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SUMP4BALKANS PROJECT | EUROPEAN CLIMATE INITIATIVE (EUKI)

Assessment of optimal photovoltaic and electric bus charging locations in Ptuj

Technical and techno-economic location assessment

Companion document to the feasibility study for the transition to electric buses and integration of photovoltaic generation



Ptuj and the Drava corridor. Source: supplied project material.

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Document control

Field	Value
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Decision level	Location selection, pre-investment and concept-design brief

Status and use

This assessment selects and phases candidate locations for electric-bus charging and photovoltaic integration. It supports a municipal concept decision and the preparation of site surveys, distribution-system enquiries and procurement briefs. It is not a cadastral survey, detailed electrical or civil design, grid-connection consent, fire-safety study, environmental permit or binding investment appraisal.

Disclaimer

This project is part of the European Climate Initiative (EUKI) of the German Federal Ministry for the Environment, Climate Action, Nature Conservation and Nuclear Safety (BMUKN). It is the overarching goal of the EUKI to foster climate cooperation within the European Union (EU) in order to mitigate greenhouse gas emissions. The opinions put forward in this study are the sole responsibility of the author(s) and do not necessarily reflect the views of the German Federal Ministry for the Environment, Climate Action, Nature Conservation and Nuclear Safety (BMUKN).

Decision statement

Recommended configuration. CERO Gajke should be developed as the principal depot and controlled overnight charging base. The Ptuj wastewater treatment plant should be developed as the secondary daytime charging and PV-integration hub, subject to confirmed duties, access and measured PV residual. The main bus station should remain a protected later-stage option and should not be included in the base procurement without a demonstrated operational need.

Table 1. Recommended role of the candidate locations

Location	Weighted score	Recommended role	Current decision
CERO Gajke	**89.0 / 100**	**Main depot and controlled overnight charging**	**Advance to concept design**
Wastewater treatment plant	**85.0 / 100**	**Secondary daytime charging and PV hub**	**Advance in the same concept-design package**
Ptuj main bus station	62.0 / 100	Optional future opportunity charging	Protect space and cable route; defer equipment

1 Executive summary

This document provides the stand-alone location assessment that accompanies the Ptuj electric-bus feasibility study. It evaluates CERO Gajke, the Ptuj wastewater treatment plant and the Ptuj main bus station as a coordinated charging and renewable-energy system. It uses Ptuj-specific route, energy-community, vehicle and site evidence.

The result is not a single winner for every function. CERO Gajke is the strongest operational base because it offers a controlled municipal context for parking, charging, cleaning and fleet management. The wastewater treatment plant is the strongest existing photovoltaic node because the original SONCE 8P schedule assigns it 606.10 kWp and 632.31 MWh/year. The main bus station is the best network node, but its constrained public-space setting, absence of dedicated PV and complex ownership and connection conditions make it unsuitable as the first investment.

Table 2. Key decision metrics

Decision metric	Result	Interpretation
Central fleet charging demand	246.7 MWh/year	345,000 vehicle-km/year, 0.65 kWh/km and 10% charging losses
CERO depot concept	About 180 kW controlled aggregate	Three modular outputs in the feasibility model; final rating follows duties and DSO conditions
WWTP PV design reference	606.10 kWp / 632.31 MWh/year	Largest individual location in the original municipal design schedule
Preferred two-site scenario	**Scenario 2**	**CERO overnight base plus the WWTP daytime top-up that the reference midibus needs, with PV alignment**
Same-hour PV contribution	72.1 MWh/year or 29.2%	Residual community PV after modelled existing public-consumer load
Modelled peak	88.8 kW	Controlled diversified peak, not a requested connection capacity
Whole-project gross CAPEX	EUR 2.893 million	Fleet, common project and two-site charging allowances
Financial conclusion	No-grant central case: S2 12-year NPV -EUR 0.22m; payback 9.6 years	Break-even capital support about EUR 0.22m; an 80% grant would be an upside (+EUR 1.37m), but the current Borzen allocation has been reached

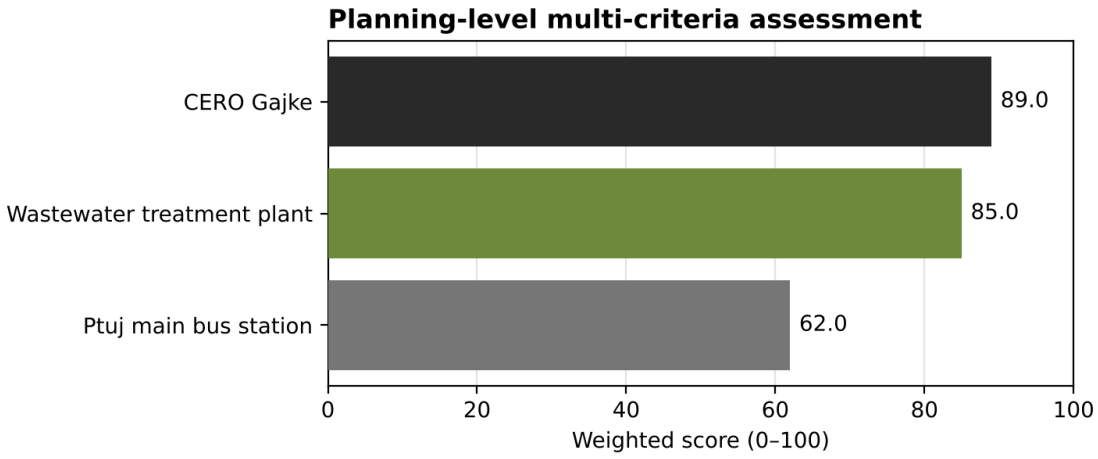


Figure 1. Planning-level weighted site scores

CERO and the wastewater treatment plant are complementary rather than competing locations.

Implementation recommendation. Procure the first concept-design package as one coordinated CERO plus wastewater-treatment-plant system. The package should include depot and vehicle-circulation surveys, separate distribution-system enquiries, a secondary-charger access study, verified as-built PV and metering data, and a measured-duty test. Stationary storage and a bus-station fast charger should remain outside the base investment until operational evidence shows that they solve a defined problem.

2 Purpose and scope

2.1 Decision question and system boundary

The decision question is where Ptuj should place and phase the infrastructure required to operate a battery-electric urban bus fleet while making credible use of municipal solar electricity. The assessment covers site function, access, charging windows, spatial and ownership conditions, photovoltaic links, grid readiness, indicative investment, implementation risk and the evidence required for concept design.

The system boundary begins at the vehicle charging inlet and includes the charger, local connection, managed-load interface, relevant photovoltaic generation and metering boundary. It also considers depot circulation, passenger-interface constraints, deadhead implications and the municipal operating model. It does not design cable routes, transformer protection, foundations, canopies, drainage, fire compartments or traffic arrangements.

2.2 Meaning of optimal location

Optimal does not mean the site with the largest theoretical PV area or the site closest to every route. A robust location must support reliable public transport first, then provide a credible energy benefit without creating disproportionate grid, safety, ownership or procurement risk. Because depot charging and daytime PV coincidence are different functions, the assessment permits a coordinated two-site solution.

Table 3. Assessment layers and acceptance tests

Assessment layer	Question	Acceptance test
Transport operation	Can vehicles reach, circulate, charge and return to service without harming the timetable?	Confirmed duties, deadhead, swept paths, dwell windows and reserve strategy
Electrical system	Can the site host controllable charging within a realistic connection envelope?	DSO conditions, transformer and protection study, load-management concept
Photovoltaic integration	Does the site provide existing or credible new PV and useful hourly coincidence?	As-built plant data, interval production, local load and export evidence
Implementation	Can land, access, permitting and procurement be resolved on the required timetable?	Ownership map, access rights, planning and fire-safety review, quotations
Economics	Does the function justify the incremental cost and risk?	Scenario comparison, sensitivity and defined decision trigger

3 Local context and site selection requirements

3.1 Urban bus operating context

Ptuj has five urban bus lines connected through the main bus station. The published service is strongly daytime-oriented: Lines 2 to 5 generally finish by approximately 16:15, while Line 1 continues until around 21:30. The feasibility model converts the published service into approximately 345,000 vehicle-km/year and a central input-energy requirement of 246.7 MWh/year. A conservative upper case reaches 341.6 MWh/year.

This pattern creates a clear functional split. CERO must provide the reliable overnight and post-school base load. A secondary site provides the scheduled daytime top-up that full school-day duties need with the 9 m reference midibus, as well as emergency recovery. The bus station can provide network-level flexibility only if verified dwell time, space and grid capacity justify a fast charger.

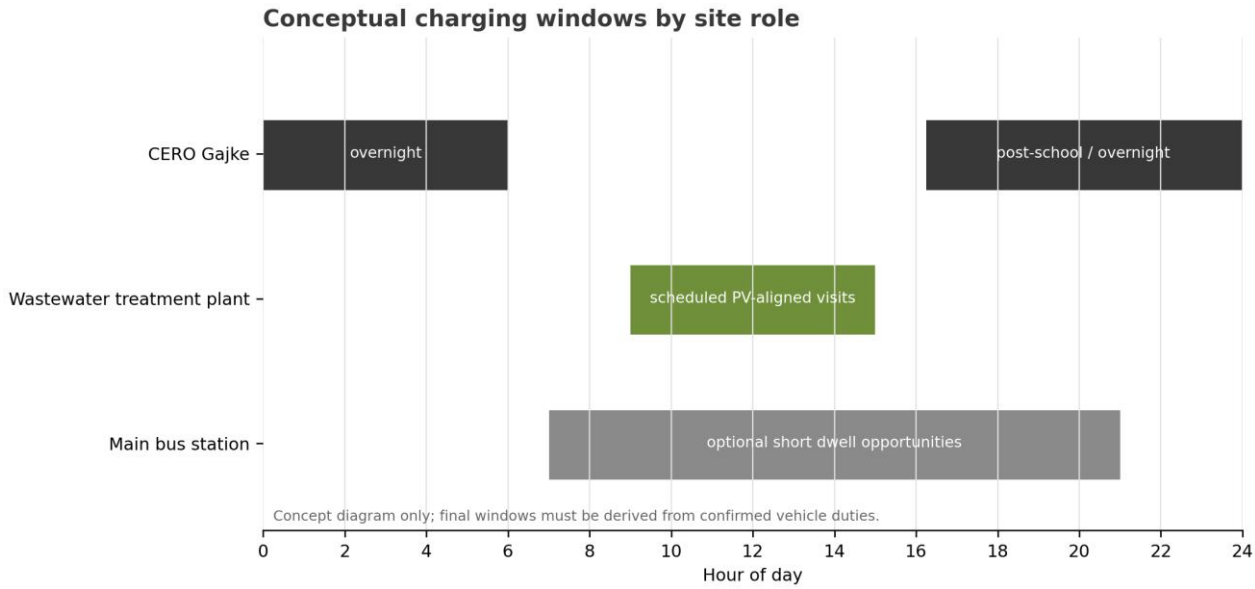


Figure 2. Conceptual charging windows by site role

The figure is a planning concept and not a final duty schedule.

3.2 Municipal PV and energy community

The latest public municipal aggregate reports 17 photovoltaic systems with 1,614.51 kWp of installed capacity. The 13-system community component totals 1,491.51 kWp and is expected to produce approximately 1,549.27 MWh/year for 35 public consumers. The supplied 2025 meter list totals 1,686.99 MWh/year of existing consumer demand. The community is therefore not an unused annual surplus: buses add a new load and can use only energy that is physically or contractually available under the relevant metering and settlement rules.

The original SONCE 8P design schedule is still useful for location-level comparison. It identifies the wastewater treatment plant as the dominant single site at 606.10 kWp and 632.31 MWh/year. CERO Gajke is not part of the as-built portfolio; this assessment adds a 250 kWp PV plan on part of the 1.96 ha area that Javne službe Ptuj has offered for solar development [S10].

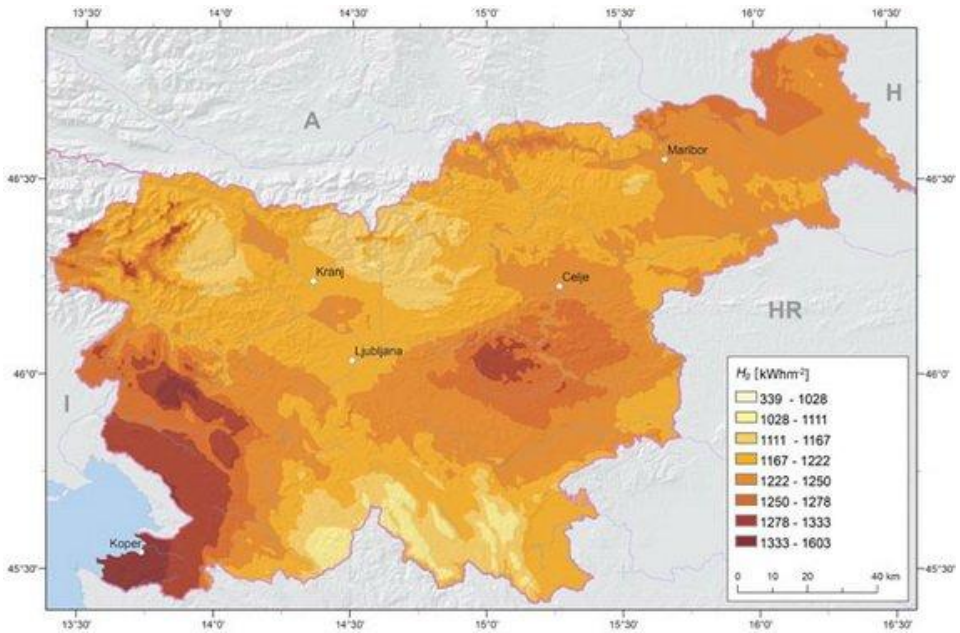


Figure 3. Annual solar irradiation on a horizontal surface in Slovenia

Source: supplied project material.



Figure 4. Example municipal photovoltaic installation in Ptuj

Source: supplied project material.

3.3 Site selection criteria

Table 4. Site selection criteria and weights

Criterion	Weight	Feasibility-level interpretation
Operational fit	30%	Depot circulation, access, charging windows, deadhead, timetable resilience and recovery role
PV integration	25%	Existing PV, credible expansion potential, metering position and hourly charging coincidence
Grid readiness	20%	Indicative electrical context, controllable demand and likelihood of connection reinforcement
Ownership and implementation	15%	Municipal control, agreements, planning path, procurement complexity and delivery timing
Spatial and environmental	10%	Available area, traffic safety, public-space effects, plant operations and environmental constraints

Each criterion is scored from 1, poor, to 5, strong. Weighted totals are expressed on a 100-point scale, equal to the weighted average score multiplied by 20. The scores are evidence-informed planning judgements. Grid and spatial scores are planning-level and are refined with DSO conditions, topographic survey, cadastral verification and geotechnical study in the concept-design phase.

4 Candidate locations and spatial relationship

The three sites are close enough to operate as one municipal system but have different functional strengths. Straight-line distances are approximately 2.9 km between CERO and the wastewater treatment plant, 2.8 km between CERO and the main bus station, and 1.5 km between the wastewater treatment plant and the bus station. Actual bus access and deadhead must be measured on the road network and in vehicle duties.

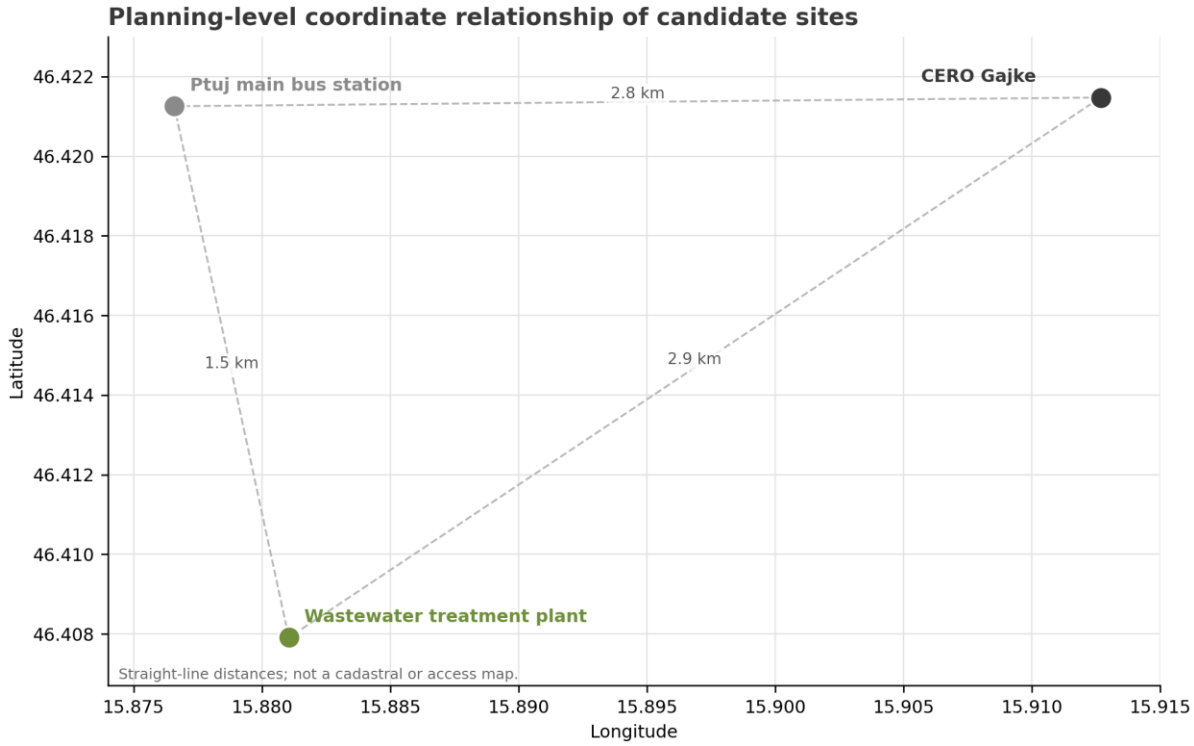


Figure 5. Planning-level coordinate relationship of the three candidate locations

Straight-line distances are indicative only.

4.1 CERO Gajke

CERO Gajke at Dornavska cesta 26, approximately 46.421474 N and 15.912677 E, is the preferred main depot. Its role is operational: secure parking, overnight charging, cleaning, minor support functions and central control. The location also has a public waste-management and degraded-land context: Javne službe Ptuj has offered a 19,622 m² (about 1.96 ha) area at the site for solar development [S10], which is used for the PV plan in Section 5.3.

4.2 Ptuj wastewater treatment plant

The wastewater treatment plant at Ob Dravi 7, approximately 46.407907 N and 15.881046 E, is the preferred secondary charging and PV-integration hub. Its original PV design is much larger than the annual bus demand, but the relevant value is the residual same-hour output after plant and community demand, not gross annual generation.

4.3 Ptuj main bus station

The main bus station, approximately 46.421255 N and 15.876581 E, is the common network node for all five urban lines. It has the strongest theoretical opportunity-charging position, but no dedicated PV, connection concept or unconstrained equipment area at present. It is therefore a protected option rather than a first-stage asset.

5 Assessment of CERO Gajke

5.1 Technical and spatial characteristics

Table 5. Technical and spatial characteristics of CERO Gajke

Attribute	Assessment	Next design step
Address and coordinate	Dornavska cesta 26; 46.421474 N, 15.912677 E	Cadastral and ownership plan
Primary function	Main depot, overnight charging, parking, cleaning and operational control	Functional depot brief and staffing model
Site context	Municipal waste-management function and publicly identified degraded-land context	Environmental, fire-safety and plant-interface review
Usable area (plan)	Depot about 1,450 m² (7 bays, manoeuvring aisle, charger island and service unit); area offered for PV 19,622 m² (about 1.96 ha), of which about 0.25 ha for the 250 kWp plan [S10]	Cadastral plan, landfill-cap engineering and topographic survey
PV status	250 kWp ground-mounted PV plan on about 0.25 ha (Figure 6); optional depot canopy of about 80 kWp	Landfill-cap, gas-well, shading and connection survey
Charging concept	About 180 kW aggregate controlled depot charging in the model	Duty simulation and DSO connection conditions
Main advantage	Controlled fleet base with coherent operations	Formal access and operating responsibility
Main constraints	Grid capacity, circulation, civil works, environmental interface and deadhead	Topographic, utility and swept-path survey

CERO receives the highest operational score because it allows charging to be integrated with vehicle preparation and dispatch. It avoids using a public passenger bay as a primary energy asset and permits load management over several hours. The site must nevertheless be designed as a bus facility rather than treated as an available empty area within a waste-management complex.

5.2 Depot charging concept

The feasibility model uses three modular outputs with an aggregate controlled capacity of approximately 180 kW. This capacity recharges the fleet sequentially across the evening and overnight window. Overnight charging alone does not, however, cover a full school-day duty with the 9 m reference midibus: a 200-250 km duty needs about 130-165 kWh of traction energy, while the vehicle has about 120 kWh of battery capacity, of which roughly 95-100 kWh is usable. Each duty therefore needs a daytime top-up of roughly 35-70 kWh, which the wastewater treatment plant provides in Scenario 2 (Section 6.2). The final rating must be recalculated from confirmed duties, battery sizes, charging curves, winter consumption and the available connection limit.

Table 6. Depot charging concept at CERO Gajke

Design element	Feasibility concept	Procurement requirement
Charger topology	Multiple independent outputs rather than one single point	N+1 operational tolerance and independent fault isolation
Load management	Site limit plus departure and state-of-charge priority	Open protocol, remote control, event logs and manual override
Vehicle interface	CCS-based depot charging for the current reference offers	Compatibility matrix and acceptance test for every vehicle class
Metering	Separate charger and site-energy measurement	Certified meters and exportable 15-minute data
Civil layout	Drive-through or low-conflict parking where practical	Swept-path study, bollards, drainage, snow and maintenance access
Safety	Emergency isolation and separation from waste operations	Fire and electrical design, signage, training and incident plan

5.3 New PV plan

Javne službe Ptuj has offered a 19,622 m² (about 1.96 ha) area at CERO Gajke for solar development [S10]. This assessment plans a 250 kWp ground-mounted field on about 0.25 ha of it (about 13%), sized to the central bus energy rather than to the full plot, plus an optional canopy of about 450 m² (about 80 kWp) over the depot bays (Figure 6). At the municipal community forecast yield of approximately 1,039 kWh/kWp/year, the 250 kWp field would generate about 259.7 MWh in year one, similar to the central annual bus charging energy but not in the same hours. The sketch shows the planning layout; landfill-cap loading, gas wells, shading and the connection point are fixed in the site survey of the concept-design phase.

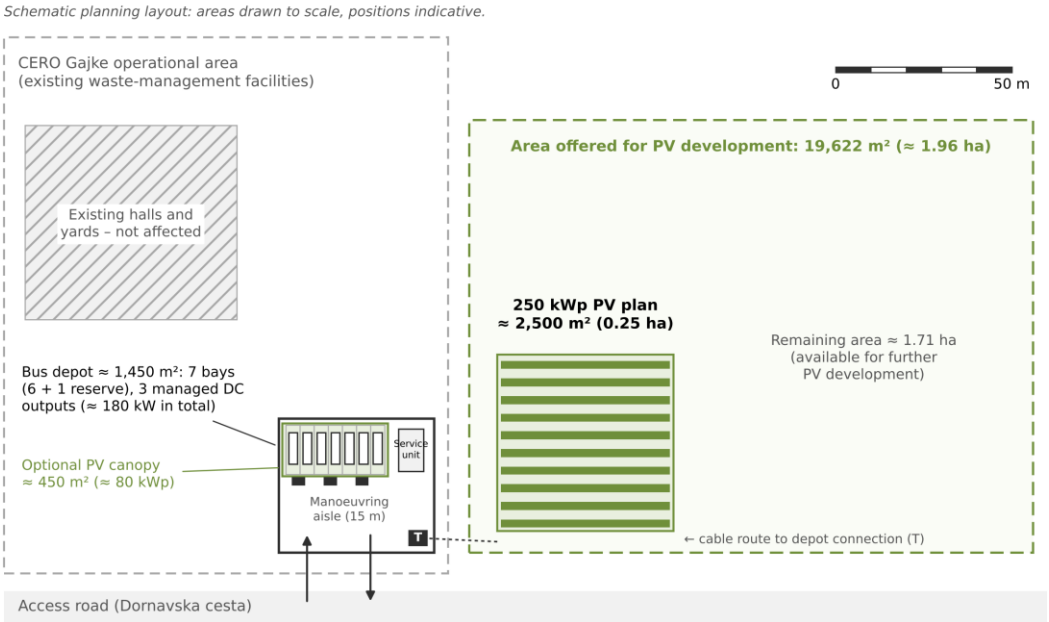


Figure 6. CERO Gajke depot and PV plan – schematic layout

Own planning sketch; PV development area from Javne službe Ptuj [S10]. Areas to scale, positions indicative.

The PV plan is screened with a simplified unlevered, pre-tax discounted cash flow over 25 years at a 5% real discount rate. It includes fixed O&M, 0.5% annual degradation and a mid-life inverter replacement allowance of 10% of initial CAPEX in year 14. Simple payback is initial CAPEX divided by the year-one net benefit. The

values exclude VAT, financing, grants and site-specific premiums, and the CAPEX sensitivity scales O&M and the inverter allowance with the investment.

Table 7. CERO Gajke 250 kWp PV plan – inputs and results

Input or result	Central value	Interpretation
Planned capacity	**250 kWp**	**Ground-mounted field on about 0.25 ha of the 1.96 ha area offered for PV**
Year-one production	259.7 MWh	Scaled from 1,549.27 MWh / 1,491.51 kWp
Turnkey CAPEX	EUR 250,000	EUR 1,000/kWp; excludes site-specific premiums and reinforcement
Fixed O&M	EUR 3,000/year	1.2% of initial CAPEX
Inverter replacement	EUR 25,000 in year 14	10% of initial CAPEX; mid-life allowance
Energy value	EUR 0.10/kWh	Central opportunity-value assumption
Year-one gross value	EUR 25,970	Year-one production multiplied by the energy value
Year-one net benefit after O&M	EUR 22,970	Basis for the simple payback
Degradation, discount, horizon	0.5%, 5%, 25 years	Constant 2026 EUR; no terminal value
Simple payback	10.9 years	Initial CAPEX divided by year-one net benefit
IRR and NPV	6.8% and EUR 44,300	Central case; sensitive to realised self-consumption value

Table 8. Sensitivity of the CERO PV plan to energy value and CAPEX

Sensitivity case	IRR / 25-year NPV	Interpretation
Energy value -20% (EUR 0.08/kWh)	3.9% / -EUR 25,600	Below the break-even value of about EUR 0.087/kWh
Energy value -10% (EUR 0.09/kWh)	5.4% / +EUR 9,300	Marginally above the 5% discount rate
Base case (EUR 0.10/kWh)	**6.8% / +EUR 44,300**	**Central case**
Energy value +10% (EUR 0.11/kWh)	8.1% / +EUR 79,200	Moderate avoided-cost case
Energy value +20% (EUR 0.12/kWh)	9.4% / +EUR 114,100	Stronger avoided-cost case
EUR 0.16/kWh	14.2% / +EUR 253,800	High-value self-consumption case
EUR 0.20/kWh	18.6% / +EUR 393,400	Upper stress test
CAPEX -10% (EUR 900/kWp)	8.3% / +EUR 74,800	Lower contractor price
CAPEX +10% (EUR 1,100/kWp)	5.5% / +EUR 13,800	Site premiums remove most of the margin

The plan is most exposed to the realised value of its electricity and to the final installed cost. Break-even lies at approximately EUR 0.087/kWh, so the plan clears the 5% threshold only if most of its output displaces purchased electricity rather than being exported at a low settlement value. A 10% CAPEX increase leaves a narrow positive margin of about EUR 13,800.

5.4 Constraints and next design steps

CERO should not advance to tender until the municipality confirms the depot boundary, bus circulation, utility corridors, available connection capacity, emergency access and environmental interface with waste operations.

The new-PV option must remain separate from the base depot decision: depot charging can proceed without a CERO PV plant, while the 250 kWp PV plan proceeds only if survey, grid and landfill-cap evidence support it.

6 Assessment of the wastewater treatment plant

6.1 Technical and energy characteristics

Table 9. Technical and energy characteristics of the wastewater treatment plant

Attribute	Assessment	Next design step
Address and coordinate	Ob Dravi 7; 46.407907 N, 15.881046 E	Access, ownership and cadastral plan
Primary function	Secondary daytime charging, emergency recovery and PV-integration hub	Duty-level visit plan
Original PV design	606.10 kWp and 632.31 MWh/year	As-built capacity, inverter limits and current production
Usable area (plan)	Existing PV about 3,000 m² of module area (606.10 kWp design); charging zone about 420 m² (one bay with drive-through lane) outside the treatment process area (Figure 7)	As-built layout, access and swept-path survey
Relation to bus demand	Gross design production equals about 2.56 times central annual bus energy	Residual same-hour output after existing load
Charging concept	One scheduled secondary DC charger or shared outputs	Connection and charger quotation
Main advantage	Strongest existing PV node and controllable infrastructure setting	Metering and energy-allocation confirmation
Main constraints	Access, deadhead, treatment operations, metering and DSO conditions	Traffic, hygiene, safety and plant-interface design

The treatment plant is the strongest immediate site for demonstrating PV-aligned bus charging. It combines a large municipal PV asset with an infrastructure environment where managed energy use is technically credible. Its role is not to become a second depot or informal parking area. Every visit must be tied to a defined duty, secure access and a safe separation from treatment-plant operations.

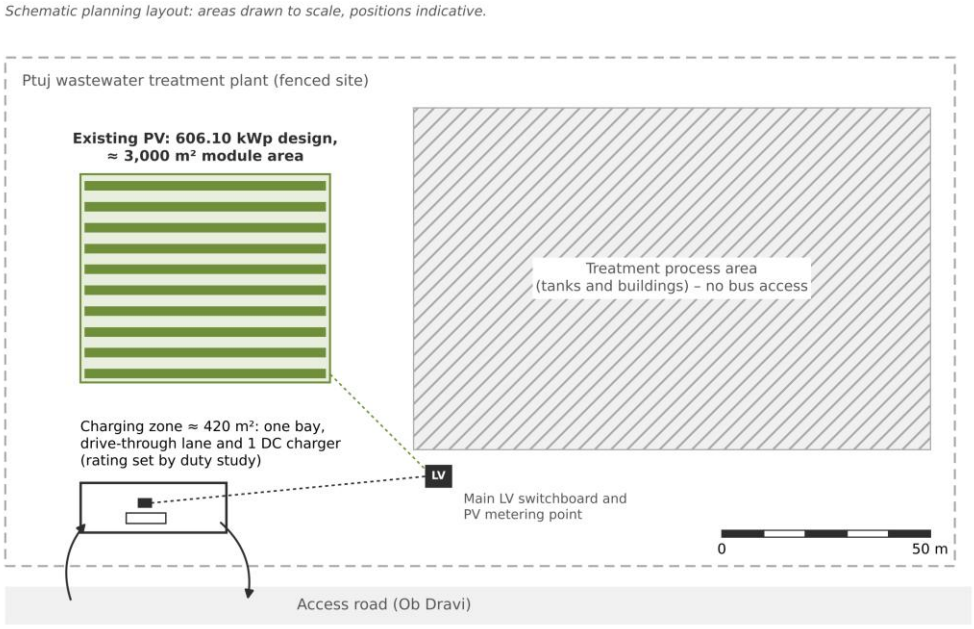


Figure 7. Wastewater treatment plant secondary charging point – schematic layout

Own planning sketch; module area derived from the 606.10 kWp design at about 5 m²/kWp. Areas to scale, positions indicative.

6.2 Daytime charging and PV coupling

Scenario 2 shifts a limited share of charging into the solar window and uses CERO for the remaining controlled overnight demand. The hourly model estimates 72.1 MWh/year of incremental same-hour PV for buses after the modelled existing community load, equal to 29.2% of annual charging. The result is a planning estimate that is recalibrated with 15-minute plant, community and charger data during concept design.

Incremental bus PV = min(bus charging, PV output remaining after existing load) in each modelled hour

Table 10. Scenario 2 energy results for daytime charging at the wastewater treatment plant

Energy measure	Scenario 2 result	Meaning
Annual bus charging	246.7 MWh	Central case including 10% charging losses
Incremental same-hour PV	**72.1 MWh**	**Residual PV available after modelled existing public-consumer demand**
PV share of bus charging	**29.2%**	**Physical hourly coincidence estimate, not a contractual allocation guarantee**
Grid or non-incremental supply	174.6 MWh	Remaining charging energy
Modelled diversified peak	88.8 kW	Outcome of the assumed controlled schedule, not a connection request

The model therefore supports one targeted daytime charging function at the wastewater treatment plant. It does not support an uncontrolled high-power charger sized solely to maximise nominal PV use. The power rating should follow the duty gap that must be recovered, the vehicle charging curve and the connection limit.

6.3 Constraints and next design steps

- Confirm the as-built PV capacity, inverter arrangement, export limit and meter topology.
- Export at least 12 months of 15-minute PV production, plant load, import and export data.
- Measure road access, entry geometry, turning, reversing, standing position and safe separation from plant traffic.
- Quantify deadhead and schedule impact for every candidate duty; reject visits that consume more energy or time than they recover.
- Obtain a separate DSO condition and supplier quotation for the charger, cable route and protection changes.
- Document whether community energy can be allocated to the charger and how physical and accounting claims will be reported.

7 Assessment of Ptuj main bus station

7.1 Network value

The main bus station has a unique operational advantage: all five urban lines already pass through the node. A vehicle can therefore receive a short top-up without a dedicated passengerless trip if the timetable contains a safe dwell window. This makes the site strategically valuable for future network resilience, especially if measured winter duties reveal a recurring range bottleneck.

Table 11. Characteristics of the main bus station

Attribute	Assessment	Next design step
Coordinate	46.421255 N, 15.876581 E	Exact bay, land and utility boundary
Primary function	Optional short opportunity charging at the common network hub	Measured dwell and vehicle assignment
PV status	No PV installation at present	Canopy or nearby-roof feasibility if retained
Main advantage	All five lines connect to the node	No special trip if charging fits normal layover
Main constraints	Bay occupation, pedestrian safety, regional services, ownership, visual impact and grid work	Integrated traffic, urban-design and DSO review

7.2 Optional opportunity charging

A bus-station charger should be justified by a specific recurring duty shortfall, not by the general attractiveness of the location. If later retained, the concept should minimise bay occupation and protect passenger circulation. A cable route and equipment zone can be reserved during other works without purchasing the charger. The final technology and power must remain compatible with the selected vehicle fleet and the available connection.

Table 12. Decision tests for optional opportunity charging

Decision test	Proceed only if	Otherwise
Operational need	Measured duties show a repeated winter or disruption-related energy gap	Use CERO and WWTP only
Dwell time	A safe and reliable charging window exists in the timetable	Do not plan an opportunity charger
Passenger and traffic safety	Equipment and cable routes do not obstruct bays, pedestrians or regional services	Protect only a future corridor
Grid capacity	Connection cost and programme are proportionate to the operational benefit	Defer until reinforcement or load conditions change
Economic value	Reliability benefit exceeds the whole-life incremental cost	Retain the site as a strategic option

7.3 Constraints and next design steps

The bus station is the least mature candidate from a physical implementation perspective: a bay plan, ownership map, utility survey, passenger-flow study, charger foundation concept and DSO assessment would all be needed before a charger could be specified. The site should therefore not create first-stage procurement risk. Preserving an option is rational; committing to equipment before a proven duty need is not.

8 Comparative multi-criteria assessment

8.1 Base-case ranking

Table 13. Base-case multi-criteria assessment

Criterion	Weight	CERO	WWTP	Bus station	Rationale
Operational fit	30%	5	4	5	CERO is the coherent depot; bus station is the network hub; WWTP requires selected visits
PV integration	25%	4	5	2	WWTP has the largest existing design asset; CERO has the 250 kWp plan; bus station has no PV at present
Grid readiness	20%	4	4	3	Planning-level scores; refined with DSO studies
Ownership and implementation	15%	5	4	2	CERO is simplest operationally; public-space interfaces weaken the bus station
Spatial and environmental	10%	4	4	2	Bus station has the strongest space and pedestrian constraints
Weighted total (0–100)	**100%**	**89.0**	**85.0**	**62.0**	**CERO and WWTP form the strongest complementary first-stage system**

CERO leads because reliable bus operation is the first requirement. The wastewater treatment plant nearly matches it because its PV and daytime-energy role are unusually strong. The bus station remains strategically important, but its operational centrality does not yet outweigh its spatial, ownership, safety and PV limitations.

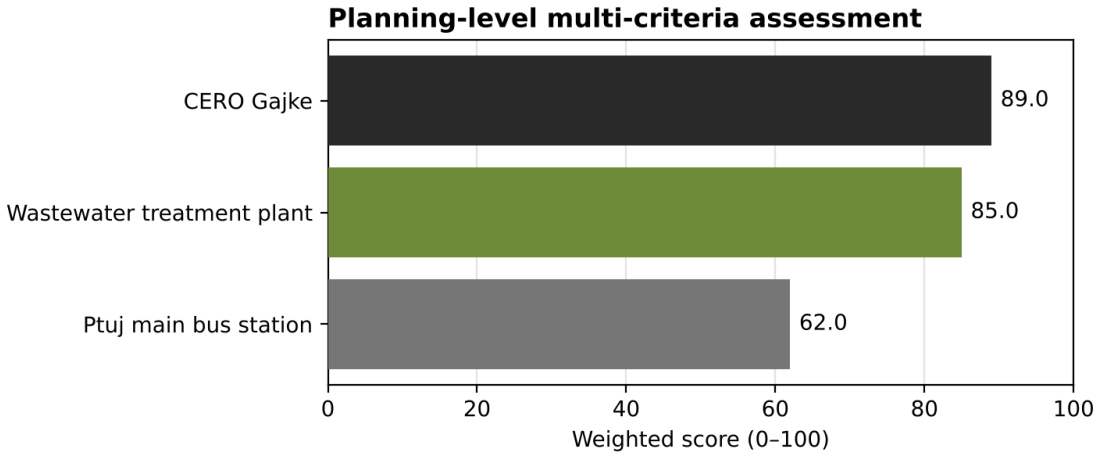


Figure 8. Base-case weighted site ranking

8.2 Weight sensitivity and robustness

The ranking was tested against alternative policy priorities. CERO remains first when operational fit or grid readiness receives additional weight. The wastewater treatment plant moves narrowly into first place only in a PV-first case. The bus station remains third in every tested weighting. The decision is therefore robust at the system level: CERO and the wastewater treatment plant should advance together, while their internal priority depends on whether the immediate task is fleet operation or solar integration.

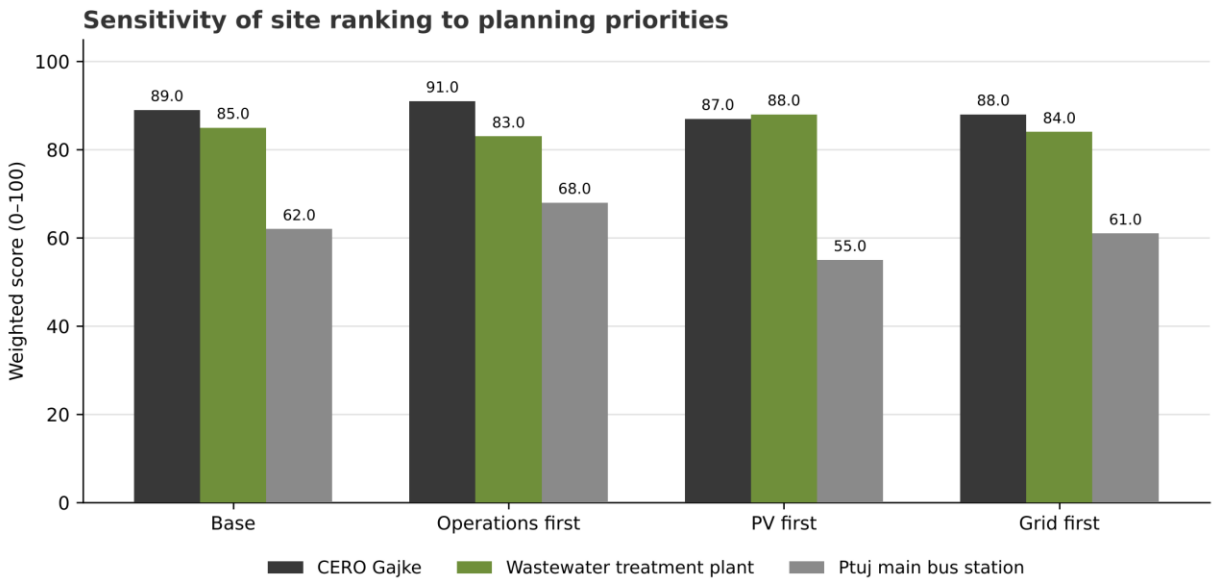


Figure 9. Sensitivity of site ranking to alternative planning priorities

Table 14. Site ranking under alternative weighting cases

Weighting case	CERO	WWTP	Bus station	Decision implication
Base	**89.0**	**85.0**	**62.0**	**CERO leads; two-site concept**
Operations first	91.0	83.0	68.0	CERO lead increases
PV first	87.0	88.0	55.0	WWTP narrowly leads; two-site concept unchanged
Grid first	88.0	84.0	61.0	CERO remains first, subject to actual DSO evidence

9 Optimal location and development concept

9.1 Preferred main depot

CERO Gajke is the optimal main operating location. Its selection is driven by the need for secure, controllable and maintainable fleet infrastructure rather than by an assumption of immediate on-site PV. The first design task is a depot and managed-charging concept that proves circulation, connection power, overnight recovery and operational responsibility.

9.2 Preferred secondary PV hub

The wastewater treatment plant is the optimal secondary location. It should provide only the charging function that confirmed duties require, supported by measured residual PV and a clearly documented metering arrangement. Its value is the combination of existing solar generation and a practical daytime recovery role, not the gross annual PV figure by itself. With the reference midibus this function is required rather than optional: it supplies the daytime top-up of roughly 35-70 kWh per full school-day duty.

9.3 Optional future network hub

The bus station is the preferred protected option for a later network-level charger. It should enter procurement only if a year of measured electric-bus operation or a final duty simulation demonstrates that CERO and WWTP cannot provide the required reliability at lower whole-life cost and lower public-space risk.

9.4 Recommended phased configuration

Table 15. Recommended phased site configuration

Phase	CERO Gajke	Wastewater treatment plant	Main bus station	Decision trigger
1 Evidence and concept design (2027)	Land, utilities, circulation, load and DSO enquiry; depot layout	As-built PV, interval data, access, load and DSO enquiry	Ownership, bays, utilities and future corridor	Validated evidence package; concept and funding approval
2 Procurement and first implementation (2028-2029)	**Main depot and controlled charging**	**One secondary charger only if duties confirm the need**	**No charger in base procurement**	**Funding, grid conditions and contracts in place**
3 Measured optimisation (2029-2030)	Tune schedules; decide on the 250 kWp PV plan	Tune charging to measured residual PV	Reassess with real dwell and range data	Twelve months of operational data
4 Advanced integration (2030-2031)	Fleet energy-management expansion; storage interface and space reserved	Community and charger EMS integration; storage only where residual export and peak cost support it	Opportunity charger only with proven business case	Quantified reliability, grid or storage value; SUMP 2031 review

The four phases and their years are identical to the implementation roadmap of the companion feasibility study and end at the 2031 horizon of the local SUMP.

10 Hourly energy and charging assessment

10.1 Monthly energy balance

The annual community production forecast is large relative to bus demand, but the 35 existing consumers already use more electricity annually than the community systems are forecast to generate. The monthly result therefore distinguishes gross PV, existing load and the incremental bus share. Scenario 2 uses residual PV most effectively in spring and summer, while winter charging remains predominantly grid supplied.

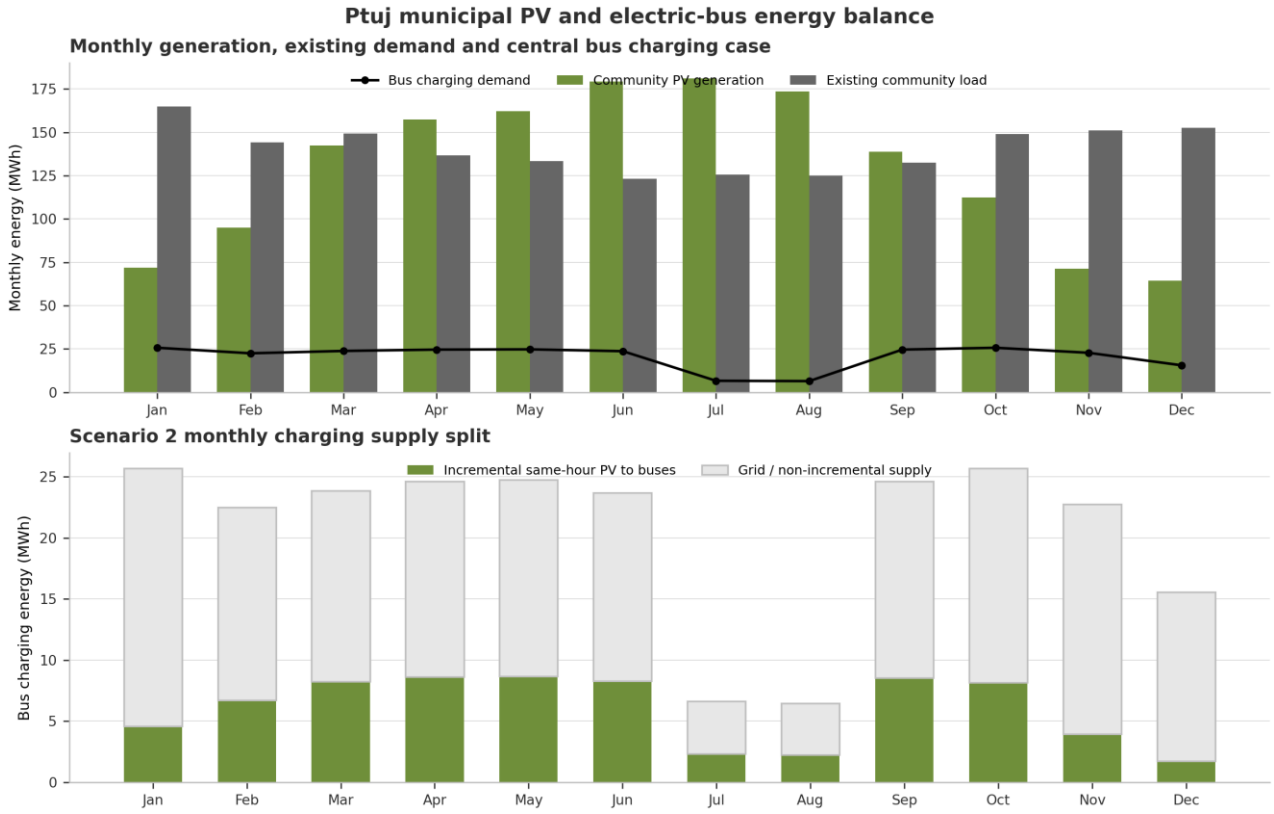


Figure 10. Monthly municipal PV, existing community demand and Scenario 2 bus charging balance

10.2 Representative daily coincidence

The representative winter and summer profiles show why site function matters. Overnight-only charging at CERO is operationally reliable but has little direct same-hour PV overlap. A scheduled WWTP charging window around midday can absorb part of the residual solar output. The summer opportunity is larger, while winter production and vehicle heating demand make conservative grid-backed operation essential.

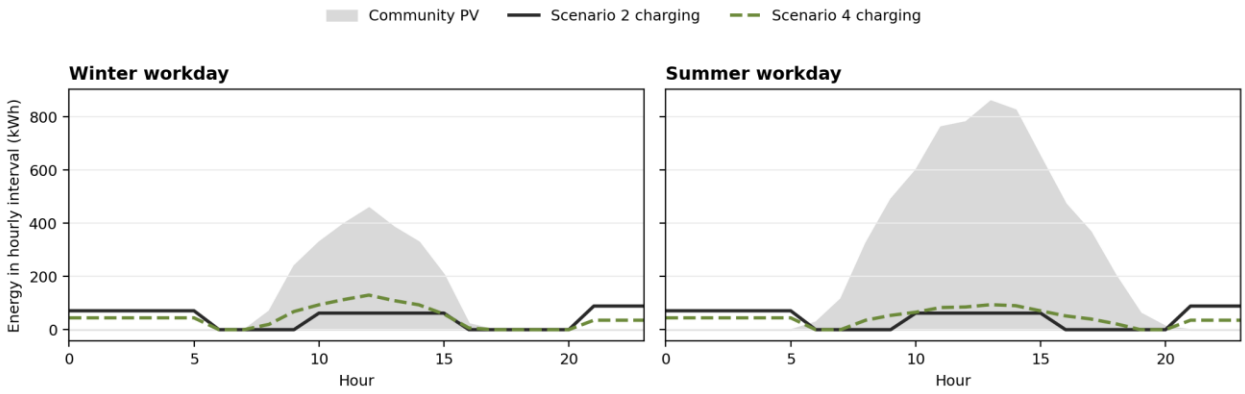


Figure 11. Representative winter and summer relationship between community PV and conceptual charging schedules

10.3 Scenario result

Table 16. Annual charging, PV contribution and peak demand by scenario

Scenario	Site concept	Annual charging	Incremental PV	PV share	Modelled peak
S1	CERO depot only	246.7 MWh	0.0 MWh	0.0%	177.6 kW
S2	**CERO plus WWTP daytime charging**	**246.7 MWh**	**72.1 MWh**	**29.2%**	**88.8 kW**
S3	CERO, WWTP and planned opportunity charging	246.7 MWh	108.0 MWh	43.8%	135.5 kW
S4	Multi-site smart charging	246.7 MWh	121.0 MWh	49.1%	151.2 kW

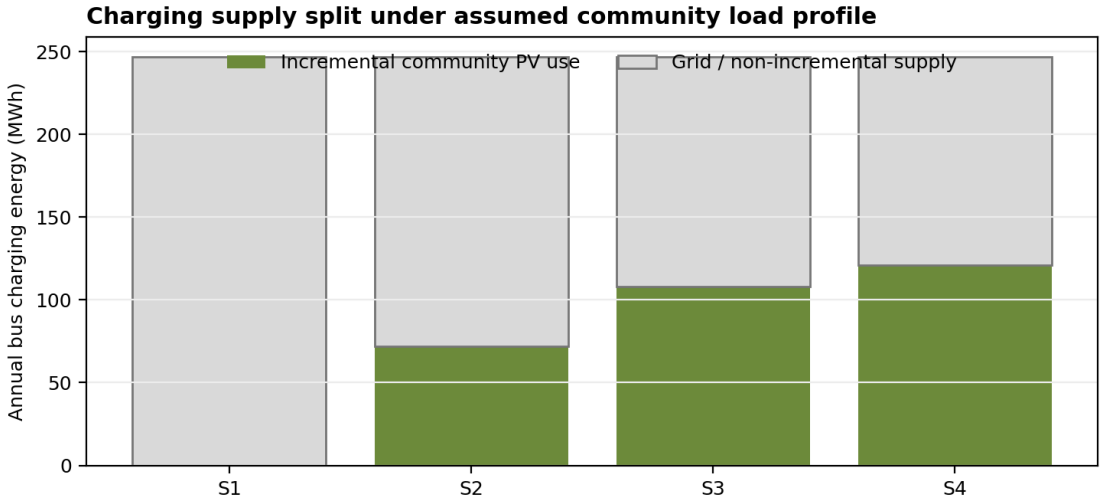


Figure 12. Annual charging supply split after prioritising the modelled existing community load

The additional 48.9 MWh/year of modelled PV use between Scenario 2 and Scenario 4 is modest relative to the approximately EUR 350,000 increase in indicative charging and control CAPEX. Advanced charging can still be justified by resilience, avoided grid reinforcement or future tariff value, but not by solar-energy arbitrage alone under the central assumptions. Scenario 2 also has the lowest modelled peak (88.8 kW). Scenarios 3 and 4 move more charging into the short midday solar window and add opportunity-charging sessions, which raises their diversified peaks to 135.5 kW and 151.2 kW; advanced control keeps each site within its connection limit but does not lower peak demand below Scenario 2.

11 Indicative techno-economic assessment

11.1 Cost boundary

The location assessment uses the whole-project scenario model because charging sites cannot be valued independently of fleet size, operating organisation and funding. The current municipal outsourced-service figure of approximately EUR 1.2 million/year is a budget benchmark, not automatically an avoided cost. The values below are constant 2026 EUR and exclude VAT, financing, tax, land and connection-reinforcement costs.

Table 17. Central cost assumptions

Input	Central value	Status
Reference fleet	6 x 9 m midibus plus 1 compact e-minibus; approx. EUR 1.99m	Anonymised supplier offers; configuration remains to be tendered
Common depot and project CAPEX	EUR 0.400m	Feasibility allowance
Charging and site CAPEX	EUR 0.350m in S1 to EUR 0.850m in S4	Feasibility allowance; quotations and DSO studies required
Capital grant	None in the central case; 80% of vehicle CAPEX tested as upside	Borzen M2/M3 allocation reached [S5]; no other grant confirmed
Non-energy municipal OPEX	EUR 0.850m/year	Requires bottom-up staffing and maintenance validation
Grid electricity and PV value	EUR 0.18 and EUR 0.10 per kWh	Sensitivity assumptions
Discount rate and horizon	5% real over 12 years	No terminal value

11.2 Site-specific costs and value

Table 18. Site-specific cost increments and value

Increment	Indicative amount	Value created	Caution
CERO depot and common project base	Included in S1 gross CAPEX of EUR 2.743m	Reliable fleet base and controlled overnight charging	Final civil, charger and connection cost set by design and quotations
WWTP secondary function	**S2 adds about EUR 150,000 to S1**	**Daytime top-up the reference midibus needs, lower modelled peak and 72.1 MWh/year incremental PV**	**Scenario increment, not a supplier quote**
Planned opportunity charging	S3 adds about EUR 220,000 to S2	Raises incremental PV use to 108.0 MWh/year and provides more flexibility	Site, power and technology set after measured operation
Advanced multi-site controls	S4 adds about EUR 130,000 to S3	Highest modelled PV share and integrated control	Institutional complexity and modest extra energy value
CERO 250 kWp PV plan	EUR 250,000	259.7 MWh/year reference production and positive central NPV	Layout fixed by site survey

Table 19. Whole-project scenario comparison – central no-grant case and funding upside

Scenario	Gross CAPEX	12-year NPV without grant (central)	Break-even capital support	12-year NPV with 80% grant (upside)	Role
S1	EUR 2.743m	-EUR 0.096m	EUR 0.10m	+EUR 1.498m	Minimum case; needs larger-battery buses or midday depot returns
S2	**EUR 2.893m**	**-EUR 0.222m**	**EUR 0.22m**	**+EUR 1.372m**	**Preferred first implementation (Phase 2)**
S3	EUR 3.113m	-EUR 0.455m	EUR 0.46m	+EUR 1.139m	Optimisation option (Phase 3)
S4	EUR 3.243m	-EUR 0.599m	EUR 0.60m	+EUR 0.995m	Long-term option (Phase 4)

Why Scenario 2 rather than Scenario 1. Without a grant, Scenario 1 has the better 12-year NPV (-EUR 0.10 million against -EUR 0.22 million); the difference is essentially the EUR 0.15 million secondary charging function at the wastewater treatment plant. Scenario 1 is, however, calculated with the same 9 m midibus fleet, which cannot complete 200-250 km school-day duties on overnight charging alone. It would need 9.5 m large-battery buses, costing about EUR 1.5-2.1 million more for six vehicles and harder to manoeuvre on Lines 1 and 2, or midday returns to CERO that add deadhead kilometres and take buses out of service. The range limit of the reference bus is therefore the decisive argument for Scenario 2.

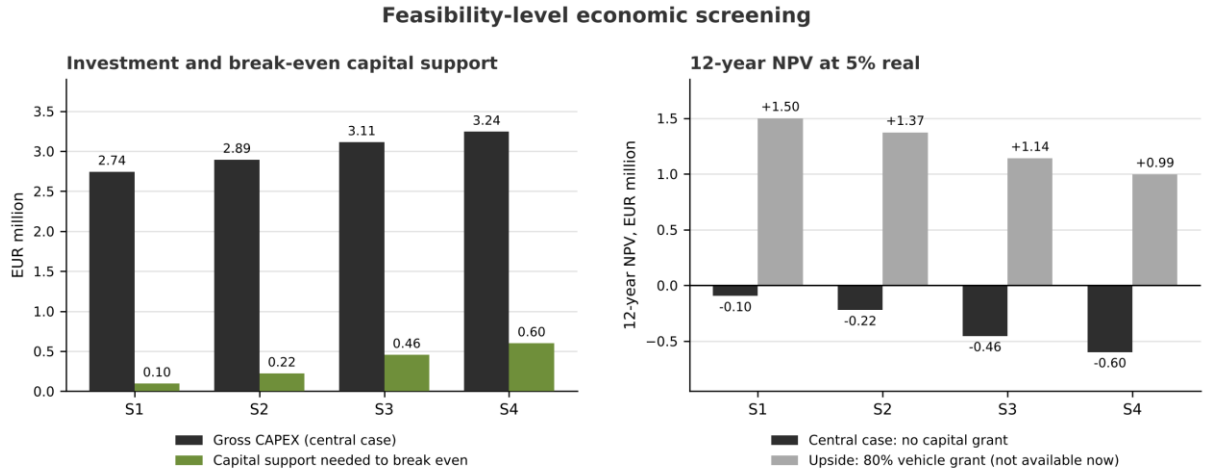


Figure 13. Feasibility-level economic screening

Central case without a capital grant; the 80% grant is shown only as an upside that is not currently available.

11.3 Financial sensitivity

Without a capital grant, every scenario has a slightly negative 12-year NPV, from -EUR 0.10 million (S1) to -EUR 0.60 million (S4), while simple paybacks of 9.2-10.9 years stay within the 12-year vehicle life. Scenario 2 needs about EUR 0.22 million of capital support, or about EUR 25,000/year of lower operating cost, to break even. An 80% vehicle grant would add about EUR 1.59 million to every NPV, but it is treated as an upside because the current Borzen allocation for M2/M3 buses has been reached [S5]. A EUR 100,000/year upward error in municipal non-energy OPEX reduces 12-year NPV by approximately EUR 0.89 million. The staffing, maintenance and service-scope model therefore matters more than the grant gap or small differences in PV energy value.

Table 20. Key financial sensitivities

Variable	Central case	Sensitivity	Decision implication
Capital grant	None (central case)	80% grant would add about EUR 1.59m to every NPV; S2 breaks even with EUR 0.22m of support	Confirm the funding mix before contracting; keep the project application-ready
Municipal non-energy OPEX	EUR 0.850m/year	+EUR 0.100m/year reduces NPV by about EUR 0.89m	Prepare bottom-up staffing and maintenance plan
PV versus grid value spread	EUR 0.08/kWh	Advanced-scenario energy value is small relative to added CAPEX	Justify advanced charging through reliability or grid value
Traction consumption	0.65 kWh/km	170.8 to 341.6 MWh/year input-energy range	Require winter duty evidence and measure kWh/km
CERO PV value	EUR 0.10/kWh	Break-even at about EUR 0.087/kWh; 25-year NPV negative at EUR 0.08 and strongly positive at higher self-consumption values	Survey site and validate load before procurement

The instruments that can close the Scenario 2 gap are the Climate Change Fund programme for 2025-2028, which earmarks EUR 375 million for sustainable mobility, future cohesion-policy calls for integrated territorial investments of urban municipalities (charging, depot and digital components), Eko sklad loans for the municipal share and the municipal budget; the Social Climate Fund is relevant mainly for complementary services. The companion feasibility study (Section 8.6) sets out their current status and the recommended financing strategy.

12 Implementation requirements and next steps

12.1 Pre-design evidence

Table 21. Pre-design evidence requirements by site

Evidence	CERO	WWTP	Bus station	Owner or output
Land, ownership and access	Required	Required	Required if option retained	Municipality and legal map
Topographic and utility survey	Required	Required	Future corridor only	Licensed surveyor
DSO connection study	Required	Required	Optional phase	Elektro Maribor conditions
15-minute meter data	Current site load	PV, load, import and export	Site load if retained	Municipality and portal export
Vehicle swept path	Depot circulation	Entry, turning and standing	Bay and passenger interface	Traffic engineer
Environmental and fire review	Waste and degraded-land context	Treatment-plant operations	Public-space interface	Competent designers
CAPEX quotation	Depot, civil and electrical	Charger, cable and grid	Only after proven need	Suppliers and contractors
Duty evidence	Return time and overnight need	Candidate visits and energy recovery	Measured dwell shortfall	Operator and transport planner

The concept-design commission should deliver one coordinated package: a CERO functional depot layout and managed-charging concept, a wastewater-treatment-plant access and secondary-charger concept tied to measured PV residual, and a protected but unfunded bus-station option. Any change to the vehicle battery, charging curve, fleet size or depot location must trigger an updated hourly and connection-capacity calculation.

12.2 Risk register

Table 22. Risk register

Risk	Rating	Consequence	Mitigation and gate
Insufficient CERO connection capacity	High	Reinforcement cost or commissioning delay	Early DSO enquiry, managed charging and staged connection
WWTP access conflicts with plant operations	High	Unsafe or unusable secondary charging	Swept-path, hygiene, traffic and operational-access plan
No useful daytime duty window	High	WWTP charger provides little value	Duty simulation before power and procurement are fixed
PV double counting	Medium-high	Overstated savings and climate claims	Interval data and separate physical versus settlement accounting
Bus-station spatial conflict	Medium-high	Passenger or regional-service disruption	Defer charger; protect only a future route and equipment zone
Insufficient capital support	High	Central no-grant case: S2 NPV -EUR 0.22m; a grant would add up to EUR 1.59m	Secure about EUR 0.22m of support or equivalent OPEX savings; phase procurement if needed
Underestimated municipal OPEX	High	Business case may reverse	Bottom-up organisation model and independent cost review
Multi-vendor interoperability	Medium	Vehicle or charger downtime	Protocols, compatibility matrix, acceptance tests and response times
Premature battery storage	Medium	High cost without dispatch value	Exclude from base case and require measured economic trigger

12.3 Monitoring and decision gates

Table 23. Monitoring and decision gates

Gate	Evidence	Acceptance condition
Concept approval	Land, access, utilities, DSO conditions and duty model	CERO and WWTP can perform assigned functions without unresolved fatal constraints
Procurement approval	Funding, quotations, final fleet and municipal OPEX model	Whole-project scenario remains affordable under conservative sensitivity
Commissioning	Factory and site acceptance, trained staff and emergency procedures	Every vehicle and charger completes tested operational cases
End of first summer	PV, load, charger and route data	WWTP control settings and allocation claims can be recalibrated
End of first winter	Range, HVAC, delays and recovery events	Evidence supports or rejects a bus-station opportunity charger
Storage decision	Residual export, peaks, tariffs and charger dispatch	Positive whole-life case for a defined operational or grid service

13 Conclusions

The assessment confirms that Ptuj should not select one universal location for every charging and photovoltaic function. The robust solution is a two-site first stage. CERO Gajke is the preferred main depot because it provides the strongest operational control and implementation logic. The wastewater treatment plant is the

preferred secondary location because it combines a large existing PV design asset with a credible daytime charging role.

The main bus station remains strategically valuable, but it should not lead the first investment. Its network position is offset by weaker PV evidence, more complex ownership and public-space interfaces, and an unproven need for high-power opportunity charging. Protecting a future cable route and equipment zone is proportionate; purchasing a charger before measured duty evidence is not.

Scenario 2 is therefore the recommended first full implementation: controlled charging at CERO plus one secondary function at the wastewater treatment plant. In the hourly model it supplies 72.1 MWh/year, or 29.2% of bus charging, from residual same-hour PV and limits the modelled diversified peak to 88.8 kW. The scenario has a whole-project gross CAPEX of approximately EUR 2.893 million. It is preferred to Scenario 1 because the 9 m reference midibus cannot complete a full school-day duty on overnight charging alone. Without a capital grant its 12-year NPV is about -EUR 0.22 million with a 9.6-year simple payback; it becomes NPV-neutral with about EUR 0.22 million of support or equivalent operating savings, and its economic case depends above all on a validated municipal operating-cost model.

The next step is concept design in Phase 1 (2027), not equipment tendering. Ptuj should first obtain confirmed duties, 15-minute energy data, separate DSO conditions, topographic and traffic surveys, as-built PV evidence and supplier quotations. Once these inputs are available, the companion hourly workbook can be recalculated without changing the decision logic set out in this assessment.

14 Limitations of the assessment

This document is a feasibility-level location assessment based on supplied project files, official public information and transparent planning assumptions. It does not constitute final structural, electrical, civil, fire-safety, traffic, environmental, heritage or grid design. It does not confirm cadastral ownership, legal access, final developable PV layout, transformer capacity, soil conditions, charger power, route duties, battery life, public-procurement eligibility or the availability of funding.

The hourly energy result uses a PVGIS-derived production shape normalised to the official municipal annual forecast and a modelled community-load profile. It is suitable for comparing concepts and defining design inputs, not for guaranteeing renewable shares, savings or emissions claims. All investment values are feasibility allowances and must be replaced by quotations and connection conditions before approval.

15 References

Table 24. Source register

ID	Source
S1	City Municipality of Ptuj, completion of the municipal photovoltaic system, 20 April 2026. https://www.ptuj.si/objava/1283519
S2	City Municipality of Ptuj, successful SONCE 8P application, 3 February 2025. https://www.ptuj.si/objava/1049498
S3	Arriva Slovenia, Ptuj urban bus timetables, September 2026 PDFs. https://arriva.si/avtobusni-prevozi/mestni-avtobusni-prevozi/mestni-avtobusni-prevozi-ptuj/vozni-redi-in-cenik-ptuj/
S4	European Commission Joint Research Centre, PVGIS 5.3 hourly series and documentation. https://re.jrc.ec.europa.eu/api/v5_3/seriescalc
S5	Borzen, support for environmentally friendly buses; call and status page checked 1 November 2026. https://borzen.si/sl-si/podpore-za-mobilnost/subvencije-za-okolju-prijaznejse-avtobuse
S6	Javne sluzbe Ptuj, CERO Gajke regional centre. https://www.js-ptuj.si/odpadki/koristne-informacije/regijski-center
S7	Komunalno podjetje Ptuj, public information on the Ptuj wastewater-treatment-plant location and infrastructure. https://www.komunala-ptuj.si/
S8	Jozef Stefan Institute, Centre for Energy Efficiency, Slovenian electricity greenhouse-gas factor for 2024. https://ceu.ijs.si/izpusti-co2-tgp-na-enoto-elektricne-energije/
S9	Supplied project documents: Ptuj feasibility-study draft, SONCE 8P investment programme, PV and meter/allocation workbooks, three electric-bus offers and the Ptuj hourly model workbook.
S10	Javne službe Ptuj, call for solar partners on 19,622 m² at CERO Gajke; Ptujinfo, 10 January 2025. https://ptujinfo.com/novica/lokalno/cero-gajke-bo-dobil-novo-vlogo-javne-sluzbe-ptuj-iscejo-partnerje-za-soncne

Appendix A Calculation and design handover

Table 25. Calculation steps and design-phase refinement

Calculation step	Input	Current result	Refinement in the design phase
Service volume	Published route lengths and departures	About 345,000 vehicle-km/year	Operator duty and AVL export including deadhead
Bus charging energy	0.65 kWh/km and 10% losses	246.7 MWh/year	Measured seasonal kWh/km and charger-meter data
Community PV	1,491.51 kWp and 1,549.27 MWh/year	Official aggregate forecast	As-built register and inverter production exports
Existing community load	1,686.99 MWh/year and modelled shape	Modelled hourly residual PV	15-minute import, export and consumption data
CERO PV plan	250 kWp on about 0.25 ha and EUR 1,000/kWp	259.7 MWh/year; central NPV EUR 44,300	Surveyed area, yield study, grid conditions and quotations
Site ranking	Five weighted criteria	CERO 89.0, WWTP 85.0, bus station 62.0 of 100	Surveys, DSO conditions and confirmed ownership
Scenario 2	CERO and WWTP charging schedule	72.1 MWh/year incremental PV; 88.8 kW peak	Confirmed duties and measured interval data
Economics	Fleet offers, feasibility allowances and 12-year model	S2 gross CAPEX EUR 2.893m	Tender prices, funding decision and bottom-up municipal OPEX

Model handover. The companion workbook contains the assumptions, 8,760-hour model, monthly balance, scenario comparison, site assessment and sources. Update interval load first, then duties and consumption, then charger and grid CAPEX, and finally the municipal operating-cost model. Recalculate the site and scenario decision after every material change.