



# Landscape Review of Electrification, Automation, and Labor in California Ports

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## Table of Contents

- Executive Summary.....2**
  - Summary of Key Findings ..... 2
  - Knowledge Gaps ..... 3
  - Next Steps for Decision-Makers ..... 3
- Detailed Findings .....4**
  - Introduction ..... 4
  - Electrification in Port Operations ..... 5
  - Automation in Port Operations..... 6
  - Interaction Between Electrification and Automation ..... 8
  - Job Impacts and Skill Shifts ..... 11
  - Union Dynamics and Workforce Governance ..... 11
  - Summary of Key Themes..... 13
  - Knowledge Gaps for California Decision-Makers ..... 13
  - Areas for Deeper Analysis ..... 14
  - Next Steps ..... 15
- Bibliography .....16**

## Executive Summary

This review involves selecting relevant studies, news articles, and reports, and synthesizing their key themes and findings to provide an overview of electrification, automation, and labor in California ports.

### Summary of Key Findings

California ports are undergoing two major transitions (electrification and automation) driven by climate mandates, air quality regulations, and competitive pressures. These changes have significant implications for infrastructure, labor, and governance.

#### Electrification Trends

- Mandates such as CARB’s At-Berth and Advanced Clean Fleets regulations require zero-emission operations by 2030–2035. California ports report strong compliance with shore-power rules and are rapidly scaling zero-emission strategies ranging from widespread Alternative Maritime Power (AMP) deployment to aggressive 2030 targets and major investments in electric and hydrogen cargo-handling equipment and drayage truck replacements (e.g., Los Angeles, Oakland, and San Diego).
- Electrification of shore power, cargo handling equipment (CHE), and drayage trucks is accelerating, supported by federal and state funding programs.
- Workforce impacts include a shift from diesel-centric mechanical work to electrical and software-based maintenance, creating demand for high-voltage electricians, energy management specialists, and IT technicians.

#### Automation Dynamics

- Automation spans remote-controlled cranes, automated stacking, and digital yard systems.
- Evidence on productivity gains is mixed: some terminals report efficiency and job growth, while others show job losses and reduced throughput.
- Labor concerns center on job displacement, safety, and governance. Successful cases emphasize early engagement, retraining, and enforceable transition provisions. U.S. port automation remains limited and contested, with studies, unions, operators, and contracts offering sharply different conclusions about its effects, but overall the debate centers on whether automation enhances efficiency and sustainability or instead reduces jobs, shifts power to foreign owners, and harms local communities.

#### Interaction Between Electrification and Automation

- Electrification enables automation by providing stable power for advanced systems, but rapid electrification mandates can unintentionally accelerate automation without parallel workforce agreements. For example, operators may feel pressured to adopt the expensive automation technologies quickly to stay compliant and competitive. According to the UCLA Labor Center report, several interviewees said that strict local regulations are making the San Pedro Bay Complex less competitive and pushing discretionary cargo toward ports with looser rules.
- Strict air-quality rules (e.g., Indirect Source Rule (ISR)) may push operators toward expensive, job-reducing automation even though simpler electrification upgrades could have met the same emissions standards.

- Workers face a double squeeze as equipment becomes both electric (requiring fewer mechanical repairs and different skills) and automated (reducing direct human operation), threatening traditional diesel-era maintenance roles and manual yard jobs.
- New long-term job opportunities emerge in high-voltage electrical work, instrumentation, automation maintenance, cybersecurity, and systems integration if training and job classifications are negotiated early.
- Both transitions require integrated planning for infrastructure, labor standards, and governance to avoid social and operational conflicts.

#### Labor and Governance

- Union contracts (e.g., ILWU-PMA) set rules for technology adoption, staffing, and retraining.
- Workforce development initiatives like the Goods Movement Training Campus aim to prepare workers for emerging roles, but gaps remain in scale and integration.

#### Knowledge Gaps

- Absence of comprehensive port-wide projections of job losses and gains.
- No longitudinal tracking of displaced workers' career trajectories.
- Unclear effectiveness of upskilling programs and mitigation tools like automation taxes.
- No integrated analysis of how electrification and automation together affect employment, job quality, and community economic health.
- Missing frameworks for aligning training programs to the skill requirements.
- Lack of unified monitoring systems for labor impacts and equity outcomes.

#### Next Steps for Decision-Makers

- Targeted Research and Data Collection: Conduct longitudinal studies on employment outcomes and develop integrated labor impact forecasts for electrification and automation.
- Evaluate and Expand Workforce Development Programs: Work with unions, community colleges, and industry to ensure accessibility and job quality and assess current retraining programs and adapt curricula for dual transitions.
- Develop and Test Policy Tools: Pilot automation taxes or displaced worker fees. Implement wage and benefit standards for new technology-driven roles.
- Create Integrated Monitoring Systems: Build unified platforms for tracking labor impacts and enable real-time feedback for adaptive policy responses.
- Foster Cross-Agency and Stakeholder Coordination: Establish joint planning bodies involving ports, labor, utilities, and communities. Align technical, economic, and social goals through inclusive governance frameworks.

## Detailed Findings

### Introduction

California ports are simultaneously navigating rapid decarbonization requirements for ships at berth, cargo handling equipment (CHE), and drayage, and ongoing debates about the effects of electrification and automation on productivity, resilience, and dock work. Electrification is being driven by California's air quality and climate mandates, including the At Berth regulation for ocean going vessels<sup>1</sup> and the Advanced Clean Fleets (ACF) regulation that phases drayage trucks to zero emission by 2035<sup>2</sup>. Port-level strategies (e.g., the San Pedro Bay Clean Air Action Plan) translate these mandates into equipment and infrastructure roadmaps<sup>3</sup>. Funding programs like federal grants such as EPA's Clean Ports Program<sup>4</sup> and state vouchers such as HVIP<sup>5</sup> and CORE<sup>6</sup> shape adoption pathways by subsidizing early deployments and requiring project reporting. In practice, electrified equipment increases dependence on power quality, charging logistics, and software systems conditions that can enable automation and reshape labor demand.

California's AB 639 required UCLA Labor Center to assess automation impacts through stakeholder panels and interviews. Stakeholders agreed that the San Pedro Bay Port Complex faces major challenges, including rising competition for cargo, insufficient investment, supply chain inefficiencies, and strict local regulations (e.g., emissions standards). They favored alternatives to automation such as extended operating hours, inland ports, and on-dock rail, while expressing doubts about automation's benefits and warning of safety hazards and negative impacts on the harbor community<sup>7</sup>. Automation's employment impacts at the San Pedro Bay complex have been a point of contention, primarily due to concerns about potential job losses. However, an analysis of Long Beach Container Terminal (LBCT) and TraPac (a major container terminal operator and vessel stevedore) shows that automation significantly increased container throughput and efficiency while also boosting paid labor hours, demonstrating a win-win for productivity and job growth, while emphasizing that outcomes depend on terminal design choices and governance context<sup>8</sup>.

Labor implications of port automation cluster around four recurring pressure points. First, job classifications are challenged as remote operations, Information Technology (IT) / Operational Technology (OT) integration, and high-voltage systems become core to terminal operations, requiring unions to secure coverage for new roles and prevent outsourcing. Second, safety and workspace governance become critical in mixed fleets of manual and automated equipment and related reports noting risks from accidents and psychosocial stress and calling for health and safety committees. Third, training pipelines are essential as automation demands new technical skills such as high-voltage safety, software diagnostics, and cybersecurity, with evidence of retraining needs and external hiring due to skill gaps. Finally, the distribution of productivity benefits (e.g., covering wages, staffing, hours, and community investments) remains a contentious issue, with examples of negotiated arrangements like reduced hours without pay loss and wage-linked productivity gains. Co-decision mechanisms and transparent cost-benefit analyses are vital to mitigate social costs and ensure fair outcomes for workers<sup>9 10</sup>.

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<sup>1</sup> <https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2019/ogvatberth2019/fro.pdf>

<sup>2</sup> [https://ww2.arb.ca.gov/sites/default/files/2022-03/ACF\\_Fact\\_Sheet\\_ADA.pdf](https://ww2.arb.ca.gov/sites/default/files/2022-03/ACF_Fact_Sheet_ADA.pdf)

<sup>3</sup> [https://cityclerk.lacity.org/onlinedocs/2017/17-1283\\_misc\\_12-01-2017.pdf](https://cityclerk.lacity.org/onlinedocs/2017/17-1283_misc_12-01-2017.pdf)

<sup>4</sup> <https://www.epa.gov/ports-initiative/clean-ports-program>

<sup>5</sup> <https://ww2.arb.ca.gov/resources/fact-sheets/clean-truck-and-bus-vouchers-hvip>

<sup>6</sup> <https://ww2.arb.ca.gov/our-work/programs/clean-off-road-equipment-voucher-incentive-project>

<sup>7</sup> <https://labor.ucla.edu/wp-content/uploads/2023/11/Automation-and-Dockwork-Report.pdf>

<sup>8</sup> [https://gspp.berkeley.edu/assets/uploads/research/pdf/Nacht\\_and\\_Henry\\_Automation\\_Report\\_FINAL\\_w\\_page\\_numbers.pdf](https://gspp.berkeley.edu/assets/uploads/research/pdf/Nacht_and_Henry_Automation_Report_FINAL_w_page_numbers.pdf)

<sup>9</sup> [https://www.oecd.org/content/dam/oecd/en/publications/reports/2021/10/container-port-automation\\_98f01599/8db18610-en.pdf](https://www.oecd.org/content/dam/oecd/en/publications/reports/2021/10/container-port-automation_98f01599/8db18610-en.pdf)

<sup>10</sup> [https://www.itfglobal.org/sites/default/files/node/resources/files/ITF\\_Dockers\\_Fow\\_Campaign\\_Toolkit\\_EN.pdf](https://www.itfglobal.org/sites/default/files/node/resources/files/ITF_Dockers_Fow_Campaign_Toolkit_EN.pdf)

Across the literature, a persistent gap is the lack of shared, comparable metrics for workforce outcomes (job quality, health and safety, career progression) that can be tracked alongside emissions and throughput. A practical next step is to embed workforce metrics, training commitments, and data transparency requirements into funding and permitting so electrification and automation projects generate comparable evidence for California decision-makers. The goal of the next sections of this review is to map the technological, labor, and policy environment shaping electrification and automation in California’s port sector.

## **Electrification in Port Operations**

Electrification in ports refers to substituting electricity for diesel combustion in port operations. It includes shore power for vessels at berth, electrified cargo handling equipment (CHE) (yard tractors, forklifts, top handlers, reach stackers, and rubber-tired gantry cranes), and charging and power distribution infrastructure (substations, feeders, transformers, microgrids, and energy management systems). California’s electrification trajectory is shaped by both regulations and infrastructure realities. Shore power is governed by CARB’s At Berth regulation<sup>11</sup>, and CARB reports high compliance rates under the updated rule<sup>12</sup>. At the Port of Los Angeles, Alternative Maritime Power (AMP) infrastructure has been scaled across terminals, reflecting a long running strategy to reduce at berth emissions<sup>13</sup>.

For CHE, California historically relied on engine standards and diesel particulate matter control strategies in the Mobile Cargo Handling Equipment regulation (13 CCR §2479)<sup>14</sup>. More recent port and state plans focus on full zero emission CHE transitions by 2030 at major gateways<sup>15</sup> and fleet conversion roadmaps supported by CEC and CARB funding programs<sup>16</sup>. The Port of Oakland secured an EPA Clean Ports grant to replace 475 drayage trucks and 188 cargo handling units with zero-emission hydrogen and battery-electric technology<sup>17</sup>. San Diego’s Maritime Clean Air Strategy also sets a 2030 target for 100% zero emission cargo handling equipment and trucks calling at cargo terminals<sup>18</sup>.

Electrification of port operations, especially CHE, drayage trucks, and shore power systems tends to be labor-transforming rather than purely labor-reducing. Across studies and program documents, the most consistent finding is a shift in maintenance and operations tasks away from diesel-centric mechanical work toward electrical, power-electronics, diagnostics, and software-enabled troubleshooting. This includes high-voltage safety procedures, battery management and replacement, charging system operation, and grid-interface coordination. Workforce assessments for the Port of Long Beach’s zero-emissions transition explicitly emphasize increased demand for extensive workforce upskilling in high-voltage safety, energy efficiency planning, and electro-automotive skills, with critical demand for electricians, solar installers, automotive technicians, electrical engineers, and power-line installers<sup>19</sup>.

Similarly, the “High Road to the Port” initiative frames decarbonization investments as a chance to formalize training pipelines, raise job quality, and expand equitable access to port careers. It emphasizes that meeting zero-emission goals requires upskilling incumbent workers and introducing new entrants through innovative, worker-centered programs like the lashing training initiative. These efforts aim to ensure safe workplaces, career pathways, and inclusive hiring while aligning environmental sustainability

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<sup>11</sup> <https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2019/ogvatberth2019/fro.pdf>

<sup>12</sup> <https://ww2.arb.ca.gov/our-work/programs/enforcement-policy-reports/enforcement-data-portal/2024-shore-power-enforcement>

<sup>13</sup> <https://portoflosangeles.org/environment/air-quality/alternative-maritime-power-%28amp%29>

<sup>14</sup> <https://www.law.cornell.edu/regulations/california/13-CCR-2479>

<sup>15</sup> [https://portoflosangeles.org/references/2024-news-releases/news\\_100424\\_emissions\\_inventory](https://portoflosangeles.org/references/2024-news-releases/news_100424_emissions_inventory)

<sup>16</sup> <https://www.energy.ca.gov/sites/default/files/2024-04/CEC-600-2024-042.pdf>

<sup>17</sup> <https://cte.tv/post/epa-awards-322-million-to-port-of-oakland-for-historic-zero-emissions-transformation>

<sup>18</sup> <https://pantheonstorage.blob.core.windows.net/environment/20211214-Final-MCAS.pdf>

<sup>19</sup> [https://cdn.agilitycms.com/csulb-cpie/documents/citt/CITT\\_POLB\\_ZEV\\_Workforce\\_Development\\_Report\\_040219.pdf](https://cdn.agilitycms.com/csulb-cpie/documents/citt/CITT_POLB_ZEV_Workforce_Development_Report_040219.pdf)

with economic resilience<sup>20</sup>. Policy syntheses of the zero-emission CHE transition in San Pedro Bay also highlight that fear among communities and workers of job loss is a significant barrier to adopting zero-emission cargo handling equipment. They warn that without strong commitments to job preservation, local hiring, and workforce training, the transition could harm frontline communities and lead to resistance. To mitigate this, the report recommends policies that protect existing jobs, create local employment opportunities, and expand upskilling and reskilling programs so workers can operate and maintain new technologies<sup>21</sup>.

Electrification can also affect labor via economics and competitiveness. For example, a macroeconomic analysis of CHE electrification at ports of Los Angeles and Long Beach finds that while the transition requires large capital and infrastructure investments, the resulting net losses in jobs and economic output are relatively small compared to California's overall economy. The actual impact depends heavily on who bears the costs (government vs. private sector), the ability of ports to pass costs to customers, and how quickly technology improves and reduces costs. Sensitivity analyses show that government incentives and faster technology learning curves can significantly reduce negative impacts, while limited cost pass-through or higher costs increase losses<sup>22</sup>. From a labor perspective, this points to an important governance lever: financing and rate design can shift the distribution of impacts across operators, supply-chain users, and workers (e.g., if costs are recovered through higher terminal fees, cargo diversion risks can translate into reduced work hours). Conversely, targeted subsidies, strategic grid upgrades, and coordinated infrastructure planning can reduce transition costs, minimize operational disruptions, and help stabilize employment.

Finally, electrification has direct workplace health and safety implications. Replacing diesel equipment reduces on-terminal exposure to combustion-related air toxics, noise, and vibration benefits that matter for both workers and surrounding communities<sup>23 24</sup>. However, electrification can also introduce new hazards (high-voltage arc flash, battery thermal events, and charging-interface failures), making updated training, protective equipment, and incident protocols central to maintaining job quality and safety<sup>25</sup>.

## **Automation in Port Operations**

Automation in port operations spans a spectrum from decision support software to highly automated physical handling. Core components include automated ship to shore cranes, automated stacking cranes, automated guided vehicles (AGVs) or autonomous terminal tractors, remote operations centers, optical character recognition (OCR) and gate automation, and digital yard/terminal operating systems (TOS) that coordinate work<sup>26 27 28 29</sup>. Global evidence indicates that automation outcomes depend heavily on implementation choices and context. A cross-port assessment report concludes that port automation is not a universal solution for improving efficiency, especially in ports facing volatile cargo flows and workload peaks from larger ships. Extensive automation has been adopted by very few terminals because evidence of productivity gains and cost reductions remains limited. Automation can be cost-effective in specific contexts, such as large gateway terminals with stable container volumes or where labor shortages exist. However, it often leads to social conflicts and unaddressed societal costs like job losses and reduced

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<sup>20</sup> [https://cwdb.ca.gov/wp-content/uploads/sites/43/2019/11/High-Road-to-the-Port-11-25-2019\\_ACCESSIBLE.pdf](https://cwdb.ca.gov/wp-content/uploads/sites/43/2019/11/High-Road-to-the-Port-11-25-2019_ACCESSIBLE.pdf)

<sup>21</sup> <https://www.law.berkeley.edu/wp-content/uploads/2023/11/A-Heavy-Lift-DIGITAL-2.pdf>

<sup>22</sup> [https://www.mettrans.org/assets/research/psr-18-sp90\\_genevieve\\_giuliano\\_final\\_report.pdf](https://www.mettrans.org/assets/research/psr-18-sp90_genevieve_giuliano_final_report.pdf)

<sup>23</sup> [https://www.pnnl.gov/sites/default/files/media/file/Port\\_Electrification\\_Handbook\\_Executive%20Summary\\_FINAL.pdf](https://www.pnnl.gov/sites/default/files/media/file/Port_Electrification_Handbook_Executive%20Summary_FINAL.pdf)

<sup>24</sup> [https://theicct.org/wp-content/uploads/2023/02/Ports-electrification-US\\_final.pdf](https://theicct.org/wp-content/uploads/2023/02/Ports-electrification-US_final.pdf)

<sup>25</sup> <https://www.portwiseconsultancy.com/blog/what-safety-protocols-are-essential-when-operating-high-voltage-equipment-in-port-environments/>

<sup>26</sup> <https://roboticsandautomationnews.com/2026/01/29/automated-port-and-terminal-operations-robots-moving-global-trade/98362/>

<sup>27</sup> <https://www.smartloadinghub.com/insights/conveyor-handling/how-ship-to-shore-crane-automation-reshaping-quay-to-yard/>

<sup>28</sup> <https://www.konecranes.com/en-us/port-equipment-services/container-handling-equipment/automated-guided-vehicles/agv>

<sup>29</sup> <https://new.abb.com/ports/solutions-for-marine-terminals/our-offerings/container-terminal-automation/sts-crane-automation>

tax revenues. Policymakers should focus on flexible labor arrangements, transparent cost-benefit analyses, fostering cooperation between employers and workers, and incorporating social impacts into decision-making to ensure balanced and sustainable automation strategies<sup>30</sup>.

The GAO report finds that all major U.S. container ports have adopted some automation technologies, primarily process automation like automated gates, while only a few use automated cargo handling equipment. Foreign ports generally have more advanced and widespread automation due to larger cargo volumes, labor conditions, and operational factors. Automation offers benefits such as improved safety and reduced emissions but has mixed impacts on workforce size, job skills, and terminal performance (sometimes increasing efficiency and capacity, other times slowing operations). U.S. terminal operators weigh labor agreements, high costs, return on investment, environmental goals, and terminal characteristics when deciding to automate. Federal involvement is limited, with few programs explicitly supporting port automation; most related activities focus on broader supply chain performance and emissions reduction rather than automation alone<sup>31</sup>.

The Dockers' Future of Work Toolkit by the International Transport Workers' Federation (ITF) addresses the growing challenge of automation and digitalization in ports, emphasizing that automation often reduces productivity, eliminates jobs, and harms communities without delivering promised benefits. It outlines ITF's position against union-busting automation, calls for economic transparency, job security, and gender equality, and warns of cybersecurity risks and privacy concerns linked to AI and remote operations. The toolkit provides strategies for unions, including collective bargaining, political lobbying, community engagement, and international solidarity, along with sample contract clauses and campaign examples from various countries. Its core message is that automation should not undermine workers' rights or community welfare, and unions must proactively shape the future of work through education, advocacy, and negotiation<sup>32</sup>.

In Southern California, empirical analyses disagree on net job impacts but converge on the importance of governance: staffing models, work rules, and how technology changes the distribution of tasks across job categories. An in-depth analysis of terminal automation at the San Pedro Bay Port Complex (Los Angeles and Long Beach) and its implications for competitiveness, job growth, and environmental sustainability examines how automation (ranging from partial systems like remote-controlled cranes and automated stacking to fully integrated solutions with autonomous vehicles) can help overcome physical capacity limits, reduce supply chain bottlenecks, and meet environmental regulations. The report also addresses labor impacts, showing that automation has increased paid hours and workforce size while creating opportunities for retraining and upskilling, supported by financial safety nets. Ultimately, it concludes that automation is essential for maintaining the ports' market share, improving efficiency, and achieving sustainability goals, while failure to modernize risks cargo diversion and economic losses for Southern California<sup>33</sup>.

However, another analysis argues that automation at the San Pedro Bay ports has significantly reduced dockside employment without delivering the promised efficiency gains. The report measures dockside employment by analyzing labor-hour data from the ports and the Pacific Maritime Association. It compares hours of dock work required per container before and after automation, and also evaluates the ratio of dockside hours to shipside hours. By calculating how many labor hours disappeared and converting those hours into full-time positions, the report determines that automation eliminated hundreds of dockworker jobs. At LBCT and TraPac, automation cut dock work by 34–52%, eliminating an estimated 572 full-time jobs annually in 2020 - 2021. This job loss also triggered other effects, reducing

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<sup>30</sup> [https://www.oecd.org/content/dam/oecd/en/publications/reports/2021/10/container-port-automation\\_98f01599/8db18610-en.pdf](https://www.oecd.org/content/dam/oecd/en/publications/reports/2021/10/container-port-automation_98f01599/8db18610-en.pdf)

<sup>31</sup> <https://www.gao.gov/assets/d24106498.pdf>

<sup>32</sup> [https://www.itfglobal.org/sites/default/files/node/resources/files/Dockers\\_FOW\\_Toolkit\\_WEB\\_VERSION\\_FINAL\\_112025.pdf](https://www.itfglobal.org/sites/default/files/node/resources/files/Dockers_FOW_Toolkit_WEB_VERSION_FINAL_112025.pdf)

<sup>33</sup> [https://gspp.berkeley.edu/assets/uploads/research/pdf/Nacht\\_and\\_Henry\\_Automation\\_Report\\_FINAL\\_w\\_page\\_numbers.pdf](https://gspp.berkeley.edu/assets/uploads/research/pdf/Nacht_and_Henry_Automation_Report_FINAL_w_page_numbers.pdf)

household spending and eliminating 254 additional non-port jobs in local businesses. Despite high capital costs (\$1.5 billion for LBCT and over \$617 million for TraPac) studies show automated terminals are often 7–15% less productive than conventional ones, and any cost savings primarily benefit foreign owners rather than U.S. workers. Future automation could erase up to 75% of dockside work, costing \$627.6 million in wages and thousands more jobs statewide, undermining California’s economy and tax revenues<sup>34</sup>.

While automation is often promoted as one of the solutions for the challenges facing the San Pedro Bay Port Complex (e.g., rising competition, insufficient investment, and strict local regulations), stakeholders questioned its benefits, noting limited evidence of improved productivity or cost savings and highlighting risks such as safety hazards, increased surveillance, and ripple effects across the supply chain. Alternatives like expanding operating hours, investing in inland ports and on-dock rail, and improving worker training were seen as more effective and less disruptive. Concerns also centered on automation’s potential to affect job quality, displace workers, and harm the harbor community by exporting economic benefits to foreign-owned firms<sup>35</sup>.

Automation technologies often transform manual, physically demanding, and hazardous jobs into safer, more comfortable office-based roles, such as remote crane operations or gate clerks working in centralized offices. Additionally, automation shifts skill requirements, creating demand for higher-skilled positions in IT and mechanics, and some ports are investing in workforce training and “upskilling” to meet these needs<sup>36</sup>. Successful terminal automation requires treating labor transformation as strategically important as the technology itself. Operators who integrate workforce planning into every stage planning, pre-implementation, implementation, and post-implementation achieve smoother transitions, stronger labor relations, and better long-term performance<sup>37</sup>.

The Pacific Coast Longshore Contract Document 2022–2028 directly addresses port automation by establishing that the introduction of new technologies including fully mechanized and robotic-operated marine terminals falls under the jurisdiction of the Longshore and Warehouse Union (ILWU) for maintenance and repair work, except at certain red-circled facilities with historical exceptions. The contract requires that installation, maintenance, and repair of automation-related equipment be performed by ILWU workers. It also sets minimum manning requirements for automated terminals, restricts remote operation of cargo handling equipment to on-terminal locations, and mandates transition plans and retraining for affected workers. If employers violate these provisions, they may lose the right to introduce new technologies or hire steady labor until the issue is resolved. Overall, the contract ensures that automation is implemented in a way that protects union jurisdiction, job security, and provides for workforce adaptation through training and negotiated staffing levels<sup>38</sup>.

## **Interaction Between Electrification and Automation**

Electrification can enable automation by giving cranes and port equipment a constant and powerful source of electricity instead of relying on diesel engines. This is important because automated systems need steady power to work with other technologies like positioning and data communication. It also means less maintenance because the system is contactless and doesn’t wear out like traditional systems. Most importantly, it creates the base for automation: once power is stable, sensors can track the exact

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<sup>34</sup> <https://economicrt.org/wp-content/uploads/2023/05/Someone-Elses-Ocean-final.pdf>

<sup>35</sup> <https://labor.ucla.edu/wp-content/uploads/2023/11/Automation-and-Dockwork-Report.pdf>

<sup>36</sup> <https://www.gao.gov/assets/d24106498.pdf>

<sup>37</sup> <https://www.portwiseconsultancy.com/blog/what-is-the-impact-of-automation-on-labor-management-in-terminals/>

<sup>38</sup> [https://ilwu13.com/wp-content/uploads/simple-file-list/Contracts/Pacific\\_Coast\\_Longshore\\_Contract\\_Document\\_2022-2028.pdf](https://ilwu13.com/wp-content/uploads/simple-file-list/Contracts/Pacific_Coast_Longshore_Contract_Document_2022-2028.pdf)

position to the millimeter, and data systems can send real-time instructions. Together, these steps allow remote control and even fully automation<sup>39</sup>.

Electrification can also be applied to conventional, human-operated equipment like forklifts, gantry cranes, and terminal tractors without requiring automation, with some technologies already widely available and others in pilot stages<sup>40</sup>. Electrification focuses on reducing emissions by replacing diesel-powered equipment with electric alternatives, supporting environmental and climate objectives. Automation, however, involves introducing labor-saving technologies that reduce or transform human involvement. According to the UCLA Labor Center report, several interviewees said that strict local regulations are making the San Pedro Bay Complex less competitive and pushing discretionary cargo toward ports with looser rules. Strict air-quality rules (e.g., Indirect Source Rule (ISR)) may push operators toward expensive, job-reducing automation even though simpler electrification upgrades could have met the same emissions standards. When local environmental rules are stricter than federal ones, operators may feel pressured to adopt the expensive automation technologies quickly to stay compliant and competitive, even though cheaper and less disruptive options like electrification could achieve the same environmental goals without eliminating jobs<sup>41</sup>. However, this may also affect different operational and maintenance regimes and certain forms of labor demand for electricians, solar installers, automotive technicians, electrical engineers, and power-line installers<sup>42</sup>. For example, at the Port of Long Beach, the shift to zero-emission operations will increase demand for electrical, technical, and energy-focused occupations, especially electricians, high-voltage technicians, solar installers, and ZEV-ready automotive specialists, while reducing reliance on diesel-engine maintenance roles<sup>42</sup>. Conversely, some automation investments (e.g., a container terminal yard digital twin<sup>43</sup>) can occur without electrification, and their primary rationale may be throughput or labor substitution rather than emissions.

For labor, the dual transition can amplify both risks and opportunities. Workers whose tasks are tied to diesel-era mechanical maintenance or to manual yard moves can face a double squeeze as equipment becomes both electric (fewer moving parts, different maintenance regimes) and automated (less direct operation). Electrification also increases the relevance of electrical trades (e.g., utility and building-trades jurisdictions) while automation shifts work toward IT/controls and ports may need new frameworks to coordinate training and work assignment across ILWU classifications and other unions and contractors. However, the dual transition can also create durable demand for high-voltage electricians, instrumentation and controls technicians, automation maintenance, cybersecurity, and systems integration roles that can be organized as high-quality union jobs if training and classification pathways are negotiated early. Electrification and automation are not assessed together in the reviewed documents, leaving unanswered questions about how the combined shift will reshape port jobs, required skills, and worker transitions. As a result, the impacts on different groups are overlooked, and no coherent policy or monitoring framework emerges. Addressing these gaps will require focused research, coordinated workforce planning, and continuous evaluation.

Automated terminals generate extensive operational data that can be used for productivity management and labor evaluation. Transparent, jointly governed data practices are repeatedly emphasized as a condition for trust and credible evaluation of automation claims. Additionally, it is suggested that systems of feedback driven by workers be established to monitor the effects of automation on job quality and safety, and that training initiatives such as the Goods Movement Training Campus be developed to ensure workers are adequately prepared for technological changes without sacrificing employment opportunities<sup>41</sup>.

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<sup>39</sup> <https://www.vahleinc.com/assets/pdfs/brochures/24/Port%20Automation%20-%20VAHLE.pdf>

<sup>40</sup> [https://www.pnnl.gov/sites/default/files/media/file/Port\\_Electrification\\_Handbook\\_Executive%20Summary\\_FINAL.pdf](https://www.pnnl.gov/sites/default/files/media/file/Port_Electrification_Handbook_Executive%20Summary_FINAL.pdf)

<sup>41</sup> <https://labor.ucla.edu/wp-content/uploads/2023/11/Automation-and-Dockwork-Report.pdf>

<sup>42</sup> [https://cdn.agilitycms.com/csulb-cpie/documents/citt/CITT\\_POLB\\_ZEV\\_Workforce\\_Development\\_Report\\_040219.pdf](https://cdn.agilitycms.com/csulb-cpie/documents/citt/CITT_POLB_ZEV_Workforce_Development_Report_040219.pdf)

<sup>43</sup> <https://www.mdpi.com/2227-9717/11/7/2223>

Comparative examples suggest that negotiated governance arrangements can make the difference between automation as conflict and automation as managed transition. Automation at the Port of Rotterdam has significantly reshaped its labor landscape, reducing traditional dockside roles like crane operators while creating new positions in remote operations, IT, and system maintenance. This shift has improved efficiency and safety but raised concerns about job displacement, as highly automated terminals handle far more cargo with fewer workers. Labor unions, particularly FNV Havens, have played a critical role in negotiating collective labor agreements and social contracts to protect workers during these transitions, securing job guarantees and severance provisions. Despite these efforts, disputes and strikes have occurred when unions perceived breaches of agreements, highlighting the ongoing tension between technological progress and employment security in one of Europe's most advanced ports and implying that stronger compliance mechanisms, transparent communication, and collaborative planning between unions, terminal operators, and the Port Authority are essential to prevent conflicts and ensure a just transition during automation and modernization efforts<sup>44</sup>.

In 2017, the Port of Los Angeles signed a 10-year Project Labor Agreement (PLA) to both ensure quality and timely construction of facilities and large-scale port infrastructure projects, as well as to provide more job and training opportunities for residents in communities surrounding the Port. The PLA identifies several key stakeholder groups, each with distinct priorities. The Los Angeles Harbor Department seeks smooth, timely, and disruption-free delivery of its Capital Improvement Program while expanding economic opportunities for local and disadvantaged residents. The Building and Construction Trades Council and signatory unions prioritize maintaining jurisdiction over craft labor, protecting wages and benefits, ensuring labor stability through no-strike commitments, and supporting apprenticeship pathways. Contractors and subcontractors aim to retain essential management rights such as hiring decisions and work methods while complying with prevailing wage, safety, and targeted-hiring requirements. Local Residents and Transitional Workers are central beneficiaries, with structured provisions guaranteeing them access to construction jobs and apprenticeships. Apprenticeship programs focus on training and workforce development, supported by mandated hours. Oversight entities such as the Bureau of Contract Administration and the Joint Administrative Committee ensure compliance, resolve issues, and administer the agreement. Overall, the PLA balances labor stability, workforce equity, and project efficiency across all parties<sup>45</sup>.

A practical implication from the California-centered literature is sequencing: if electrification mandates advance faster than labor–technology governance arrangements, terminals may pursue compliance-first investments that inadvertently accelerate automation (e.g., integrated electric yard equipment packages) without parallel agreements on training, job quality, and work assignment. Conversely, if automation proposals advance without credible workforce transition plans, they can trigger bargaining conflict that delays both automation and electrification projects risking missed climate and air-quality deadlines. Therefore, many reports and studies recommend joint planning institutions (port authorities, terminal operators, labor organizations, utilities, and workforce agencies) and call for inclusive processes that involve frontline communities and workforce organizations in decision-making to align technical, economic, and social goals and integrate technology adoption and workforce transition into a single, unified program rather than treating them as separate tracks<sup>46 47</sup>.

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<sup>44</sup> <https://oliverhartwich.com/wp-content/uploads/2025/06/09-Rotterdam-Port-History-and-Growth.pdf>

<sup>45</sup> <https://kentico.portoflosangeles.org/getmedia/9bab7fcf-2c7a-4cfa-ae0-7aef1ae36c6b/PLA-2017-2027>

<sup>46</sup> <https://www.law.berkeley.edu/wp-content/uploads/2023/11/A-Heavy-Lift-DIGITAL-2.pdf>

<sup>47</sup> <https://portoflosangeles.org/business/supply-chain/workforce-development>

## **Job Impacts and Skill Shifts**

Electrifying cargo handling equipment at the Ports of Los Angeles and Long Beach is projected to result in a cumulative loss of about 96,771 job-years between 2020 and 2045, averaging 3,721 job-years lost annually. The Economic Impacts of Electrification of Cargo Handling Equipment at POLA/POLB report measures these employment impacts by feeding all annual cost changes from CHE electrification (e.g., equipment, batteries, chargers, infrastructure, fuel, and maintenance) into the REMI PI+ macroeconomic model, which simulates how these costs shifts affect industry output, prices, and competitiveness across California. REMI then converts these effects into job-years (one full-time job for one year) for each year from 2020–2045, and the report sums these yearly results to estimate total employment losses over the full period. These employment impacts are most pronounced in the early years of the transition, when significant investments in new equipment and infrastructure are required. The port-related sector, transportation, wholesale and retail trade, and other services experience the largest job losses, while gains are limited to sectors like zero-emission equipment manufacturing and utilities. The main reasons for these losses are the high upfront capital costs, the fact that much of the equipment is sourced from outside California (limiting local economic stimulus), and the ability of ports to pass increased costs downstream. However, relative to California’s overall employment base, these losses represent less than 0.02%, making the impact modest in percentage terms despite the large absolute numbers. The negative employment impacts can be significantly reduced by implementing government incentive programs that help offset the high upfront capital costs for equipment and infrastructure. These subsidies lessen the financial burden on ports and reduce the need to pass increased costs downstream, which in turn lowers job losses. Additionally, faster development of battery technology and reductions in equipment and infrastructure costs can further minimize negative impacts<sup>48</sup>.

Electrification also drives skill shifts that can be substantial but are often less visible than automation. Battery electric and fuel cell equipment changes the need for technicians familiar with power electronics, thermal management, and software updates. Charging operations create additional work in energy management, charger maintenance, and operational planning (e.g., charge scheduling aligned with peak demand and yard cycles).

Across the literature, automation’s employment impacts are not well summarized by a single jobs lost number. Impacts vary by automation configuration, baseline work organization, and whether new tasks (systems monitoring, IT integration, safety oversight) are created and staffed by existing bargaining units or shifted to nonunion contractors. In the San Pedro Bay context, one analysis reports that paid hours for ILWU labor at the two automated terminals rose from 2015 to 2021 while output increased and argues that automation can coincide with overall workforce growth under certain conditions<sup>49</sup>. Another analysis argues that automation can reduce job opportunities while automated terminals remain less productive<sup>50</sup>. The UCLA synthesis highlights that automation at the San Pedro Bay Port Complex affects ILWU locals and job categories unevenly, primarily displacing dockside roles while transforming others into tech-driven positions<sup>51</sup>.

## **Union Dynamics and Workforce Governance**

The International Longshore and Warehouse Union (ILWU) and the Pacific Maritime Association (PMA) collective bargaining agreement governs all West Coast ports, setting rules for staffing, technology installation, and dispute resolution. Since the mechanization agreement of 1963, negotiations have evolved to address new technologies, with the 2023 contract adding restrictions on automating lashing,

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<sup>48</sup> [https://www.mettrans.org/assets/research/psr-18-sp90\\_genevieve\\_giuliano\\_final\\_report.pdf](https://www.mettrans.org/assets/research/psr-18-sp90_genevieve_giuliano_final_report.pdf)

<sup>49</sup> [https://gspp.berkeley.edu/assets/uploads/research/pdf/Nacht\\_and\\_Henry\\_Automation\\_Report\\_FINAL\\_w\\_page\\_numbers.pdf](https://gspp.berkeley.edu/assets/uploads/research/pdf/Nacht_and_Henry_Automation_Report_FINAL_w_page_numbers.pdf)

<sup>50</sup> <https://economicrt.org/wp-content/uploads/2023/05/Someone-Else-Ocean-final.pdf>

<sup>51</sup> <https://labor.ucla.edu/wp-content/uploads/2023/11/Automation-and-Dockwork-Report.pdf>

requiring remote crane operations to remain on-dock, and creating new positions such as automation clerks<sup>52</sup>.

Internationally, dockworker organizations have developed Dockers' Future of Work Toolkit to help dockworkers' unions and affiliates address the challenges posed by automation, remote operations, autonomous vehicles, and digital technologies in ports. Its purpose is to educate unions about the risks of these technologies, provide strategies for collective bargaining and campaigning, and promote global solidarity to protect jobs, working conditions, and safety. The playbooks emphasize transparency, community impact, and the need for unions to influence policy and investment decisions, ensuring that technological changes benefit workers and communities rather than undermine them<sup>53</sup>. Case research from European ports (e.g., Antwerp) documents a multifaceted strategy to counter automation and protect labor standards. They leverage strong institutional frameworks to maintain control over hiring, wages, and working conditions, while using their structural bargaining power and the implicit threat of operational disruption to deter full automation. Unions emphasize professional training as a key tool to preserve high skill levels and prevent employers from hiring low-skilled, non-unionized labor, ensuring productivity and reinforcing union legitimacy. Following strikes against EU liberalization directives, they consolidated workforce cohesion, enabling them to negotiate compromises such as increased operational flexibility without sacrificing influence. Overall, Antwerp's unions combine institutional strength, workplace solidarity, and strategic negotiation to resist disruptive innovation while safeguarding the interests of dockworkers<sup>54</sup>.

A three-day strike by 45,000 dockworkers on the U.S. East and Gulf Coasts ended after a tentative wage deal, but the core dispute over port automation remains unresolved. Unions argue that technologies like automated gate systems threaten jobs and violate contracts, while port operators say automation boosts efficiency and complies with existing agreements. Similar clashes have erupted across North America, including major disputes in Vancouver and on the U.S. West Coast, where unions have pushed for training guarantees and staffing protections. Europe offers other models like long-standing contracts in places like Rotterdam prevent layoffs due to automation<sup>55</sup>.

In 2019, thousands of ILWU members and allies rallied, and a packed Port Commission hearing featured concerns about job loss, environmental impacts, and the questionable economic value of Maersk's proposal to automate Terminal 400 at the Port of Los Angeles, with critics citing studies showing that automation often fails to improve productivity or recoup costs. Political leaders, including the mayor, urged delaying the project, and the Port Commission ultimately postponed action while considering mediation, leaving the future of the automation plan uncertain<sup>56</sup>.

AB 639, passed in 2020, required the California Workforce Development Board to commission a study on the impacts of automation at the Ports of Los Angeles and Long Beach. The UCLA Labor Center led this effort by convening a 10-member stakeholder panel representing labor unions (ILWU), terminal operators, port authorities, and legislative appointees. Over 18 months, the panel met six times to guide research, review case studies, and develop recommendations. The bill's intent was to ensure that workers and communities have a voice in shaping responses to automation, focusing on mitigating job loss and supporting workforce development. During panel discussions and interviews, stakeholders repeatedly emphasized the need for robust training infrastructure to prepare workers for emerging technologies and zero-emission equipment. This feedback shaped the decision to invest \$110 million in the Goods Movement Training Campus, which will provide advanced training, upskilling, and safety programs to

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<sup>52</sup> <https://labor.ucla.edu/wp-content/uploads/2023/11/Automation-and-Dockwork-Report.pdf>

<sup>53</sup> [https://www.itfglobal.org/sites/default/files/node/resources/files/Dockers\\_FOW\\_Toolkit\\_WEB\\_VERSION\\_FINAL\\_112025.pdf](https://www.itfglobal.org/sites/default/files/node/resources/files/Dockers_FOW_Toolkit_WEB_VERSION_FINAL_112025.pdf)

<sup>54</sup> <https://d-nb.info/1271175037/34>

<sup>55</sup> <https://www.reuters.com/world/us/us-port-strike-throws-spotlight-big-union-foe-automation-2024-10-04/>

<sup>56</sup> <https://www.ilwu.org/newest-automation-plan-hits-a-nerve-with-la-port-communities/>

ensure workers can adapt to automation and environmental mandates<sup>57</sup>. Recent labor disruptions and negotiations have kept automation on the agenda nationally and regionally, reinforcing that technology choices are inseparable from bargaining and governance design<sup>58</sup>. For California, this translates into a practical expectation that public funding for modernization will be accompanied by labor standards, training commitments, and credible transition governance.

## **Summary of Key Themes**

Electrification and automation converge in several ways that reflect shared technical foundations and interdependent infrastructure needs. Electrification increasingly relies on software-driven control systems for remote diagnostics, energy management, and equipment health monitoring (the same digital capabilities that underpin automated operations). Large-scale electrification also requires substantial upgrades to power systems, networks, and data infrastructure, which are the prerequisites for advanced automation. Finally, both transitions depend on similar operational optimization tools like real-time data, predictive scheduling, and integrated asset-management systems. Electrification introduces new constraints around charging windows, energy costs, and equipment availability, all of which require the same data architecture and scheduling logic used in automated yards. In this sense, electrification pushes ports toward the digital backbone that automation also relies on, even when the two transitions are pursued for different policies or operational reasons.

Despite these complementarities, electrification and automation can also come into conflict when their timelines, requirements, or incentives diverge. Emissions-driven electrification targets often emphasize rapid equipment conversion within existing operating models, whereas automation initiatives typically require longer planning horizons and redesigned workflows. Funding and procurement rules may unintentionally privilege one pathway over the other, encouraging demonstrations of innovation without ensuring operational readiness or workforce alignment. Analyses of electrification highlight sensitivity to electricity costs and infrastructure capacity, often prompting operational changes that carry labor implications even in the absence of automation and that may interact with bargaining constraints around scheduling and staffing.

Labor concerns are most acute where technology shifts control, discretion, or the location of work. Remote operations centers can relocate tasks off-dock and alter skill requirements. Automated dispatch and gate systems can reshape pacing, assignment, and accountability and new maintenance regimes may shift work from mechanical tasks to vendor-controlled software and electronics. In these contexts, job security is only one dimension of worker impact and job quality, safety, and governance structures become equally central. Comparative labor guidance emphasizes early engagement, enforceable transition provisions, and transparency around workforce impacts, while California-specific research underscores that outcomes vary across locals and that control over technology (not merely its presence) plays a decisive role in shaping labor relations. Accordingly, California studies recommend joint planning bodies that bring together port authorities, operators, labor, utilities, workforce agencies, and frontline communities to align technical, economic, and social goals and integrate technology and workforce transition into a unified program.

## **Knowledge Gaps for California Decision-Makers**

It is clear that some important knowledge gaps remain for California decision-makers regarding the labor impacts of electrification, automation, and their intersection in California ports. While this review includes a range of technical assessments, regulatory texts, case studies, workforce development reports, and

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<sup>57</sup> <https://labor.ucla.edu/wp-content/uploads/2023/11/Automation-and-Dockwork-Report.pdf>

<sup>58</sup> [https://www.pmanet.org/press\\_releases/pma-statement-re-continued-ilwu-work-action-at-ports-of-la-and-long-beach-april-13-2023/](https://www.pmanet.org/press_releases/pma-statement-re-continued-ilwu-work-action-at-ports-of-la-and-long-beach-april-13-2023/)

international comparisons, none of the documents provide comprehensive, California-specific, quantitative, or longitudinal evidence that fully addresses the following gaps.

For electrification, the reviewed documents describe the need for new skills (such as electricians and high-voltage technicians), mention workforce development programs, and outline pilot projects at California ports. However, they do not offer robust forecasts of net job creation versus displacement, nor do they track the long-term effectiveness of retraining and upskilling programs for incumbent workers. There is also a lack of data on whether new electrification jobs offer comparable wages, benefits, and job security to traditional roles, and little information on how these opportunities are distributed across demographic groups or whether disadvantaged communities are benefiting equitably. The evolving role of unions in shaping job classifications and work rules for electrified equipment is discussed but not analyzed in depth.

Regarding automation, the reviewed documents provide case studies and estimates of job losses at automated terminals, and they discuss the creation of new roles in IT and remote operations. However, there is no comprehensive, port-wide forecast of future job losses if automation expands, nor is there tracking of what happens to displaced workers such as whether they are retrained, re-employed, or exit the workforce and their long-term wage and benefit trajectories. The number, type, and accessibility of new jobs created by automation for current port workers are not quantified, and the effectiveness of upskilling programs for automation-related roles is not evaluated. While labor agreements are described, there is no assessment of best practices for ensuring automation delivers net public benefit, and proposed mitigation tools like displaced worker fees or automation taxes remain untested.

When considering the combined effects of electrification and automation, none of the documents provide an integrated analysis of how these trends together will affect total port employment, job quality, or community economic health. There is no mapping of the combined skill requirements or alignment of training programs to address both trends, nor are there clear, evidence-based transition pathways for workers moving from traditional roles to new roles created by both electrification and automation. The intersectional impacts on different worker groups such as older workers, women, or workers of color are not studied, and there is no unified policy framework or monitoring system for tracking and adapting to the combined labor impacts as these technologies advance. Addressing these gaps will require new, targeted research, integrated workforce planning, and ongoing monitoring and evaluation that go beyond what is currently available.

### **Areas for Deeper Analysis**

- Comparative case studies of specific terminals (manual, semi-automated, and automated) to document work organization and workforce outcomes under comparable conditions.
- Workforce transition strategy design for electrification: quantify training needs, credential pathways, and staffing requirements for high-voltage and operations and maintenance.
- Policy alignment analysis: examine how grant requirements could embed labor standards, transparency, and community-benefit commitments without slowing deployment.
- Energy system planning: assess grid capacity, power quality, and microgrid strategies as both operational and labor issues (outage response, maintenance, safety).
- Labor governance mechanisms: evaluate models for co-design (joint labor-management committees, technology impact assessments, data governance agreements).

## **Next Steps**

### **Targeted Research and Data Collection**

- Conduct longitudinal studies to track the long-term employment outcomes of workers affected by electrification and automation, including job placement, wage progression, and career satisfaction.
- Develop robust labor impact forecasts for both electrification and automation, as well as their combined effects, at the port, regional, and state levels.
- Collect demographic and equity data on new job creation, displacement, and access to training, with a focus on age, gender, ethnicity, and disadvantaged communities.

### **Evaluate and Expand Workforce Development Programs**

- Assess the effectiveness of existing retraining and upskilling programs for incumbent workers, and adapt curricula to address the integrated skill requirements of electrification and automation.
- Work with unions, community colleges, and industry to ensure training programs are accessible, relevant, and lead to high-quality jobs with comparable wages and benefits to traditional roles.
- Pilot new transition pathways for workers moving from traditional roles to new roles created by electrification and automation. Track and evaluate the results of these pilot programs to see how well they support workers in making successful career transitions.

### **Develop and Test Policy Tools for Labor Impact Mitigation**

- Pilot automation taxes or displaced worker impact fees to evaluate their effectiveness in offsetting public costs and supporting workforce transition.
- Design and implement wage/benefit policies to ensure new jobs created by electrification and automation offer comparable compensation and security.
- Establish best practices for union-management collaboration in shaping job classifications, work rules, and safety standards for new technologies.

### **Create Integrated Monitoring and Evaluation Systems**

- Develop a unified data platform for tracking labor impacts, workforce transitions, and equity outcomes as electrification and automation progress.
- Implement real-time monitoring and feedback mechanisms to allow for adaptive policy responses as new evidence emerges.

### **Foster Cross-Agency and Stakeholder Coordination**

- Establish a coordinated policy framework involving state agencies, port authorities, labor unions, industry, and community organizations to address the combined labor impacts of electrification and automation.
- Engage stakeholders in regular dialogue to ensure policies are responsive to the needs of workers, employers, and communities.

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