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INNOVATIVE CHARGING SOLUTIONS FOR DEPLOYING THE NATIONAL CHARGING NETWORK: TECHNOECONOMIC ANALYSIS

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OUTLINE

Background

- Innovative Charging Solutions
- Overview

Methodology

- Overview of Methodology
- Modeling Approach
- HEVISAM Model

Key Assumptions and Inputs

Techno-Economic Analysis Results (Nationwide)

- Baseline Scenario & Sensitivity Analysis
- BES-Integrated DCFC Scenario & Sensitivity Analysis
- PV-Integrated Off-Grid Charging

Deployment Analysis (Nationwide)

Case Study: California

Conclusion

BACKGROUND

Accelerate transportation electrification by leveraging innovative charging solutions

- Recent studies and literature consider only conventional charging approaches in estimating future investment needs for charging infrastructure and associated electric grid upgrades
  - *The 2030 National Charging Network (2023)*[1]*:* $31-55 billion cumulative investment in just the public charging infrastructure itself through 2030
  - *Electrification Impacts Study (2023)*[2]*:* California requires up to $50 billion in distribution grid infrastructure by 2035
- Cost-effectiveness of unconventional and innovative charging solutions needs to be assessed to capture a more holistic outlook for the deployment of public charging infrastructure
  - *CEC (2021)*[3]:

$$\text{Cost of Enabled Charging}\left(\frac{\$}{kWh/year}\right) = \frac{\text{Public Investment}}{\frac{kW * (h_{measured} + h_{projected})}{Station} * \frac{\text{Stations Installed}}{Year}}$$

- **This study provides estimates of public investments associated with station charging load and deployment rate for innovative charging solutions**

1. Wood et al. (2023). The 2030 National Charging Network
2. CPUC (2023). Electrification Impacts Study Part 1.
3. CEC (2021). Assembly Bill 2127 Electric Vehicle Charging Infrastructure Assessment Analyzing Charging Needs to Support ZEVs in 2030. A concept of measuring the cost to enable charging for a solution by comparing its request for public funding to its benefit in terms of energy delivered and speed of deployment.

INNOVATIVE CHARGING SOLUTIONS

- Innovative charging solutions can (1) reduce delays associated with connection to the grid and (2) reduce related costs
- Improved utility planning and operation
  - Flexible interconnection and managed charging
  - Hosting capacity maps
- Charging infrastructure technologies
  - **<u>Integrated distributed generations and storage (focus of this study)</u>**
  - Mobile charging
  - Battery swapping
- Smart and shared charging operations
  - Private charging sharing
  - Smart charge adapter
- These categories of ICS are described on the following slides

IMPROVED UTILITY PLANNING AND OPERATION

Flexible interconnection and managed charging

- Utilities can offer customers non-firm grid service while upgrades are in progress
  - SCE's automated Load Control Management System (LCMS) pilot provides EVSE access to the distribution system sooner than would otherwise be possible while "SCE completes necessary upgrades in areas with capacity constraints"
  - SCE uses LCMS to limit customers' load during peak periods until completing upgrades and providing firm, unrestricted service
- The UL 3141 standard for power control systems (PCS) facilitates flexible interconnection programs
  - Manufacturers can use this standard to develop devices that utilities can use to limit peak period EV charging energy consumption
  - The standard gives utilities a clear technological framework for load control programs to flexibly connect new EVSE more quickly
- Industry, DOE, and national labs are advancing managed charging technologies that avoid grid upgrades
  - Itron announced partnerships with Schneider, GE Vernova, and Mobility House to enable EV charging in constrained grid areas and optimize grid operation to facilitate the connection of more DERs
  - The Energy Services eXchange (ESX) (funded by DOE) is a platform for utilities to manage EV charging across distribution systems

Hosting capacity maps

- Many utilities publish distribution hosting capacity maps indicating to developers where new EV loads and DERs can be readily connected
  - They can focus developer or fleet investments in locations that are more likely to offer fast, low-cost connection

SMART AND SHARED CHARGING OPERATIONS

Private charger sharing

- Opening private chargers up for public use can increase the value of existing private stations and provide additional revenue to the owner of the charger
- One company that facilitates the sharing and renting of EV charging stations is EVMatch
  - EVMatch developed a software platform for sharing, reserving, and renting EV charging stations, which allows charging station owners to serve more EV drivers and earn additional revenue, maximizing the benefit of each deployed charger
  - The city of Burlington, Vermont, launched a program to offer larger rebates for chargers installed at multi-unit dwellings that are available to the public between 9am and 5pm using EVMatch's software
- By allowing greater utilization of chargers, sharing installed EVSE can improve the materials and time deployment effectiveness of the EVSE serving EV demands

Smart charge adapter

- EVMatch is also rolling out a new product called the EVMatch adapter in partnership with Argonne National Laboratory
- The EVMatch adapter is a smart charging adapter that can turn any Level 1 or 2 EVSE into a smart charger that can remotely monitor and control charging to enable even more efficient utilization of existing chargers

CHARGING INFRASTRUCTURE TECHNOLOGIES

Integrated distributed generation and storage

- Battery- and PV-integrated charging are analyzed in detail in this study
- Additional technologies including traditional generators, linear generators (such as MainSpring's), and fuel cells can also be used to provide on-site power and limit the need to draw power from the grid

Mobile charging

- Mobile EV chargers move to charge EVs in different places and provide power from batteries or generators
- Mobile chargers that use batteries can be recharged where it's easier or cheaper to access the grid
- Examples include battery-powered DC fast chargers from Lightning eMotors and Sparckcharge, Blink's generator-powered charger for roadside assistance, and EV Safe Charge's robotic mobile EV charger

Battery swapping

- An alternative business model for EV charging in which depleted batteries are removed from EVs and replaced within minutes with fully charged batteries, instead of charging at fast charging stations
- Recharging is fast for the customer, but the batteries can be recharged slowly to reduce grid strain
- The company Ample had deployed several dozen battery swapping stations in California as of 2023

OVERVIEW

Objective: How can innovative charging solutions (ICS) defer required distribution grid investments to support faster deployment of the national charging network?

Bottom-up techno-economic analysis of ICS impacts on levelized cost of charging (LCOC)

- Establish baseline *LCOC ($/kWh)* and *capital investment ($/station),* including the charging infrastructure and distribution grid upgrades under TEIS 2032 scenario*
- Characterize alternative charging scenarios enabled by ICS
- Evaluate the delta in LCOC across ICS scenarios compared to the baseline scenario

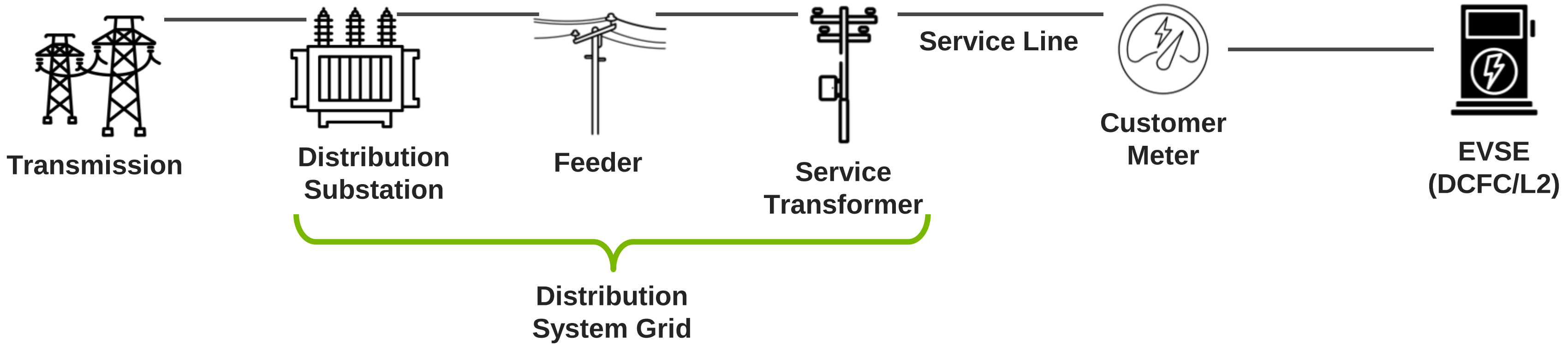
Analysis of ICS potential to expedite charging infrastructure deployment

- Estimate deployment timeframes and identify constraints across grid-upgrade and ICS
- Generate potential strategies to facilitate the deployment of the public charging network required under TEIS 2032 scenario*
- Evaluate delta in *grid capacity (kW)-year* savings across deployment strategies enabled by ICS

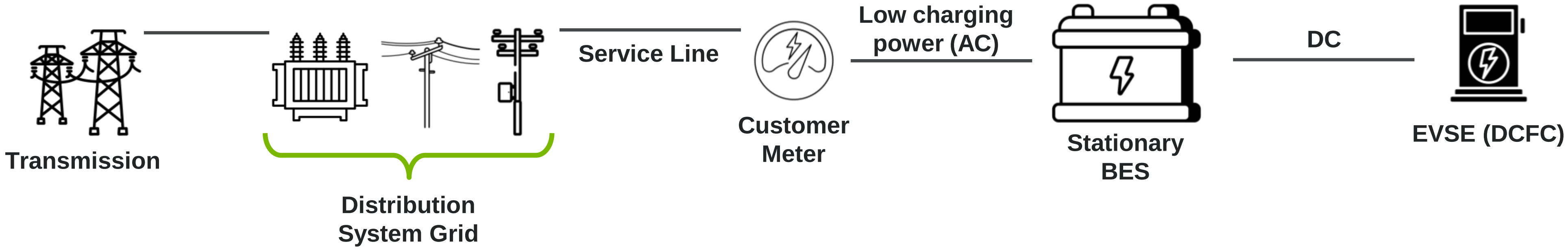
*Forthcoming, *Multi-State Transportation Electrification Impact Study (2024)*

CONSIDERED INNOVATIVE CHARGING SOLUTIONS

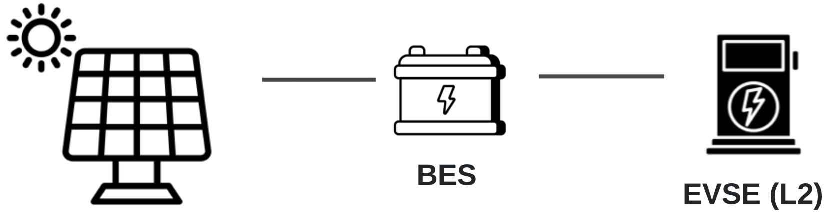
Grid-Upgrade (Baseline)



Battery Energy Storage (BES)-Integrated DCFC



PV-Integrated Charging (Off-Grid)



***Note:** The innovative charging solutions listed are not exhaustive and do not preclude other technologies or potential innovative charging solutions from being cost-effective.*

Sources of icons in flowcharts: "Car battery" by Rabiya Anwer, "Electric pole" by SetiawanAP Design Works, "EV" by Uswa KDT, "Power line" by Olena Pavasovska, "Power line" by Fran Couto, "Power meter" by Aneka Rosariana, "Power transformer" by SAM Designs, "Power meter" by Aneka Rosariana, "Solar panel" by ProSymbols. From Noun Project (CCBY3.0), www.thenounproject.com.

COMMERCIAL EXAMPLES

BES-Integrated DCFC

- FreeWire Boost Charger 200
- Jule Hub / Chargers

PV-Integrated Charging (Off-Grid)

- BEAM EV ARC
- Paired Power




Image Source: https://www.pexels.com/

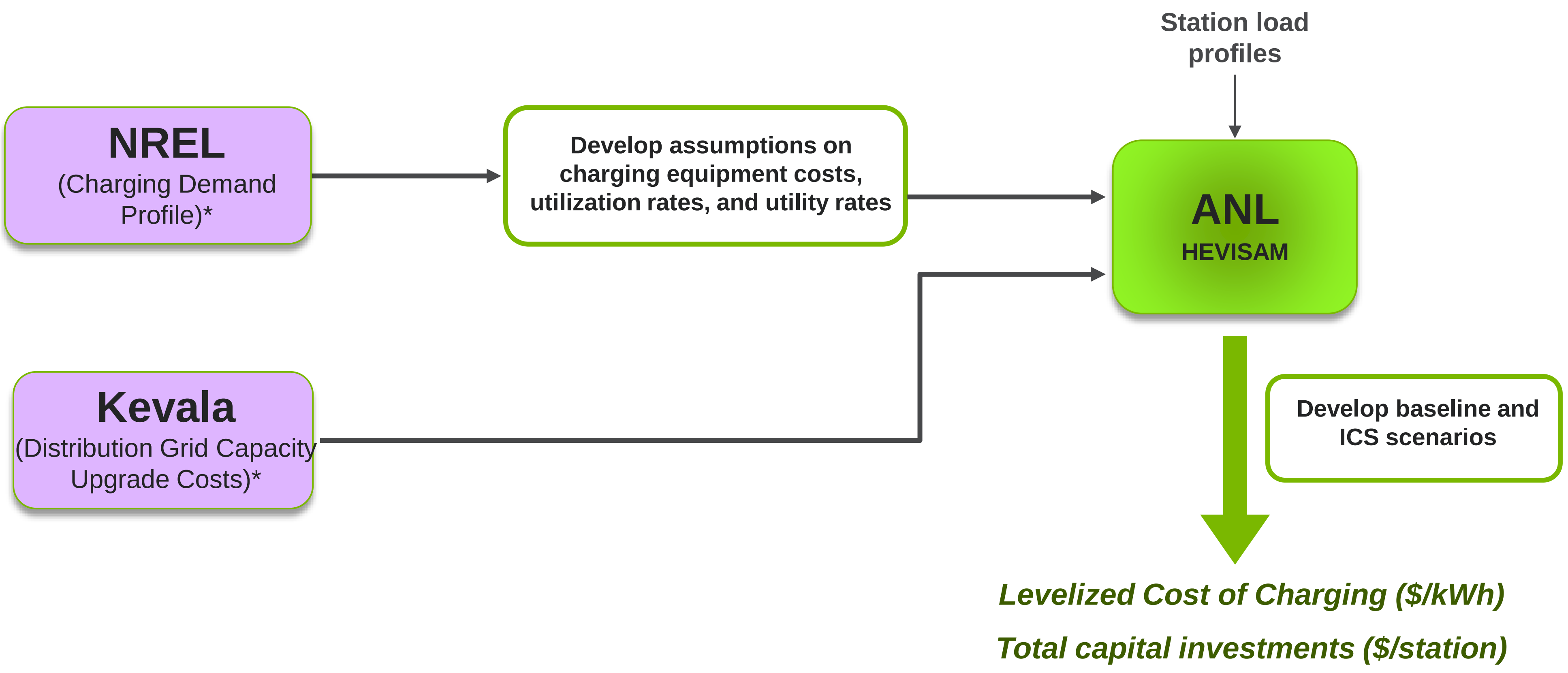
KEY TAKEAWAYS

from techno-economic analysis

- **Electricity rates and station utilization** rate are the major drivers of levelized cost of charging ($/kWh) across all regions and charging scenarios
- Battery energy storage mitigates peak load of a DCFC station, which can lead to sizeable **demand charge savings** and avoid **grid capacity upgrade delays**
- PV-integrated off-grid charging can potentially achieve **charging cost parity** with current tax incentives, while offering significant **deployment rate and emissions benefits**

METHODOLOGY

OVERVIEW OF METHODOLOGY



*Forthcoming, *Multi-State Transportation Electrification Impact Study (2024)*

MODELING APPROACH

***Station utilization rate is a key cost driver**

***Utility rate is another key cost driver**

Assumptions on station size

Assumptions on station utilization rates

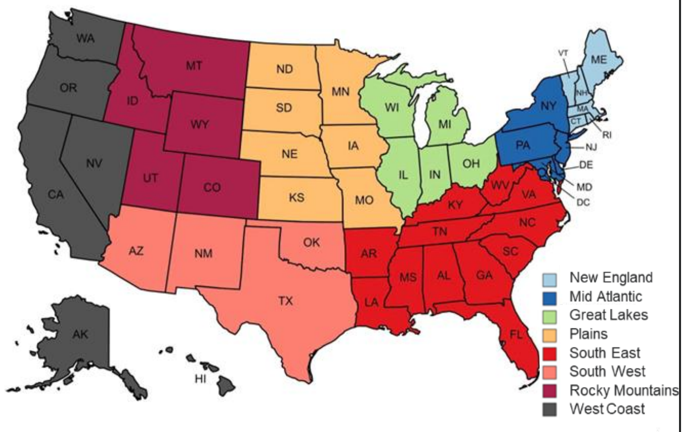
Utility rates by region

County-level PEV charging demand profiles

Station charging profiles

HEVISAM

Aggregate county-level charging demand profiles to regions



Source: The Bureau of Economic Analysis

Check for average distance between stations (<5 miles in major metro cities)

Station-Level Results:
- *Levelized Cost of Charging*
- *Capital Cost of Investment*

HEVISAM: A TEA TOOL THAT EVALUATES LEVELIZED COST ($/KWH) OF CHARGING SCENARIOS OF BEVS

Inputs

Station Configurations
- w/ or w/o battery storage
- - Equip. type
  - # of charging points

Fleet Parameters
- Fleet type and size
- Vehicle charging schedule
- Battery charging profile

Cost Data
- Equipment cost
- Electricity rates

Economic and financial inputs

Outputs

Station Capital and O&M Costs
- Direct capital investment
- Other capital investment
- O&M and energy

Output Cost Information
- Levelized cost ($/kWh)
- Cash flows

https://hdsam.es.anl.gov/index.php?content=hevisam

HEVISAM= Heavy-Duty Battery Electric Vehicle Infrastructure Scenario Analysis Model
TEA = Techno-Economic Analysis

KEY ASSUMPTIONS AND INPUTS

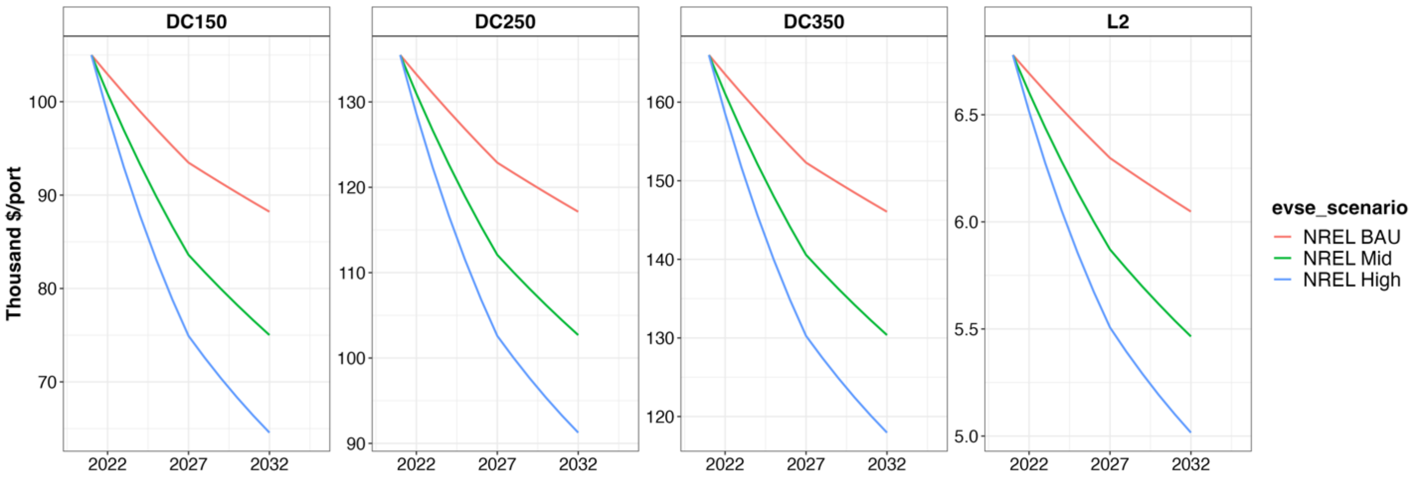
EVSE CAPITAL COST ASSUMPTIONS

- EVSE capital costs include:
  - **Charging equipment costs**
  - **Installation costs** (labor and materials for construction on the customer side of the meter)
- Learning rates applied to base-year EVSE costs to estimate future cost reduction

Base-Year EVSE Capital Cost Assumptions[1]

Charger Hardware	Unit Cost per Port in 2021	Installation Cost per Port in 2021
L2	$2,696	$3,810
DC 150 kW	$69,000	$36,000
DC 250 kW	$75,500	$60,000
DC 350 kW	$82,000	$84,000

Projected EVSE installed capital cost trajectories for 2021-2032 (Action scenario)[2]

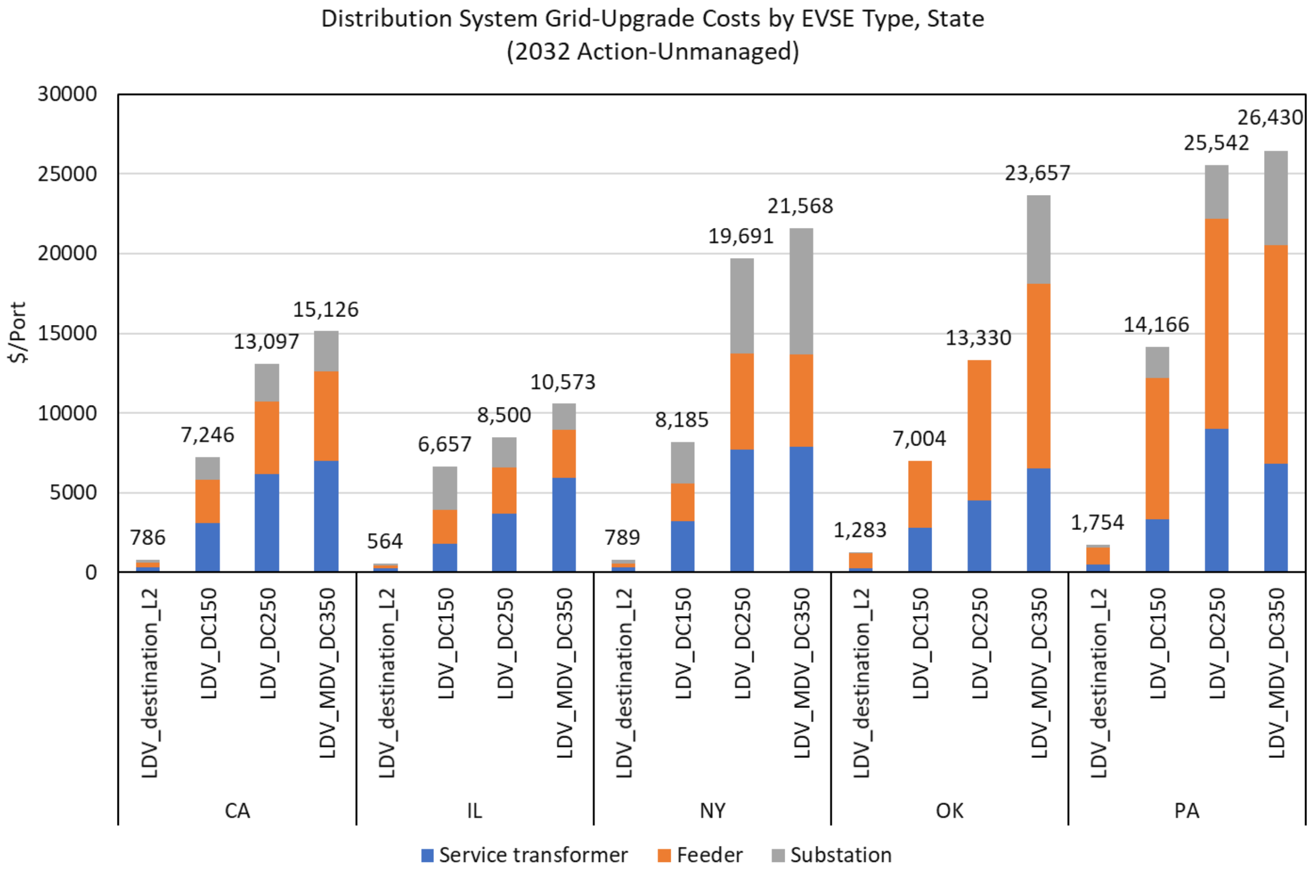


1. *Bloomberg New Energy Finance (2022)*
2. forthcoming, *Multi-State Transportation Electrification Impact Study (2024)*

DISTRIBUTION SYSTEM GRID-UPGRADE COSTS

Kevala/TEIS provided results for 5 States and national averages

- Grid-upgrade costs are from Kevala/TEIS[1]: distribution grid infrastructure necessary to support EV charging load across adoption scenarios
  - This study considers total upgrade cost and does not account for each utility's cost allocation of upgrades to customers
- In this study, these cost estimates are used as **to-the-meter (utility side of the meter)** infrastructure costs for **state-level** analysis of these 5 states only.

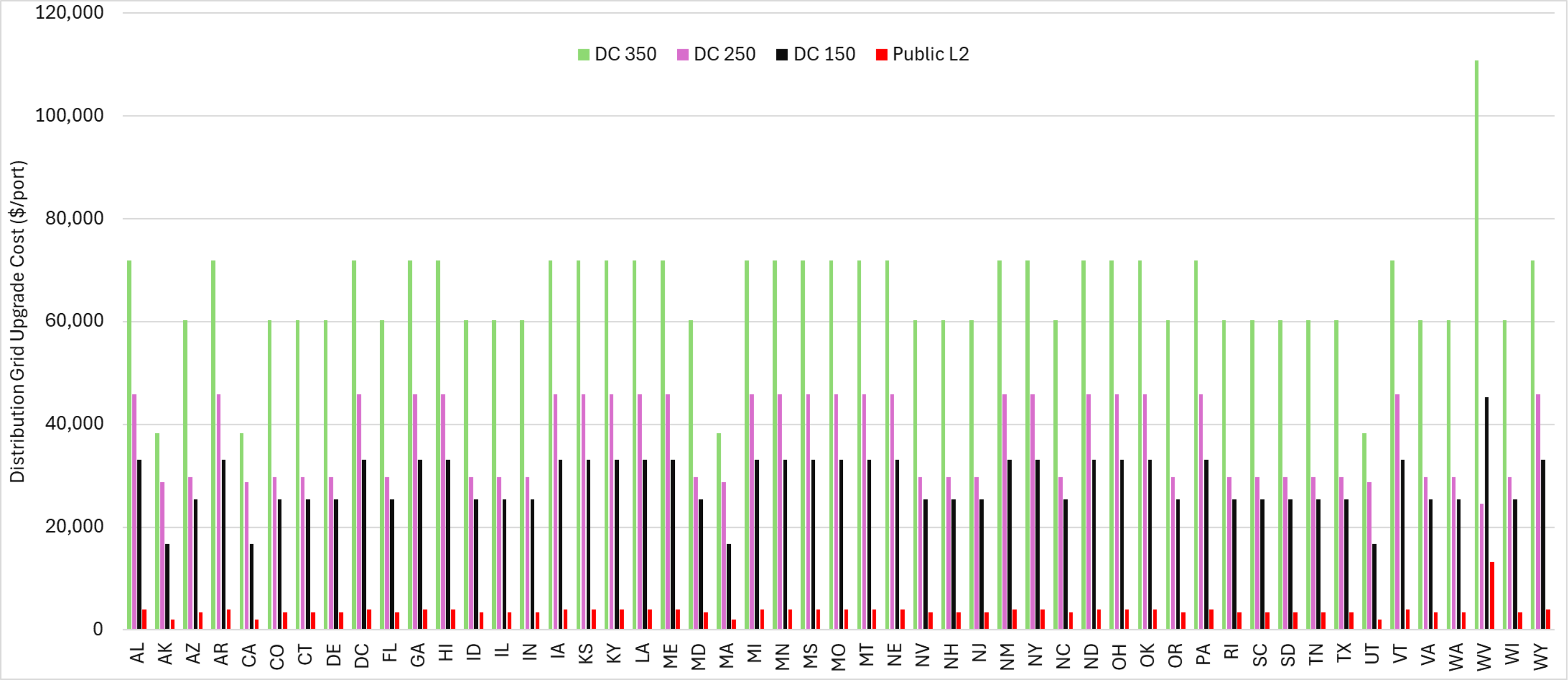


1. forthcoming, *Multi-State Transportation Electrification Impact Study (2024)*

DISTRIBUTION SYSTEM GRID-UPGRADE COSTS[1]

National Averages

- **Region-level** analysis for national results in this study assume extrapolated cost estimates for all states (including the 5 states) from the 5-state results shown on the previous slide
- In practice, baseline grid upgrade costs are likely to be lower than current assumptions because developers would seek alternative charging solutions (BES-integration) at highly grid-constrained locations
- While this study uses the average values shown below, note that actual grid upgrade costs vary across locations



1. forthcoming, *Multi-State Transportation Electrification Impact Study* (2024)

KEY INPUTS: BASELINE

Base Case

	Public L2	DCFC
Station Size	10 ports (19 kW)	10 ports (4 DC150, 3 DC250, 3 DC350)
Peak Hour Utilization	55% (Average daily utilization: 20%)	20% (Average daily utilization: 10%)
EVSE Costs	2032 Mid EVSE cost scenario	
Grid-Upgrade Costs	National extrapolation estimates ($/port)[1]	
Utility Rates (TOU & Demand Charges)	Representative utility rates in each region[2]	
Construction Period	1 year	3 years[3]

Alternate Cases

	Public L2	DCFC
Station Size	5,10,20 ports	5,10,20 ports
Peak Hour Utilization	55-80% (Average daily utilization: 20-50%%)	20-50% (Average daily utilization: 10-30%)
EVSE Costs	2032 Low & High EVSE cost scenarios	
EVSE tax credit eligibility (IRA 30C)	(0-30% of EVSE costs)	
Station construction type	Conventional / Pre-fabricated[4]	
Grid-Upgrade Costs	National extrapolation estimates ($/port)	
Utility Rates (TOU & Demand Charges)	**Low**: lowest utility rate in the region **High**: highest utility rate in the region	
Construction Period	1 year	3 years

1. forthcoming, *Multi-State Transportation Electrification Impact Study (2024)*
2. *Utility rates Database (OpenEI).* This analysis assumes current rate schedules and does not project future electricity prices.
3. Assuming projects experience 2 years of delays on average due to transformers shortage, utility service energization, and distribution capacity upgrades (https://efiling.energy.ca.gov/GetDocument.aspx?tn=250051&DocumentContentId=84769)
4. Pre-fabricated units correspond to 15% reduction in EVSE installation costs (https://insideevs.com/news/657795/tesla-shows-how-prefabricated-supercharger-units-save-time-costs/)

KEY INPUTS: BES-INTEGRATED DCFC

Base Case

	Baseline DCFC	BES+DCFC
Station Size	10 ports (4 DC150, 3 DC250, 3 DC350)	
Peak Hour Utilization	20% (Average daily utilization: 10%)	
EVSE Costs	2032 Mid EVSE cost scenario	
BES Size[1]	NA	~1200 kWh
BES Costs[2]	NA	\$157/kWh \$677/kW
BES Manufacturing Tax Credit[3]	NA	(\$45/kWh)
BES Investment Tax Credit[4]	NA	(30% of BES costs)
Grid-Upgrade Costs[5]	National extrapolation results (\$/port)	National extrapolation results (per port cost equivalent to L2)
Utility Rates (TOU & Demand Charges)	Representative utility rates in each region	
Construction Period	3 years	1 year

Alternate Cases

	Baseline DCFC	BES+DCFC
Station Size	5,10,20 ports	
Peak Hour Utilization	20-50% (Average daily utilization: 10-30%)	
EVSE Costs	2032 Low & High EVSE cost scenarios	
BES Size[1]	NA	~1200 kWh
BES Costs[2]	NA	\$134-\$220/kWh \$487-\$797/kW
BES Manufacturing Tax Credit[3]	NA	(\$45/kWh)
BES Tax Credit[4]	NA	30%
EVSE tax credit eligibility (IRA 30C)	(0-30% of EVSE costs)	
Grid-Upgrade Costs[5]	National extrapolation results (\$/port)	Low: cost equivalent to a public L2 port High: cost equivalent to a DC150 port
Utility Rates (TOU & Demand Charges)	**Low**: lowest utility rate in the region	
	High: highest utility rate in the region	
Construction Period	3 years	1 year

1.BES size depends on daily charging load, and it is optimized to minimize LCOC based on regional utility (TOU and demand charges) rates.
2. NREL ATB (2023). The cost of a battery-integrated DCFC system has not been studied in detail, but there could potentially be significant system-level cost-savings due to fewer power conversion steps required for the battery to discharge in DC power to the DC chargers. The lower end estimate accounts for battery inverter savings.
3.Publication 5886 (11-2023) (irs.gov)
4.Battery Storage Technology Tax Credit | ENERGY STAR
5. The level of grid-upgrades for a BES+DCFC station is assumed to have lower and upper bound corresponding to public L2 and DC150 grid-upgrade costs per port, respectively. The upper bound is chosen conservatively to test the sensitivity of per-port grid upgrade cost.

KEY INPUTS: PV-INTEGRATED OFF-GRID CHARGING

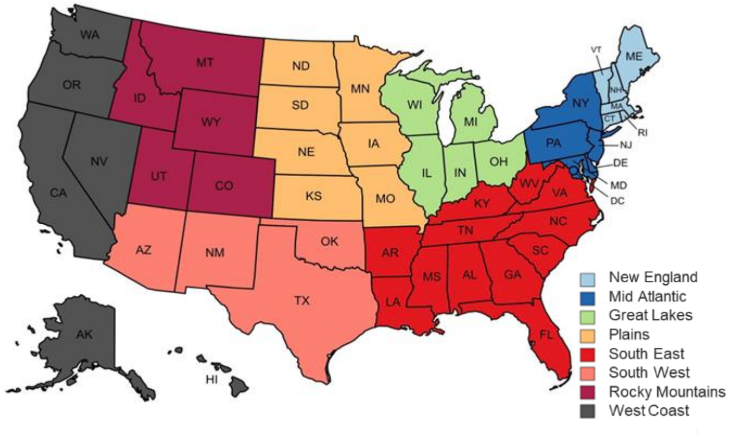
		Case-A	Case-B	Case-C
		5 kW Canopy (Avg. Unit Cost from OEMs)	5 kW Canopy (Cost Estimate from ATB[2])	10 kW Detached PV (Cost Estimate from ATB[2])
Capacity (Per Unit)	PV Power	5 kW	5 kW	10 kW
	Charger	8 kW	8 kW	16 kW
	BES	20 - 30 kWh	20 - 30 kWh	40 - 60 kWh
	Annual Avg. Energy Generation[1]	14.8 – 24.13 kWh/unit-day	14.8 – 24.13 kWh/unit-day	29.6 – 48.26 kWh/unit-day
Cost Data (Per Unit)	PV+BES System[2] (20 kWh BES integrated)	-	$1,045/kW	$1,045/kW
	Additional cost for BES larger than 20 kWh[3]		$157/kWh $677/kW	$157/kWh $677/kW
	Charger[6]	-	$6,439	$6,439
	Final Cost	$39,000[5]		
	After Tax-credit[4]	$23,400		
	Miscellaneous	-	$5,000	$5,000
Station Parameters	Number of units in station	10		
	Daily Fleet	10		
	Average Energy Dispensed to BEV	14.8 – 24.13 kWh	14.8 – 24.13 kWh	29.6 – 48.26 kWh
	Average Daily Utilization	10%		

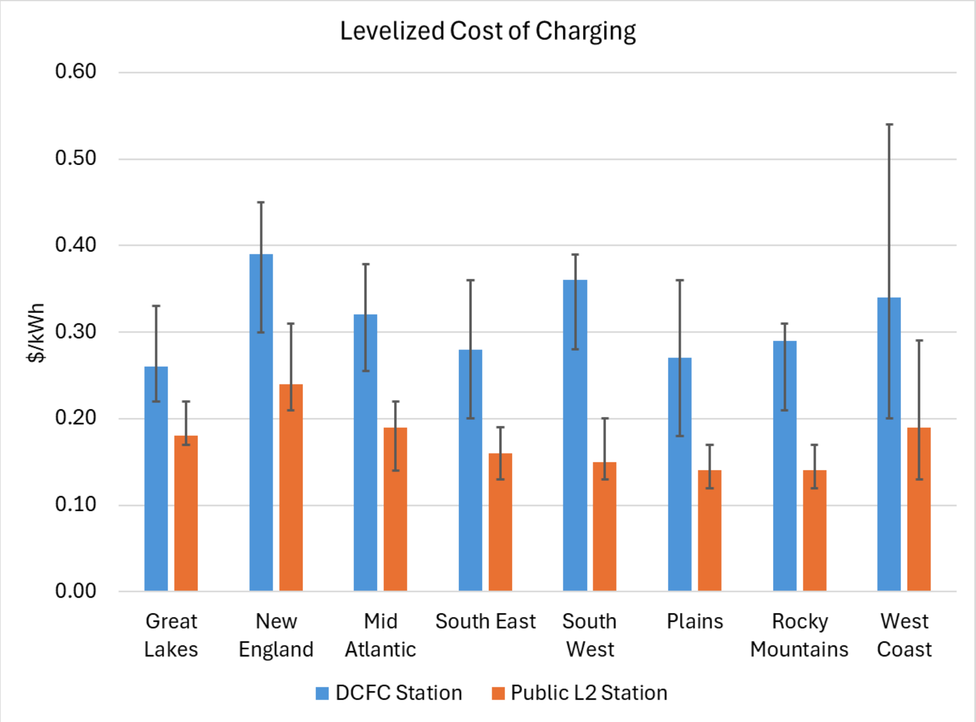
1. Solar Energy Production PV Watts: Solar irradiation and corresponding PV generation capacity varies across regions.
2. Utility-Scale PV-Plus-Battery | Electricity | 2022 | ATB | NREL
3. Commercial Battery Storage | Electricity | 2022 | ATB | NREL
4. Clean Electricity Investment Tax Credit (IRA 48E)
5. Unit cost obtained directly from OEMs followed by learning-rate applied to get reduced cost in 2032
6. ANL/NREL Estimate for 2032

NATIONAL RESULTS:
Baseline Scenario

BASELINE LEVELIZED COST OF CHARGING BY REGION VARIES WIDELY WITH UTILITY RATES

- Under TEIS action scenario* in 2032, median baseline LCOC ranges between **$0.26-0.39/kWh for DCFC** and **$0.14-$0.24/kWh for Public L2** across all regions
- Includes utility-side distribution grid-upgrade costs
- This analysis does not address cost allocation as costs assigned to the project developer vary in practice
  - For instance, utility-side grid upgrade costs could be allocated to ratepayers

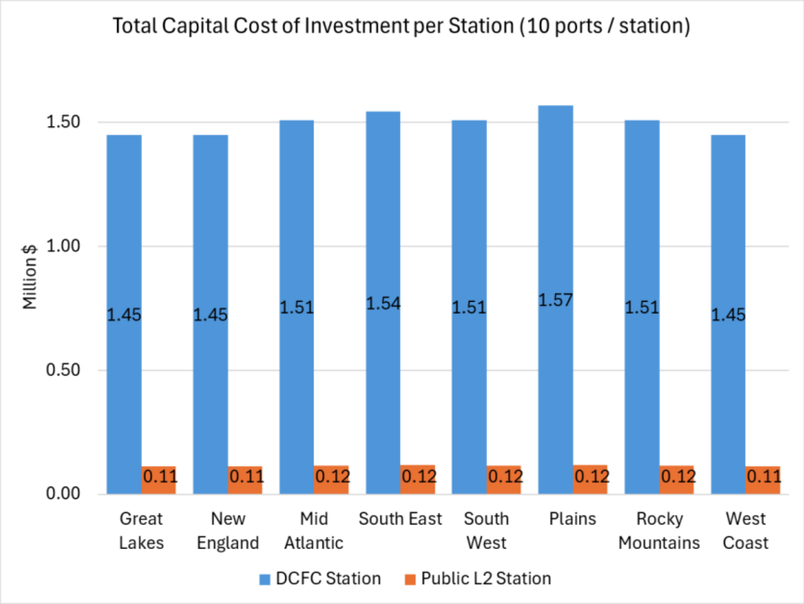


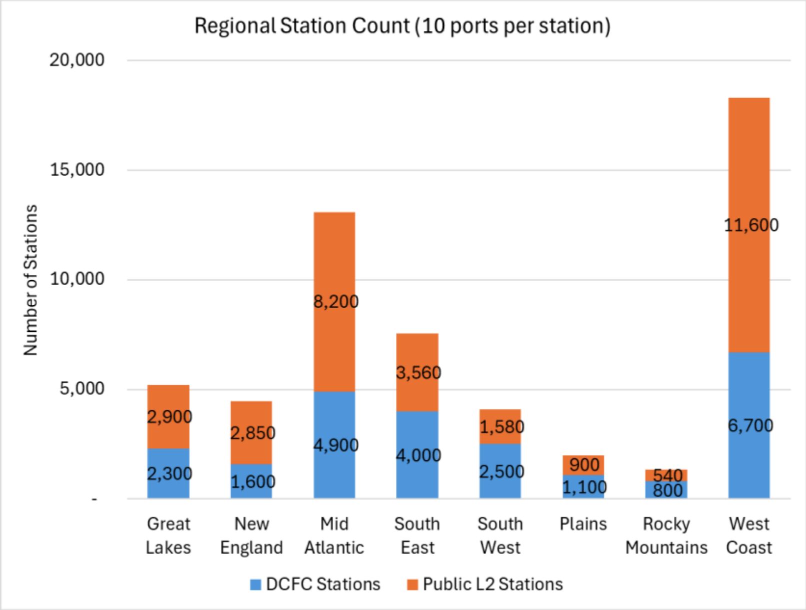


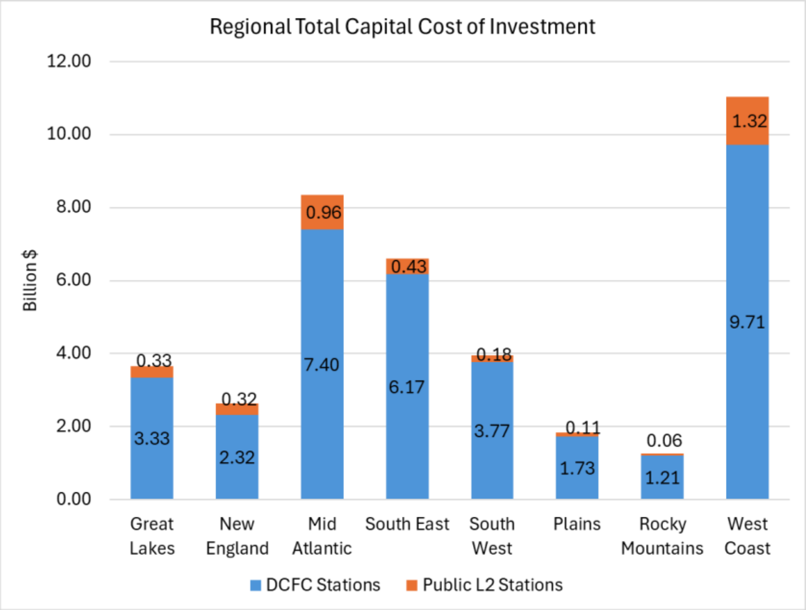
*Forthcoming, *Multi-State Transportation Electrification Impact Study (2024)*

PUBLIC CHARGING INFRASTRUCTURE CAPITAL INVESTMENT VARIES BY REGION

- Total capital investment needed by 2032 to support PEVs **(Class 1-3)** public charging needs under TEIS action scenario:
  - DCFC (DC150, DC250, DC350): **$36 Billion**
  - Public L2: **$3.7 Billion**
- Includes utility-side distribution grid-upgrade costs
- Does not include any L1, private, or depot EVSE types.



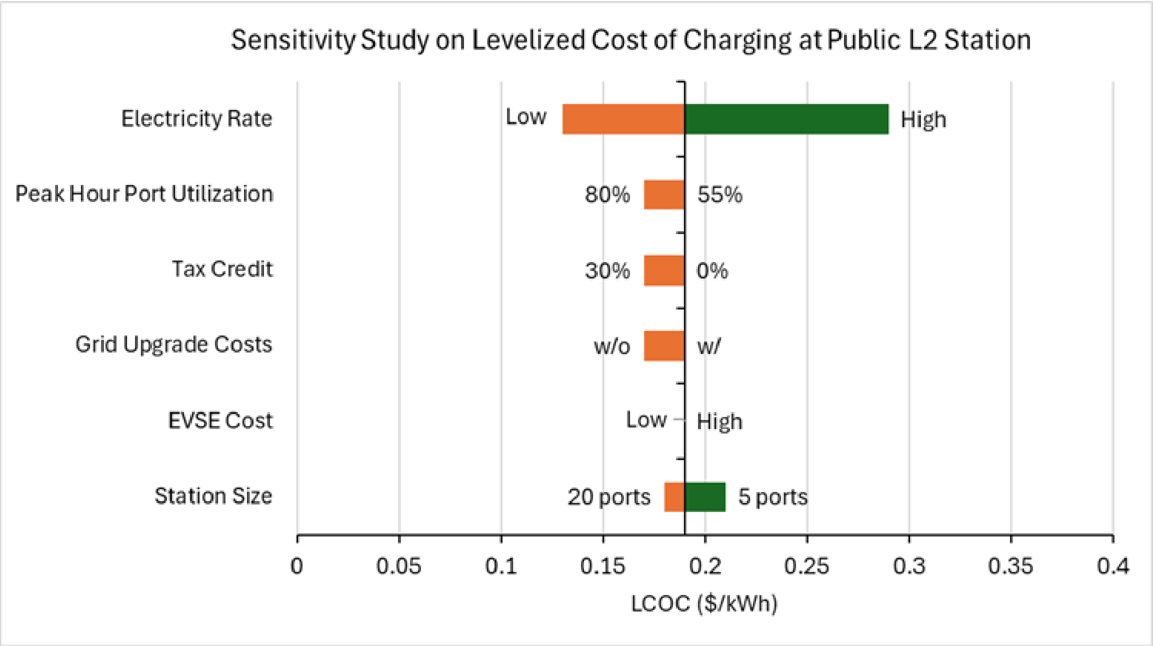


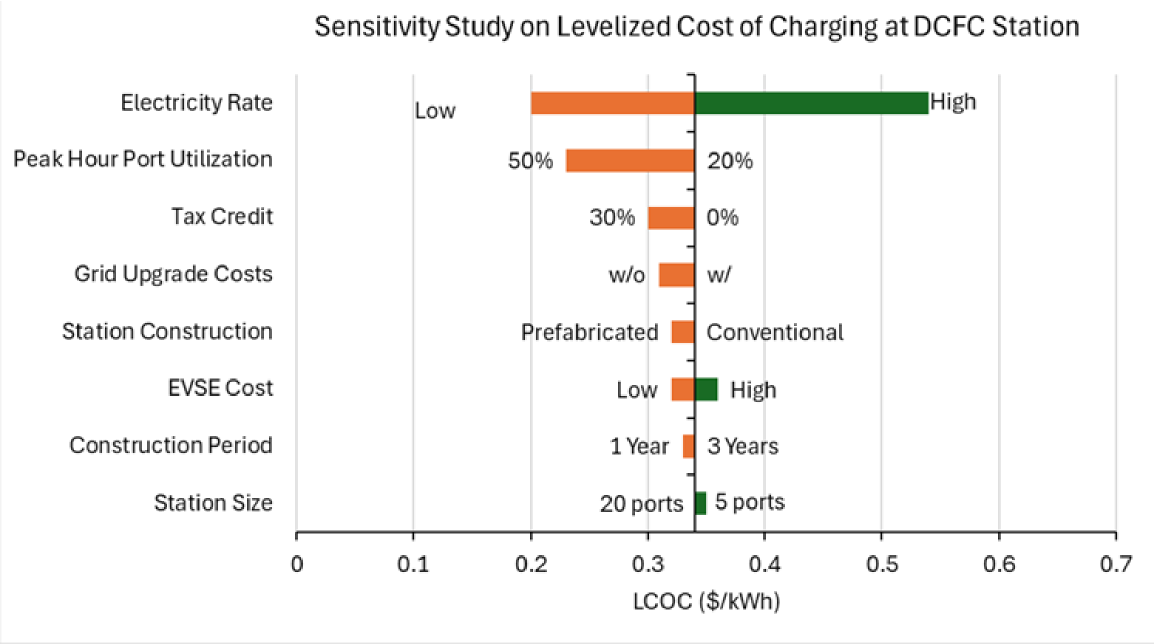


UTILITY RATES AND STATION PORT UTILIZATION RATES ARE TWO KEY COST DRIVERS OF LCOC

West Coast

- Baseline LCOC for West Coast DCFC stations can range from **$0.20-0.54/kWh** due to utility rates
- Higher station port utilization in the future can also significantly reduce charging costs[1]

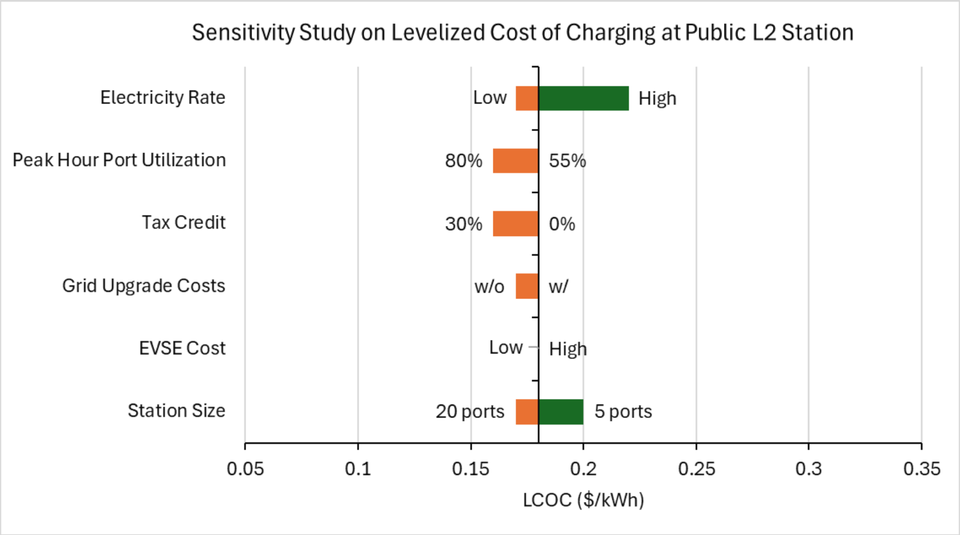




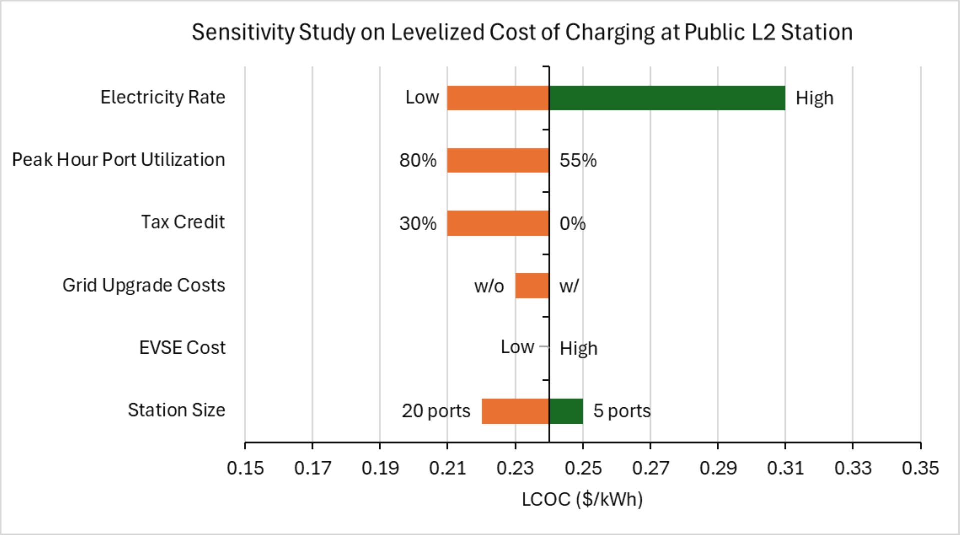
1. RMI (2019), DCFC Rate Design Study. A mature EV market could experience DCFC station average utilization rate of up to 30% (corresponding to ~50% peak hour utilization in this simulation).
https://rmi.org/wp-content/uploads/2019/09/DCFC_Rate_Design_Study.pdf

SENSITIVITY ANALYSIS – PUBLIC L2

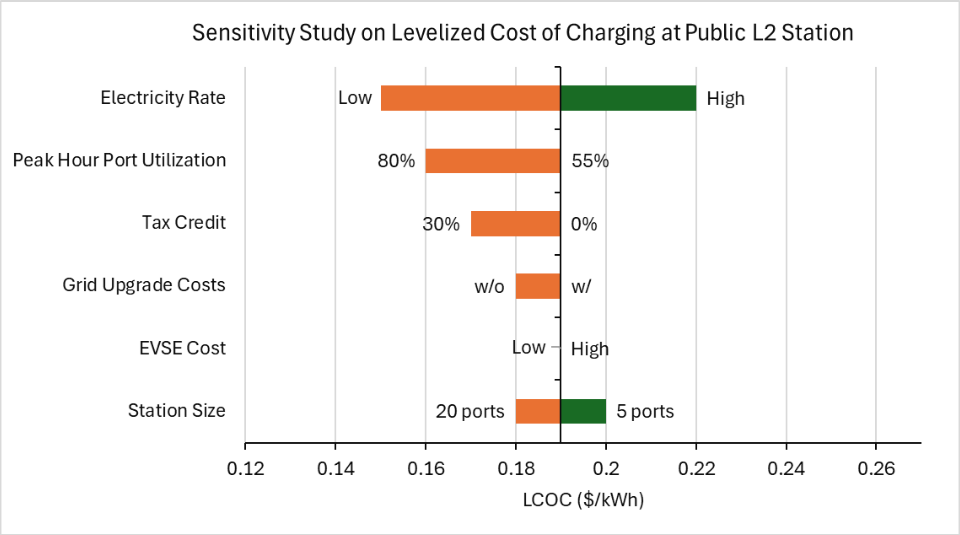
Great Lakes



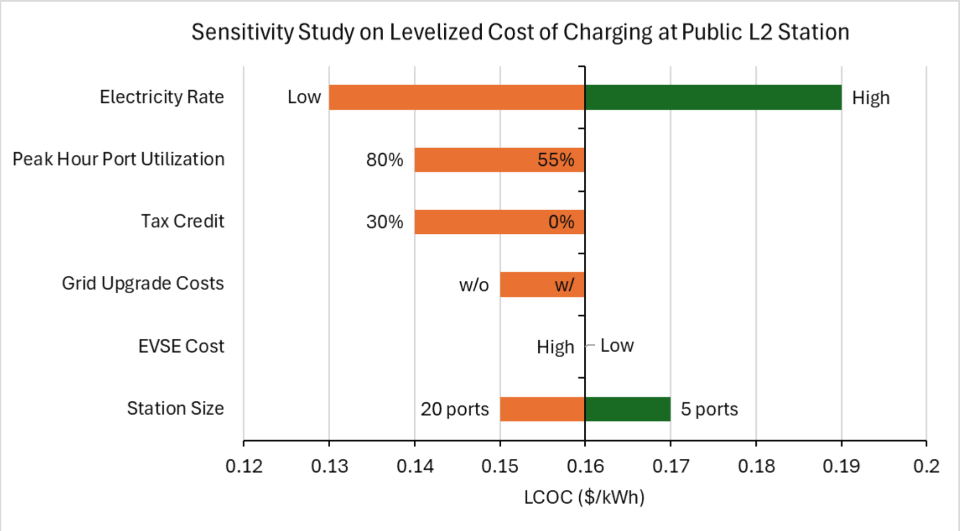
New England



Mid Atlantic

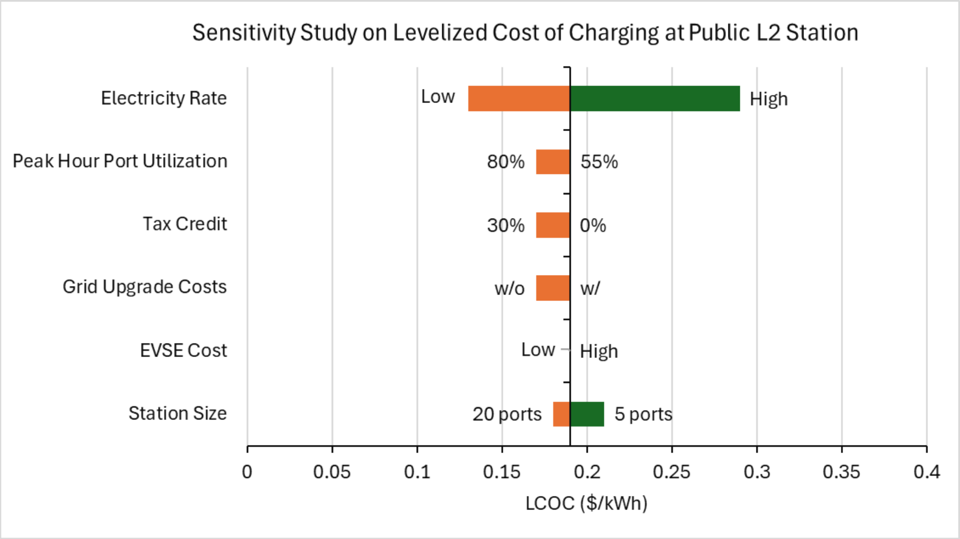


South East

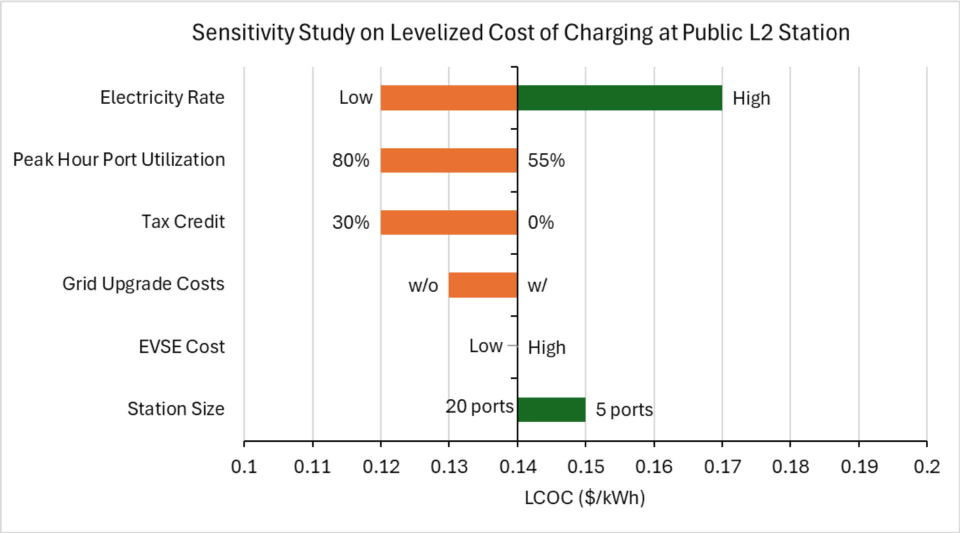


SENSITIVITY ANALYSIS – PUBLIC L2

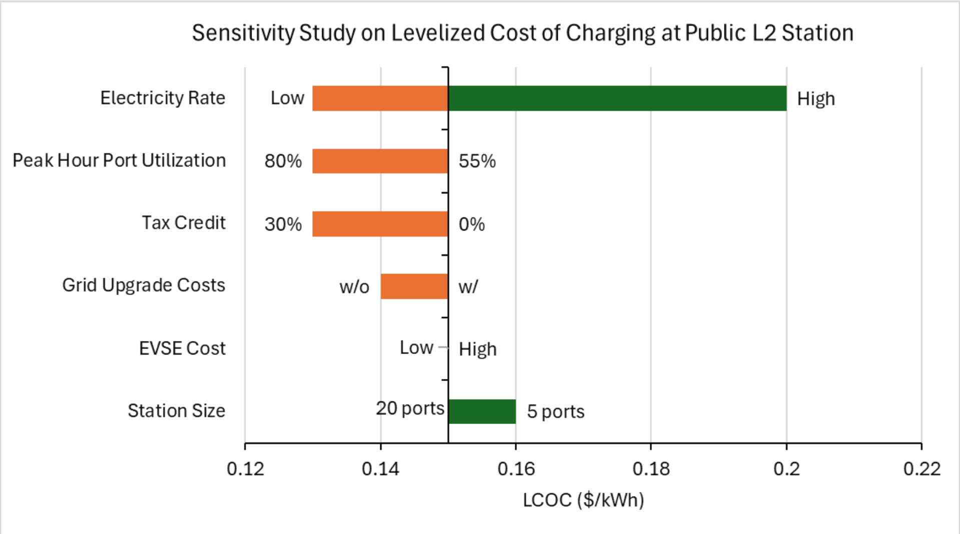
West Coast



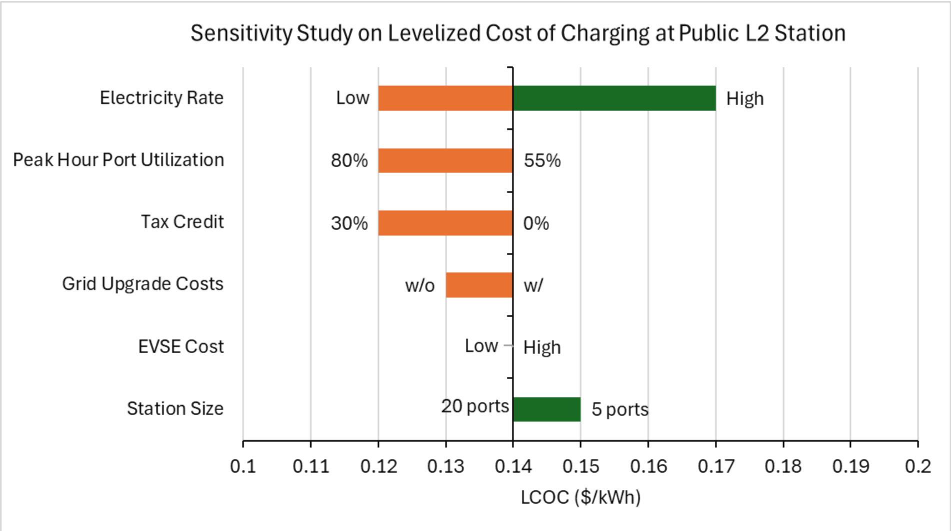
Rocky Mountains



South West

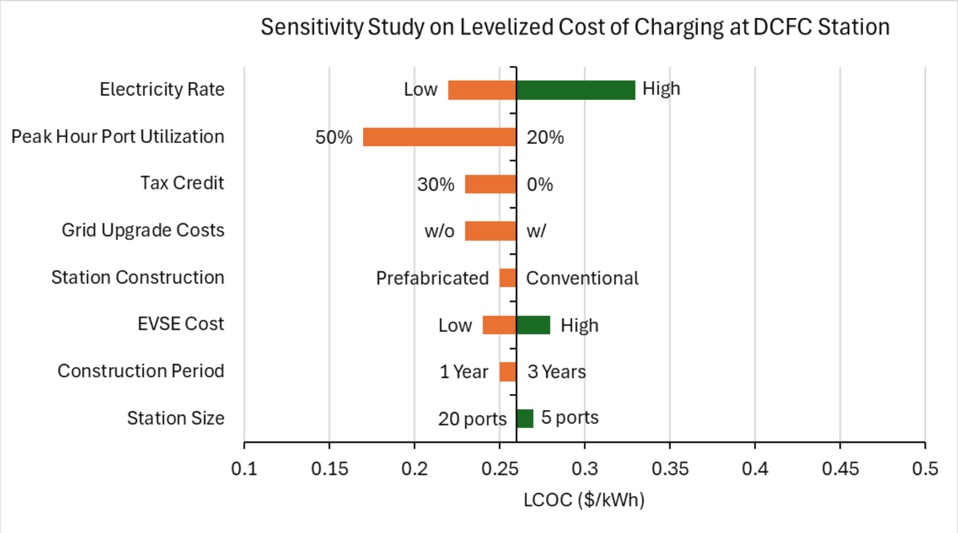


Plains

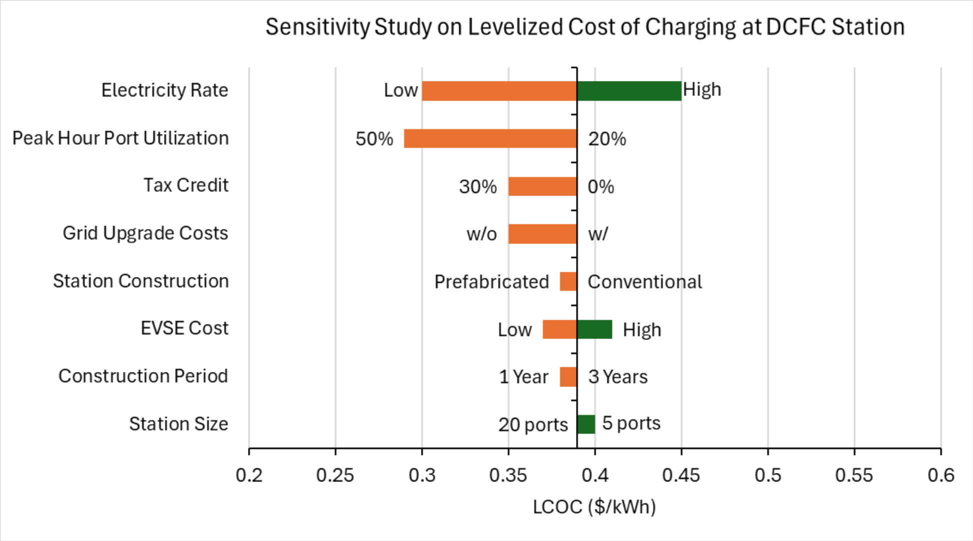


SENSITIVITY ANALYSIS – DCFC

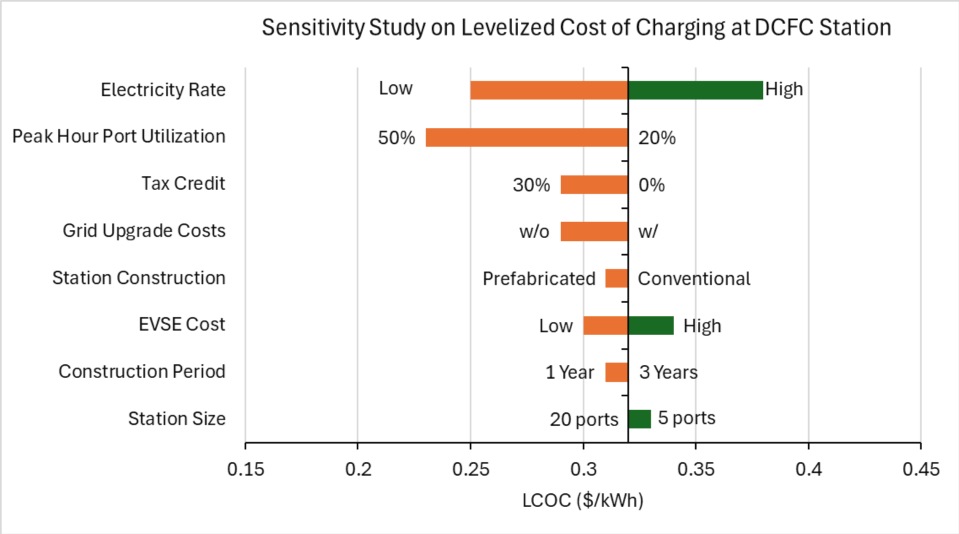
Great Lakes



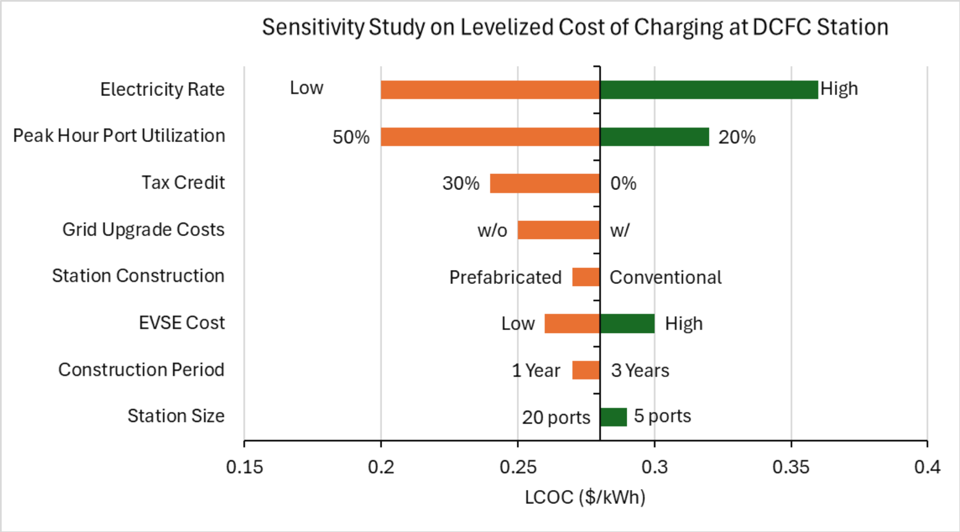
New England



Mid Atlantic

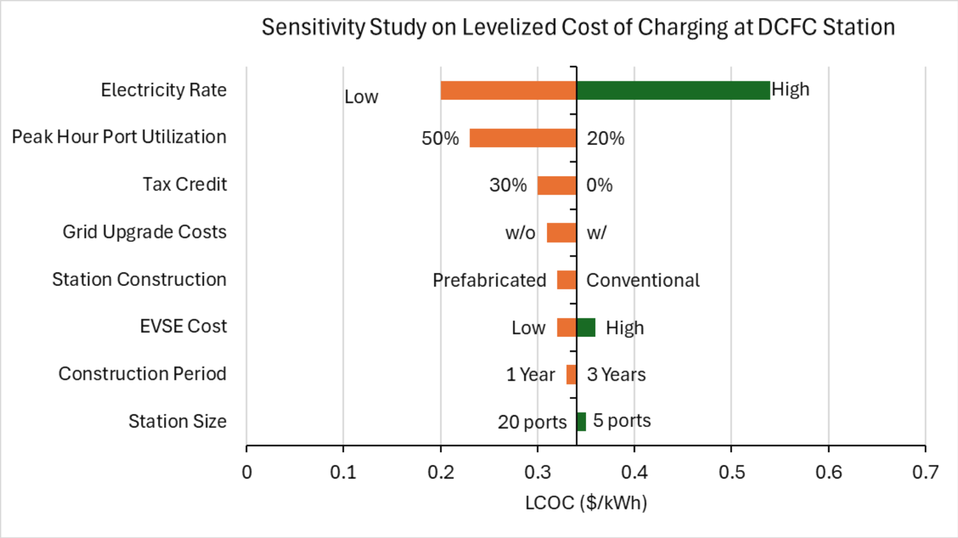


South East

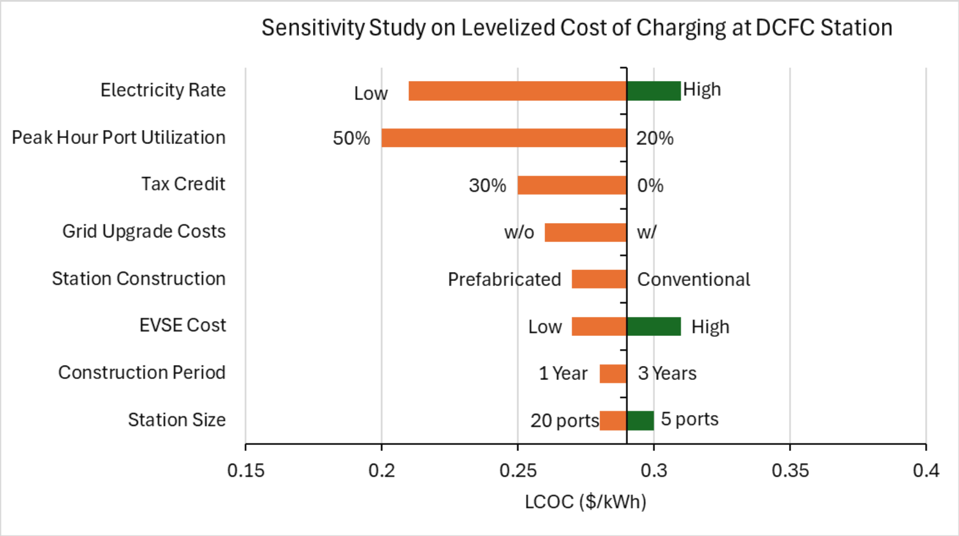


SENSITIVITY ANALYSIS – DCFC

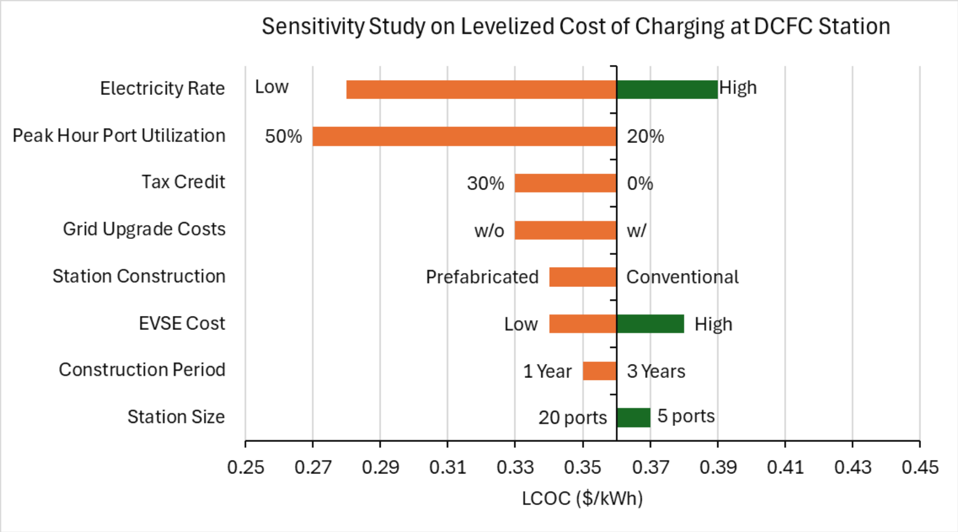
West Coast



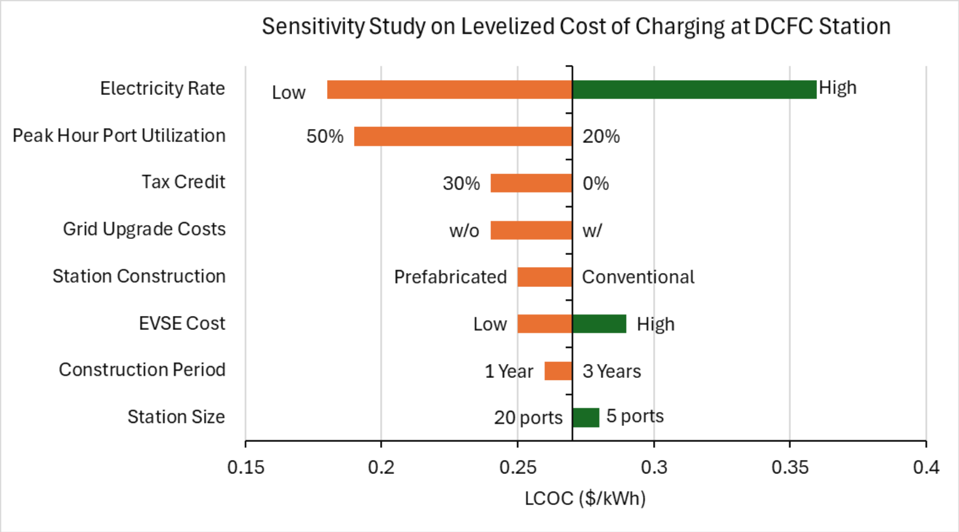
Rocky Mountains



South West



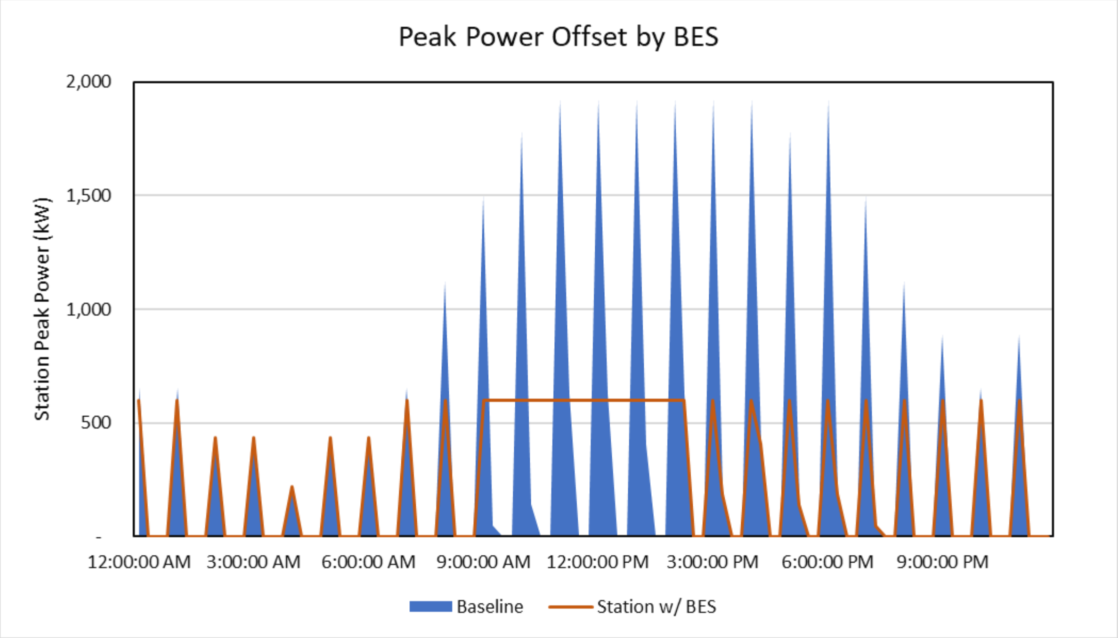
Plains

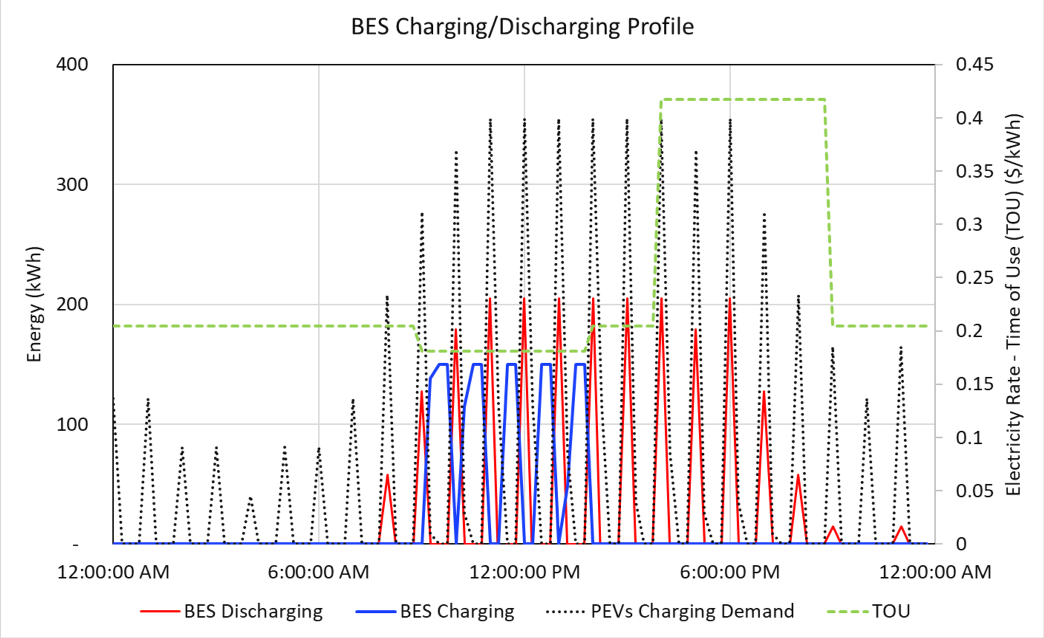


NATIONAL RESULTS:
BES-integrated DCFC Scenario

BES-INTEGRATION MITIGATES THE IMPACT OF CHARGING LOAD ON THE GRID

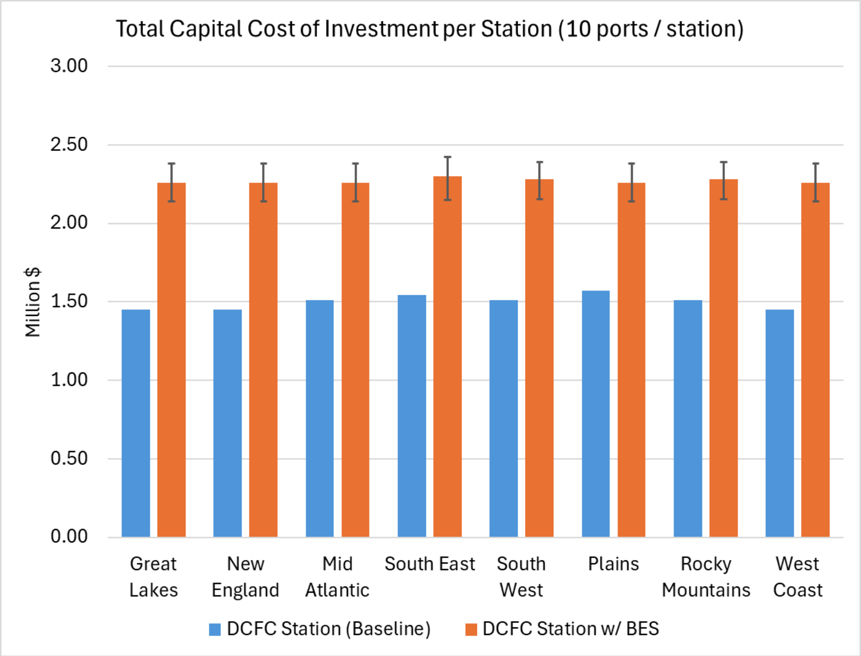
- BES charges during non-peak hours and significantly reduce station charging load during peak hours
- For a 10-port DCFC station, peak load of 1800-2000 kW can be reduced to **220-600 kW** with a **~1200 kWh BES**



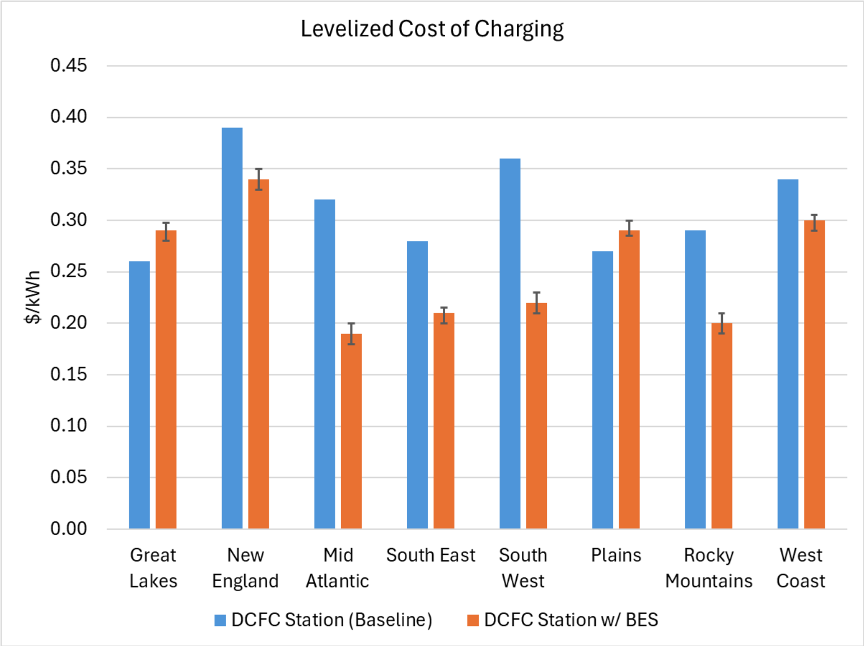


BES HAS THE POTENTIAL TO REDUCE LCOC EVEN WITH HIGHER UPFRONT CAPITAL COSTS

- BES-integration with DCFC can result in **40% decrease to 12% increase in LCOC** across regions
- **Net savings in LCOC** can be achieved through demand charge management
- Evaluated the potential for BES-integration to **avoid grid-upgrade delays** and **expedite charger deployment** (slide 38)



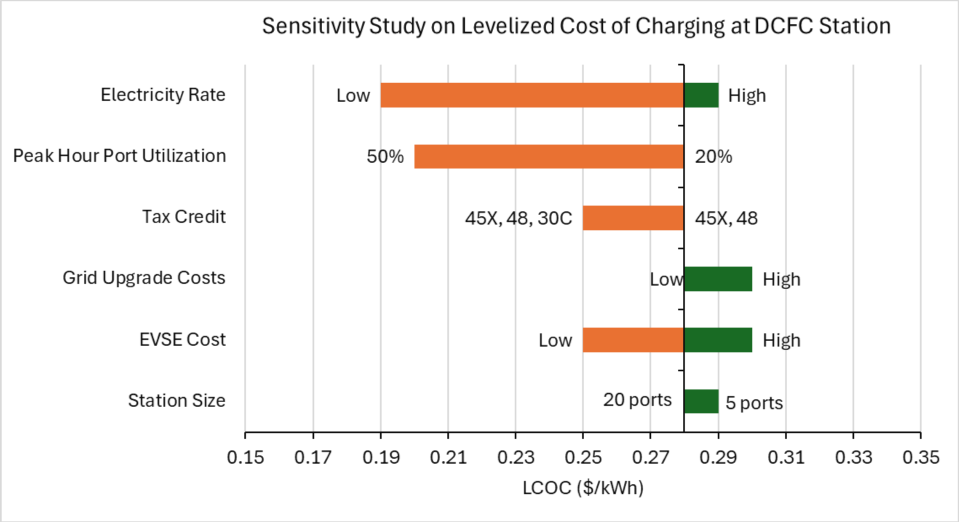
Bar plot shows the median cost of investment for BES-integrated DCFC stations by region. Bounds reflect impact of **level of grid-upgrade (L2 or DC150) for stations with BES.**



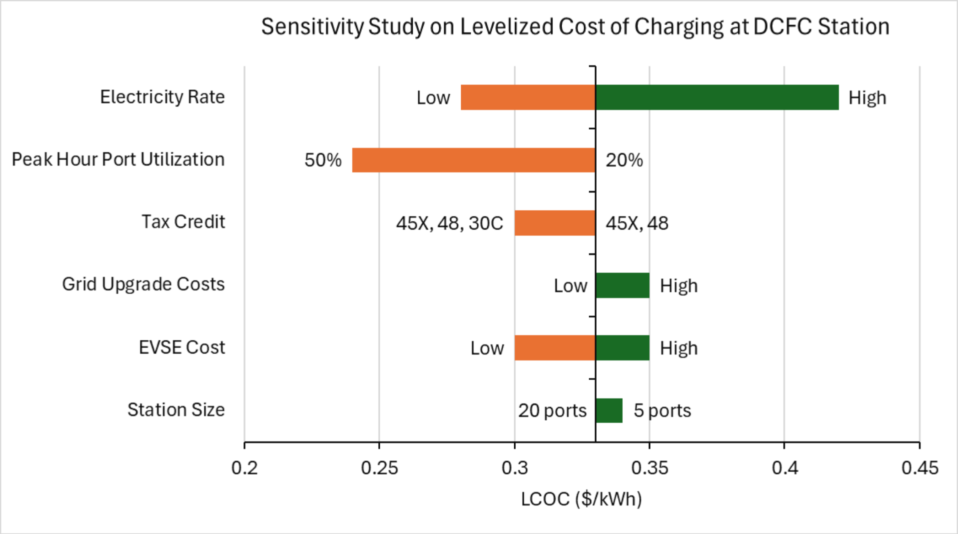
Bar plot compares the median cost of charging for a DCFC station with and without BES-integration. Bounds reflect impact of **level of grid-upgrade (L2 or DC150) for stations with BES.**

SENSITIVITY ANALYSIS – BES-INTEGRATED DCFC

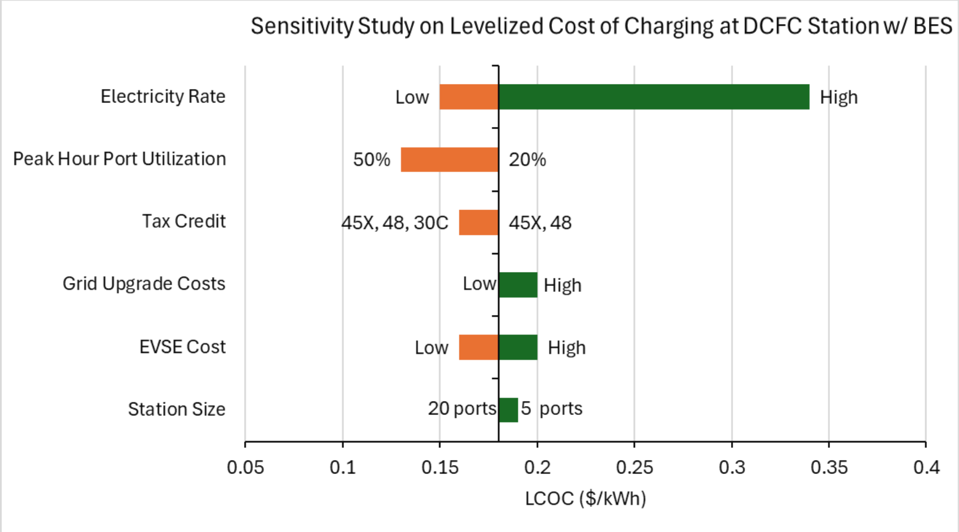
Great Lakes



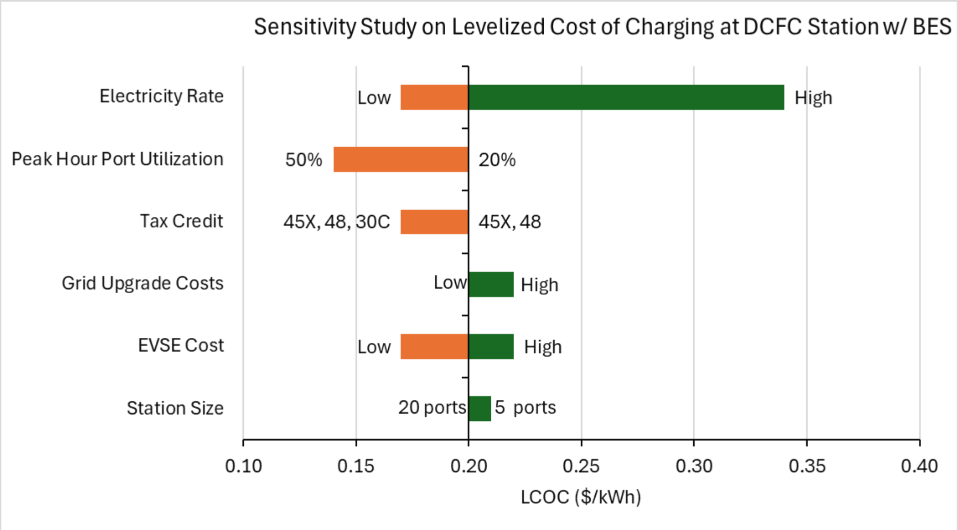
New England



Mid Atlantic

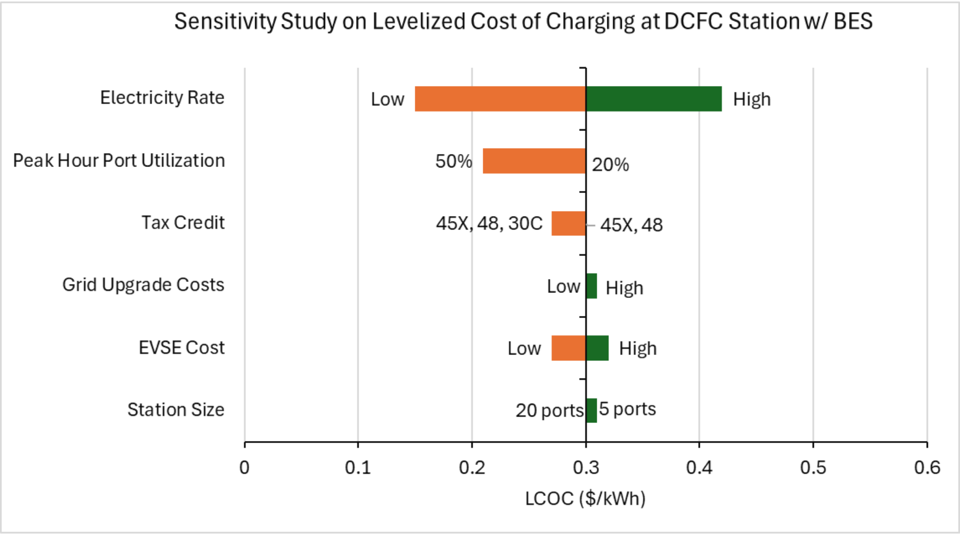


South East

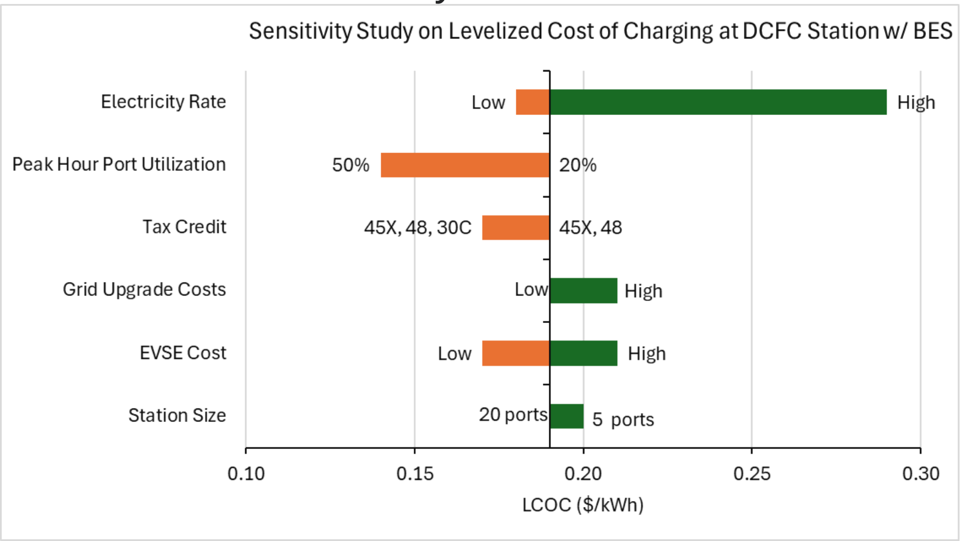


SENSITIVITY ANALYSIS – BES-INTEGRATED DCFC

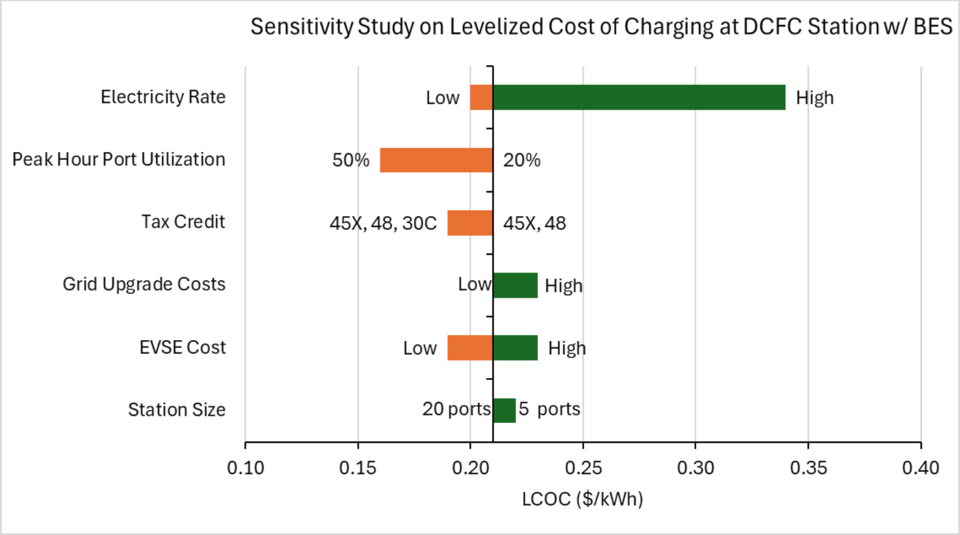
West Coast



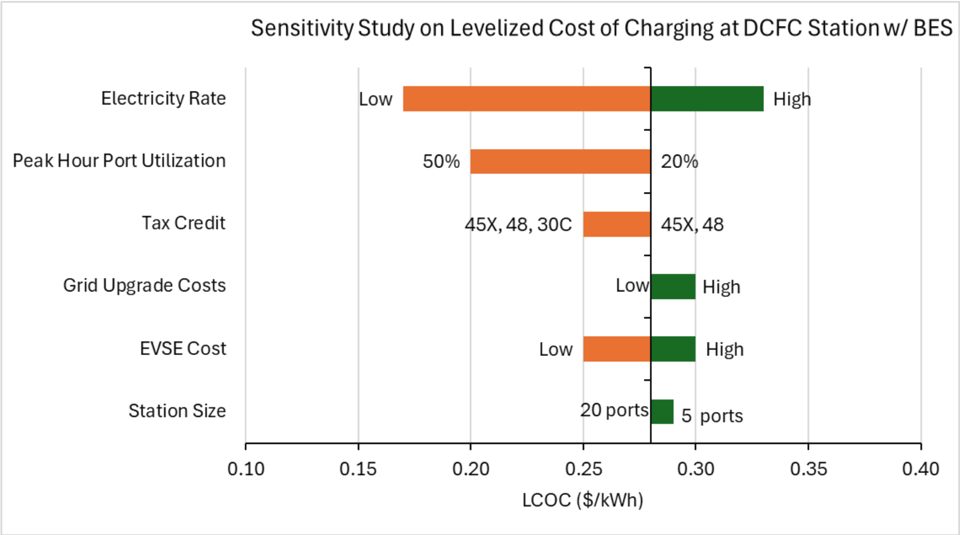
Rocky Mountains



South West



Plains



NATIONAL RESULTS:
PV-Integrated Off-Grid Charging

OFF-GRID SOLAR SOLUTION CAN SUBSTANTIALLY REDUCE DELAYS AND ELIMINATE GHG EMISSIONS

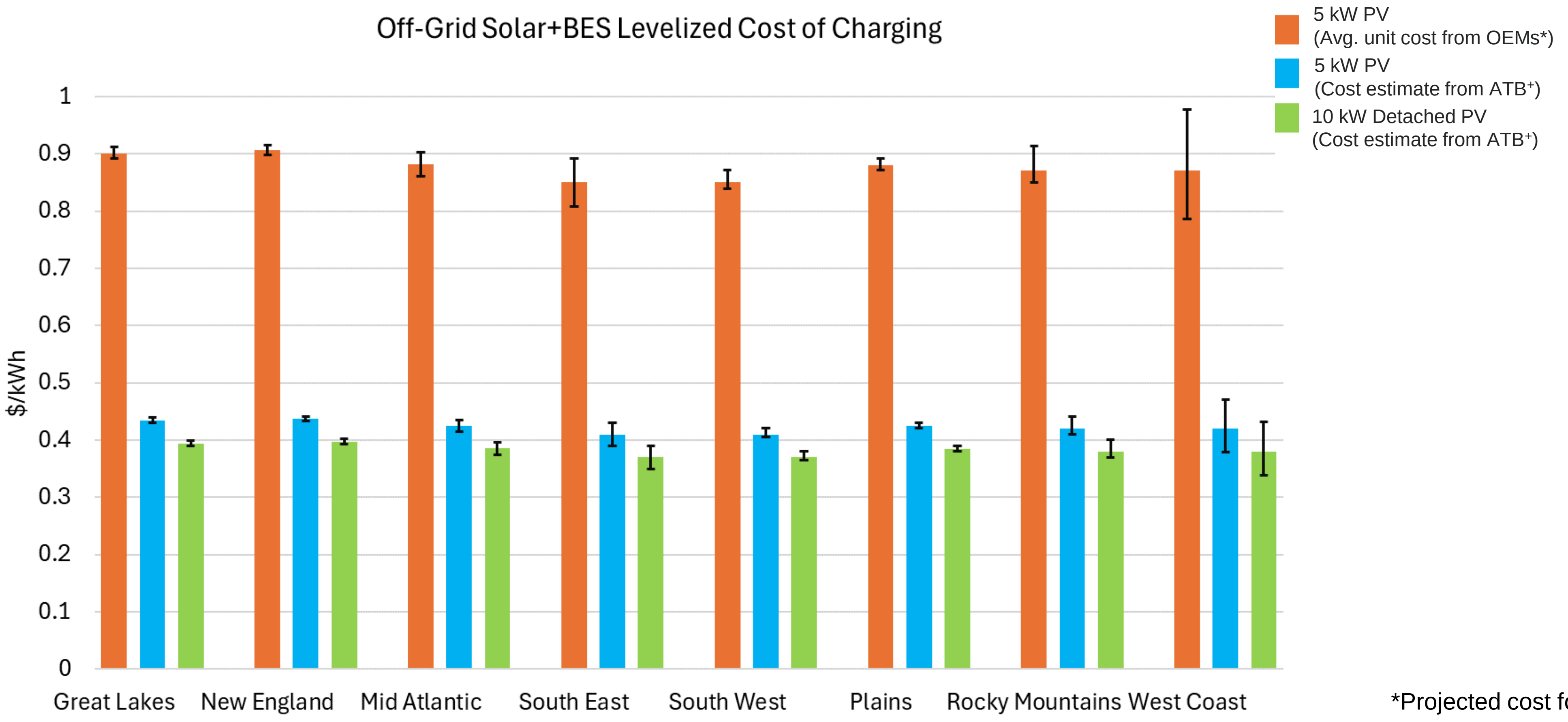
- Clean Electricity Investment Tax Credit* (IRA 48E) significantly reduces station capital cost
- Daily solar energy production is a major bottleneck to achieve lower levelized cost of charging
- However, average time for entire system delivery is **3 months**, and installation can be completed in **1 day****
- Reliance on renewable energy source for charging implies zero GHG emissions

*https://www.energy.gov/eere/solar/federal-solar-tax-credits-businesses

** Interview with OEMs

FUTURE COST REDUCTIONS IN PV AND BES COMPONENTS PROMOTE FURTHER DEPLOYMENT

- Benefits from mitigating delays and avoiding GHG emissions are not captured in the cost analysis



Bar plot showing the regional median LCOC for off-grid solar + BES station. Bounds indicate variation due to solar irradiance across the region

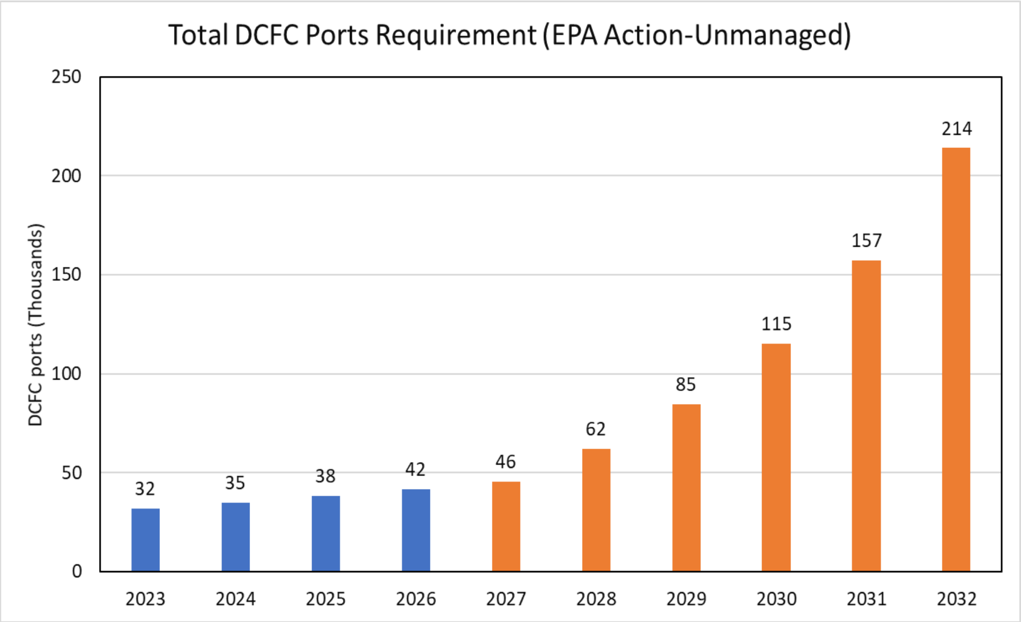
*Projected cost for 2032. Utility-Scale PV-Plus-Battery | Electricity | 2022 | ATB | NREL

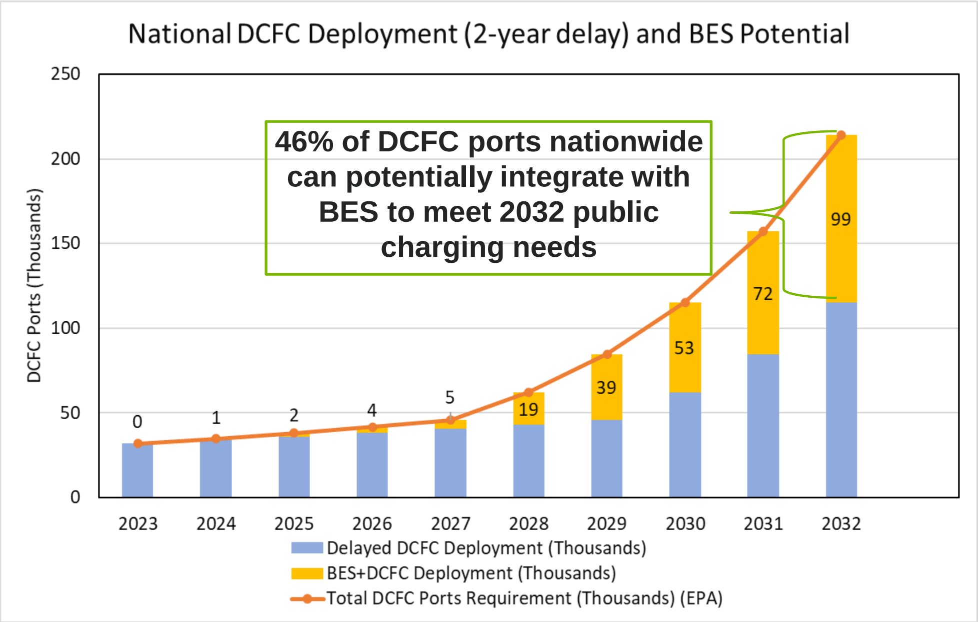
⁺Unit cost obtained directly from OEMs followed by learning-rate applied to get reduced cost in 2032

DEPLOYMENT ANALYSIS (NATIONWIDE)

DELAYS IN DCFC DEPLOYMENT DUE TO UTILITY-SIDE UPGRADES AND SUPPLY-CHAIN CONSTRAINTS CAN BE REDUCED WITH BES INTEGRATION AND OTHER ICS

- Current backlog of utility load service upgrades could lead to delays by **2+ years***
- Transformers shortage could cause delays of **18-24 months***
- BES integration can significantly reduce the lead time for distribution system upgrades, thereby expediting DCFC deployment



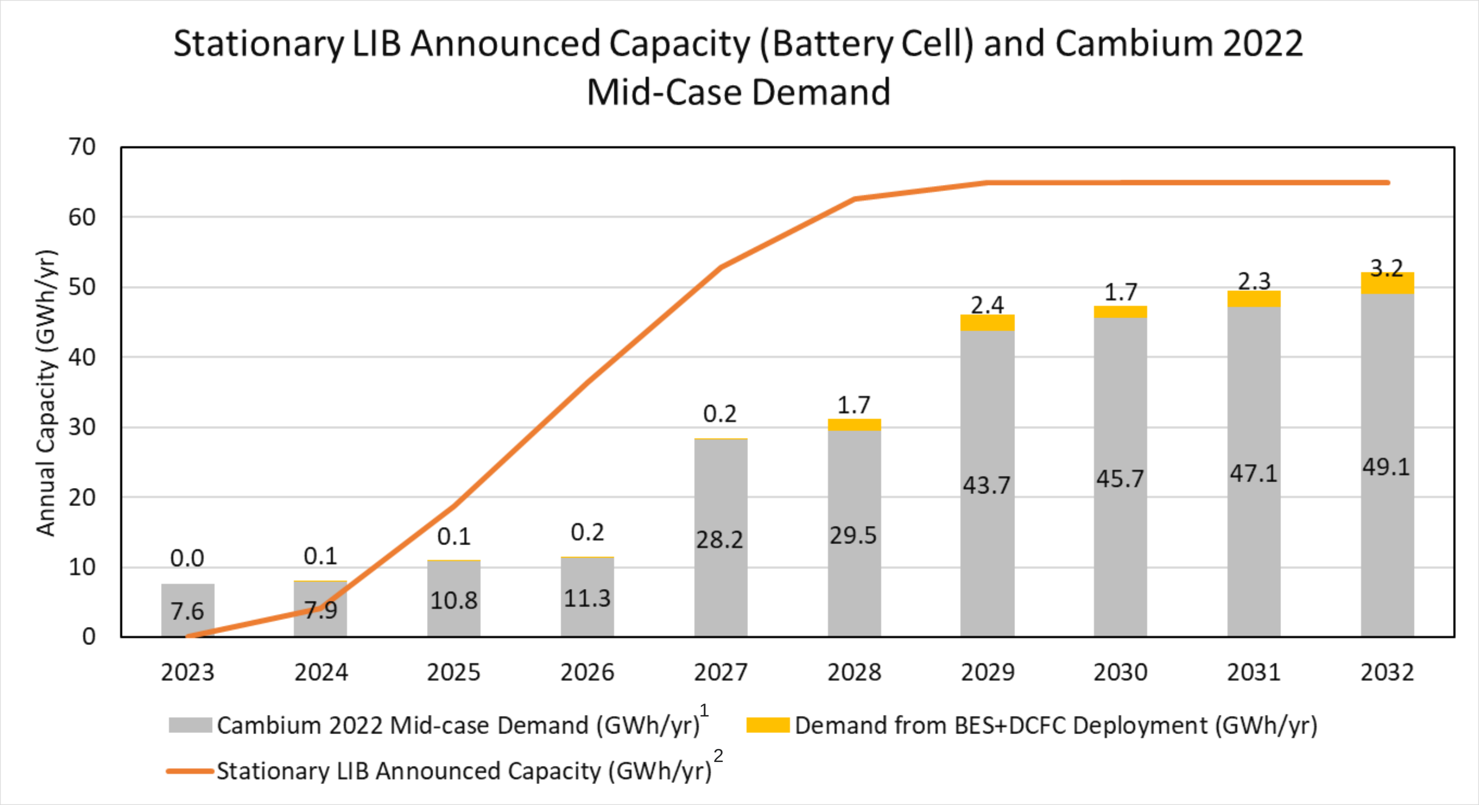


* *Tesla: Scaling EV Charging Infrastructure (2023 Integrated Energy Policy Report Workshop Distribution Recommendations)*
https://efiling.energy.ca.gov/GetDocument.aspx?tn=250045&DocumentContentId=84763

ANNOUNCED U.S. MANUFACTURER CAPACITY FOR STATIONARY LIB CELLS CAN SATISFY BES DEMAND

Includes demand from both utilities and public BEV charging

- Projected annual demand from BES-enabled LDV and MDV (Class 1-3) DC fast charging is modeled based on the number of DCFC ports requiring BES integration each year, assuming:
  - 2-year delayed deployment of conventional (grid-upgrade) DCFC
  - 1.2 MWh stationary BES system for every 10 BES+DCFC ports
- Cambium 2022 Mid-Case projects annual stationary BES (LIB) demand from electric utilities[1]



1. Cambium | Energy Analysis | NREL
2. *Gohlke, D. et al. (2024),* Quantification of Commercially Planned Battery Component Supply in North America through 2035. *(No. ANL-24/14). Argonne National Lab. (ANL).*

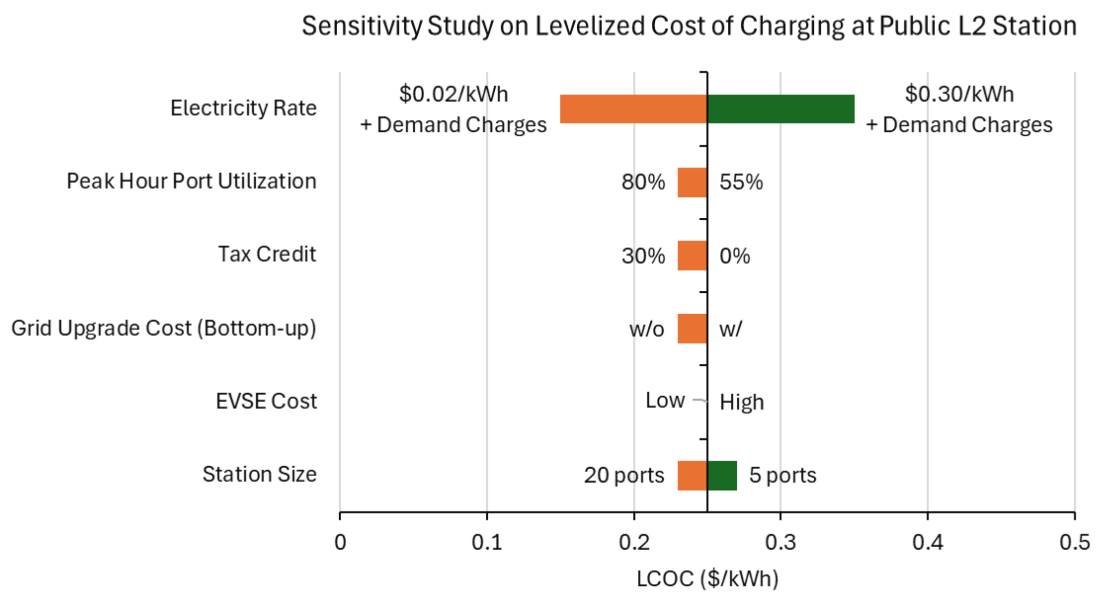
CASE STUDY: CALIFORNIA

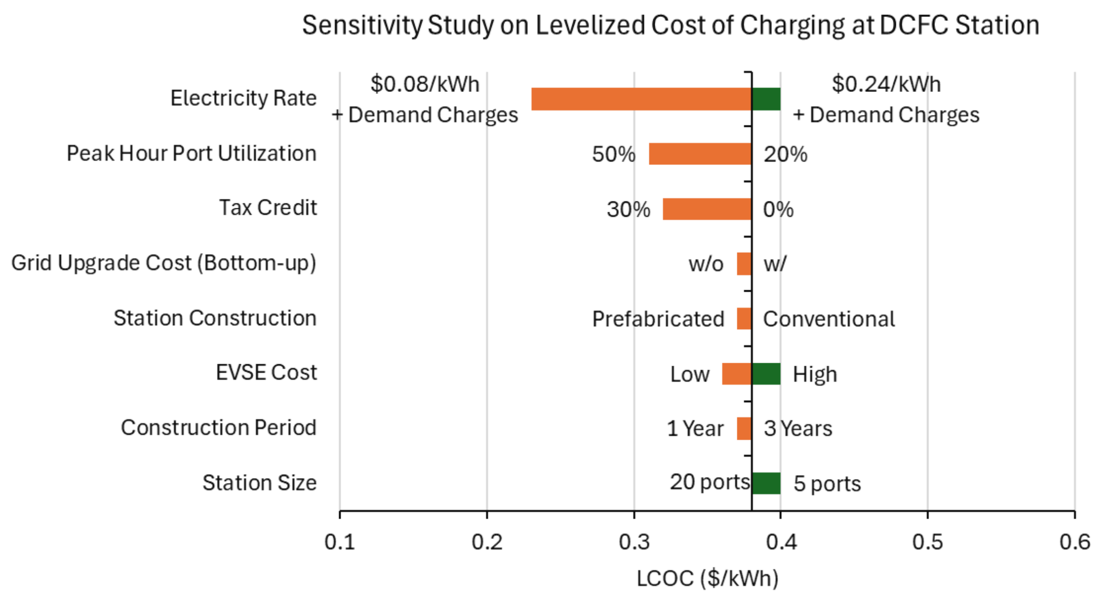
CALIFORNIA BASELINE LCOC

- **$0.15-0.35/kWh** for a public L2 station, **$0.22-0.40/kWh** for a DCFC station
- Utility costs and utilization rates are key cost drivers

Key Assumptions and Inputs (CA)

	Public L2	DCFC
Station Size	5,10,20 ports	5,10,20 ports
Peak Hour Utilization	55-80% (Average daily utilization: 20-50%%)	20-50% (Average daily utilization: 10-30%)
EVSE Costs	2032 Low & High EVSE cost scenarios	
EVSE tax credit eligibility (IRA 30C)	(0-30% of EVSE costs)	
Station construction type[1]	Conventional / Pre-fabricated	
Grid-Upgrade Costs	$800/port	$7,000-15,000/port
Utility Rates (TOU & Demand Charges)	**Low**: SDG&E: AL-TOU Secondary	**Low**: SDG&E: Schedule EV-HP
	High: SCE: TOU-EV-8	**High**: SCE: TOU-EV-9
Construction Period	1 year	3 years



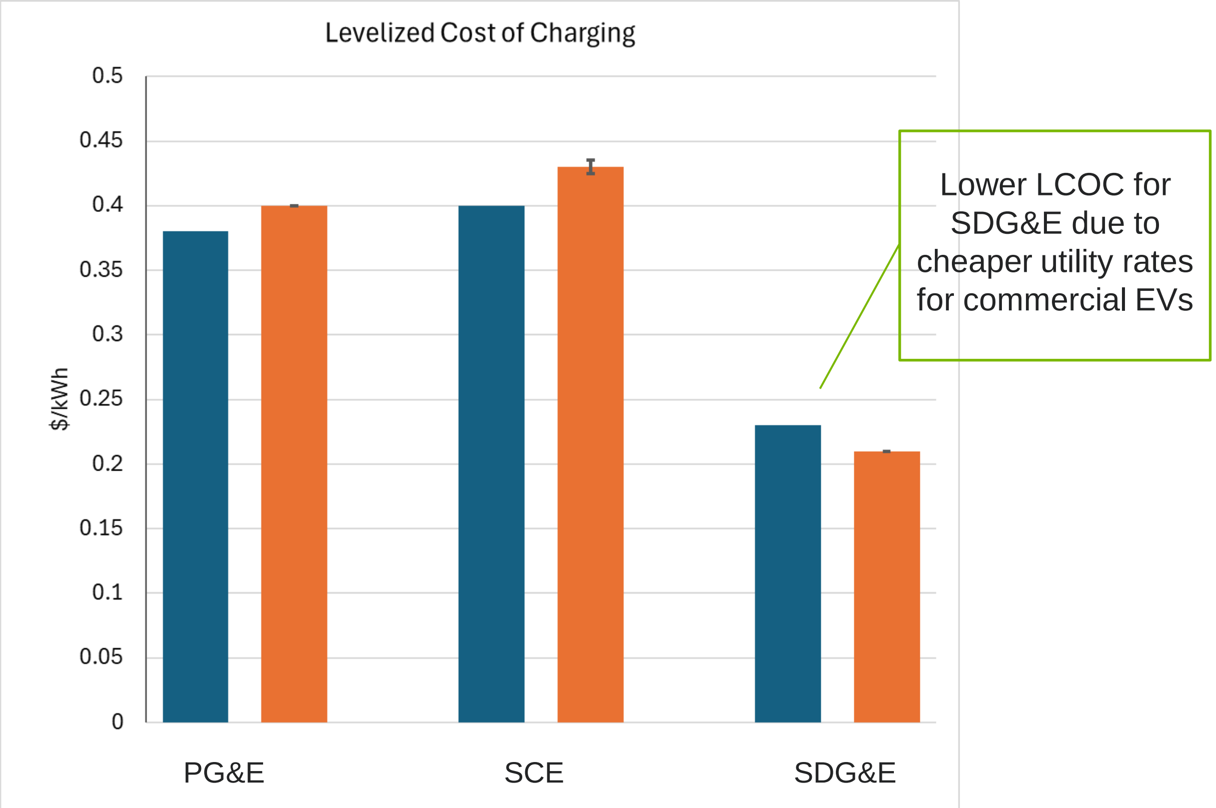


BES CAN IMPACT LCOC IN CALIFORNIA BY +8% TO -9% DEPENDING ON UTILITY RATES

- Average LCOC for each utility territory is shown, with minimal variation due to level of grid-upgrades assumed for BES-integrated DCFC stations

Key Assumptions and Inputs (CA)

	Baseline (DCFC)	ICS (BES+DCFC)
Station Size	10 ports (4 DC150, 3 DC250, 3 DC350)	
Peak Hour Utilization	20%	
EVSE Costs	2032 Mid EVSE cost scenario	
BES Costs	NA	$134-$220/kWh $487-$797/kW
BES Manufacturing Tax Credit	NA	($45/kWh)
BES Tax Credit	NA	30%
Grid-Upgrade Costs	$7,000-15,000/port	Low: cost equivalent to a public L2 port ($800/port) High: cost equivalent to a DC150 port ($7,250/port)
Utility Rates (TOU & Demand Charges)	PG&E, SCE, SDG&E	
Construction Period	3 years	1 year



This figure compares the cost of charging for a DCFC station with and without BES across the IOUs. Bounds reflect (minimal) impact of **level of grid-upgrade (L2 or DC150) for stations with BES.**

DELAYS IN DCFC DEPLOYMENT DUE TO UTILITY-SIDE UPGRADES AND SUPPLY-CHAIN CONSTRAINTS CAN BE REDUCED WITH BES INTEGRATION

- Current backlog of utility load service upgrades could lead to delays by **2+ years***
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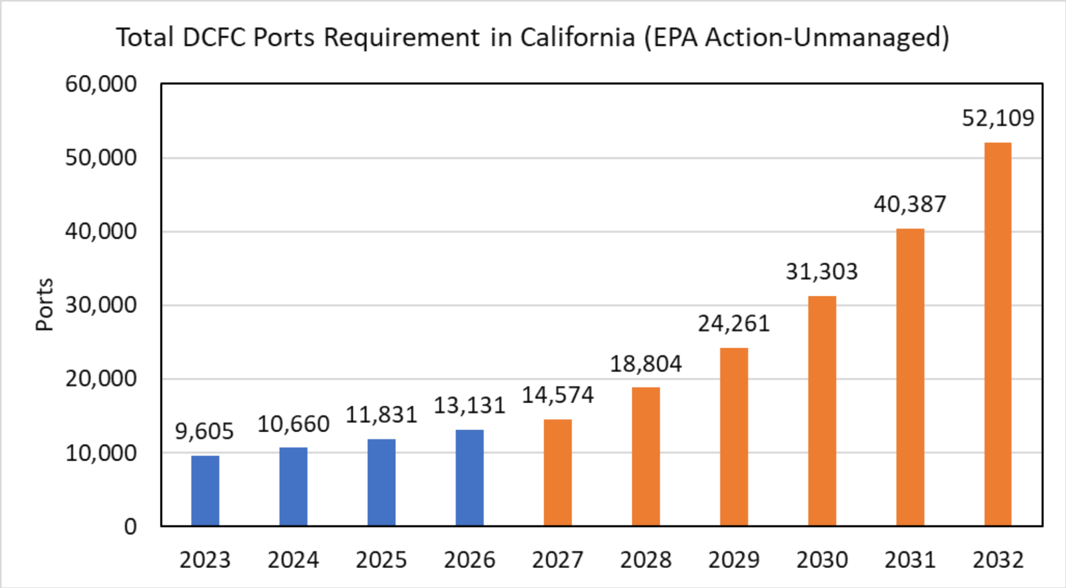
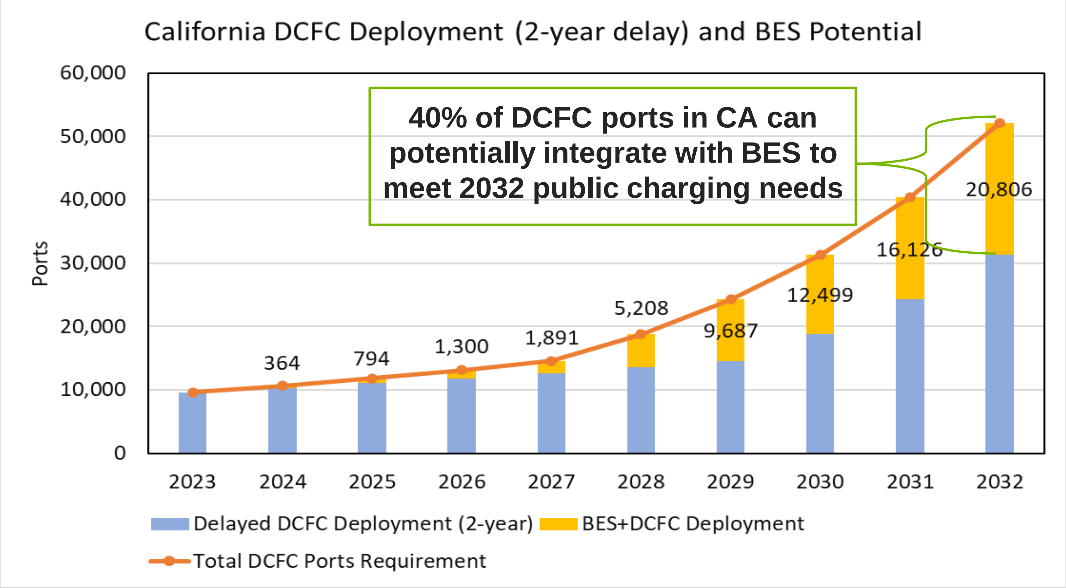
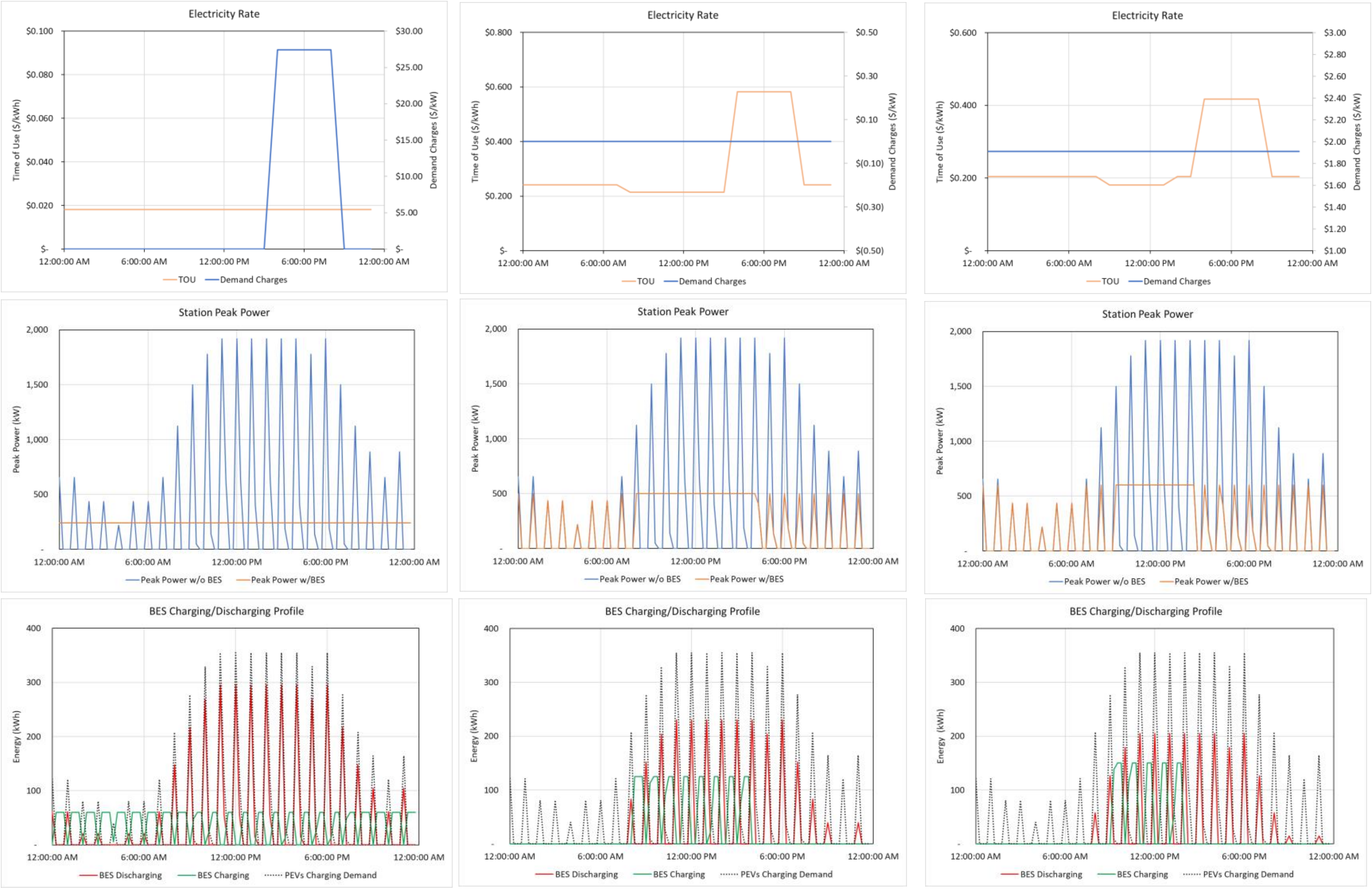




* *Tesla: Scaling EV Charging Infrastructure (2023 Integrated Energy Policy Report Workshop Distribution Recommendations)*
https://efiling.energy.ca.gov/GetDocument.aspx?tn=250045&DocumentContentId=84763

BES-INTEGRATED DCFC STATION PEAK GRID LOAD REQUIREMENT DEPENDS ON UTILITY RATES SCHEDULE

San Diego G&E (Coverage: 13%*) | Southern California Ed Co (Coverage: 22%) | Pacific G&E (Coverage: 30%)



40% of DCFC stations in CA assumed to have BES integration

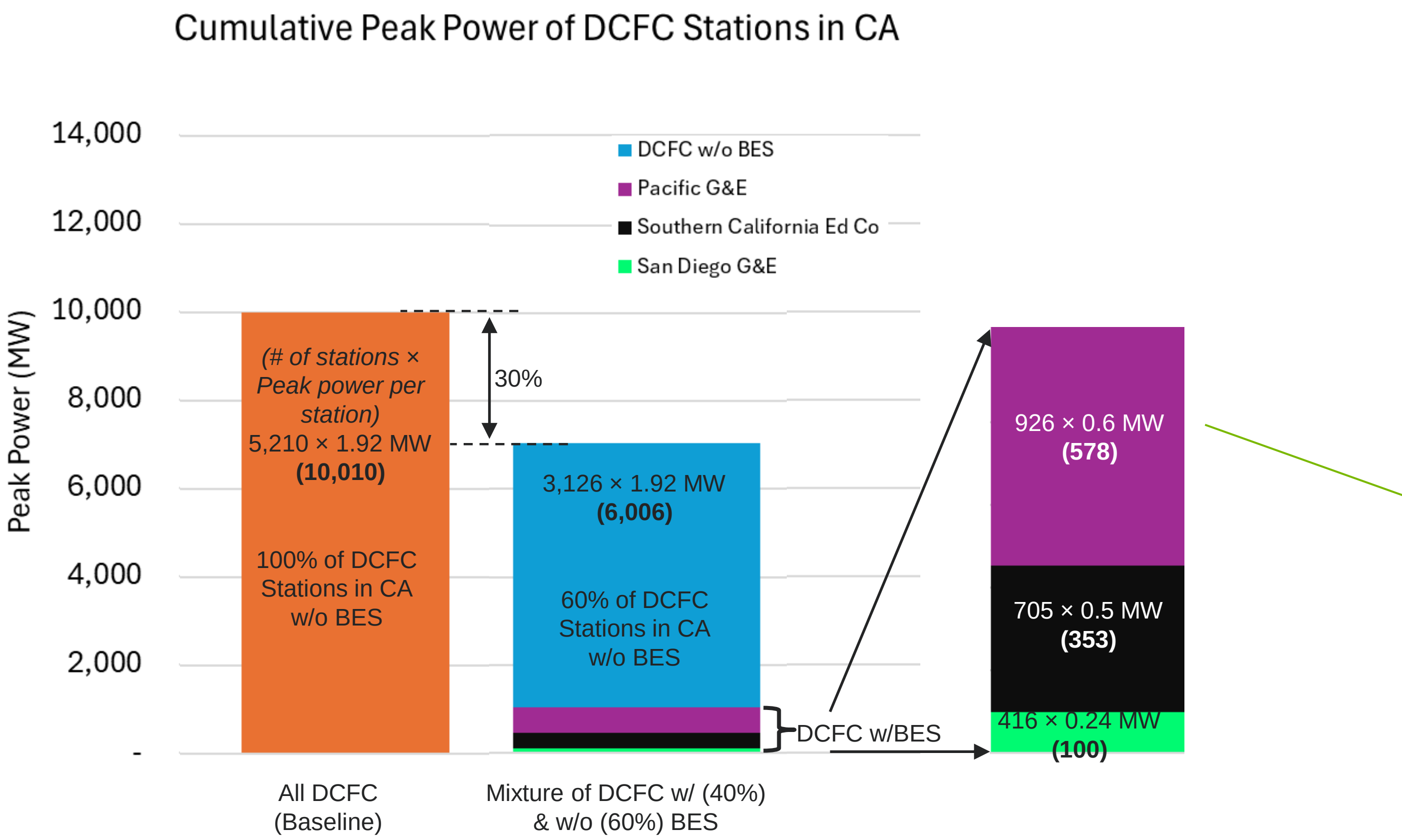
Proportion of BES integrated DCFC station and corresponding peak power

- **13% → 240 kW**
- **22% → 500 kW**
- **30% → 600 kW**

** Share of Total CA's projected DCFC ports within a utility's service territory. Actual coverage of the 3 IOUs sum up to 65%, which can be proportionately scaled to 100%.*

BES INTEGRATION CAN REDUCE TOTAL GRID CAPACITY REQUIREMENT BY 30% TO SUPPORT DCFC DEPLOYMENT THROUGH 2032

- One-to-one quantification of distribution grid assets (transformers, substations, feeder) for corresponding EVSE load is required to further evaluate the benefits of ICS on network deployment through deferring grid-upgrade investments



Shares of projected DCFC ports within IOU territories in CA (PGE: 30%, SCE: 22%, SDGE: 13%) are proportionately scaled to 100%

CONCLUSION

QUANTIATIVE RESULTS SUMMARY

- BES-integration's impact on baseline DCFC levelized cost of charging ($/kWh) ranges between **40% decrease to 12% increase** across regions' median utility rates nationwide
- BES-integration significantly reduces DCFC station peak load and generates demand charge savings to potentially offset the higher upfront capital investment and become cost-effective
  - In California, we estimate that BES can reduce a 10-port DCFC station's peak load by **60-90%** with negligible effects on LCOC
- In addition, BES-integration can accelerate deployment of DCFC stations by avoiding grid capacity upgrade delays and supply chain constraints using the currently-announced U.S. capacity for stationary storage
  - **40% of DCFC** ports in CA can integrate with BES to meet 2032 public charging needs and mitigate delays
  - BES-integrated DCFC can potentially fill the gap and reduce total grid capacity requirement by **30%**, absent other innovative charging solutions
- Sensitivity analysis across all charging scenarios and regions shows **utility rates** and **station utilization** are key cost drivers for LCOC
- LCOC for off-grid solar PV (L2) chargers can be **as low as $0.39/kWh with tax incentives** in 2032, while additionally offering significant deployment **time-savings** as well as **net GHG emission reductions**

FUTURE RESEARCH

- In addition to BES-integrated and off-grid solar charging, numerous innovative charging solutions can accelerate the energization of new EV loads
  - Flexible interconnection
  - Hosting capacity maps
  - Mobile charging
  - Battery swapping
  - Private charger sharing
  - Smart charger adapter
- Future research can evaluate costs, use cases, as well as deployment and GHG emissions impacts of these approaches

ACKNOWLEDGEMENTS

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Thank you!