ResPT – steps to a resilient electric bus system

SEI workshop report
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This report provides public transport authorities (PTAs), public transport operators (PTOs), grid operators (DSOs), original equipment manufacturers (OEMs), and public authorities with insights and concrete actions to anticipate and mitigate real-world disruptions in electrified bus systems. The following combines practitioner experiences with practical policy and operational recommendations for reliable services and sustainability, as reported at a workshop held on 9 May 2025, bringing together key Swedish public transport stakeholders to share insights, challenges and strategies for more resilient electrified bus services.

1. Introduction and workshop overview

Public transport electrification in Sweden is advancing rapidly, yet resilience of these systems in the face of climate change, adoption of new technologies and various operational threats remains under-addressed. Battery electric bus fleets confront grid capacity constraints, data gaps in evaluation, and fragmented governance. To increase resilience of public transport, the project "ResPT: Investigating Swedish public transport resilience from an engineering and socio-ecological perspective", focuses on how regional authorities can build strategies to protect and adapt services and functions for a sustainable recovery from disruptions from both engineering and socio-ecological perspectives, to create more resilient systems.

Led by SEI in collaboration with KTH Royal Institute of Technology and funded by the Swedish Energy Agency, ResPT examines resilience solutions in Sweden, with an added global perspective. The project also analyses investments to ensure they align with priorities to build resilience in a just energy transition, highlighting the need for new planning practices, regulations and collaborations.

This guide summarizes the main outcomes from a workshop organized within the frame of the project and provides recommendations for increased public transport resilience, focused on electric buses in Sweden. Session 1 of the workshop focused on "building resilience", in which participants group discussions identified ways to address electric bus–related disruptions, and a full-group discussion in which they explored how to work together to strengthen public bus transport resilience. Session 2 focused on "supporting resilience in practice": a full-group discussion explored tools and approaches to support practical decision-making, e.g. for a "resilient bus depot" and improved procurement; and a second full-group discussion examined interactions between the public transport system and society.

Image: Volvo electric articulated buses, Gothenburg, Sweden © Volvo

2. Workshop outcomes

In total, 27 stakeholders participated online or in person. An overview of participants and their roles is presented in Table 1. Prior to the workshop, the project team prepared a comprehensive list of disruptions to electrified bus transport, grouped across the various stages of the value chain (see appendix).

Table 1. Overview of participating stakeholders and their area of responsibility. Number of attendees per organization type in parenthesis.

Participants	Responsibility areas
Public transport authority (PTA; 14)	Infrastructure and depot management Safety, risk and security Strategy and planning Business development
Public transport operator (PTO; 2)	Safety and security Sustainability and governance
Trade association (2)	Industry development and expertise
Energy interest organization (1)	E-mobility
Original equipment manufacturer (OEM; 2)	Research Public affairs for buses
Municipality/government agency (2)	Infrastructure management Case handling
Research organization (4)	Research

GRID OPERATING STATES

- **Normal (firm, N-1 secure):** standard grid topology with contingency margin.
- **Constrained/non-firm:** capacity is available most hours but can be curtailed during peaks or failures. Curtailment windows are possible (e.g. 17:00–20:00).
- **Planned maintenance mode:** temporary reconfiguration schedule when voltage or thermal limits can decrease the available power for days or weeks.
- **Seasonal mode:** different limits across seasons due to higher winter baseload.
- **Contingency mode:** after an upstream fault, where supply exists but at reduced limits.
- **Depot island/microgrid mode (local):** depot operates with backup (e.g. combined heat and power or CHP and storage), useful for planning reduced service for partially or fully unavailable grid.

Below is a summary of main outcomes from the workshop discussions, organized into eight themes (O1–O8).

O1. Grid capacity and timing

Participants called for earlier dialogue where all relevant actors take a more active role in the capacity planning process. They emphasized structured dialogues with distribution system operators (DSOs) before tenders. Also required are early and clear prognoses of grid capacity across different grid operating states (see box), using night/off-peak charging where feasible. PTAs asked for access to basic power use data from PTOs to understand where and when capacity is available.

O2. Depots and siting

Charger and electric bus depot locations could be determined by available grid capacity rather than service needs, which can place depots far from routes and create long-term lock-in, especially considering the dynamic nature of service needs and the static nature of infrastructure. Several depots in Sweden are already utilized fully, complicating upgrades. Participants raised the need for regional depot siting guidance (to guide DSO planning), mobile/seasonal charging and multifuel support points (e.g. electricity and biogas), and clearer rules on ownership for low-voltage grid/on-site infrastructure, with increased responsibility placed on PTOs.

O3. Outages and preparedness

Night-time short outages (e.g. 02:00–04:00) are particularly disruptive since the majority of the electric bus fleet would charge at exactly that time, leading to missed morning departures. Participants noted both short and longer outages could occur and should be addressed. Two-week island-only operation is not considered feasible. Instead, stakeholders asked to define realistic reduced-service levels (e.g. 48 hours) and priority corridors. Styrel rules, regarding who gets first access to electricity during a power crisis, need to be clearer: public transport is recognized as a critical societal function, but the electricity needs of electric buses are not yet explicitly included when prioritizing between competing operations during outage periods. Backup options discussed included depot N-1 support (e.g. CHP/hybrid system plus stationary battery) with a business case via district heating network connections and keeping conventional fuel access (e.g. biogas where available) for replacement services. Staff availability in crises (e.g. Home Guard, *hemvärnet* in Swedish) was also noted as a constraint. Ideas like vehicle-to-vehicle (V2V) and vehicle-to-grid (V2G) solutions were raised as exploratory rather than near-term solutions that were nevertheless interesting alternatives.

O4. Range and winter operations

Cold weather and heavy traffic reduce range, leading to a need for more frequent charging and higher risk of service gaps. Participants noted that older buses underperform compared to newer models with larger batteries (this was noted as the main new challenge vs generic "range anxiety"), and that timetables often lack flexibility to absorb cold weather effects. Participants discussed planning extra charging (when/where) and installing fast and support charging at depots and turn-ends (*vändplatser*) to stabilize operations in cold conditions. Allocating buses by duty (battery size vs. line profile) and using more generous state-of-charge (SoC) buffers (e.g. >50% for critical services) were also mentioned.

DEFINITION OF MTTR

Average time from when a fault starts until the affected equipment/vehicle/infrastructure is back in service. Chargers: from alarm/failed session until status is "available" or first successful charge. Buses: from time a fault is logged until the vehicle is cleared for service.

O5. Standards and data

Participants described uneven standards and access to data. Charger systems and vehicle telematics do not always match; open charge point protocol (OCPP) versions differ; OEM portals can limit export/application programming interface (API) access. There are no shared datasets, and access to them varies by procurement contract and system for information on SoC, charging logs, alarms and fault codes, ambient temperature and charger status/uptime. Data ownership and rights are unclear in some cases. Reporting the mean time to repair/restore (MTTR) could help in understanding at least how often faults occur. The Bus Nordic procurement standard is a starting place for integrating new requirements for electrified bus fleets. Participants asked for a small common dataset and a simple shared dashboard.

O6. Procurement variation

Large differences in procurement requirements and processes were noted between regions in Sweden. In some cases, very detailed mandatory requirements (*ska-krav*) are used; in others, function-based (*funktionskrav*) procurement dominates. Participants said that excessive requirements can discourage bids and that pre-procurement dialogue between PTAs and PTOs often starts too late. Existing industry forums (e.g. KollA) are useful, but a sector-level exercise focused on electrified operations and resilience is needed. Stakeholders want more flexibility in requirements and to begin dialogues earlier; they also want more shared experiences and knowledge on what works or not, while keeping confidentiality to protect competitiveness. Risk and vulnerability analysis is not consistently required in tenders today, according to several participants, and should be to ensure resilience later.

O7. Cost uncertainty

Regions face large upfront investments in depot charging within already tight budgets, and participants noted that some new entrants underestimate true operating and maintenance costs at the tender stage, which can lead to financial stress later in contracts. Component lead times and technology immaturity add cost and risk. Mismatched contract length vs asset life (ca. 10-year operating contracts vs 20–30-year depot infrastructure) delays necessary infrastructure investments. In discussions on backup solutions, cost/benefit depends on added value (e.g. heat sales in district-heating networks). Furthermore, solutions risk being unaffordable even if technically sound, if preparedness is not translated into concrete value.

O8. Tools and research support

Participants asked for simple, practical support, such as:

- a small common dataset with a simple dashboard;
- a depot–grid planning aid (to show likely capacity and implementation timelines);
- reduced-service exercises with simple checks to see if plans work;
- a comparison of backup/storage options (batteries, CHP/hybrid generators, hydrogen) for short vs long outages, including costs and benefits;
- including V2G and V2V solutions to maximize uptime in crisis and improve investment revenue streams;
- options to share charging access between actors; and
- examples/standards from other sectors for handling outages.

2.1 Workshop outcomes from a resilience lens

Workshop outcomes could also be analysed from a resilience lens, following the classic "prepare-absorb-recover-adapt" approach, summarized in Table 2.

Table 2: Workshop outcomes (thematic grouping) mapped per resilience function: prepare-absorb-recover-adapt

	Prepare	Absorb	Recover	Adapt
O1. Grid capacity and timing	X			
O2. Depots and siting	X			X
O3. Outages and preparedness		X	X	X
O4. Range and winter operations		X	X	X
O5. Standards and data	X	X	X	X
O6. Procurement variation	X			X
O7. Cost uncertainty	X	X		X
O8. Tools and research support	X		X	X

Prepare (anticipate and plan)

- Earlier DSO dialogue and capacity planning before tenders (O1).
- Regional guidance on depot siting and charger placement; avoid speculative grid builds, but coordinate on understanding future capacity needs (O1, O2).
- Minimal, shared data standard to monitor states (SoC, alarms, ambient temperatures) and support analysis (O5, O8).

- Harmonized baseline in procurement and earlier market dialogue; align contract terms with long-lived infrastructure investments (O6, O7).
- Clarify ownership/responsibility for low-voltage infrastructure at depot–grid connection points and consider mobile/dynamic charging options (O2).

Absorb (withstand disturbances)

- N-1 thinking for grid connection at depots and modular backup (e.g. CHP/hybrid generators and battery); maintain access to conventional fuels for replacement services where needed (O3).
- Winter routines and SoC buffers; layover/support charging on critical nodes (O4).
- Standardization and open interfaces to reduce integration faults (O5).
- Fleet allocation and battery sizing that cope with winter profiles and ageing vehicles (O4, O7).

Recover (restore essential service)

- Defined reduced-service plans with prioritized corridors (O3).
- Access to alternative charging and mutual assistance between operators; clear routines for faults and MTTR focus (O5).
- Use of spare vehicles/drivers to shorten recovery (O4, O5).

Adapt (learn and improve)

- Cross-operator reviews of faults and “near-misses” using shared data; feedback loop establishment (O5, O8).
- Adjust procurement language over time (from detailed mandatory to functional requirements with resilience clauses especially under crises) and share model text across regions (inspiration Bus Nordic) (O6).
- Manage vehicles and update fleet mix; revisit siting and charging strategies as usage patterns change (O2, O4, O7).
- Explore storage/backup pathways (batteries/CHP/hydrogen) with business cases tied to normal operations on top of emergencies to ensure profitability (O3, O8).

SUGGESTED CONTENT IN A GRID CAPACITY REPORT

- Available connection today and after planned reinforcement (kW/MVA).
- Flexible vs. curtailable capacity and any curtailment windows.
- Lead times for connection or grid upgrades (weeks/ months) plus dependency on permits.
- Assumptions and validity period (e.g. 6 months).
- Optional: Indicative cost range and what’s included/ excluded.

3. Recommendations

In this section, practical recommendations for strengthening resilience are summarized. These were expressed directly by workshop participants and derived from analysis based on workshop insights (see Table 3).

3.1 Workshop-based recommendations

W1. Depot–grid capacity study

- **What:** Perform a short study before each tender to confirm capacity and timelines.
- **Why:** Avoids speculative builds; promotes earlier, structured dialogue with the grid company.
- **Who:** PTA (lead); DSO (capacity/timelines); municipality (permits/land); PTO (operational constraints).

Table 3: Overview of recommendations, grouped by source and timeframe.

When → Source ↓	Short-term	Medium-term	Long-term
From workshop	**W1. Depot–grid capacity study** Owners: PTA + DSO + Municipality + PTO Grid capacity needs notice; shared critical path; fallbacks (plan Bs)	**W2. Reduced-service plans + tests** Owners: PTA (lead) with DSO + Municipality + PTO Recurring theoretical + practical exercises	**W3. Common data standard** Owners: PTA + PTO (+ OEM) Short data sharing specification; data timeliness/ completeness targets; simple depot specifications overview
Research reflections	**R1. Off-peak default + connection status** Owners: PTA + DSO Set off-peak charging targets; recurring grid connection and costs check	**R2. Align terms + clarify on-site/LV responsibility** Owners: PTA + DSO + Municipality Term/ownership note; responsibility matrix	**R3. Decision-support tool for backup & flexibility options** Owners: PTA + PTO (+ DSO, OEM) Method + simple tool comparing battery/CHP generator/V2G or V2V; site-level recommendation + costs estimation
Enhanced (advanced)	**E1. Continuity clause (e.g. 48 hours operation)** Owner: PTA (procurement) Develop example clause; test with PTOs	**E2. Depot backup module** Owners: PTA + PTO + OEM Specification for hybrid system + battery; candidate sites selection	**E3. National coordination on resilience** Owners: Svensk Kollektivtrafik (lead) with Transportföretagen, PTAs, PTOs, DSOs Shared clauses; data-standard governance; mutual-assistance and charger-access framework

Legend: *From workshop = directly asked by participants; research reflections = based on our analysis of the workshop material; enhanced = more advanced steps that still address workshop needs and require collaboration of more actors across the value chain.*
Roles: *PTA = public transport authority (regional); DSO = electricity grid network operator; municipality = land and permits, occasionally depot ownership; PTO = public transport operator; OEM = original equipment manufacturer, such as for vehicles, chargers, and other infrastructure*
Terms: *SoC = state of charge; LV = low-voltage; MTTR = mean time to repair/restore*

- **Output:** Short grid capacity report (1-2 pages), shared critical path (timeline of essential tasks that can delay all processes), "plan B options" list (including flexible options, curtailment windows with conditional agreements with DSO, mobile chargers and storage).
- **When:** Before procurement.
- **Resilience rationale:** Improves anticipation by establishing verified capacity, timelines and mitigations, reducing uncertainty before procurement. Can address situations where depots are full.

Notes: *Works for new and old depots; for rural areas, focus on a few key sites only. Capacity map will steer DSO planning. Mobile/seasonal charging and various fuels (e.g. biogas) can be included.*

SUGGESTED CONTENT IN REDUCED-SERVICE PLAN

- Priority corridors: the minimum network to keep society functioning.
- Depot charging allocation: which buses get charged first, by how much, and when.
- Shared chargers: if another operator has spare capacity.
- Alternative fuels/vehicles: how many biodiesel (including hydrotreated vegetable oil – HVO) compatible buses or electric hybrid buses are available.
- Staffing arrangements: considering driver work/rest limits.
- Passenger communication plan.

W2. Reduced-service plans

- **What:** Agree on two reduced-service plans (e.g. 48 hours, 14 days) and test them regularly (theoretically and, if possible, practically).
- **Why:** Night-time outages hit morning departures; fully independent, island mode operation for the whole bus fleet is unrealistic, so priorities need to be defined; Styrel rules are unclear and do not explicitly protect electric bus charging.
- **Who:** PTA (lead) with PTO, DSO, municipality; county administrative board for Styrel.
- **Output:** Two plans; test exercise schedule; review and action list after exercise.
- **When:** Ideally biannually, once plans are in place.
- **Resilience rationale:** Increases absorptive capacity and recovery speed by predefining viable service patterns under power constraints.

Notes: *Include driving time and rest periods; agree priority corridors with the municipality. Urban routes need more and shorter corridors; rural need fewer and longer routes; severe winter conditions need support-charging sites spread in the bus network and in addition to depot charging.*

W3. Common data standard and shared view

- **What:** Agree on a simple common dataset and show it in a simple shared view; review faults together.
- **Why:** Interfaces differ; PTAs lack consistent access to SoC, alarms, charger status and uptime.
- **Who:** PTA and PTO (data supply and quality); OEM (access).
- **Output:** Data specification, shared view.
- **When:** Short-term measure, implemented once parties agree.
- **Resilience rationale:** Enables shared awareness and earlier fault detection, supporting coordinated response and shorter MTTR.

Notes: *Use existing sources first (depot charging logs; energy-mapping data) to build overnight charging profiles. Start with a small "not sensitive" indicator set shared across contracts and PTOs.*

COMMON DATASET INDICATORS

- Vehicle ID, charger ID, SoC
- Timestamp
- Charger status (available, charging, fault)
- Session start and stop; energy delivered (kWh)
- Alarm code and severity
- Ambient temperature
- Charger uptime and MTTR

3.2 Research-based recommendations

R1. Off-peak charging as default, with connection-status transparency

- **What:** Set a target share for off-peak energy (e.g. ≥70% of total amount of kilowatt hours used for charging between 22:00 and 06:00); follow up on depot status monthly.
- **Why:** Capacity varies by time and season; operators need visibility to plan.
- **Who:** PTA with DSO and PTO.
- **Output:** Target share should be set in operating plans or contracts; monthly status reports.
- **When:** Short-term action is to set the target share; long-term, to implement with DSO and follow-up.
- **Resilience rationale:** Enhances predictability and reduces peak vulnerability.

Notes: *In grid-constrained areas, tie flexible connections and conditional grid supply contracts to night charging.*

R2. Align contract term with asset life and clarify responsibility

- **What:** In the next procurement, offer takeover clauses or public ownership for long-lived depot infrastructure and clearly state who owns and maintains the LV grid on-site.
- **Why:** Operating contracts are shorter than depot infrastructure life; responsibilities are unclear.
- **Who:** PTA with municipality (in case they own the depot) and PTO (runs the depot's everyday operations).
- **Output:** Ownership note; responsibility matrix in the procurement documentation.
- **When:** Next procurement round for PTAs.
- **Resilience rationale:** Reduces governance and maintenance gaps, improving robustness.

Notes: *Takeover clauses are already well established for chargers in operation.*

R3. Decision-support tool for backup and flexibility options

- **What:** Build a simple method or tool that helps PTAs and PTOs decide how best to keep buses running when the grid or chargers fail.
- **Why:** Help needed to weigh backup choices and flexibility via e.g. V2G/V2V; sizing depends on electrification share (e.g. 10% vs 75% electrified fleets have different needs, same as urban vs rural).
- **Who:** PTA with PTO (use cases and data); DSO (grid capacity limits and curtailment information); OEM (data exchange interfaces); researchers to develop the tool.
- **Output:** Short method notes, case studies (e.g. urban core, rural), optional: web tool. For optimal site setup with costs for different electrification scenarios.
- **When:** Short-term, start of tool development; long-term, distribution and training on tool use, plus updates to and encouragement to use the tool.
- **Resilience rationale:** Matching backup options to outage duration and site context optimizes robustness and cost-effectiveness.

Notes: *Include V2G/V2V losses and operational complexity; add preparedness value and a "societal cost/value-of-continuity" dimension if possible. Provide two sizing modes: current share and target share of electrified fleet. Where links to heating systems exist, include heat value.*

SUGGESTED TECHNOLOGIES TO CONSIDER IN TOOL

- Battery storage
- CHP/hybrid generator on biogas
- Biodiesel/HVO/diesel generators
- V2G, V2V or both
- Biogas, hydrogen or both

3.3 Advanced recommendations

E1. Continuity targets under power constraints (procurement clause)

- **What:** A proposed contract requirement stating that the PTO must maintain a defined minimum level of service if a depot loses grid power or charging capacity, for two reference durations: 4 hours (short disruption) and 48 hours (prolonged disruption).
- **Why:** Service levels during constrained operation are not explicit today.
- **Who:** PTA procurement.
- **Output:** Local minimum level of service definitions; draft clause for contracts.
- **When:** Next procurement round for PTAs.
- **Resilience rationale:** Institutionalizes minimum service under constraint and continuous performance under crisis.

Notes: *Specify priority rules for shared charging and stationary batteries. Define priority corridors with municipalities and emergency services. Consult Styrel rules.*

EXAMPLE OF CONTINUITY CLAUSE IN BUS CONTRACT

- Minimum share of scheduled trips to be delivered in short- and long-term outages.
- Routes or service types to be prioritized.
- Acceptable alternative charging, infrastructure sharing or fuelling arrangements.

E2. Depot backup design

- **What:** A design and procurement principle that each electrified bus depot should be able to continue operating priority services if a single critical component fails (cable, transformer, charger unit).
- *Note: Compared to R3, which is about decision-making, E2 is about technical redundancy and single failure tolerance, which creates valorization potential for available backup options.*
- **Why:** Backup should also be valuable in day-to-day operation (e.g. peak-shaving, heat).

- **Who:** PTA with PTO and municipality (if they own the depot).
- **Output:** Specification; candidate sites.
- **When:** Produce specification requirements when depot upgrade project starts.
- **Resilience rationale:** Adds redundancy and operational flexibility, sustaining priority services during component or grid failures.

Notes: *Consider diesel generators and fuel tanks (both fossil and renewable diesel such as HVO that can be stored in contrast to first-generation biodiesel like FAME) including analysis of tank size, storage times and district heating interconnection; make the business case clear for preparedness and normal operation. Avoid single-technology lock-in by keeping a hybrid fuel mix option. Split charging cables to independent sections; build in cable redundancy.*

E3. National coordination on resilience

- **What:** A proposal for sector-level coordination on public transport resilience (e.g. through Styrel), facilitated by Svensk Kollektivtrafik. Shift resilience from an issue being handled individually by each PTA or PTO to having shared standards.
- **Why:** Workshop participants asked for sector-level coordination beyond existing forums.
- **Who:** Svensk Kollektivtrafik (lead) with Transportföretagen (Sveriges Bussföretag), PTAs and PTOs; DSOs and county administrative boards invited to participate depending on context.
- **Output:** Function-based wording in procurement processes (avoiding over-prescriptive requirements); a simple data set; resilience exercise templates (e.g. for 4-h and 48-h reduced-service periods); data-sharing governance (including MTTR); mutual-assistance and charger-access framework; work with existing forums (e.g. KollA Kollektivtrafikens Avtalskommitté); include Sveriges Bussföretag in drafting and dialogue.
- **When:** Work should start as soon as possible.
- **Resilience rationale:** Builds system-level adaptive capacity through standardized practices, mutual assistance, and cross-sector learning.

Notes: *Inspiration from Bus Nordic and similar initiatives on how to set the platform.*

Appendix

Links to information shared during the workshop

- Example of backup generator standards for data centres: https://www.techtarget.com/searchdatacenter/tip/Data-center-backup-power-systems-standards-to-address-downtime
- UITP large-scale bus electrification IT checklist: https://www.uitp.org/publications/large-scale-bus-electrification-it-systems-checklist/
- Reliability-as-a-service tool: Hussain, A., & Musilek, P. (2022). Reliability-as-a-service usage of electric vehicles: suitability analysis for different types of buildings. *Energies*, *15*:665. https://doi.org/10.3390/en15020665

Participant quotes

"Then, coordinate with the grid owner/operator so it's done smartly, electrify in the right order. Don't push just because there's a new contract; make sure it works in practice."

"We often think the power grid is binary on/off but there are different operating modes. The grid company designs for peak loads the coldest day or for solar production; those are the dimensioning factors/cases."

"We don't own the vehicles; we have zero visibility into power draw, yet we're expected to know the power need. Can we have more openness in sharing? Agree on common key metrics."

"Electrification places new demands beyond classic traffic planning. Keep competition. Not too much nitty-gritty, some flexibility is needed."

Group discussion

Participants were initially divided into five groups based on whether they registered to attend in person or online, with the aim of keeping each group exclusively in person or online. Group sizes were limited to between four and nine people and selected to have diverse teams, considering participants' roles. The 43 identified disruptions were distributed across the groups, with each assigned 10 disruptions. While some overlap occurred, the organizers sought to give each group a largely unique and thematically diverse set, considering the disruptions' value chain position.

Changes were made the day of the workshop, where several in-person registrants joined online and were redistributed accordingly. The structure shifted to one in-person group and three online groups; therefore, in the presented results, some disruptions were not discussed by any group (see Table A1).

Each group was tasked to select the five most important disruptions from their assigned 10 and to discuss consequences, solutions, and whether these solutions aligned with existing action plans or required operational changes. Table A1 presents the final group compositions, their assigned and selected disruptions, and the disruptions not discussed by any group.

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Table A1. Group discussion composition and the distribution of analysed disruptions. Highlighted disruptions were selected as the most important.

In person	Online	Online	Online	Undiscussed
PTO (2) **PTA** (2) **Research organization** (1) **Energy interest organization** (1) **Trade association** (1)	**PTA** (2) **Municipality** (1) **Research organization** (2)	**PTA** (7) **OEM** (2)	**PTA** (3) **Research institute** (1) **Government agency** (1) **Trade association** (1)	Disruptions initially assigned that did not overlap with disruptions in other groups
ID_1: Battery hazards	ID_4: Blocked charger access	**ID_19: Grid capacity constraints**	**ID_3: BEV replacement traffic constraints**	ID_2: BEV and component supply challenges
ID_5: Bus contract challenges	**ID_7: Charger deployment delays**	ID_21: HVAC system issues	ID_8: Charger failure	ID_6: Bus range shortfall
ID_10: Charger permits denied	ID_11: Contract lock-ins	ID_12: Data ownership issues	**ID_12: Data ownership issues**	ID_9: Charger performance issues
ID_14: Dead mileage increase	ID_17: EU directive incompatibility	ID_23: IT failure	ID_15: Energy costs escalate	ID_13: Deport space shortages
ID_25: Lack of charger standards	**ID_20: High initial costs**	**ID_25: Lack of charger standards**	**ID_16: Energy supply shortage**	ID_18: Few companies bid for tenders
ID_29: Misaligned charger placement	**ID_24: Lack of BEV crisis preparedness**	**ID_29: Misaligned charger placement**	ID_22: Inflexible routeing	ID_26: Lack of stakeholder dialogue
ID_33: Prolonged power outage	ID_25: Reduced service convenience	ID_27: Limited repair services	ID_28: Passenger trust and brand value loss	ID_39: Skill gaps
ID_34: Range constraints from detours	**ID_36: Reduced range from traffic and weather**	ID_28: Passenger trust and brand value loss	**ID_30: Narrow electrification planning focus**	
ID_40: New workflow problems	**ID_38: Short-term power outage**	ID_31: OEMs fail to meet procurement criteria	ID_41: Underestimated energy demand	
ID_43: Unexpectedly high O&M costs	ID_32: Operator reluctance towards BEVs	ID_37: Shorter than planned economic life	**ID_42: Underestimated power demand**	

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