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DEVP 226 - Economics of Innovation and Supply Chains
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April 16, 2026

National Electric Vehicle Infrastructure and Utilities: Bottlenecks Analysis in the U.S. EV Charging Stations Supply Chain

I. Introduction

The transition to electric vehicles (EVs) is a critical component of global efforts to mitigate climate change and reduce transportation-related greenhouse gas emissions. However, widespread consumer adoption of EVs hinges entirely on the availability of a reliable and accessible public charging network. Prior research consistently identifies public charging networks as a primary driver of electric vehicle uptake (Sierzechula et al., 2014; Mekky & Collins, 2024), a consensus supported by international energy monitors that classify public chargers as a key enabler of the EV transition (IEA, 2023). Despite this clear necessity, the deployment of charging infrastructure across the United States remains highly uneven and remarkably slow to scale. While EV adoption necessitates charging, the deployment of this infrastructure is fundamentally constrained by severe supply-chain bottlenecks.

To understand why existing infrastructure cannot currently match the pace of EV demand, this paper investigates the frictions embedded within the infrastructure rollout process. The primary research question is: What stages and actors deliver public Direct Current Fast Charging (DCFC), where do time and cost pile up, and how do federal programs and state/local policies change incentives and bottlenecks?

This paper goes beyond analyzing consumer demand to explicitly examine the supply-side mechanics of infrastructure deployment. First, it maps the DCFC deployment supply chain, detailing the complex coordination required between hardware manufacturing, installation, and utility interconnection. Second, it identifies the top three bottlenecks in this process, using quantitative evidence from the Alternative Fuels Data Center (AFDC) database alongside state-level case vignettes. Finally, it offers actionable policy recommendations tied directly to specific supply-chain stages to help accelerate deployment.

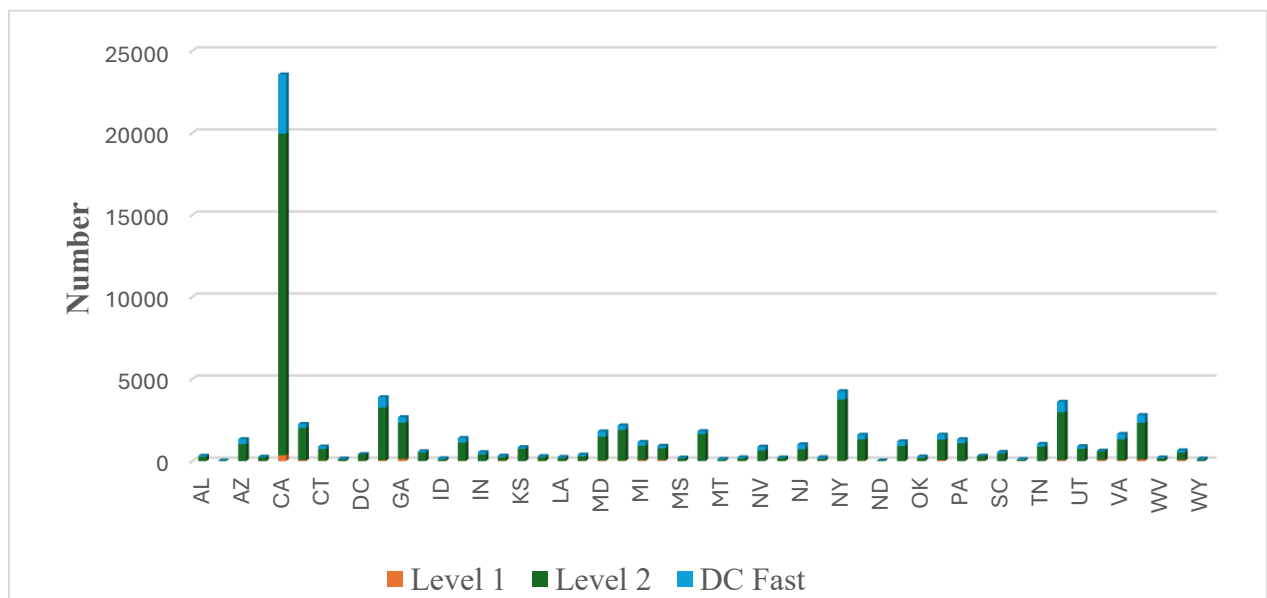
The remainder of this paper is structured to unpack these supply chain dynamics. Section II provides background on the US EV charging landscape and the current federal policy context. Section III introduces the conceptual framework, featuring a comprehensive supply chain map and an application of core economic concepts. Section IV outlines the data and methodology. Section V presents the quantitative analysis and results, followed by bottlenecks analysis in Section VI. The paper concludes with targeted policy implications in Section VII and VIII.

II. Background

1. The EV Charging Landscape

As of the first quarter of 2024, the United States electric vehicle (EV) charging network reached a total of 198,897 public and private charging ports. This infrastructure is categorized into three primary types: Level 1 (120V), which provides standard residential charging; Level 2 (240V), which offers approximately 25 miles of range per hour of charging; and Direct-Current Fast Charging (DCFC), which can provide 100 to 200+ miles of range in just 30 minutes. While the network is expanding – growing by 4.6% in the first quarter of 2024 alone – the deployment remains geographically concentrated. California stands out with a high volume of all types of charging ports, with Level 2 type reaching 19,590 public charging ports (over 32 percent of all public Level 2 ports in the country). Figure 1 suggests that there is a substantial investment in infrastructure to support the use of EVs, particularly in states with a high number of EVs, namely California, New York, Texas, and Florida.

Figure 1: Number of EV Charging Ports by State and Charger Type



Data source: National Renewable Energy Laboratory

Recent trends indicate that DCFC ports are the fastest-growing segment, with an 8.2% increase in the first quarter of 2024, reflecting their critical role in enabling long-distance travel and reducing "range anxiety" (Brown et al., 2024). However, a significant gap remains between current capacity and future requirements; to support a projected 33 million EVs by 2030, the U.S. will require approximately 1.2 million public charging ports, including 182,000 high-power DCFC ports (Wood et al., 2023).

2. Federal Policy Context

The acceleration of the U.S. charging network is primarily driven by the 2021 Bipartisan Infrastructure Law (BIL), which allocated \$7.5 billion toward EV infrastructure. A central pillar of this law is the National Electric Vehicle Infrastructure (NEVI) Formula Program, a \$5 billion initiative managed by the Federal Highway Administration (FHWA) to build high-speed chargers along Alternative Fuel Corridors (AFCs), with the requirement that stations be located every 50 miles and within one mile of highway exits. As of mid-2024, eight states had already opened their first NEVI-funded stations (National Electric Vehicle Infrastructure Formula Program, 2024).

Complementing the BIL is the Inflation Reduction Act (IRA), which significantly modified the Section 30C tax credit for alternative fuel refueling property (Grant Thornton, 2024). The IRA increased the credit cap from \$30,000 per location to \$100,000 per "item of property" (such as individual charging ports), provided the property is located in qualifying low-income or non-urban census tracts. Furthermore, the Justice40 Initiative mandates that 40% of the overall benefits from these federal climate and transportation investments must flow to disadvantaged communities (DACs). States are now required to integrate equity metrics into their NEVI deployment plans, using tools like the Climate and Economic Justice Screening Tool (CEJST) to identify underserved areas.

3. Why Supply Chains Matter

The deployment of EV infrastructure is a complex multi-stage supply chain coordination problem that involves upstream R&D and hardware manufacturing, midstream network operations (Charge Point Operators), and downstream grid integration. Effective supply chain design is critical due to several inherent frictions:

- **The Coordination Problem:** A fundamental "chicken-and-egg" failure exists where private firms under-invest in charging hardware due to low initial utilization, while consumers hesitate to adopt EVs due to a lack of visible infrastructure.
- **Grid and Permitting Bottlenecks:** A primary friction occurs at the utility interconnection stage, where grid capacity constraints and lengthy permitting processes can delay station activation by months (Joint Office of Energy and Transportation, 2024).
- **Cost Frictions:** Strategic design can significantly reduce costs; for example, installing electrical conduit and panel capacity during new construction (EV-ready) can decrease installation costs by up to 75% compared to retrofitting existing buildings.
- **Integration Dynamics:** While the market includes many horizontally coordinated third-party networks (e.g., ChargePoint), vertically integrated models like Tesla's Supercharger network – which controls hardware, software, and the vehicles themselves – currently account for 60.4% of all public DCFC ports in the U.S.

Ultimately, the structure of this supply chain – from raw material sourcing to the utility rate design – determines whether infrastructure deployment can match the pace of EV demand or if institutional bottlenecks will continue to hinder adoption (Sierzechula et al., 2014; IEA, 2024).

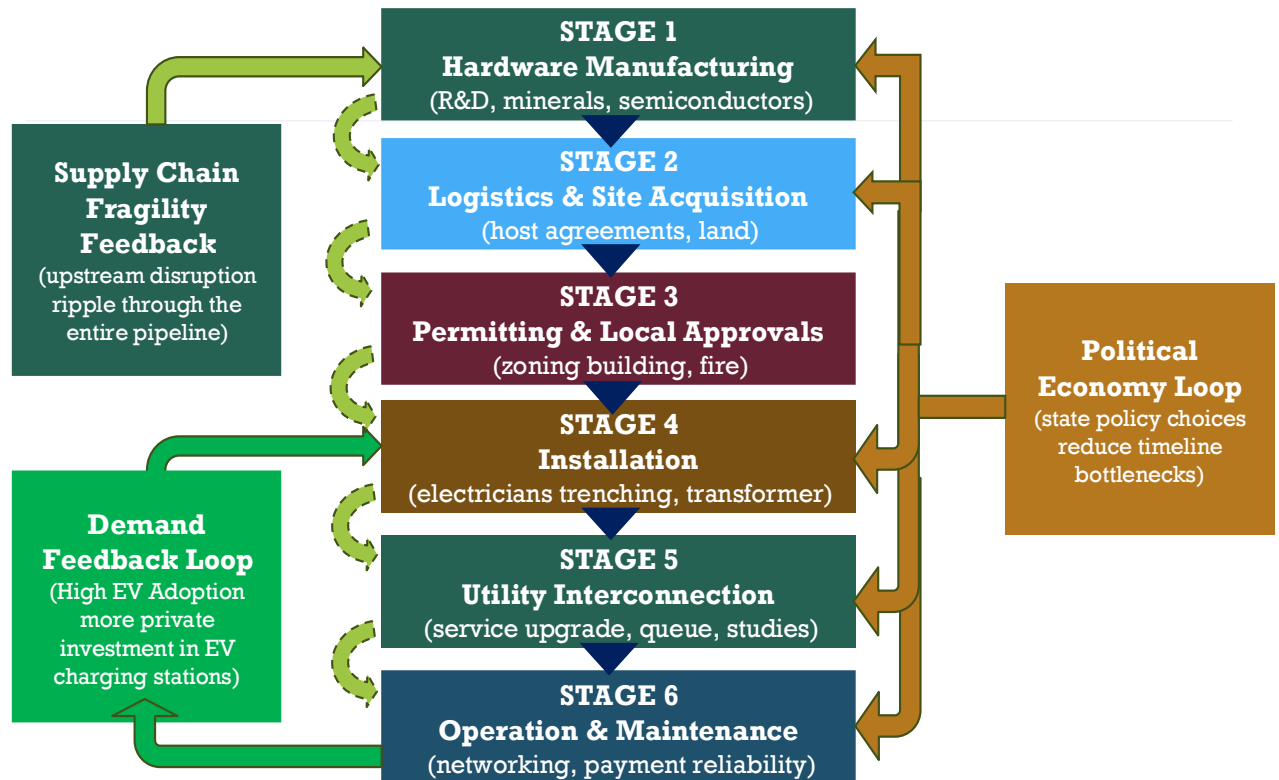
III. Conceptual Framework

1. The Multi-Stage Supply Chain

The EV charging supply chain is a complex, interdependent system involving four primary stages. As illustrated in Figure 2, these stages include:

- **Upstream (R&D and Hardware Manufacturing):** The initial stage includes the research, development, and production of DCFC units and power electronics. This part of the chain is subject to significant global disruptions, particularly regarding the sourcing of critical minerals, semiconductors, and specialized cabling components.
- **Midstream (Site Acquisition, Permitting, and Network Operations):** This stage encompasses logistics, site acquisition via host agreements, and securing permitting and local approvals. It involves Charge Point Operators (CPOs) who manage software interfaces and hardware reliability, commercial landlords or public entities that host physical station sites, and local authorities who enforce zoning, building, and fire codes.
- **Downstream (Installation and Utility Interconnection):** This is the final physical link where hardware is installed and connected to the electrical grid. This stage requires coordination with utility companies to conduct grid impact studies and perform service upgrades, such as installing new transformers or service drops, as well as on-site labor for trenching and electrical wiring.
- **End-User (Consumption and Feedback):** The final stage involves the EV driver whose adoption behavior provides utilization feedback through a demand feedback loop. High EV adoption rates signal market viability, which in turn drives increased private investment back into the earlier stages of the supply chain.

Figure 2: Supply Chain Map



2. Coordination Problems and Information Flows

A fundamental concept in this framework is the coordination failure. Private firms often under-invest in hardware due to low initial utilization, while consumers hesitate to adopt EVs because of a lack of visible, reliable infrastructure. Effective supply chain design requires improved information flows between these actors to align incentives. For instance, "EV-ready" building codes that require installing conduit during new construction can reduce installation costs by up to 75% compared to retrofitting, demonstrating how early-stage coordination improves downstream economic efficiency (Alternative Fuels Data Center, 2024).

3. Risk, Uncertainty, and Integration

The supply chain is characterized by high capital intensity and risk. DCFC hardware costs range from \$40,000 to \$150,000 per unit, with utility interconnection adding significant time and financial uncertainty (AmpUp, 2026). To mitigate these risks, different organizational structures have emerged:

- **Vertical Integration:** Models like Tesla's Supercharger network achieve higher reliability and a 60.4% market share by controlling the vehicle, hardware, and software stages internally (Brown et al., 2024).

- **Horizontal Coordination:** Third-party networks (e.g., ChargePoint) rely on contracting with disparate site hosts and utilities, often leading to slower deployment due to misaligned incentives and peaky demand charges that can account for 90% of electricity costs (Nelder, 2017).

IV. Methodology

1. Data Sources

The analysis utilizes a comprehensive dataset from the Alternative Fuels Data Center (AFDC), managed by the National Renewable Energy Laboratory (NREL). The AFDC serves as the authoritative census for alternative fueling stations in the U.S. and Canada (Brown et al., 2024). The data follows the hierarchy defined by the Open Charge Point Interface (OCPI) protocol, which distinguishes between station locations, individual ports (for simultaneous charging), and connectors (Brown et al., 2024; AFDC, 2024).

Dataset Specifications

- **Total stations accessed:** 80,597 charging stations
- **DCFC stations with valid operational dates:** 15,056 stations
- **Analysis period:** 2020–2024 (pre- and post-NEVI comparison)
- **Sample for quantitative analysis:** 9,229 DCFC stations opened 2020–2024
- **Geographic coverage:** All 50 states plus Washington, D.C.
- **Network coverage:** 93 distinct charging networks
- **Access method:** NREL API accessed March 2026

The AFDC database includes critical variables for deployment analysis: *station_name*, *open_date*, *state*, *ev_network*, *ev_dc_fast_num* (number of DCFC ports), *city*, and *status_code*. The *open_date* variable, while subject to reporting lags, provides the most comprehensive publicly available record of station operational timelines.

2. Analytical Approach

To quantify the shift in infrastructure momentum, the study calculates the **Infrastructure Deployment Rate (IDR)** for two distinct periods. This metric represents the mean monthly volume of new station openings, allowing for a standardized comparison of deployment intensity before and after the NEVI rollout.

Key Metrics:

1. **National Deployment Rate:** Percentage change in monthly DCFC deployment rate (2023–2024 vs. 2020–2021)
2. **State-Level Deployment Rates:** Monthly station openings by state, with focus on Texas, California, and Mississippi as our case study states.
3. **Network-Specific Speed:** Deployment rates by charging network (Tesla, ChargePoint, Electrify America, etc.)
4. **Temporal Trends:** Year-over-year deployment patterns (2020–2024)

Calculation Formula:

The Deployment Rate (α) is defined as the percentage change in the monthly IDR between the baseline and implementation periods:

$$\alpha = \left(\frac{IDR^{post}}{IDR^{pre}} - 1 \right) * 100$$

Where:

- **IDR^{pre} (Baseline Rate):** The average monthly station openings from January 2020 to December 2021 (n= 24 months).
- **IDR^{post} (Implementation Rate):** The average monthly station openings from January 2023 to December 2024 (n = 24 months).
- **Transition Period:** Data from the calendar year 2022 is excluded from the rate calculations to account for the policy lag between the enactment of the Infrastructure Investment *and Jobs Act (IIJA)* and the formal approval of state-level NEVI deployment plans.

Limitations:

- **Temporal Reporting Bias:** Data sourced from the NREL Alternative Fuel Data Center (AFDC) reflects when a station is added to the registry rather than the exact opening date. However, because this reporting lag is consistent across both study periods, it is treated as a systematic constant that does not bias the relative Deployment Rate.
- **Milestone Opacity:** The lack of granular data on intermediate development stages (e.g., permitting and utility interconnection) prevents the decomposition of the IDR. The model measures the rate of final commissioning rather than the speed of individual project lifecycle stages.
- **Attribution Neutrality:** This study adopts a descriptive temporal comparison to document the observed change in the Infrastructure Deployment Rate during the NEVI

rollout. It does not isolate the specific causal impact of federal funding from other concurrent market drivers, such as private capital shifts or organic EV adoption growth.

V. Quantitative Analysis and Results

1. National Deployment Acceleration (2020–2024)

Table 1 reveals a 153.5% increase in national DCFC deployment rate following the Infrastructure Investment and Jobs Act, rising from 92.1 stations/month (2020–2021) to 233.4 stations/month (2023–2024) across 9,229 stations. This acceleration validates that federal policy interventions, particularly the \$7.5 billion BIL allocation and IRA's enhanced 30C tax credit is strongly associated with EV charging stations deployment. However, the national aggregate masks significant state-level heterogeneity explored in the next section.

Table 1: National DCFC Deployment Rate: Pre-NEVI vs. Post-NEVI

Period	Total Stations	Monthly Rate	Acceleration
Pre-NEVI (2020–2021)	2,210	92.1 stations/month	Baseline
Post-NEVI (2023–2024)	5,602	233.4 stations/month	+153.5%

Note. Analysis based on 9,229 DCFC stations opened 2020–2024 with valid operational dates in AFDC database. Pre-NEVI and Post-NEVI periods each span 24 months.

2. State-Level Deployment Rates: Texas, California, and Mississippi

As shown in Table 2, cross-state comparison reveals dramatic variation in how federal funding translates into operational infrastructure. Texas exhibits 520.8% acceleration (2.21 → 13.71 stations/month) from a low baseline, while California's modest 8.7% acceleration (28.62 → 31.12 stations/month) reflects near-saturation in an already-optimized institutional environment. Mississippi's 860% acceleration yields only 2.00 stations/month – just 6% of California's rate – demonstrating that federal capital alone cannot overcome institutional capacity constraints. This variation directly correlates with state-level bottlenecks at permitting and interconnection stages, not hardware availability.

Table 2: State-Level DCFC Deployment Rate Comparison (2020–2024)

State	Pre-NEVI Rate (stations/month)	Post-NEVI Rate (stations/month)	Acceleration	Total DCFC (2020–2024)

Texas	2.21	13.71	+520.8%	462
California	28.62	31.12	+8.7%	1,728
Mississippi	0.21	2.00	+860.0%	57

Note. Deployment rates calculated as total stations opened divided by 24 months for each period. Pre-NEVI: 2020–2021; Post-NEVI: 2023–2024.

3. Network-Specific Deployment Speed

Table 3 demonstrates that ChargePoint leads deployment volume with 33.9% market share (52.17 stations/month), exceeding Tesla's 19.3% share (29.65 stations/month), challenging the conventional narrative that vertically integrated networks deploy faster. However, this reflects ChargePoint's capital-light hardware-as-a-service model and eligibility for state/federal grants versus Tesla's self-financed, high-utilization corridor strategy. The tradeoff: ChargePoint achieves scale (3,130 stations) with 85–90% uptime, while Tesla's selectivity yields superior reliability (>99% uptime) but slower network expansion.

Table 3: Top 10 Charging Networks by Deployment Volume (2020–2024)

Rank	Network	Stations Deployed	Monthly Rate	Market Share
1	ChargePoint Network	3,130	52.17	33.9%
2	Tesla Supercharger	1,779	29.65	19.3%
3	Electrify America	789	13.15	8.5%
4	EV Connect	622	10.37	6.7%
5	eVgo Network	609	10.15	6.6%
6	Blink Network	461	7.68	5.0%
7	FORD_CHARGE	216	3.60	2.3%
8	Non-Networked	209	3.48	2.3%

9	RED_E	176	2.93	1.9%
10	FCN	140	2.33	1.5%

Note. Monthly rate calculated as total stations divided by 60 months (2020–2024). Market share represents percentage of 9,229 DCFC stations analyzed.

4. Temporal Deployment Trends: Year-over-Year Acceleration

Table 4 reveals two distinct phases: gradual recovery (2020–2022) with 58.7% cumulative growth, followed by NEVI-catalyzed surge with 73.5% growth in 2023 and sustained acceleration to 262.0 stations/month in 2024. The 252% increase from 2020 (893 stations) to 2024 (3,144 stations) demonstrates that federal policy successfully de-risked private sector investment. The 2022 slowdown (7.6% growth) coincides with supply chain disruptions documented in the next section, while 2023–2024 acceleration reflects both anticipatory investment ahead of NEVI awards and operational NEVI-funded sites.

Table 4: Annual DCFC Deployment Volume (2020–2024)

Year	Stations Opened	States Active	Monthly Average	YoY Growth
2020	893	49	74.4	Baseline
2021	1,317	48	109.8	+47.5%
2022	1,417	50	118.1	+7.6%
2023	2,458	51	204.8	+73.5%
2024	3,144	50	262.0	+27.9%

Note. States Active indicates number of states with at least one DCFC station opening in that year. YoY Growth calculated relative to prior year.

VI. Bottlenecks Analysis

The data reveals substantial geographic concentration and institutional disparities in Direct-Current Fast Charging (DCFC) deployment. As of March 2026, the top ten states collectively account for 68% of all public DCFC ports, underscoring the highly uneven distribution of

charging infrastructure across the United States. California alone houses 26.7% of the nation's public charging ports (Brown et al., 2024), driven by the state's ZEV mandate, early adoption incentives, and streamlined permitting structures established under Senate Bill 1236.

Temporal analysis shows accelerated deployment post-2020, coinciding with the announcement and passage of the Infrastructure Investment and Jobs Act. Between 2020 and 2024, the U.S. DCFC network expanded by 147%, from approximately 23,000 ports to 56,845 ports as of Q1 2024 (Brown et al., 2024). However, this growth remains insufficient to meet the 182,000-port target necessary to support 33 million EVs by 2030 (Wood et al., 2023), signaling that supply-side bottleneck, rather than demand, are the binding constraint.

The utility interconnection process emerges as the single most significant temporal bottleneck, with median queue times of 6 – 18 months depending on state regulatory environment (RMI, 2022; Neubauer & Wood, 2023). DCFC stations require 150–350 kW of power per charger, often exceeding transformer capacity and triggering costly upgrades (\$5,000 – \$30,000+) with uncertain timelines that delay project commitment (IEA, 2023; RMI, 2022). California's Rule 21 reforms mandate expedited timelines and utility "make-ready" programs that reduce interconnection to 6 – 9 months, while Texas's deregulated ERCOT structure requires three-party negotiations adding 2 – 4 months (California Public Utilities Commission, 2022; Lazar & Shipley, 2023). The make-ready model – where utilities install infrastructure upfront with costs recovered through ratepayer fees – effectively shifts risk from developers to utilities (RMI, 2022).

Compounding these utility delays, local permitting introduces jurisdictional variation with timelines ranging from 2–6 weeks in streamlined municipalities to 4 – 6 months in jurisdictions lacking institutional experience (Frick et al., 2022). California Senate Bill 1236 (2022) mandates standardized checklists and maximum review timelines (60 days for commercial DCFC), reducing median permitting from 4 – 6 months to 1 – 2 months statewide (California Energy Commission, 2024). Mississippi's lack of state-level framework – leaving 82 counties with independent processes – contributes to its 2.00 stations/month deployment rate, only 6% of California's 31.12 stations/month (MDOT, 2024). Model permitting legislation paired with inspector training can reduce processing time by 50 – 70% (Frick et al., 2022).

Beyond these institutional barriers, hardware and labor constraints operate at manufacturing and installation stages, with DCFC units (\$40,000 – \$150,000) relying on semiconductor-based power electronics subject to supply disruptions that extended lead times from 3 – 4 months to 6 – 9 months (AmpUp, 2026; IEA, 2023). Labor shortages compound the bottleneck: fewer than 20% of residential electricians hold DCFC certification, with rural states having under 50 certified installers versus California's 2,400+, driving costs to \$20,000–\$40,000 (Bureau of Labor Statistics, 2023; U.S. Department of Labor, 2024; RMI, 2022). Unlike state-amenable institutional bottlenecks, hardware supply chains require federal policy: the IRA's enhanced 30C tax credit (10% bonus for domestic content) and expanded DOL EVITP workforce programs with tuition subsidies (Grant Thornton, 2024; U.S. Department of Labor, 2024).

VII. Policy Implications and Recommendations

The bottleneck and infrastructure deployment rate analyses support four targeted interventions to sustain deployment acceleration through 2030. Immediate-impact interventions should prioritize utility make-ready programs (reducing Stage E interconnection timelines by 40 – 50% through state Public Utility Commissions' mandates) and state-level model permitting legislation replicating California SB 1236 (compressing Stage C permitting from 4 – 6 months to 1–2 months), which together address the institutional bottlenecks responsible for 65 – 85% of deployment time.

Long-term capacity building requires expanding federal workforce development funding (DOL's EVITP program to certify 10,000 additional installers by 2027) and strengthening IRA domestic content (10% bonus credit expansion to power electronics and transformers, plus \$500M transformer production program). California's comprehensive policy ecosystem, combining ZEV mandates, CALeVIP grants, utility make-ready programs, and SB 1236 streamlining, demonstrates that these interventions are mutually reinforcing: make-ready programs reduce interconnection uncertainty enabling faster permitting, workforce expansion ensures permitted projects proceed immediately to installation, and domestic content incentives stabilize hardware lead times. States implementing all four policies concurrently can achieve the 12 – 15 month lower-bound deployment timeline necessary to meet 2030 infrastructure targets.

VIII. Conclusion: Institutional Reform as the Path Forward

The 153.5% national deployment acceleration documented in this analysis, from 92.1 to 233.4 stations/month following the Infrastructure Investment and Jobs Act, validates that federal policy successfully catalyzes private sector investment in charging infrastructure. However, dramatic state-level variation reveals a fundamental tension: Texas's 520.8% acceleration demonstrates rapid gains when federal funding meets moderate institutional capacity, California's modest 8.7% acceleration reflects near-saturation despite optimal policies, and Mississippi's 860% acceleration translating to only 2.00 stations/month illustrates that capital alone cannot overcome institutional deficits. This variation underscores that the deployment challenge is not technological innovation but unglamorous institutional reform: standardizing permitting checklists, training building inspectors, reforming utility interconnection queues, and expanding certified electrician pipelines. The 252% increase in annual DCFC deployments from 893 stations (2020) to 3,144 stations (2024) demonstrates momentum is building. The question is whether policymakers, utilities, and local governments will sustain this acceleration through coordinated state and federal institutional reform, or whether deployment will plateau as low-hanging fruit is exhausted and institutional bottlenecks reassert dominance.

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