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Ground-mounted PV analysis-Ungarija Integration of PV Systems into Electric Public Transport in Umag

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Executive Summary

This report provides a feasibility-level assessment of the candidate ground-mount photovoltaic (PV) site identified near Umag (Istria County, Croatia) known as "Ungarija", located on a single cadastral parcel in the city's industrial zone. It consolidates the spatial, technical and financial considerations used to judge the site's suitability as a source of renewable electricity for the City of Umag's planned electrified school bus fleet, and presents an indicative discounted cash-flow (DCF) analysis — CAPEX, Net Present Value (NPV) and Internal Rate of Return (IRR) — to gauge investment viability.

Ungarija is one of two ground-mount PV candidates screened for the City of Umag, the other being the "Donji Picudo" former-landfill site, assessed in a companion report. The two sites were selected because they are the most concrete, technically defined opportunities identified during project preparation: both have an identifiable installable area, established ownership status and preliminary capacity and production estimates, and both are large enough to substantially exceed the electricity demand of the electrified school bus fleet.

Ungarija has an estimated installable capacity of approximately 4.37 MWp on a gross plot area of 68,229 m^2, held under single private ownership on Cadastral Unit 5159/1 [1]. The terrain is predominantly flat with low vegetation, requiring only minimal site preparation, and the parcel benefits from direct road access and five potential grid connection points in the immediate vicinity [7], which substantially reduces interconnection risk compared with more remote or single-point-of-failure sites.

Under the base-case assumptions used, including the regulated HERA medium-voltage grid connection fee introduced in Croatia from 1 May 2026 [2], the site shows a strong risk-return profile: Total CAPEX of approximately €3.30 million, a Year-1 generation of approximately 5,244 MWh, an NPV at a 7% real discount rate of approximately €3.08 million over a 25-year horizon, an IRR of 16.6%, and a simple payback of approximately 5.8 years.

Feasibility recommendation

Ungarija is recommended as a financially and technically strong candidate for utility-scale ground-mounted PV development supporting the electrification of Umag's school bus fleet. Under the base-case assumptions used, including the regulated HERA grid connection fee [2], the site delivers a positive NPV of approximately €3.08 million and an IRR of 16.6% over a 25-year horizon, supported by a large 4.37 MWp technical capacity [3], flat low-vegetation terrain and five nearby grid connection points that substantially de-risk interconnection [4]. Compared with the alternative Donji Picudo candidate, Ungarija offers stronger financial performance and lower interconnection risk, while Donji Picudo retains distinct advantages as a brownfield redevelopment site with simplified public land tenure. Final investment approval remains subject to updated EPC quotations, a formal grid connection study and a bankable solar resource assessment.

1. Purpose & scope

The purpose of this report is to document the technical and financial reasoning behind the assessment of Ungarija as a candidate location for a utility-scale, ground-mounted photovoltaic power plant that will support the City of Umag's transition toward low-emission public transport. The assessment focuses on the spatial and technical suitability of the site, the applicable grid-connection cost regime in Croatia, and an indicative financial feasibility analysis, providing a transparent basis for comparing Ungarija with the alternative candidate site.

The assessment considers why Ungarija is a relevant candidate site at the present stage, how its installable capacity and expected annual generation were estimated from the gross cadastral area, what grid-connection costs apply under the current regulatory regime, what financial performance can be expected under conservative base-case assumptions, and how the site compares with the alternative Donji Picudo candidate in terms of technical risk, land tenure and financial return.

The assessment uses the project assumptions defined for the City of Umag's electric school bus fleet. The electrification programme targets four main circular school bus routes with a combined daily travel distance of 219 kilometers, requiring an estimated daily electricity demand of approximately 570 kWh and an annual demand of around 208,050 kWh. The number of buses, their routes and daily travel distances were provided by the City of Umag, while the corresponding electricity consumption (kWh) was calculated using standard engineering practice and is described in more detail in the main project document. Because opportunity charging is impractical given intermediate bus stops of less than a minute, a centralized depot-based charging strategy is used, with prolonged idle periods between the morning and afternoon shifts (07:30–14:10) that align closely with peak solar irradiance hours on the Istrian peninsula.

2. Local context & site selection requirements

2.1. Umag context relevant to PV siting

Umag is a coastal city on the western Istrian peninsula, characterized by a Mediterranean climate with warm, dry summers and mild, wetter winters [5]. This seasonal pattern is favourable for solar generation: the summer months combine high solar irradiance with the operating period of the school transport system, while the depot-based overnight and midday charging pattern of the electric bus fleet aligns closely with daytime PV production during the 07:30–14:10 idle window.

The Istrian coastal region benefits from one of the higher solar resource levels in Croatia, and the financial assessment in this report applies a conservative, planning-stage specific yield of 1,200 kWh/kWp/year for fixed-tilt ground-mounted systems, consistent with typical performance for this region once system losses, orientation and row-spacing are accounted for [6]. A bankable estimate using the European Commission's PVGIS platform, incorporating actual orientation, tilt, row spacing and shading, is recommended at the detailed design stage to refine this assumption [6].

The City of Umag's broader decarbonization strategy couples the electrification of its school bus fleet with local renewable generation, reducing grid dependency and maximizing the environmental benefit of the transition. Because the electrified fleet's annual demand of approximately 208,050 kWh is small relative to the technical

potential of either candidate ground-mount site, site selection is driven primarily by technical execution risk, land tenure and financial performance rather than by capacity constraints.

2.2. Site-selection criteria

At feasibility level, an optimal ground-mount PV location is not necessarily the site with the largest nominal capacity. It is the site that offers the best overall balance between technical suitability, execution risk, land tenure simplicity and financial performance. The following criteria were applied when screening candidate sites for the City of Umag:

Criterion	Feasibility-level interpretation
Land tenure & acquisition	Single or clearly defined ownership; minimal risk of fragmented, multi-party land acquisition or leasing negotiations.
Terrain & site preparation	Flat or gently sloping land, low vegetation and stable subsoil, minimizing grading, foundation and geotechnical costs.
Grid connection proximity	Availability of nearby medium-voltage connection point(s); manageable cabling and trenching distance and cost.
Scale relative to fleet demand	Installable capacity sufficient to substantially exceed the approximately 208,050 kWh/year demand of the electrified school bus fleet, with headroom for growth or export.
Land-use compatibility & permitting	Absence of competing agricultural, residential or environmentally sensitive use; favourable position for streamlined permitting.
Access & construction logistics	Direct road access supporting construction traffic, cabling works and long-term operation and maintenance.
Implementation readiness	Maturity of available cadastral and technical information and expected time to project realization.

3. Identification of the candidate location

The Ungarija location consists of a single Cadastral Unit (5159/1) in the City of Umag, situated within the industrial zone and held under single private ownership [1]. Single ownership eliminates the need for land assembly and the associated acquisition or leasing risk that typically complicates sites split across several private parties.

The site was identified as a candidate location because it combines a large, contiguous, flat parcel with direct road access and multiple nearby grid connection opportunities [4] — a combination of characteristics that is relatively uncommon among available industrial-zone land near Umag. Ungarija represents one of the two most concrete, technically defined ground-mount PV opportunities identified through project preparation for the City of Umag.



Figure 1 Cadastral units for Ungarija site

4. Assesment of Ungarija site

4.1. Technical and spatial characteristics

The installable PV capacity at Ungarija was estimated from the gross cadastral area [1] using a consistent three-step methodology described in Section 5.1 [3]. The gross plot area of 68,229 m^2 yields an estimated usable area of 54,583 m^2 (80% of gross area, after deducting setbacks, access roads, fencing and equipment stations) and a panel footprint of 21,833 m^2 (40% Ground Coverage Ratio of the usable area) [3]. Applying a panel capacity density of 0.2 kWp/m^2 [3], the maximum installable capacity at Ungarija is estimated at approximately 4.37 MWp.

At an assumed specific yield of 1,200 kWh/kWp/year [6], this corresponds to an expected Year-1 generation of approximately 5,244 MWh — more than 25 times the annual electricity demand of the electrified school bus fleet (approximately 208,050 kWh/year), leaving substantial headroom for fleet growth, additional depot loads, or export of surplus electricity to the distribution grid.

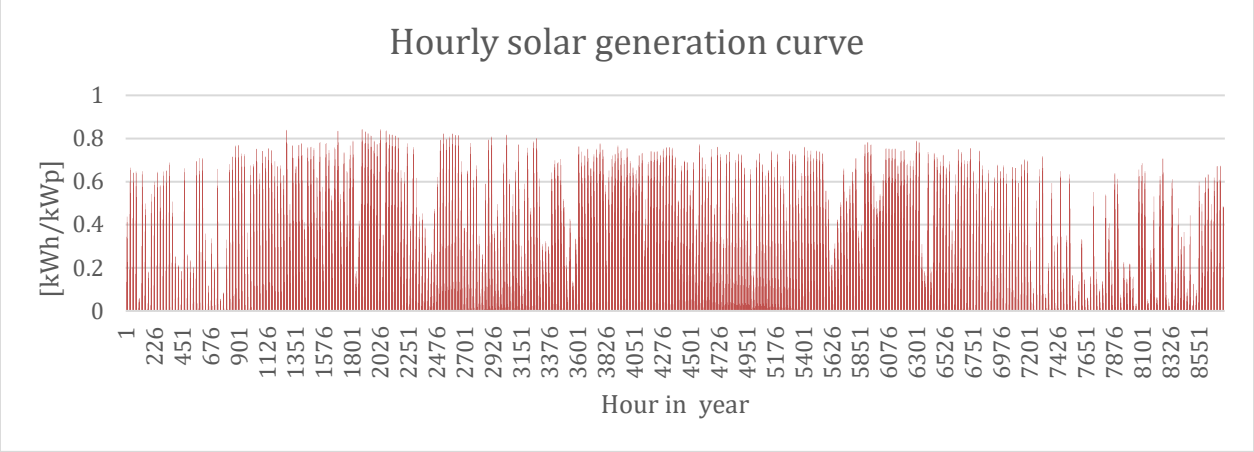


Figure 2 Hourly solar generation graph for Ungarija

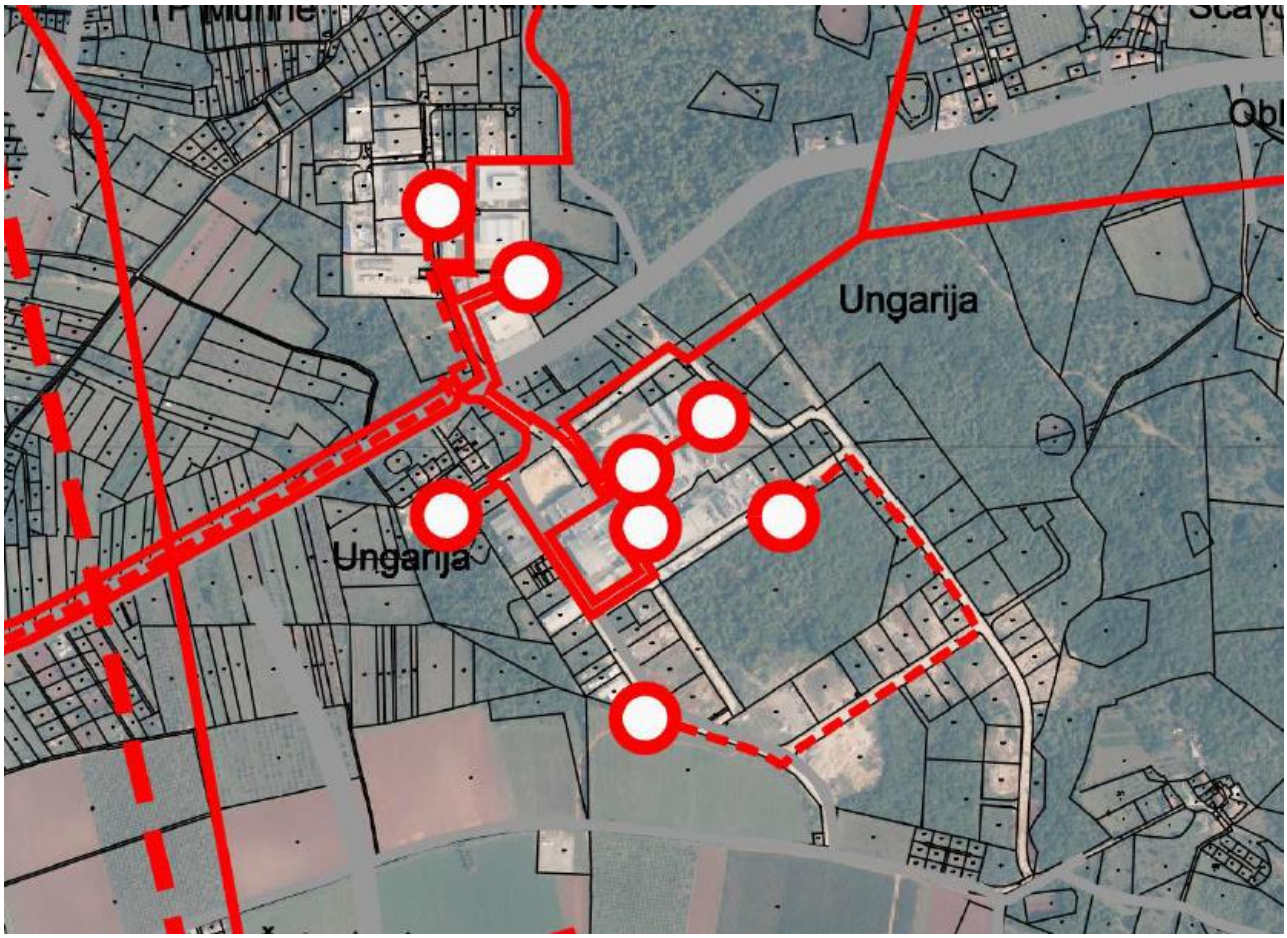


Figure 3 Locations for potential grid connection points near Ungarija

4.2. Main advantages

Set against other candidate parcels considered in the Umag area, Ungarija stands out mainly on execution risk rather than land status. The terrain is flat with low vegetation, requiring only minimal grading and no special foundation or geotechnical works, which keeps EPC costs close to standard market rates rather than the elevated CAPEX that former-landfill or uneven sites demand.

Direct road frontage further simplifies construction logistics and long-term operation and maintenance access. Single private ownership of the entire cadastral unit avoids the need for land assembly across multiple parties [1].

Most notably, the presence of five potential grid connection points in the immediate vicinity [4], rather than a single distant one, substantially de-risks interconnection, avoiding both the added cabling cost and the single-point-of-failure exposure that weigh on less-connected sites

4.3. Constraints and uncertainties

The principal uncertainties at this feasibility stage relate to the assumptions used rather than to fundamental site suitability. The financial results are based on indicative market assumptions for EPC CAPEX, OPEX, electricity yield and electricity price [7][6][8], rather than on site-specific EPC quotations or a confirmed electricity offtake agreement, and should therefore be treated as preliminary.

A formal grid connection study (Elaborat o optimalnom tehničkom rješenju priključka) is required to confirm which of the five nearby connection points [4] offers the most favourable technical and commercial terms, including available capacity, protection requirements and any need for network reinforcement. The specific PV yield used in this assessment (1,200 kWh/kWp/year) is a conservative planning-stage estimate [6]; a bankable solar resource assessment using PVGIS data or on-site irradiation measurements is recommended to refine this figure ahead of a final investment decision.

As with any greenfield industrial-zone development, standard permitting, environmental screening and construction-permit processes will apply and should be confirmed early in project preparation.

5. Methods

5.1. Capacity estimation

The installable PV capacity at the site was estimated from the gross cadastral area [1] using a consistent three-step methodology, following land-use benchmarks for utility-scale ground-mounted PV [3]. First, the usable area was calculated as 80% of the gross plot area, with the remaining 20% deducted to account for setbacks, internal access roads, fencing, inverter and transformer stations, drainage, and other non-paneled infrastructure [3]. Second, a Ground Coverage Ratio (GCR) of 40% was applied to the usable area to determine the land available for PV modules [3]. The GCR represents the proportion of available land that can be covered by PV modules while maintaining sufficient spacing between rows to minimise inter-row shading and provide access for operation and maintenance, which is a standard assumption for fixed-tilt ground-mounted PV systems [6]. Finally, the installed capacity was calculated using a panel capacity density of 0.2 kWp/m^2 [6], corresponding to a typical PV module with a nominal power rating of approximately 0.4 kWp and an area of approximately 2 m^2.

The installed capacity was therefore calculated as: Installed capacity [kWp] = Plot area [m^2] × 0.8 × 0.4 × 0.2 kWp/m^2. This corresponds to an installable capacity of approximately 0.64 MWp per hectare of gross plot area, which is consistent with typical fixed-tilt utility-scale ground-mounted PV developments in Europe [6].

For Ungarija, the gross area is 68,229 m^2 [1], the usable area is 54,583 m^2, and the available panel area is 21,833 m^2. Applying the 0.2 kWp/m^2 coefficient, the maximum installable capacity is estimated at approximately 4.37 MWp.

5.2. Grid connection costs

Since 1 May 2026, grid connection charges in Croatia are set centrally by the Croatian Energy Regulatory Agency (HERA) under its Decision on the unit fee for connection to the electricity network, applied uniformly nationwide (no more site-specific 'actual cost' billing or regional variation) [2]. The fee is calculated simply as a product of unit price (€/kW) and connection capacity (kW). Both candidate plants screened for Umag fall in the multi-MW range typical for connection at medium voltage (10/20 kV) rather than low voltage, so the €106/kW medium-voltage rate applies to both [2]. This regulated fee is modelled as an explicit CAPEX line item, in addition to a general EPC cost per MWp that excludes grid connection.

5.3. Financial assessment

The financial assessment was performed using an unlevered, pre-tax cash flow approach over a 25-year operating period [7]. NPV and IRR were calculated based on annual net cash flows, defined as the value of electricity generated and self-consumed minus operating expenses (OPEX), using a real discount rate of 7% . This discount rate is consistent with typical unlevered WACC assumptions applied for utility-scale PV projects in Central and South-East Europe [7].

The revenue assumption represents the economic value of electricity savings achieved through self-consumption, calculated using the avoided cost of electricity that would otherwise be purchased from the grid [8], as well as revenues from selling electricity in times of surplus. All financial results should be considered indicative planning-stage estimates intended for project screening and comparison purposes, and not a replacement for a bankable feasibility study or independent financial, technical or legal due diligence.

6. Financial analysis

6.1. Assumptions

The 0.5% /year panel degradation rate reflects the median value reported in the largest published field-data review of PV system performance [9], while the 2%/year escalation applied to OPEX and land-lease costs is an assumption aligned with European Central Bank's medium-term inflation stage [10].

Parameter	Value
Installed capacity	4.37 MWp
EPC CAPEX (excl. grid connection)	€650,000 / MWp
HERA medium-voltage connection fee (combined)	€106.00 / kW
Annual OPEX (O&M, insurance, admin)	€10,500 / MWp / year
Specific yield	1,200 kWh / kWp / year
Panel degradation	0.5% / year

OPEX / land-lease escalation	2.0% / year
Avoided electricity price (self-consumption savings rate)	€120 / MWh
Discount rate (real WACC)	7.0%
Project horizon	25 years

6.2. Results

Metric	**Value**
EPC CAPEX	€2,840,500
HERA MV connection fee (€106/kW)	€463,220
Total CAPEX	€3,303,720
Year-1 generation	5,244 MWh
Year-1 revenue	€629,280
NPV @ 7% (25 years)	€3,082,537
IRR	16.6%
Simple payback	~5.8 years

7. Conclusion

The Ungarija site passes the investment threshold used in this analysis: the IRR of 16.6% is above the 7% discount rate applied [7], and the project shows a positive NPV of approximately €3.08 million over a 25-year horizon. It represents a strong near-term investment opportunity, combining good technical scale, low interconnection risk, single private ownership and a healthy IRR with a relatively short payback of approximately 5.8 years.

The financial performance of the project is primarily sensitive to the assumed value of electricity savings, represented by the avoided electricity purchase price under the self-consumption model [8]. A ±10% change in the assumed electricity price results in an estimated change in IRR of approximately ±2 percentage points, based on sensitivity analysis performed by the project team, making this the most influential variable in the financial assessment.

CAPEX represents another important sensitivity, particularly in relation to site-specific requirements such as which of the five candidate grid connection points is ultimately selected, as cable routing, trenching and any network reinforcement requirements will vary between them [4].

The analysis is based on indicative market assumptions for EPC CAPEX, OPEX, electricity yield, and electricity price, rather than on site-specific EPC quotations or a confirmed electricity offtake agreement. Therefore, the financial results should be considered preliminary and should be further refined through updated EPC offers, a formal grid connection study (Elaborat o optimalnom tehničkom rješenju priključka), and a bankable solar resource assessment based on PVGIS data [6] and/or on-site irradiation measurements before making a final investment decision.

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