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Ground-mounted PV analysis-Donji Picudo 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 "Donji Picudo", a former landfill site comprising 17 cadastral units owned by the Republic of Croatia. 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.

Donji Picudo is one of two ground-mount PV candidates screened for the City of Umag, the other being the "Ungarija" industrial-zone parcel, 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.

Donji Picudo has an estimated installable capacity of approximately 2.72 MWp on a combined gross area of 42,544 m^2 across 17 cadastral units, all owned by the Republic of Croatia [1]. As a former landfill, the site has no competing agricultural, forestry or residential use, which is typically viewed favourably in permitting and can qualify for streamlined siting given its brownfield status. Its main technical drawback is a single, more distant grid connection point located approximately 300 m from the cadastral boundary, which raises interconnection cost and concentrates connection risk.

Under the base-case assumptions used, including the regulated HERA medium-voltage grid connection fee introduced in Croatia from 1 May 2026 [2] and a site-specific cabling adder for the remote connection, the site shows a positive risk-return profile: Total CAPEX of approximately €2.15 million, a Year-1 generation of approximately 2,400 MWh, an NPV at a 7% real discount rate of approximately €1.77 million over a 25-year horizon, an IRR of 15.6%, and a simple payback of approximately 6.1 years.

Feasibility recommendation

Donji Picudo is recommended as a financially viable candidate for utility-scale ground-mounted PV development supporting the electrification of Umag's school bus fleet, with the added strategic advantage of repurposing a former landfill site with no competing productive use. Under the base-case assumptions used, including the regulated HERA grid connection fee [2], the site delivers a positive NPV of approximately €1.77 million and an IRR of 15.6% over a 25-year horizon, supported by a technical capacity of 2.72 MWp and single public ownership under the Republic of Croatia across all 17 constituent cadastral parcels [1]. Its principal disadvantage relative to the alternative Ungarija candidate is a more distant and singular grid connection point, which raises interconnection cost and risk. 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 Donji Picudo 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 former landfill site, the applicable grid-connection cost regime in Croatia, and an indicative financial feasibility analysis, providing a transparent basis for comparing Donji Picudo with the alternative candidate site.

The assessment considers why Donji Picudo 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 including the site-specific remote-connection adder, what financial performance can be expected under conservative base-case assumptions, and how the site compares with the alternative Ungarija 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 [3]. 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 [4]. 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 [4].

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. Donji Picudo's brownfield status also gives it a distinct role in this strategy: repurposing degraded land avoids the land-use conflicts that can affect greenfield sites elsewhere in the Umag area.

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 Donji Picudo location comprises a group of 17 cadastral units (including 69/1–70/1 and related parcels), all owned by the Republic of Croatia [1]. Single public ownership across all parcels avoids the fragmented, multi-party land acquisition or leasing negotiations that typically complicate sites split across several private owners, simplifying contracting and reducing development risk and timeline despite the larger number of individual cadastral unit.

The site was identified as a candidate location because it repurposes a former landfill, which is land with limited alternative economic use, for productive renewable generation, a use that is typically viewed favourably in permitting and can qualify for streamlined siting given its brownfield status. Together with the alternative Ungarija site, an industrial-zone parcel under private ownership, Donji Picudo 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 Donji Picudo site

4. Assesment of Donji Picudo site

4.1. Technical and spatial characteristics

The installable PV capacity at Donji Picudo was estimated from the combined gross cadastral area [1] using a consistent three-step methodology described in Section 5.1.[6] The combined gross area of the 17 parcels, 42,544 m^2, yields an estimated usable area of 34,035 m^2 (80% of gross area, after deducting setbacks, access roads, fencing and equipment stations) and a panel footprint of 13,614 m^2 (40% Ground Coverage Ratio of the usable

area). Applying a panel capacity density of 0.2 kWp/m^2 [6], the maximum installable capacity at Donji Picudo is estimated at approximately 2.72 MWp.

At an assumed specific yield of 1,200 kWh/kWp/year [4], this corresponds to an expected Year-1 generation of approximately 2,400 MWh — roughly an order of magnitude more than the annual electricity demand of the electrified school bus fleet (approximately 208,050 kWh/year), leaving ample headroom for fleet growth, additional depot loads, or export of surplus electricity to the distribution grid.

In terms of grid access, the site has one potential connection point located approximately 300 m from the cadastral boundary [7]. This implies additional costs for cabling and trenching, as well as a greater dependence on a single interconnection point than at the alternative Ungarija site.

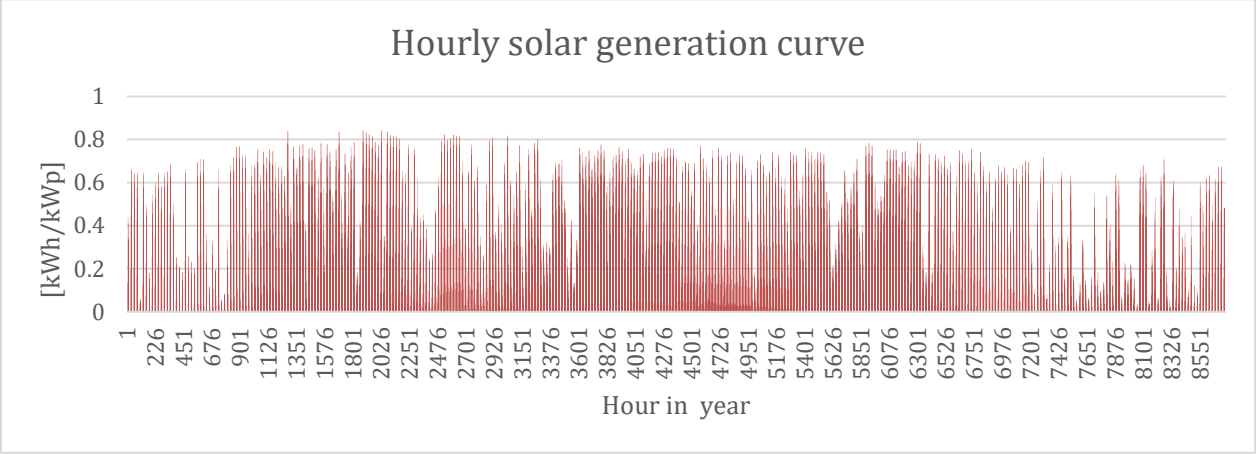


Figure 2 Hourly solar generation graph for Donji Picudo

4.2. Main advantages

Relative to alternative parcels considered for ground-mounted PV in the Umag area, Donji Picudo offers several structural advantages that make it a strong candidate site. As a former landfill, the site has no competing agricultural, forestry or residential use, so the project avoids the land-use conflicts and environmental-impact scrutiny that often slow down greenfield PV developments.

Repurposing degraded land for renewable generation is generally viewed favourably by permitting authorities and can qualify for faster siting procedures. All 17 cadastral units are owned by the Republic of Croatia [1], avoiding the fragmented, multi-party land acquisition or leasing negotiations that typically complicate sites split across several private owners; this simplifies contracting and reduces development risk and timeline.

At an estimated 2.72 MWp, the site can generate roughly an order of magnitude more energy than the school bus fleet's annual demand of around 208,050 kWh, leaving ample headroom for fleet growth, additional depot loads, or surplus export, which many smaller or more constrained sites cannot offer.

4.3. Constraints and uncertainties

The principal trade-off against these advantages is grid connection: the single point of interconnection lies approximately 300 m from the cadastral boundary, adding cabling and trenching costs and concentrating interconnection risk in one point of failure. Even after pricing in this remote-connection adder, however, the site's financial results remain positive, indicating that its siting advantages outweigh the added connection cost.

The former-landfill status of the site also implies additional foundation and geotechnical requirements relative to a standard greenfield parcel; the EPC CAPEX assumption used in this assessment (€670,000/MWp) is set higher than the general utility-scale PV cost benchmark [5], based on a project-team engineering allowance for brownfield conditions. These requirements should be confirmed through a site-specific geotechnical investigation before a final investment decision.

As with any brownfield redevelopment, environmental screening specific to the former landfill use — including any residual site-management or capping requirements — should be confirmed early in project preparation, alongside standard permitting and construction-permit processes.

5. Methods

5.1. Capacity estimation

The installable PV capacity at the site was estimated from the gross cadastral area using a consistent three-step methodology. 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 [6]. Second, a Ground Coverage Ratio (GCR) of 40% was applied to the usable area to determine the land available for PV modules. 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. 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.

For Donji Picudo, the gross area is 42,544 m^2 [1], the usable area is 34,035 m^2, and the available panel area is 13,614 m^2. Applying the 0.2 kWp/m^2 coefficient, the maximum installable capacity is estimated at approximately 2.72 MWp. [6]

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: unit price (€/kW) × 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. For Donji Picudo, a further site-specific fixed cost of €40,000 is included within the connection-fee line to cover the additional trenching required for the approximately 300 m cable route to the nearest grid connection point.[7]

5.3. Financial assessment

The financial assessment was performed using an unlevered, pre-tax cash flow approach over a 25-year operating period [5]. 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 [5].

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 EPC CAPEX per MWp is assumed to be higher to account for additional foundation and geotechnical requirements associated with the former landfill site [5]. A fixed site-specific cost of €40,000 is included to cover the additional trenching required for the approximately 300 m cable route to the nearest grid connection point [7], excluding the regulated HERA connection fee [2].

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	2.72 MWp
EPC CAPEX (excl. grid connection)	€670,000 / MWp
HERA medium-voltage connection fee (combined)	€106.00 / kW
Site-specific remote-connection cabling adder	€40,000 (fixed, one-off)
Annual OPEX (O&M, insurance, admin)	€12,000 / 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	€1,822,400
HERA MV connection fee (€106/kW)	€328,320
Total CAPEX	€2,150,720
Year-1 generation	2,400 MWh
Year-1 revenue	€288,000
NPV @ 7% (25 years)	€1,767,316
IRR	15.6%
Simple payback	~6.1 years

7. Conclusion

The Donji Picudo site passes the investment threshold used in this analysis, IRR is 15.6% which is above the 7% discount rate, and it has a positive NPV. It is a sound investment, especially attractive as a brownfield/former-landfill redevelopment.

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, making this the most influential variable in the financial assessment.

CAPEX represents another important sensitivity, particularly in relation to site-specific requirements such as grid connection distance, cable routing, trenching, and civil works [7]. These factors are expected to have a big impact due to the longer connection route and additional site preparation requirements.

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 [4] and/or on-site irradiation measurements before making a final investment decision.

Literature

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