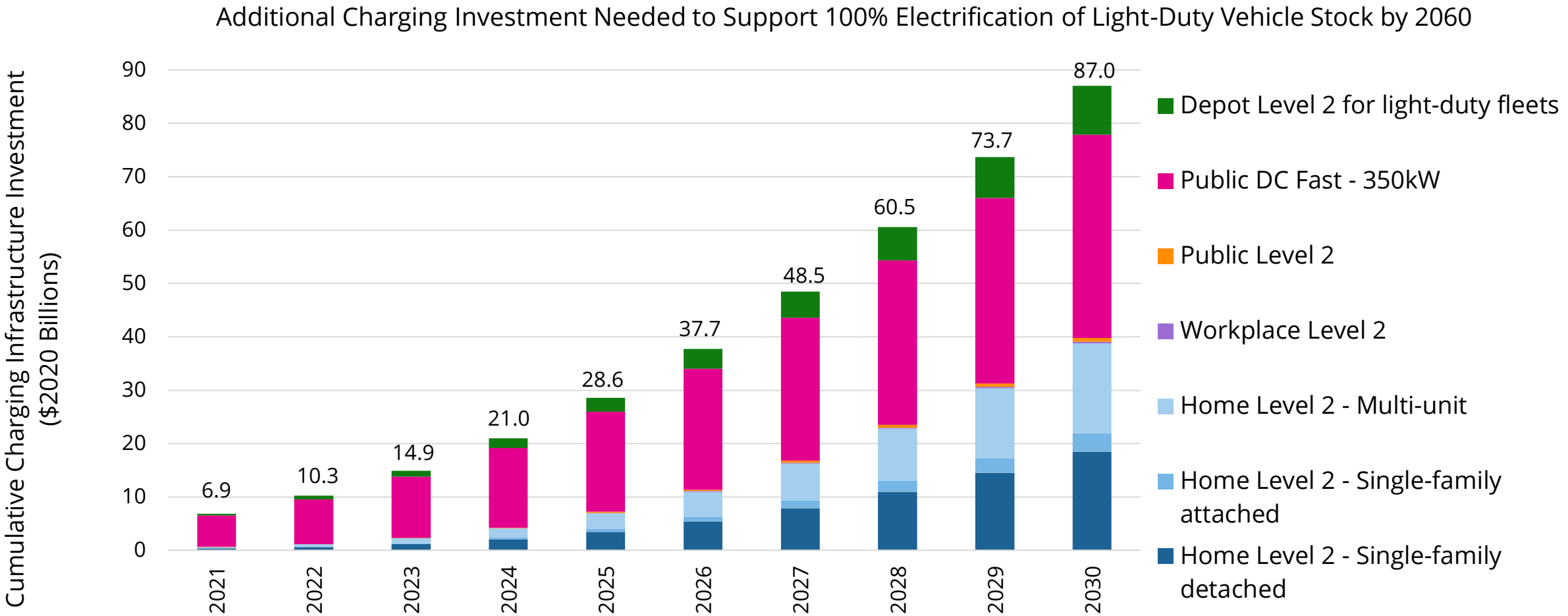


- Assumes 350kW DCFCs: Building lower-power ports would mean more are needed
  - e.g. installing the same capacity with 150kW DCFCs (assuming proportionate utilization) increases 2030 public charging need from 414K ports @ $39B to 750K ports @ $52B
- Doesn't include energy demand for very long trips (> 250 miles)

RAPID INCREASE IN PUBLIC CHARGING NEEDED FOR ALL REGIONS

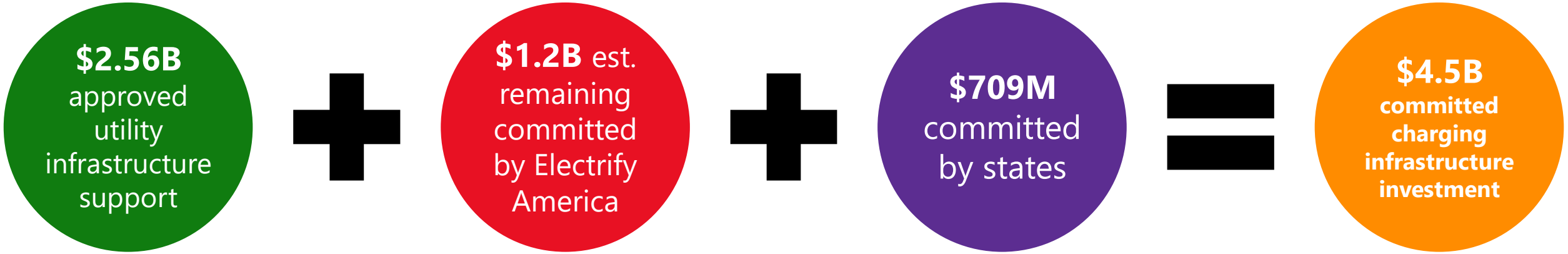


$87B NEEDED FOR CHARGING BY 2030



Installing 150kW rather than 350kW DCFC ports (assuming proportionate utilization) increases needed public charging investment from $39B to $52B

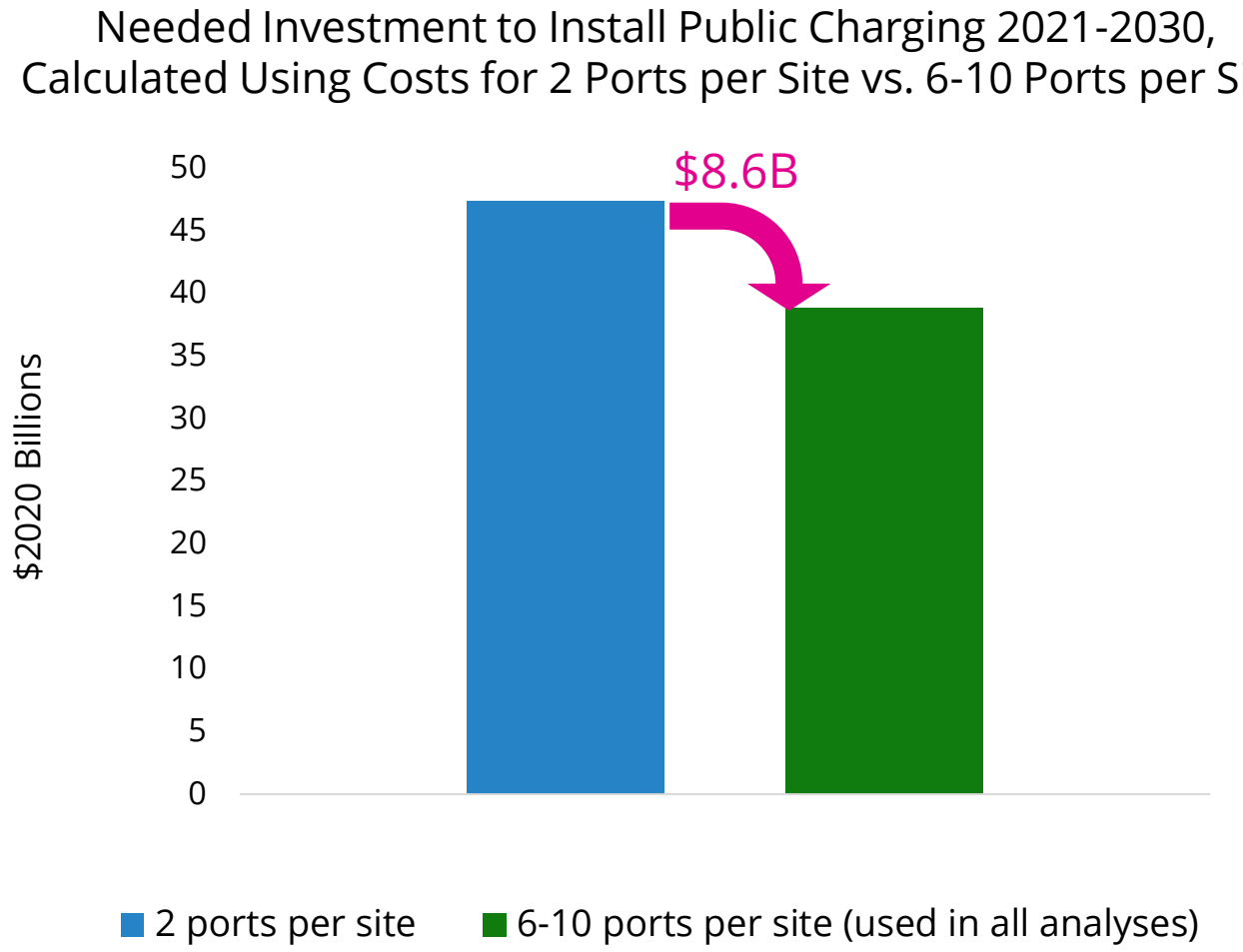
CURRENT COMMITMENTS FALL FAR SHORT & ARE GEOGRAPHICALLY LIMITED



- Included in these figures is some support for medium- & heavy-duty vehicles
- Some funds have already been invested
- 80% of state funding and 75% of utility support are in NY + CA

Source: Atlas EV Hub

INSTALLING MORE PORTS PER SITE AT THE OUTSET CAN LOWER COSTS



Source: Atlas analysis using per-port costs from The International Council on Clean Transportation, 2019, "Estimating electric vehicle charging infrastructure costs across major U.S. metropolitan areas"

MODELED COSTS INCLUDE EQUIPMENT, PERMIT, & INSTALLATION LABOR

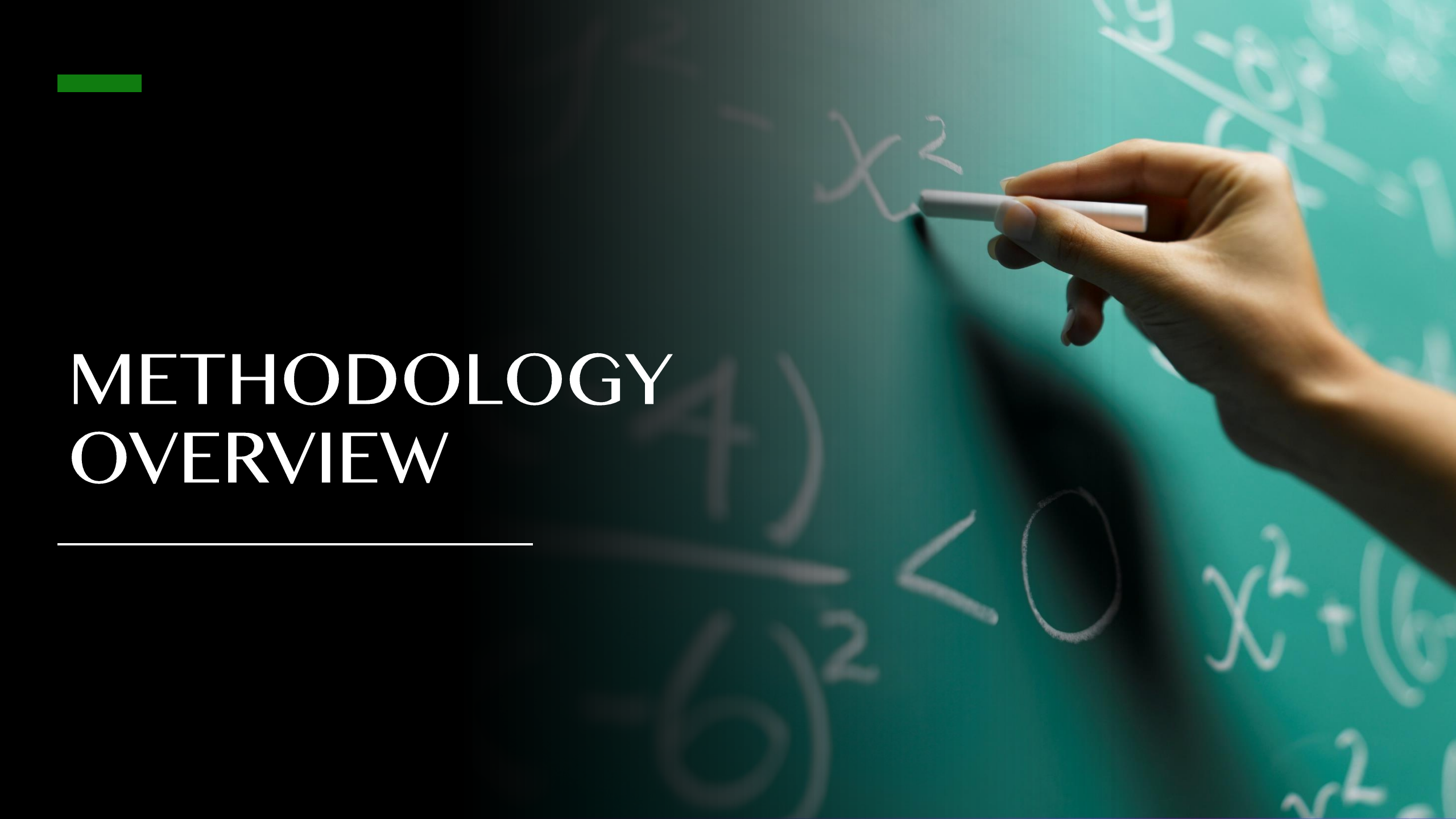
Charging Type	Included equipment, materials, permit & labor costs
Home L2 - Single-family detached *	**$974***
Home L2 - Single-family attached *	**$2,428***
Home L2 – Multi-family	**$3,857**
Workplace L2	**$3,823**
Public L2	**$4,507**
Public DCFC - 350kW	**$173,292**
Depot L2 – Light-duty	**$3,286**

Source: Atlas analysis of cost data from The International Council on Clean Transportation (2019)

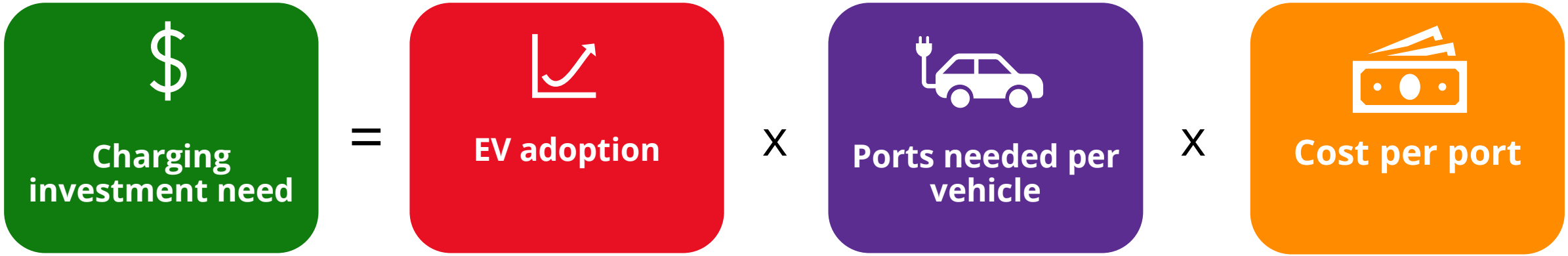
*Home charging costs are a weighted average of costs for homes requiring charging upgrades and those that do not, using the split currently found in California.

- Also includes typical utility upgrade costs for Workplace Charging, Depot Charging, Public Level 2 and up to 10 350kW DCFC ports per site
- Excludes:
  - Cost of utility network upgrades from home charging, and from public fast charging installs beyond 10 DCFC ports per site
  - Site selection, site agreement, and site upgrade costs
  - Charger maintenance, replacement, and ongoing communications costs
  - On-site battery and solar installation costs

METHODOLOGY OVERVIEW



INSITE: INVESTMENT NEEDS OF STATE INFRASTRUCTURE FOR TRANSPORTATION ELECTRIFICATION TOOL



by state, charging type, year

split by personal / fleet vehicles,

by state, year

by charging type, state

*Investment in public, workplace, and depot ports is assumed to be needed **ahead** of adoption*

by charging type, state, year

Scale labor costs by state differences;

User can choose to reduce input costs over time

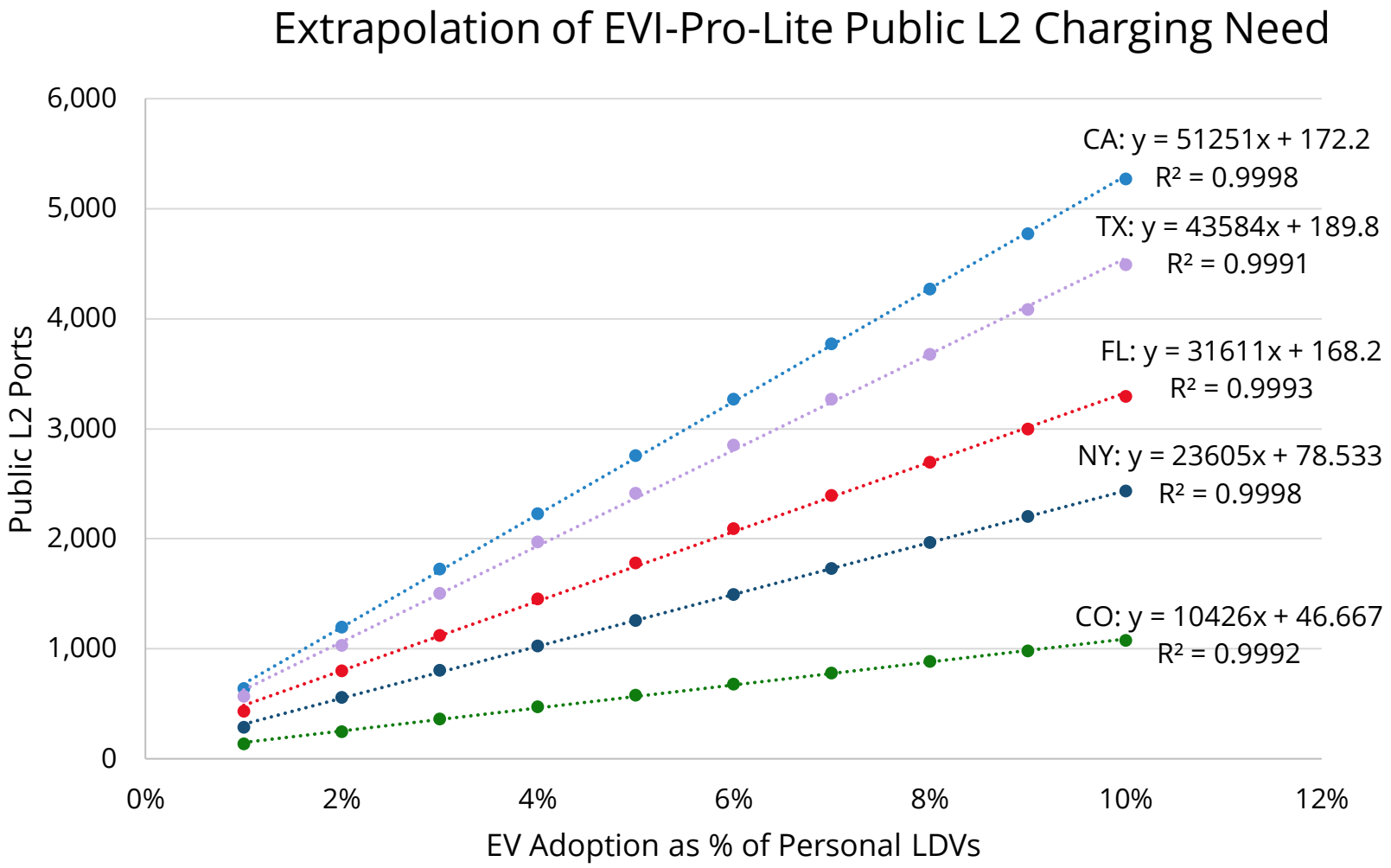
WE STUDIED 7 CHARGING TYPES

Ports needed per vehicle

Vehicle type	Charging type	kW power level	Years built prior to associated EV adoption
Personal light-duty vehicles	Home Level 2 - Single-family detached	Sufficient to fully recharge vehicle overnight	0
	Home Level 2 - Single-family attached		0
	Home Level 2 - Multi-family		0
	Workplace Level 2	6.6 kW	2
	Public Level 2	6.6 kW	5
	Public DCFC	350 kW	5
Fleet light-duty vehicles	Depot Level 2	6.6 kW	2

PUBLIC & WORKPLACE PORTS/VEHICLE EXTRAPOLATED FROM NREL'S EVI-PRO-LITE

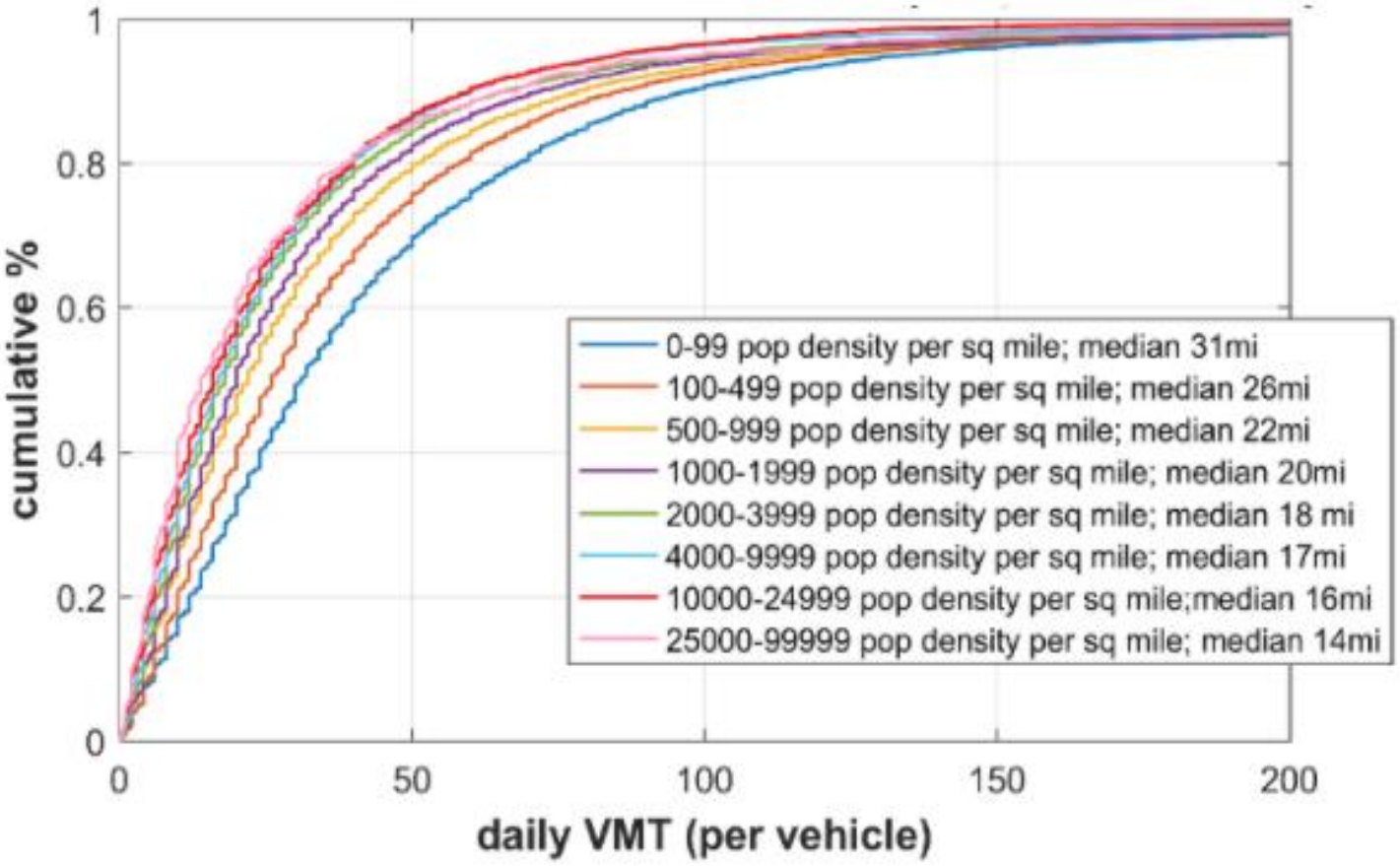
Ports needed per vehicle



- 100% 250-mile BEVs
- We extrapolate beyond NREL's 10% adoption level with linear trends
  - 10% of CA vehicles (~2M) is > total vehicles in 35 states
  - CEC/NREL analysis shows linear relationship for 5M CA vehicles
- For DCFC, we scale NREL's analysis of needed 150kW capacity to 350kW ports

MODELING 250-MILE BEVS CAPTURES VAST MAJORITY OF TRIPS

Ports needed per vehicle



Daily VMT cumulative distribution functions by population density, from the 2009 NHTS.

Source: NREL EVI-Pro –Lite Assumptions and Methodology

- 70% of daily driving under 40 miles; 95% under 100 miles
- EVI-Pro-Lite & our analysis do not capture kWh needed for >250-mile trips

Ports needed per vehicle

HOME CHARGING

50% of vehicles have home charging access

NREL survey/model:

at 100% adoption, share of vehicles parked near outlet or where owners think new electrical install could occur

All home charging is L2

With power sufficient to fully charge overnight

Census data from NREL provides % of vehicles parked in each type of housing, by state

Single-family attached, Single-family detached, Multi-family

LDV FLEET CHARGING

All fleet charging assumed to occur at depots

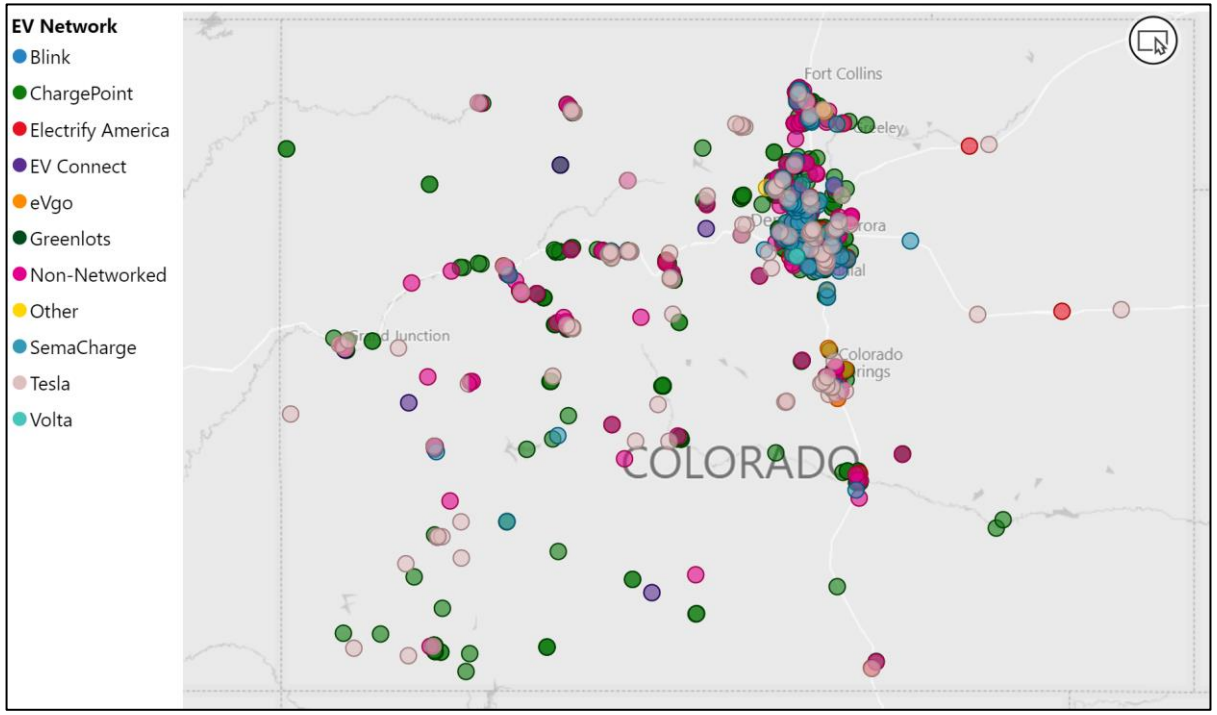
Assume two LDV fleet vehicles per port

Based on data from NYSERDA rebate recipients & conversations with NREL

EXISTING CHARGING CAPACITY

Ports needed per vehicle

Public charging ports in Colorado, by Network



Source: Atlas EV Hub

- We net out existing public charging from EV Hub
- Existing home, workplace and depot charging are assumed to be sufficient to serve existing EVs

INSTALLATION COST PER PORT

Cost per port

Charging Type	Labor	EVSE hardware	Other materials, permits, taxes	Total
Home L2 - Single-family detached *	$583	$391	$-	**$974**
Home L2 - Single-family attached *	$2,027	$400	$-	**$2,428**
Home L2 – Multi-family	$3,345	$512	$-	**$3,857**
Workplace L2	$1,435	$1,488	$900	**$3,823**
Public L2	$1,579	$1,817	$1,110	**$4,507**
Public DCFC - 350kW	$15,963	$141,907	$15,422	**$173,292**
Depot L2 – LDV	$1,435	$951	$900	**$3,286**

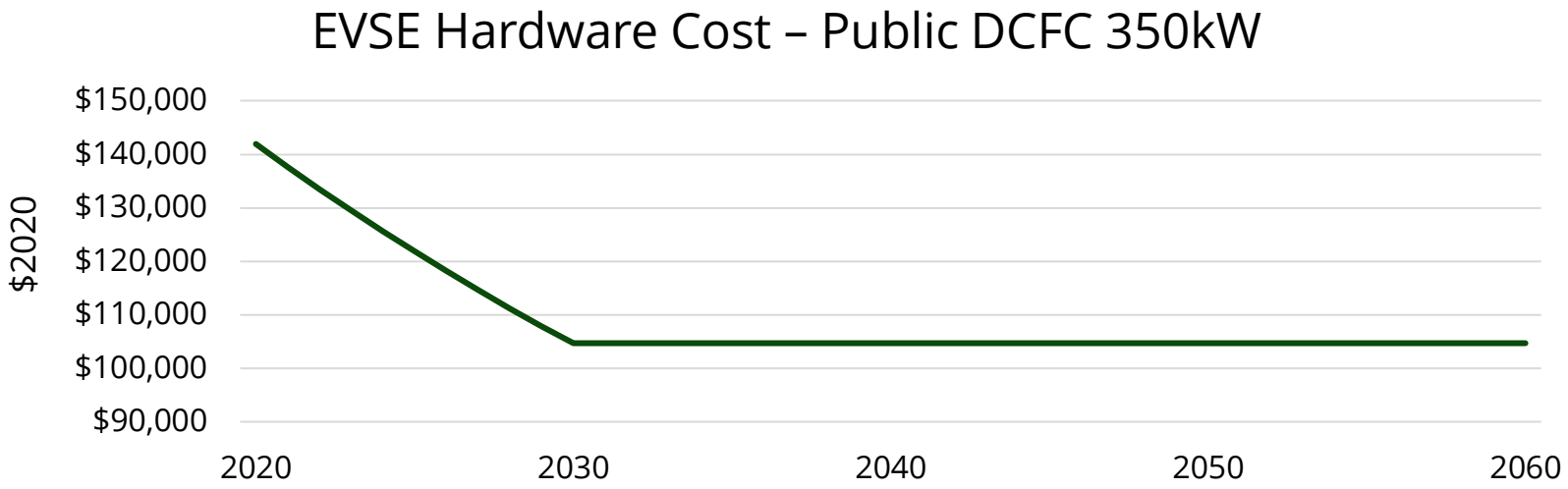
Source: Atlas analysis of cost data from The International Council on Clean Transportation, 2019

*Home charging costs are a weighted average of costs for homes requiring charging upgrades and those that do not, as reported currently for California.

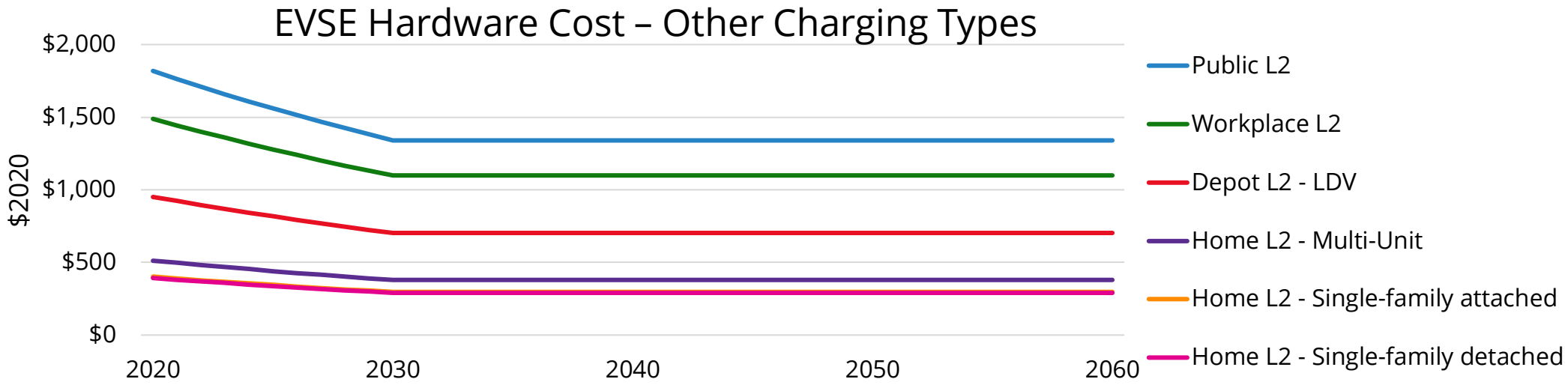
- Workplace, public and depot charging costs are based on average installed costs for 6+ ports per site
- Labor costs assume prevailing wages
- 'Other materials' includes typical utility upgrade costs for Workplace Charging, Depot Charging, Public L2 and up to 10 DCFC ports per site
- Excludes:
  - Cost of utility network upgrades caused by home charging
  - Utility upgrade costs beyond 10 x 350kW DCFC ports / site, at high-cost distribution sites, or as they may change at higher levels of EV adoption
  - Site selection costs
  - Site upgrade costs: lighting, striping, signage, security, landscaping
  - Replacement EVSE hardware at end of useful life
  - Maintenance
  - Communications costs for networked chargers
  - On-site battery and solar costs

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

Cost per port



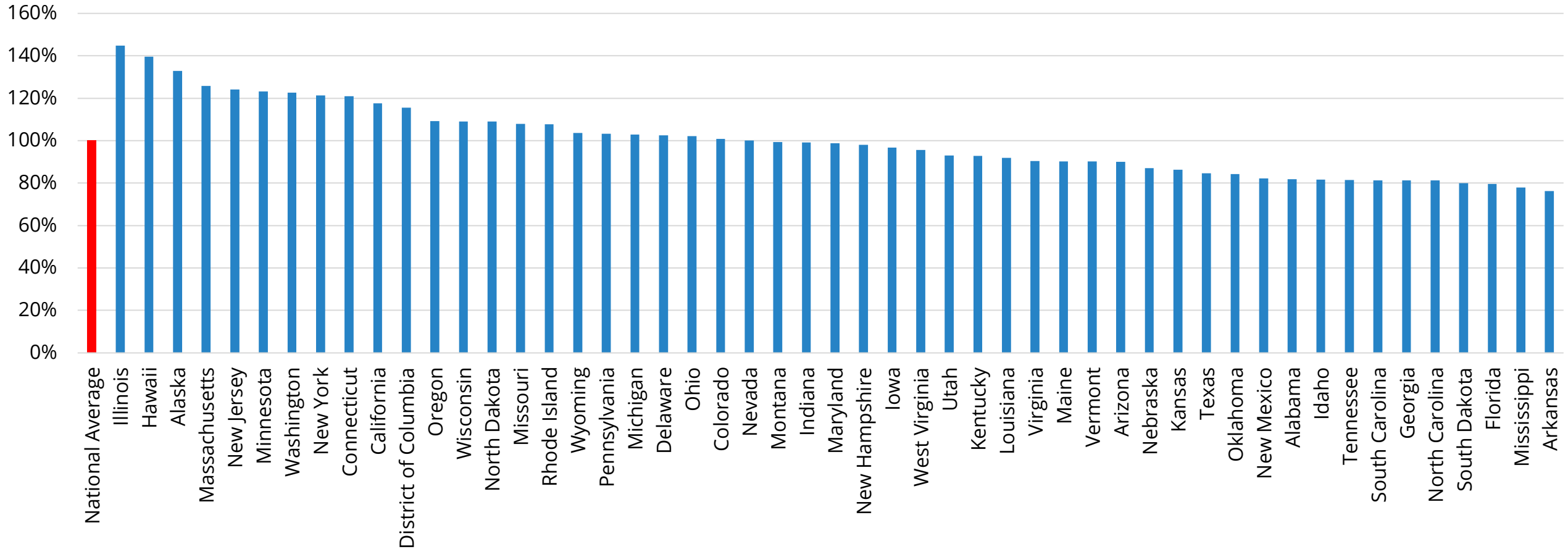
- 3% is assumption used by the ICCT (2019) for their 2019 – 2025 charging cost analysis
- We do not reduce cost of labor or other materials over time



STATE DIFFERENCES IN LABOR COSTS

Cost per port

State Median Hourly Wage as % of National Average,
Construction and Extraction Occupations



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

DISCOUNT RATE

$ Charging investment need

Where discounted results are reported, we use a 2% real discount rate

- This follows guidance put forth by the Council of Economic Advisers in 2017

NEXT STEPS

NEXT STEPS IN THIS PROJECT

- Working on a similar assessment for MD/HD trucks and will share results in Fall
- Publishing a public version of the INSITE tool by year end

MORE ON THE INSITE TOOL

- Tool will be freely available and built in Microsoft Excel
- First Release Q4 2021
- Possible future updates:
  - Add data from NREL EVI-Pro 2, EVI-RoadTrip if/when available
  - Annual update with latest data from U.S. EIA, FHWA, etc.

Use Cases

- ✓Input to jobs analyses
- ✓Deep dives on individual states
- ✓Input to distribution planning models
- ✓Assess cost savings from residential and commercial EV-friendly building codes
- ✓Assess impacts of novel home charging access approaches

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APPENDIX A – MANAGING DISTRIBUTION SYSTEM COSTS

LEADING UTILITIES ARE PLANNING AHEAD TO MANAGE SYSTEM IMPACTS OF HOME & WORK CHARGING

3 CASE STUDIES OF LEADING UTILITY ZETA MEMBERS' APPROACH TO MANAGING DISTRIBUTION SYSTEM IMPACTS OF EVS:
1. Southern California Edison, CA

Program Name	Program Description
Distribution system planning & costs forecasts	In its Pathway 2045 report, SCE identifies the need to electrify 75% of passenger vehicles, 67% of medium-duty vehicles, and 38% of heavy-duty vehicles by 2045 to achieve CA's greenhouse gas emissions reductions goals. The report forecasts electricity demand based on these EV adoption targets and performs analysis to estimate the required distribution system upgrades and the associated costs in order to reliably meet that demand. The report finds that these costs would come to about $4 billion. The report also includes analysis on how much additional energy storage would be needed given different levels of "flexibility" in EV charging load
Time-of-use (TOU) rates	SCE offers and encourages the use of several time-of-use (TOU) rates to encourage off-peak charging. Participation in SCE's utility-funded charging infrastructure programs such as the Charge Ready programs requires enrollment in a TOU rate. All SCE's commercial rates are TOU. For residential customers, SCE also offers TOU-D-PRIME, which features on-peak, off-peak, and super off-peak periods and differs on weekends and in the summer vs. the winter.
Demand Response (DR) Programs	SCE offers residential and commercial customers the option to participate in DR programs. These programs offer incentives to customers for reducing their electricity use when demand is high, including by disconnecting EV loads. DR programs help utilize existing grid infrastructure more efficiently and can help defer or costs of grid upgrades.
Smart Charging Technology Requirements	SCE offers several programs to support the installation of EV charging stations at workplaces, multi-unit dwellings, schools, parks, and other public locations. In order to ensure preparedness for efficient grid integration, Southern California Edison requires participating charging projects to install "smart" charging technology capable of a variety of functions that enable grid integration such as demand response capability. Several programs also require participants to take part in DR programs.

LEADING UTILITIES ARE PLANNING AHEAD TO MANAGE SYSTEM IMPACTS OF HOME & WORK CHARGING

2. Consolidated Edison, NY

Program Name	Program Description
SmartCharge off-peak incentives	Offers EV drivers financial incentives to charge their vehicles during off-peak hours. As of September 18, 2028, the program includes medium- and heavy-duty vehicles .
Time-of-use (TOU) rates	Offers lower rates for off-peak charging. ConEd offers a whole-house TOU rate and an EV-only TOU rate (which requires a separate meter).
On-board telematics program	ConEd is exploring the use of onboard telematics to inform system planning. A 3-month pilot program offered Honda Clarity PHEV drivers financial incentives to share charging data, and additional incentives to charge off-peak. A full-scale version of the program was launched in 2020. They have also contracted with Ford and BMW to explore onboard telematics.
~ $36M annually to enhance distribution system	ConEd was authorized in its last rate case to invest an average of $36 million annually from 2022-2022 in improving the distribution system from a safety, reliability, resiliency, efficiency, and automation standpoint. These planned improvements account for increasing penetration of distributed energy resources (DERs), including EVs .
$3.7M DERMs programs	$3.7 million approved to develop and evaluating ConEds' DERMS (distributed energy resource management system). The goal of DERMS functionality is to allow grid operators to monitor and forecast DER activity, such as EV charging, in order to increase grid flexibility and resiliency as more DERs connect to the grid.
Grid upgrades for DER integration	Investing in grid upgrades to allow management of bi-directional power flows, which is essential as DER penetration increases. For example, ConEdison is upgrading 2,000 network protector relays, which will allow DERs to export power.
$1.1M School Bus V2G Demonstration Project	ConEdison invested in 5 electric school buses in White Plains, NY that will provide vehicle-to-grid services during the summer months.

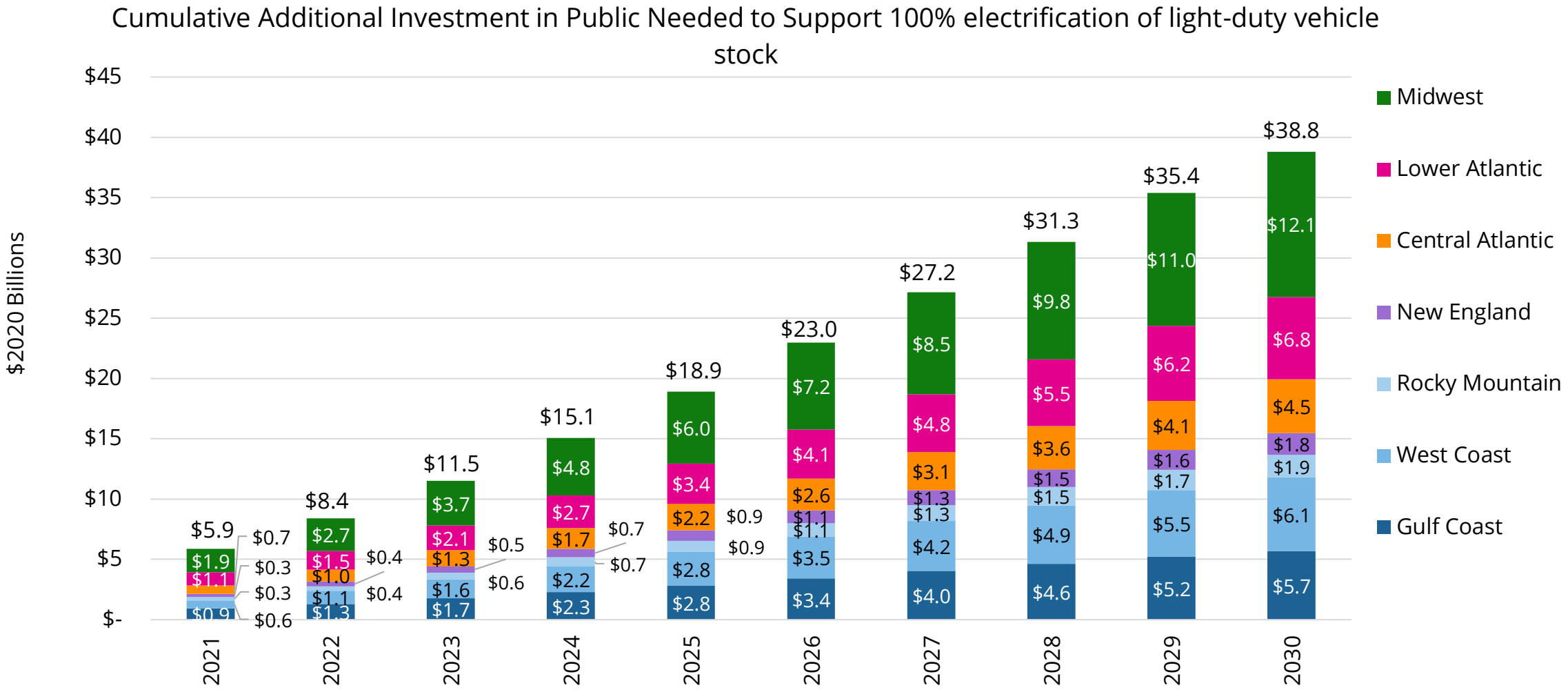
LEADING UTILITIES ARE PLANNING AHEAD TO MANAGE SYSTEM IMPACTS OF HOME & WORK CHARGING

3. Georgia Power, GA

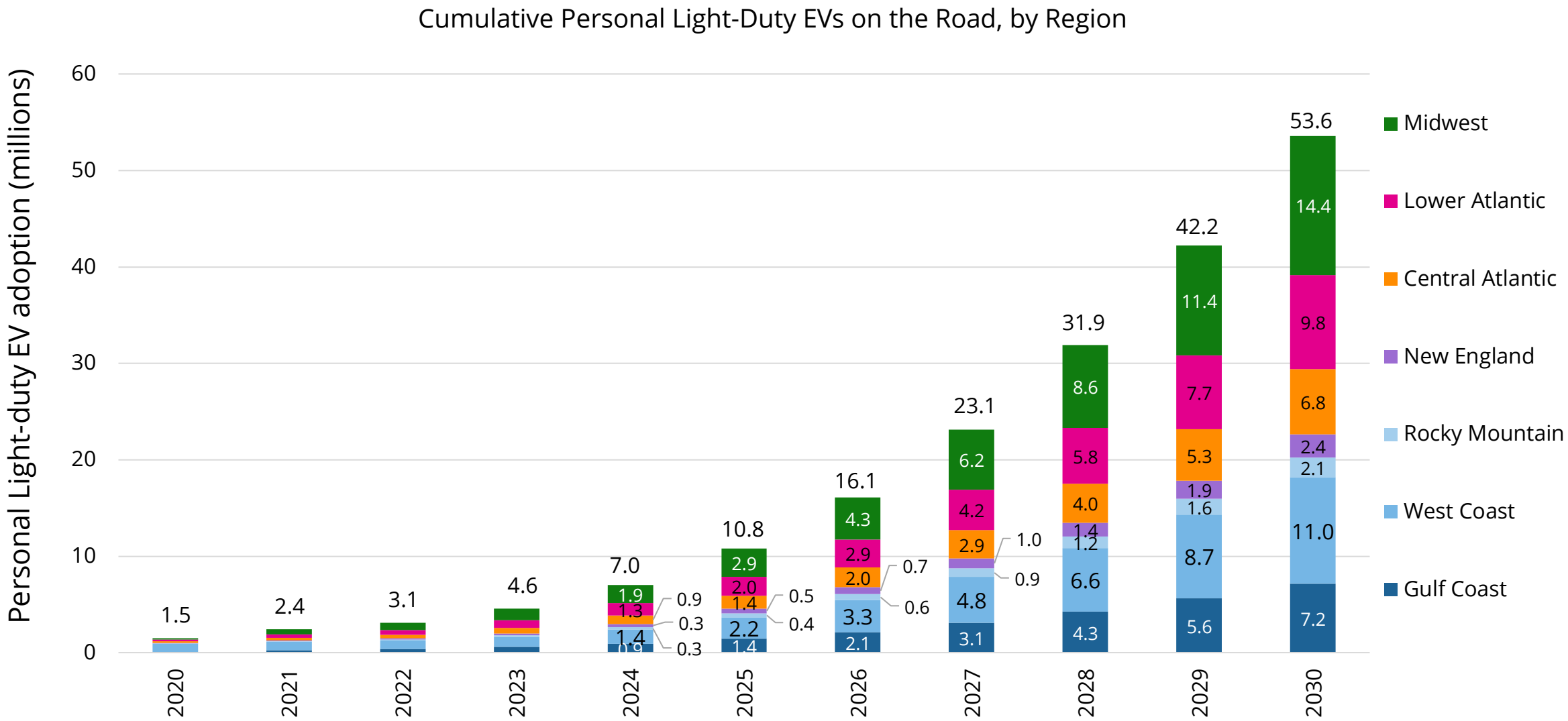
Program Name	Program Description
Develop and evaluate Distributed Energy Resource Management System (DERMS)	Over three years, from 2019-2021, Georgia Power will evaluate a DERMS to integrate various DERs into the distribution system in an optimal way. The goal is to implement a market-ready, technology-indifferent hardware and software solution that allows real-time, central monitoring of DERs. The evaluation process, will include demonstration projects where Southern Company will test DERMS with proven technologies.
Non-Wires Alternatives (NWAs)	Distributed Energy Resources (DERs), including EVs, may require increased grid flexibility but can also help provide increased grid flexibility. Georgia Power will consider NWAs, such as the use of DERs, alongside traditional transmission and distribution solutions to determine the best solution in a given situation from a reliability, cost, and lead-time perspective.
PEV TOU Rate	Georgia Power offers EV drivers a Plug-In Electric Vehicle Time-of-Use Rate (PEV TOU) to encourage off-peak charging by offering lower electricity rates during off-peak hours and even lower rates during “super off-peak hours .”
Working with EPRI to study EV charging grid impacts	Georgia Power is working with the Electric Power Research Institute (EPRI) as well as major vehicle manufacturers to study the impacts of EV charging load on grid reliability and to develop strategies to integrate EV charging load cost-effectively and beneficially. Among other topics, Georgia Power is studying the potential benefits of vehicle-to-home (V2H) and vehicle-to-grid (V2G) applications for EV charging.
Demand-Side Management (DSM) Programs	Georgia Power offers DSM programs for residential and commercial customers such as programs for “smart” products like EVs that can provide demand response. DR programs help utilize existing grid infrastructure more efficiently and can help defer or costs of grid upgrades.

APPENDIX B – ADDITIONAL REGIONAL & STATE RESULTS

NEEDED PUBLIC CHARGING INVESTMENT VARIES BY REGION

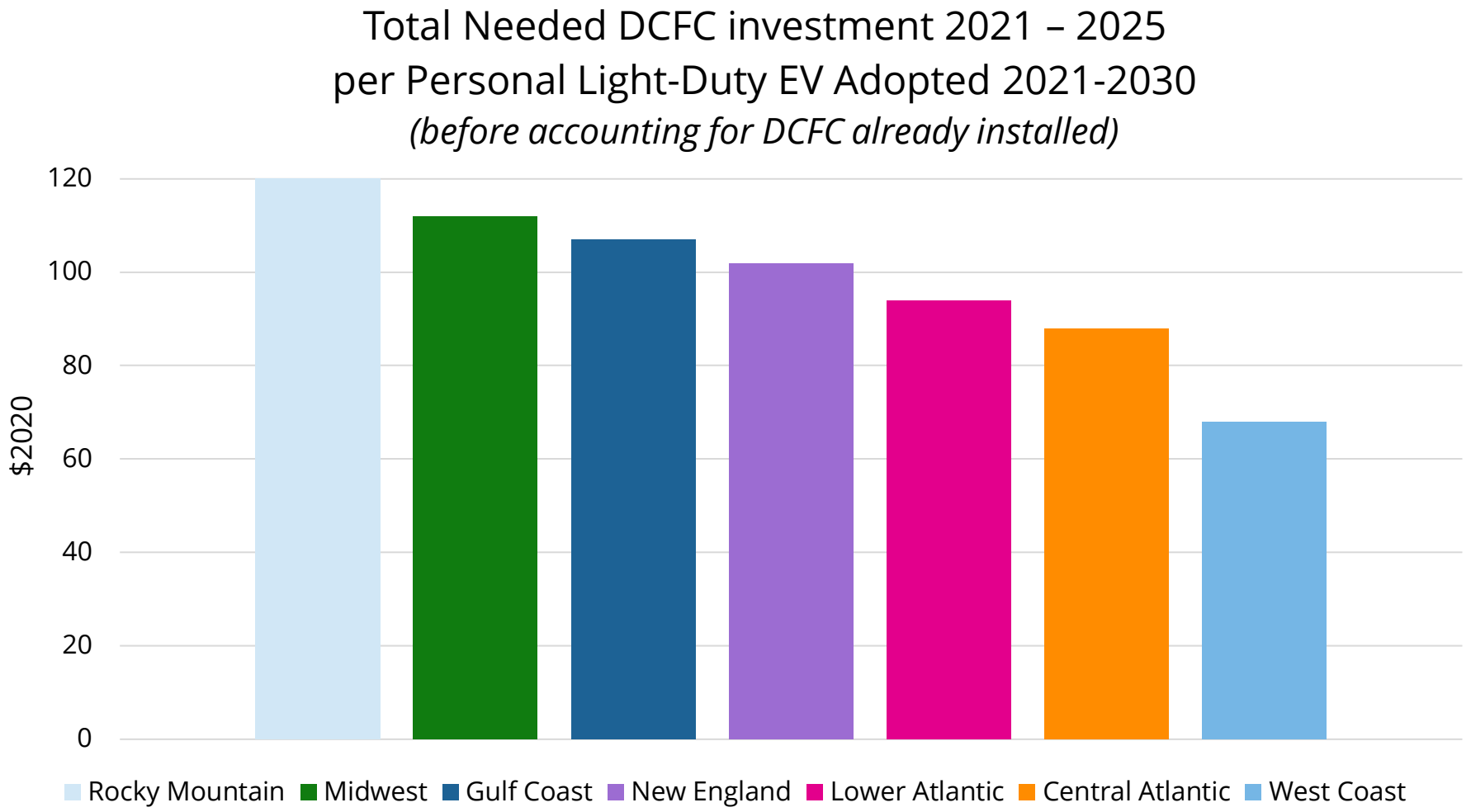


REGIONAL DIFFERENCES ARE SOMEWHAT DUE TO UNDERLYING VEHICLE STOCKS



AND SOMEWHAT DUE TO DIFFERENCES IN CHARGING NEED PER VEHICLE

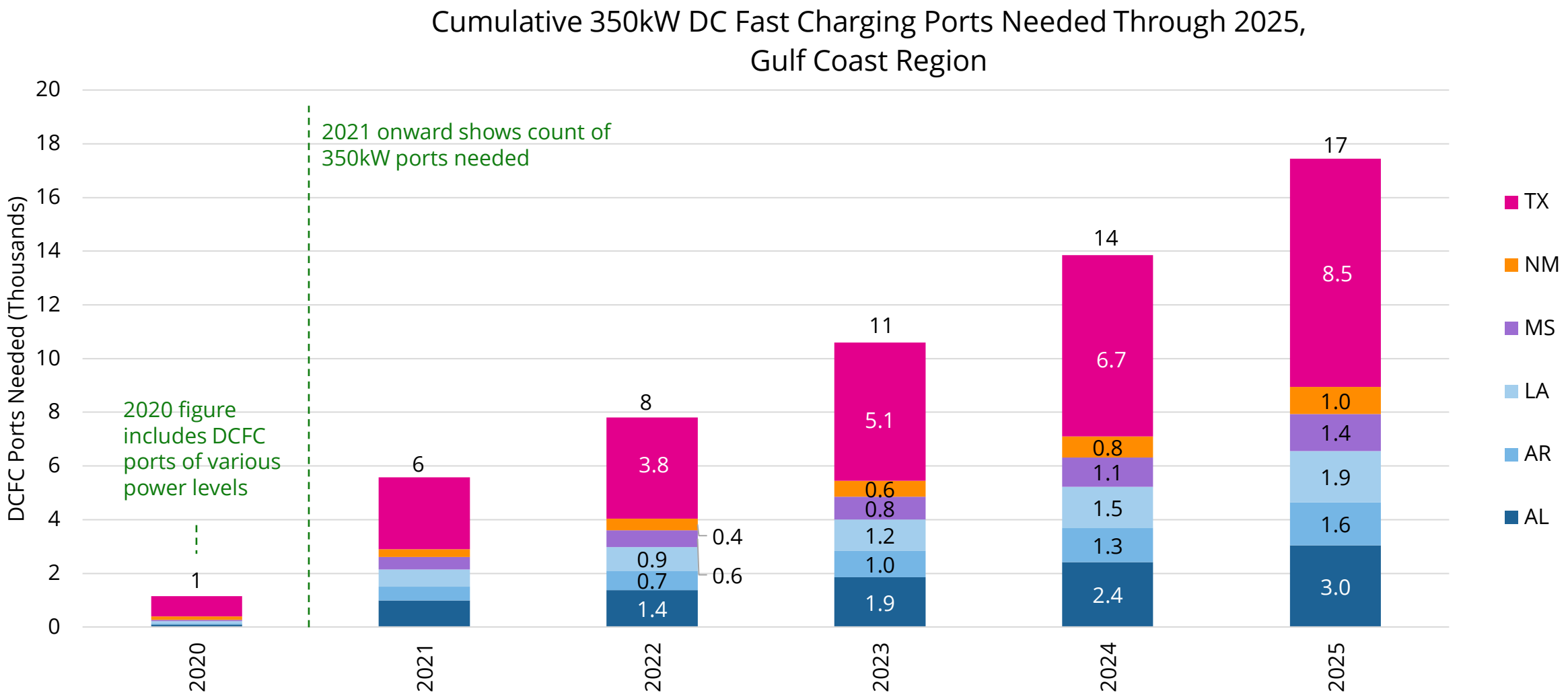
(DUE TO EVI-PRO LITE DIFFERENCES IN VMT, TEMPS, VEHICLE CONCENTRATION)



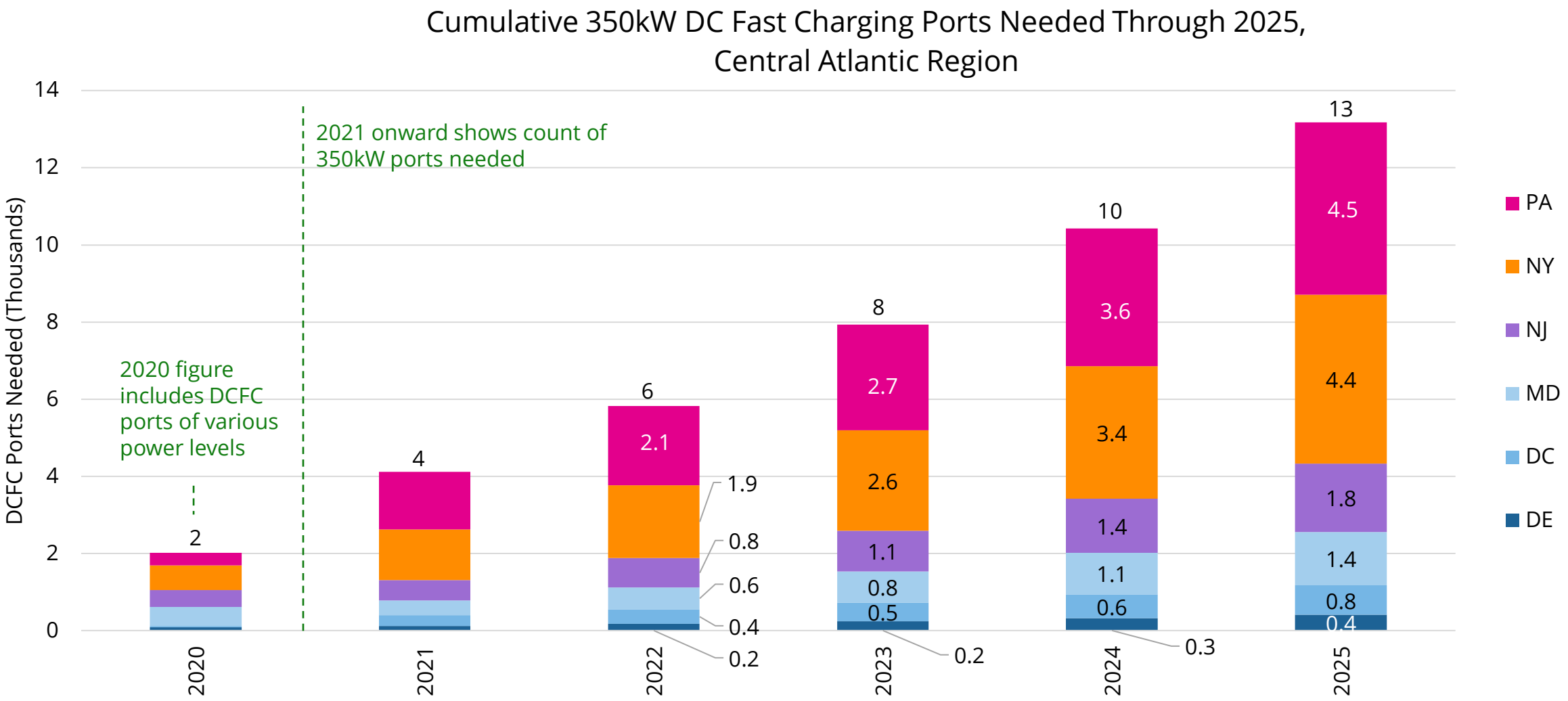
We also see smaller regional differences in needed investment due to:

- # existing DCFCs installed
- differences in labor cost

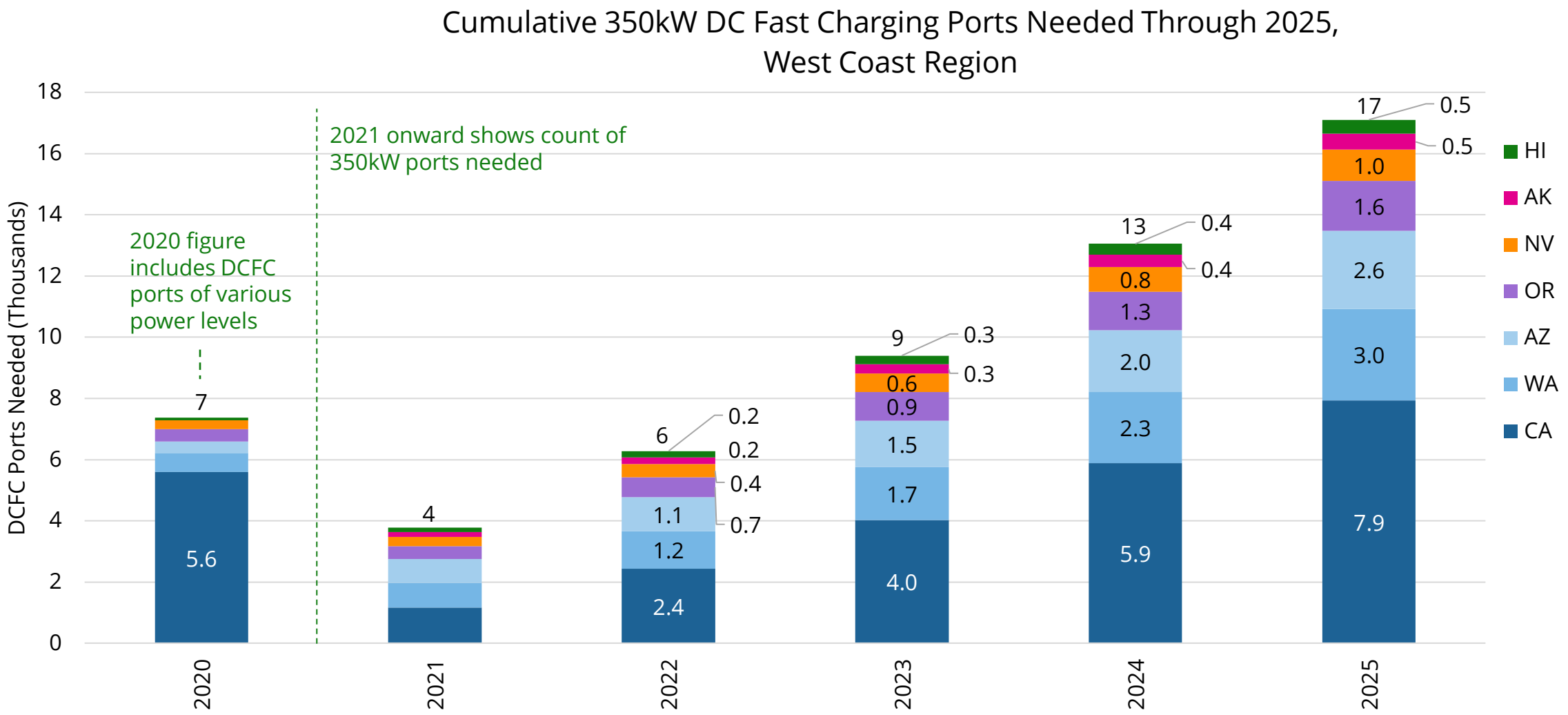
RAPID INCREASE IN PUBLIC CHARGING NEEDED FOR ALL REGIONS



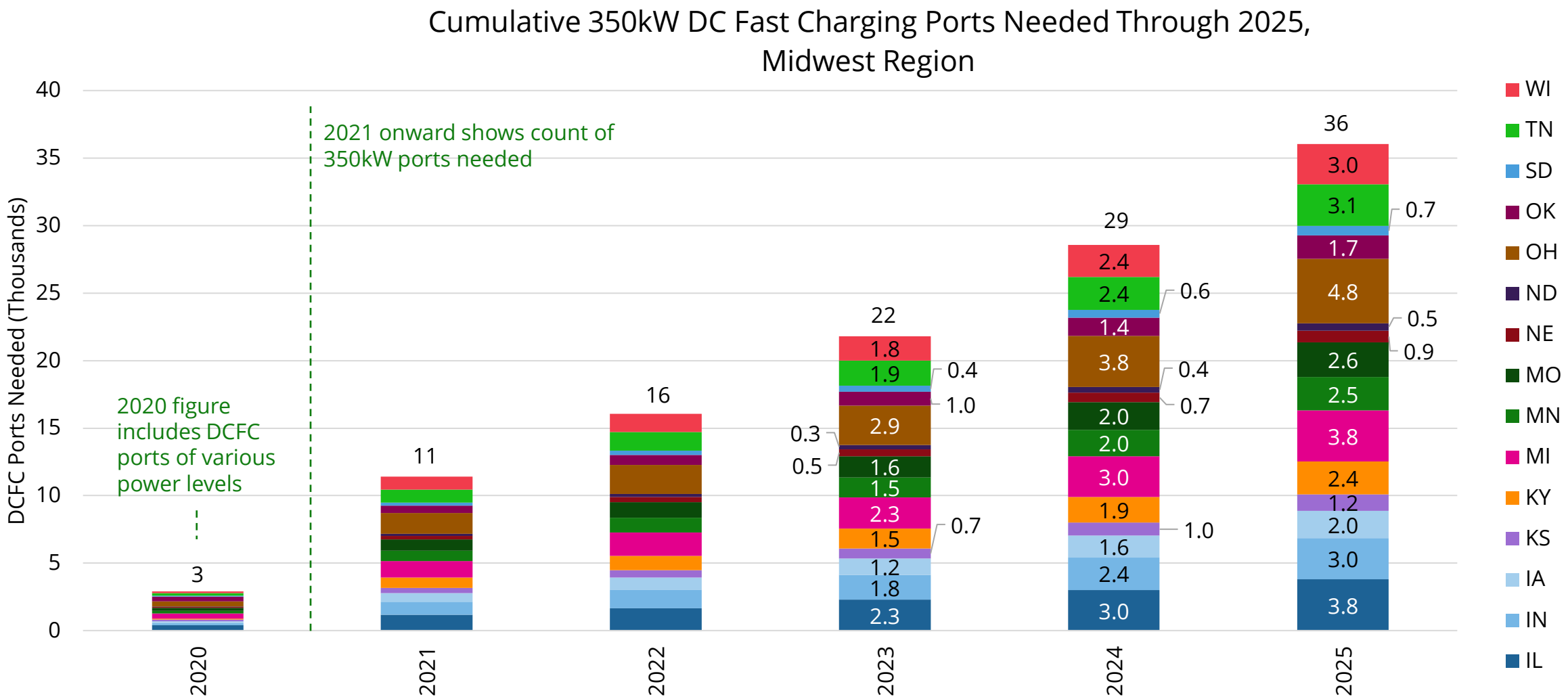
RAPID INCREASE IN PUBLIC CHARGING NEEDED FOR ALL REGIONS



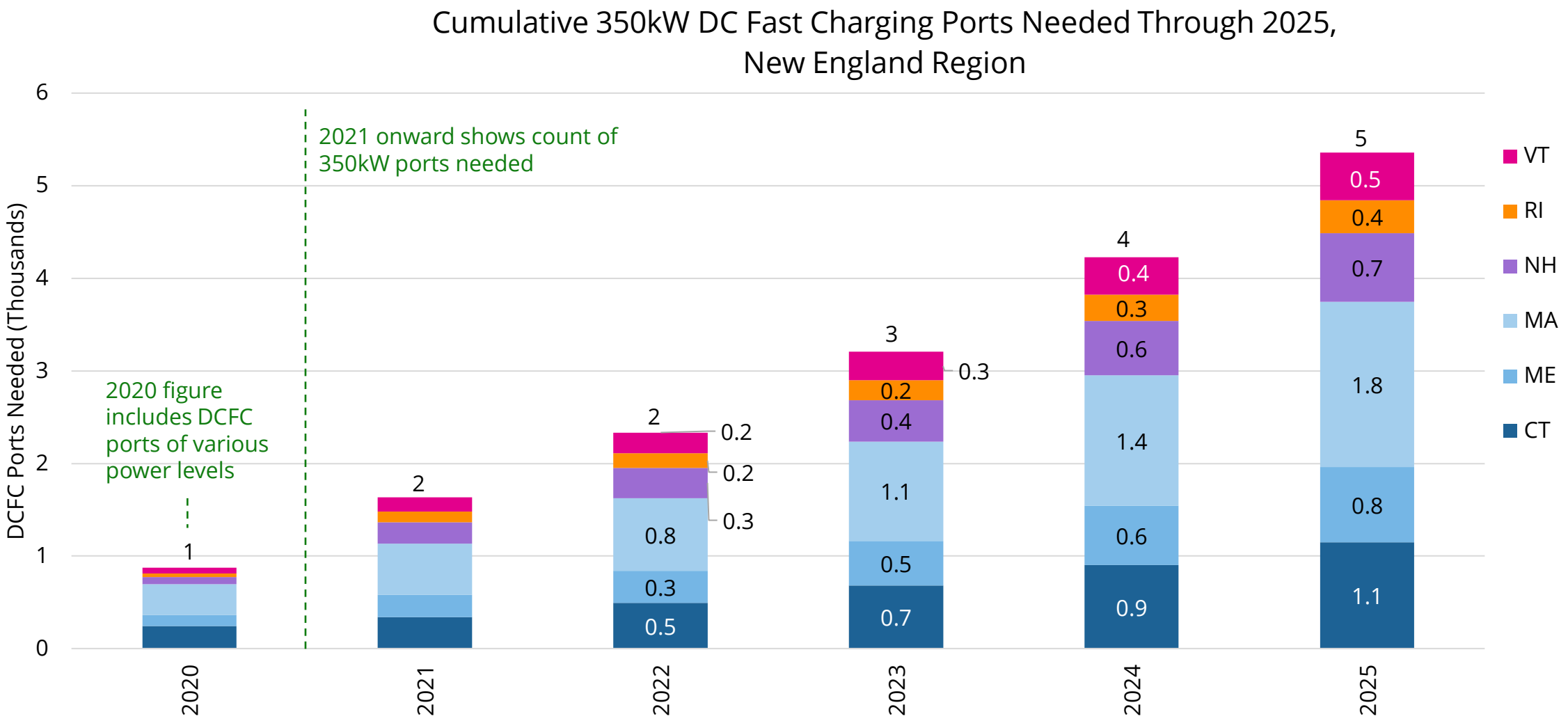
RAPID INCREASE IN PUBLIC CHARGING NEEDED FOR ALL REGIONS



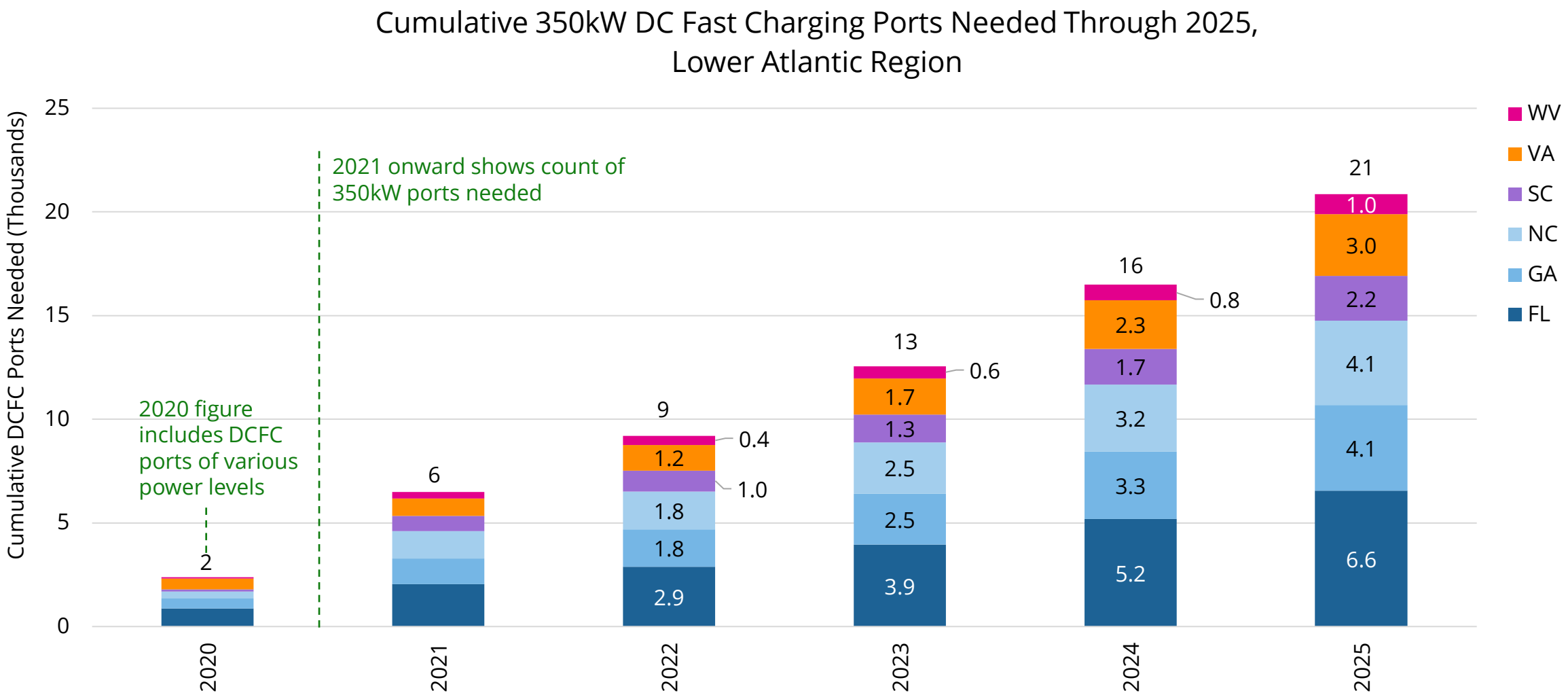
RAPID INCREASE IN PUBLIC CHARGING NEEDED FOR ALL REGIONS



RAPID INCREASE IN PUBLIC CHARGING NEEDED FOR ALL REGIONS



RAPID INCREASE IN PUBLIC CHARGING NEEDED FOR ALL STATES



Other regions show a similarly step increase in needed ports. See Appendices for additional charts.