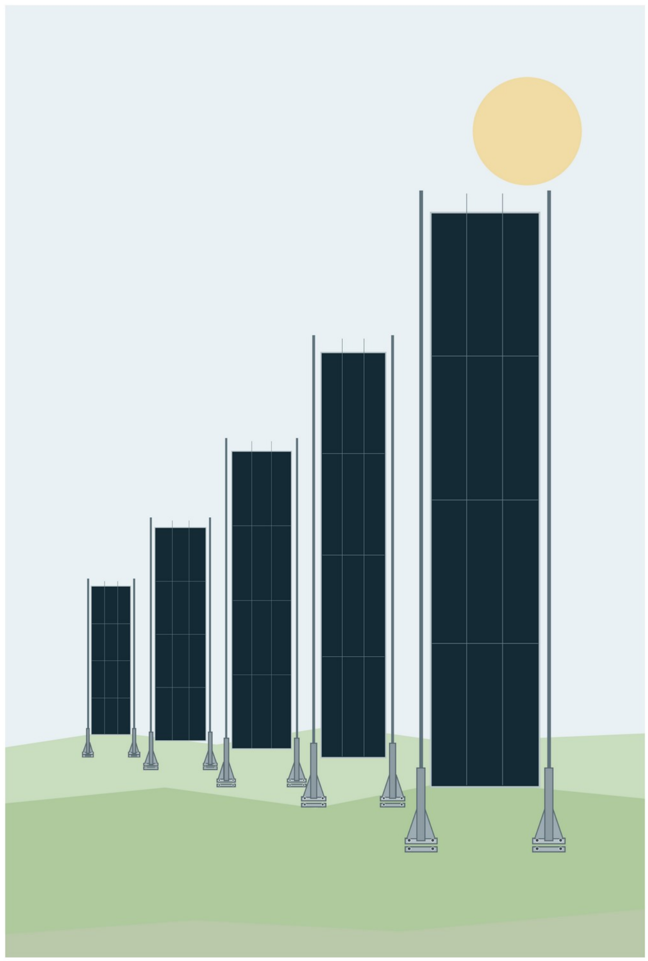
TECHNICAL AND ANALYTICAL STUDY / 1.1

Vertical bifacial PV systems
as relocatable climate–energy
infrastructure

A simulation-based comparative study of EasyVerticalPV® and a conventional photovoltaic installation



EasyClimate Spine® · EasyFootings® · ARW+ Relation Passport

Creator and author: Henryk Zawiślak | EasyFootings® | 2026

Data status: scenario model; results are not measurements from an installation and do not constitute an execution design.

Publication card

Field	Content
Title	Vertical bifacial PV systems as relocatable climate–energy infrastructure
Subtitle	Simulation-based comparative study of EasyVerticalPV® and a conventional photovoltaic installation
Creator / author / entity	Henryk Zawiślak — inventor and creator of the EasyFootings® system and the EasyVerticalPV® and EasyClimate Spine® concepts / EasyFootings®
System concept	EasyClimate Spine® — modular climate–energy corridor
Version	1.1 · authorial edition · 27 July 2026
Classification	Conceptual and analytical study; synthetic data and transparent assumptions
Scope	Energy, self-consumption, microclimate, relocatability, material circularity, data

Table 1. Document metadata and evidentiary status.

About the creator and author

Henryk Zawiślak is the inventor and creator of the EasyFootings® system and the author of the EasyVerticalPV® and EasyClimate Spine® concepts. He develops solutions that combine relocatable foundations, lightweight structures, vertical bifacial photovoltaics and environmental functions within one design system.

In this publication, he is responsible for the concept, system architecture, formulation of the research problem, comparative model, proposal for the ARW+ Relation Passport, and the project's development and validation direction. The text is an authored conceptual and analytical study; it is not a translation or compilation of another author's publication.

Statement on authorship

This text is an original synthesis of the problem, comparative model and validation proposal. It is not a translation or compilation of another author's publication. The sources used are listed in the bibliography and provide the current state-of-knowledge context for the argument. The original element of this work is the combination of vertical bifacial photovoltaics, EasyFootings® relocatable infrastructure and an evidentiary layer called the ARW+ Relation Passport. This work is not a patent opinion or a legal assessment of patentability.

How to read the results

- The numerical values in Chapters 6–11 are scenario-model results for the same 10 kWp capacity and the same demand profile.

- The model illustrates a mechanism and sensitivity range; it does not guarantee yield at every location.
- Each claim that requires measurement is marked as a pilot hypothesis or validation recommendation.
- The EasyVerticalPV® variant requires local calculations accounting for albedo, shading, height, spacing and module bifaciality.

Publication map

1. Publication problem and proposition
2. EasyClimate Spine® concept and system architecture
3. State of knowledge: vertical bifacial PV and design for disassembly
4. Research questions, hypotheses and methodology
5. Input data and comparative results
6. Self-consumption, microclimate, space and circularity
7. Uncertainty, risk and pilot protocol
8. ARW+ Relation Passport, implementation and conclusions

Abstract

This publication presents an original concept of treating photovoltaics not only as a source of kilowatt-hours, but also as relocatable climate–energy infrastructure. The reference comparison covers two systems with the same 10 kWp capacity at the same model location: a conventional installation facing south at a 35° tilt, and a vertical bifacial EasyVerticalPV® configuration oriented east–west. In the base model, the conventional variant produces 10,090 kWh/year and the vertical variant 10,300 kWh/year. The annual production difference is therefore small (+2.1%), while the clearer effect concerns timing: self-consumption increases from 5,466.9 to 6,773.5 kWh/year, and the self-consumption ratio rises from 54.18% to 65.76%.

The central proposition is that, in urban systems, the advantage of vertical PV may lie primarily in better alignment between the generation profile and the use profile, reduced conflict with the function of the site, and the ability to relocate the installation—not in a universally higher annual yield. The publication also proposes a data layer—the ARW+ Relation Passport—that connects physical parameters, energy, microclimate, water, biodiversity and disassembly measurements with operational decisions. The conclusions are formulated as hypotheses for validation because measurements from a selected pilot are not yet available.

Keywords

bifacial photovoltaics; vertical modules; E–W; self-consumption; relocatable infrastructure; EasyFootings®; EasyClimate Spine®; circularity; microclimate; digital passport; ARW+; pilot validation

Abstract

This authored study proposes a shift from treating photovoltaics as a standalone energy generator to treating them as relocatable climate–energy infrastructure. It compares two equal-power 10 kWp systems at the same model location: a conventional fixed south-facing array tilted at 35°, and an east–west vertical bifacial EasyVerticalPV® configuration. In the base scenario, the conventional system produces 10,090 kWh/year while the vertical configuration produces 10,300 kWh/year. The annual yield difference is therefore modest (+2.1%), while the time profile is more consequential: annual self-consumption increases from 5,466.9 to 6,773.5 kWh, and the self-consumption ratio rises from 54.18% to 65.76%.

The central proposition is that, in urban systems, the value of vertical bifacial PV may arise primarily from improved alignment between generation and demand, reduced land-use conflict and the ability to relocate the installation, rather than from a universally higher annual yield. The study also introduces the ARW+ Relation Passport as a data layer connecting physical parameters, energy, microclimate,

water, biodiversity and disassembly measurements with operational decisions. The results are explicitly presented as hypotheses for pilot validation because no field pilot has yet been selected or measured.

1. Publication problem and proposition

Photovoltaics has entered a stage in which the question "how much energy will the installation produce?" is no longer sufficient. In cities, it is equally important to ask when energy is produced, whether it can be consumed locally, how much land is occupied, whether the structure can be moved, how it affects temperature and water retention, and whether material value can be recovered at the end of use. This shift in perspective can be described as a move from an energy asset to relational infrastructure.

This study uses as its comparison point a conventional fixed south-facing PV layout and a vertical E–W variant using bifacial modules. Both variants have the same rated capacity, use the same load profile and are analyzed at the same model location. The difference is therefore not attributed to greater capacity, but to geometry, the daily profile and spatial assumptions.

The publication's proposition is cautious but practical: the value of a vertical bifacial layout should be assessed using multiple criteria. In the base model, the most promising advantage is not absolute annual yield, but a change in the distribution of production during the day that may increase self-consumption at nodes with morning and afternoon use profiles.

1.1. Scope and boundaries

- Technical scope: vertical bifacial PV, conventional layout, demand profile, self-consumption and grid export.
- Spatial scope: a relocatable EasyClimate Spine® module with an EasyFootings® element and a climate-corridor function.
- Evidentiary scope: transparent data model, explicit hypotheses, recommended measurement protocol and uncertainty register.
- Out of scope: execution design, structural calculations for a specific soil, grid-connection arrangements, certification and financial guarantee.

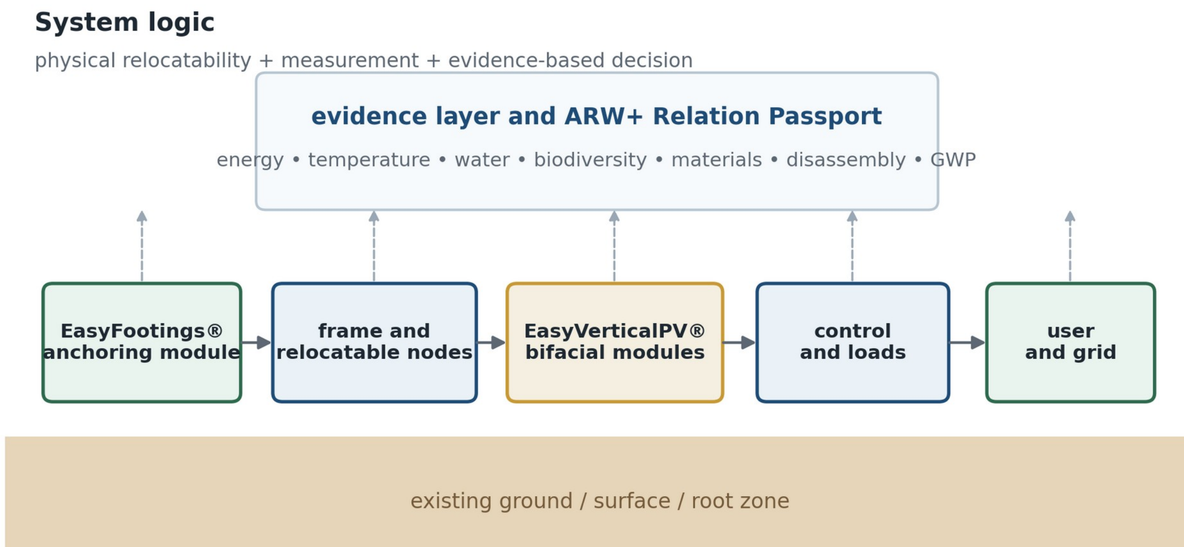


Figure 1. System architecture: from relocatable foundation and PV modules to measurement and operational decision-making.

2. EasyClimate Spine® as an infrastructure system

EasyClimate Spine® is understood here as a modular urban corridor in which the energy function is combined with shade, vegetation, water retention, lighting, sensors and a user function. It is not one product with a fixed configuration, but a family of spatial scenarios. The unit of analysis is not a single panel, but the relationship between module, place, user and environment.

This definition changes the design sequence. First, the site problem should be described—overheating, lack of shade, energy load, retention deficit or conflict between land functions—and only then should the PV geometry and foundation method be selected. The value of the solution is the sum of several streams, but they should not be added without controlling for double counting.

2.1. Four value layers

Layer	What it measures	Example metrics
Energy	production, self-consumption, reduced export, hourly profile	kWh, % of demand, kW/kWp
Climate	shade, surface temperature, user comfort, humidity	m² of shade, °C, comfort index
Spatial	land occupation, path continuity, relocation, public functions	m², relocation time, accessibility
Circularity and data	disassembly, reuse, GWP footprint, component passport	kg CO_2e, %, auditable records

Table 2. EasyClimate Spine® value layers; metrics require a defined pilot objective.

2.2. Role of EasyFootings®

In the concept, EasyFootings® functions as a relocatable interface between the structure and the site. The design assumption is to limit ground intervention and enable disassembly without treating the site as a one-time construction area. This does not automatically mean that no earthworks are required, nor that the system is universally suitable for every soil. Each variant requires geotechnical and structural verification, wind-resistance assessment and compliance with local formal requirements.

Innovation should not be claimed merely because an anchor or demountable foundation exists. Such solutions have prior art. The originality of this publication lies in the integration: foundation + vertical bifacial PV + climate function + measurement + a register of relations and decisions.

EasyFootings® illustrations should be read in accordance with the actual construction reference: as a compact steel head composed of two closely spaced plates, corner bolts, bolts joining the layers and stiffening ribs, with a square profile emerging centrally from the head. In a finished installation, the ground conceals the anchoring elements below the head; it must not be replaced by a concrete footing, a broad plate or an ordinary mounting shoe.

Figure 2a. Actual reference photograph of the EasyFootings® head—the reference geometry for the two plates, ribs, bolts and diagonal anchoring elements.

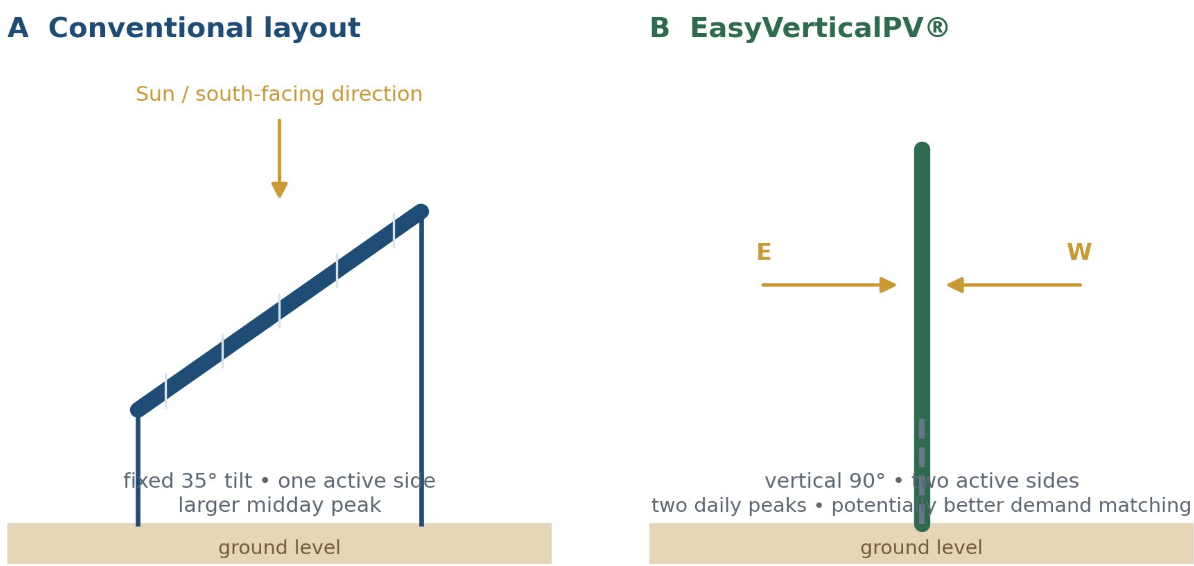


Figure 2. Comparison geometry: a conventional fixed south-facing layout and vertical E–W orientation with two active sides.

3. State of knowledge and relevance of the problem

The European Commission's PVGIS tool provides solar-radiation data and PV-performance estimates for any location in Europe and many regions worldwide. Its interface and API can calculate, among other things, fixed variants with a specified tilt and azimuth, as well as monthly and annual results [1–2]. It is a useful starting point for comparing locations, but it does not replace an engineering model for unusual geometries.

A limitation relevant to this publication is explicitly described in the PVGIS documentation: the tool currently does not perform dedicated bifacial calculations. For E–W layouts, an approximate approach is recommended, analyzing the east and west sides separately and then accounting for the rear-side contribution. The vertical variant in this publication is therefore not presented as a direct PVGIS result, but as a transparent scenario requiring later calibration with a bifacial tool or measurement [3].

Simulation studies of vertical bifacial systems show that E–W orientation can create two production peaks during the day, but the result depends on albedo, spacing, height, shading and the load profile. Some studies indicate an advantage for a conventional south-facing layout under an unobstructed horizon, and for a vertical E–W layout where time distribution matters or spatial constraints exist. The conclusion is not universal; it is conditional and local [8–11].

3.1. Regulatory and design context

European zero-emission-building policy shifts attention from device efficiency alone toward a combination of high efficiency, clean energy, flexibility, storage and demand response [4]. At the same time, the importance of the building's full life-cycle footprint is increasing: production, transport, construction, operation, replacement, demolition and reuse [5]. For modular urban infrastructure, this means documenting not only yield, but also installation, relocation and end-of-life pathways.

ISO 20887 organizes principles for design for disassembly and adaptability, while IEC TS 60904-1-2:2024 provides an important reference for measuring I–V characteristics of bifacial PV devices [6–7]. In the data domain, the European Commission is developing the Digital Product Passport; the DPP registry is live from July 2026, and the Construction Products Regulation emphasizes interoperability with BIM, open standards and machine-readable data [12–13].

These directions reveal a practical gap: there is no simple way to make an infrastructure-relocation decision depend on a shared package of energy, climate, material and spatial data. The ARW+ Relation Passport is a proposal for such a layer—not a replacement for a standard or regulatory system.

4. Research questions and hypotheses

The publication does not pretend to be an experiment that has not yet been conducted. Instead, it formulates questions that can be resolved in a controlled pilot. This structure separates an innovative idea from a result that still requires evidence.

Code	Question	Model hypothesis	Evidence
P1	Does a vertical bifacial E–W layout change the production distribution enough to increase self-consumption at the same demand?	H1: yes; base effect +11.58 percentage points in the self-consumption ratio.	15-minute PV and load measurements.
P2	At comparable capacity and conditions, does the vertical layout achieve annual yield close to the conventional layout?	H2: yes in the base model; +2.1%, but with wide uncertainty.	One year of data; common condition adjustment.
P3	Does relocatability reduce the conflict between energy generation and site function?	H3: possibly; -5% planning area is a hypothesis, not a measurement.	GIS inventory and disassembly protocol.
P4	Does ARW+ improve the quality of decisions to maintain or relocate a module?	H4: yes, if the data share an identifier, time reference and quality level.	Completeness and decision audit.

Table 3. Research questions, hypotheses and conditions for resolution.

4.1. Definition of the original contribution

The contribution of the publication consists of four elements: (1) shifting the optimization objective from yield alone to the time value of energy, (2) treating relocatable foundations as an element of spatial resilience, (3) expressing climate functions as measurable streams, and (4) designing a lightweight ARW+ data layer that connects the result to the site, component version and decision. This is an original design-and-research framework; it is not a claim that every component is new in the patent sense.

5. Comparative methodology

The comparison is designed as a model experiment controlling four variables: rated capacity, reference location, load profile and the absence of storage in both variants. The explanatory variables are geometry, bifaciality and the resulting time profile. The location is described as a proxy for Poznań, Poland; coordinates and weather data should be specified only for a particular site.

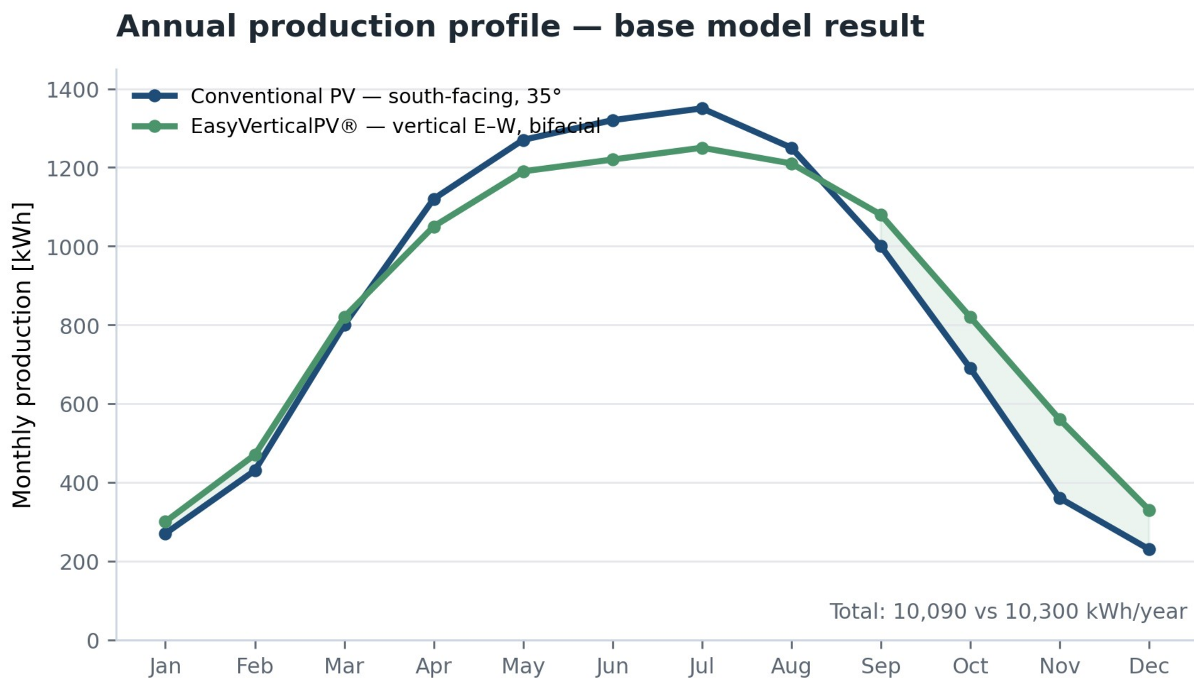


Figure 3. Monthly production distribution in the base scenario; the chart presents synthetic data described in Table 6.

5.1. Comparison conditions

Variable	Base assumption	Status / comment
Location	Poznań, Poland — model proxy	to be replaced with site coordinates
DC capacity	10 kWp in both variants	control condition
Conventional layout	south-facing, 35° tilt, fixed, monofacial	reference variant
EasyVerticalPV®	vertical E–W, bifacial module	study variant; requires a bifacial tool
Annual demand	11,650 kWh/year	synthetic public-node profile
Storage	none in either variant	isolates the effect of geometry and profile
Albedo	0.30 in the base scenario	value to be measured; scenarios 0.20–0.45
System losses	common model assumption	requires component specification

Table 4. Control conditions of the comparative model.

5.2. Equations and indicators

For each month m, annual production was calculated as: $E_\gamma = \Sigma_m E_m$. Monthly self-consumption is described by E_sc,m = E_PV,m × r_sc,m, where r_sc,m is the share of PV energy consumed locally according to the synthetic demand profile. Grid export: E_exp,m = E_PV,m − E_sc,m. Self-consumption ratio: C = E_sc / E_PV. Load coverage: K = E_sc / E_load. The indicators do not account for tariffs, energy prices, module degradation, grid-connection constraints or investment costs.

The spatial comparison uses two separate concepts: the geometric area occupied by the equipment and the functional area left available in the site plan. The −5% value is a design hypothesis resulting from the possibility of maintaining a continuous corridor and reducing layout width; it is not a result of geodetic measurement.

6. Dataset and scenarios

The dataset was designed to be reproducible in a spreadsheet. Each month has separate production, demand, self-consumption and export values for both variants. The daily profile is normalized to 100% of production, allowing the effect of geometry on temporal demand matching to be tested independently of the installation’s absolute scale.

Code	Significance	Use
S	simulated	calculated result based on transparent assumptions
A	assumed	parameter adopted for comparison, e.g. albedo 0.30
P	design-based	hypothesis concerning the layout or site function
M	to be measured	parameter that must be collected in the pilot
W	verified	result after quality control and data audit

Table 5. Evidentiary-status dictionary for the data.

6.1. Annual results of the base model

Indicator	Conventional PV	EasyVerticalPV®	Difference
PV production	10,090	10,300	+2.1%
Self-consumption	5,466.9	6,773.5	+1306.6 kWh
Grid export	4,623.1	3,526.5	-1096.6 kWh
Self-consumption ratio	54.18%	65.76%	+11.58 pp
Load coverage	46.93%	58.14%	+11.22 pp

Indicator	Conventional PV	EasyVerticalPV®	Difference
Planning area	150 m²	142.5 m²	-5.0% P

Table 6. Annual KPIs for the base model; P = design hypothesis.

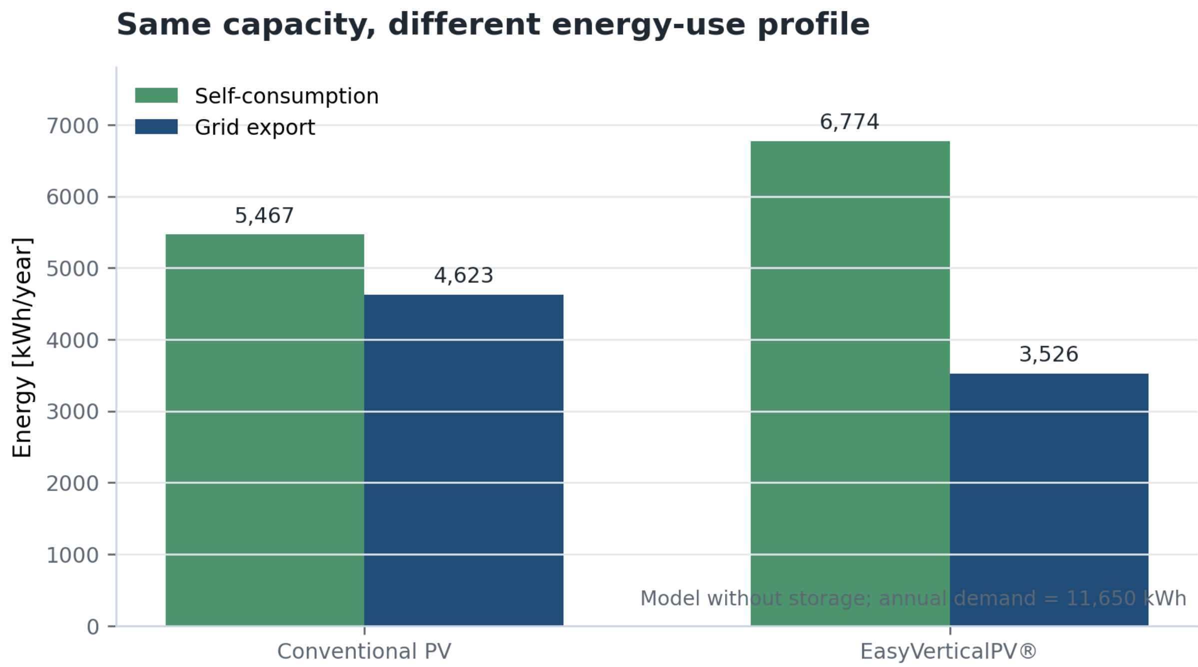


Figure 4. Self-consumption and grid-export energy in the base model.

6.2. Reading the model

The annual result does not support the claim that “vertical PV always produces more”. In the model, the difference is approximately 210 kWh/year, or 2.1%. This reflects comparable capacity and the selected parameters, not a guarantee for another location. The clearer change concerns self-consumption: an additional 1,306.6 kWh/year is used locally, while grid export falls by 1,096.6 kWh/year.

In practice, the economic meaning of this difference depends on the tariff, user profile, load-control options and grid-connection constraints. A pilot should therefore report production, demand, self-consumption, export and instantaneous power together—not only kWh/year.

7. Time profile and energy usefulness

A vertical E–W layout can distribute production across two peaks—morning and afternoon—instead of concentrating it in a narrower midday window. In the synthetic model, the combined share of production from 07:00–11:00 and 15:00–19:00 is 61% for EasyVerticalPV® and 31% for the conventional variant. The 30-percentage-point difference is a hypothesis to be tested at a real site, but it clearly illustrates the mechanism behind higher self-consumption.

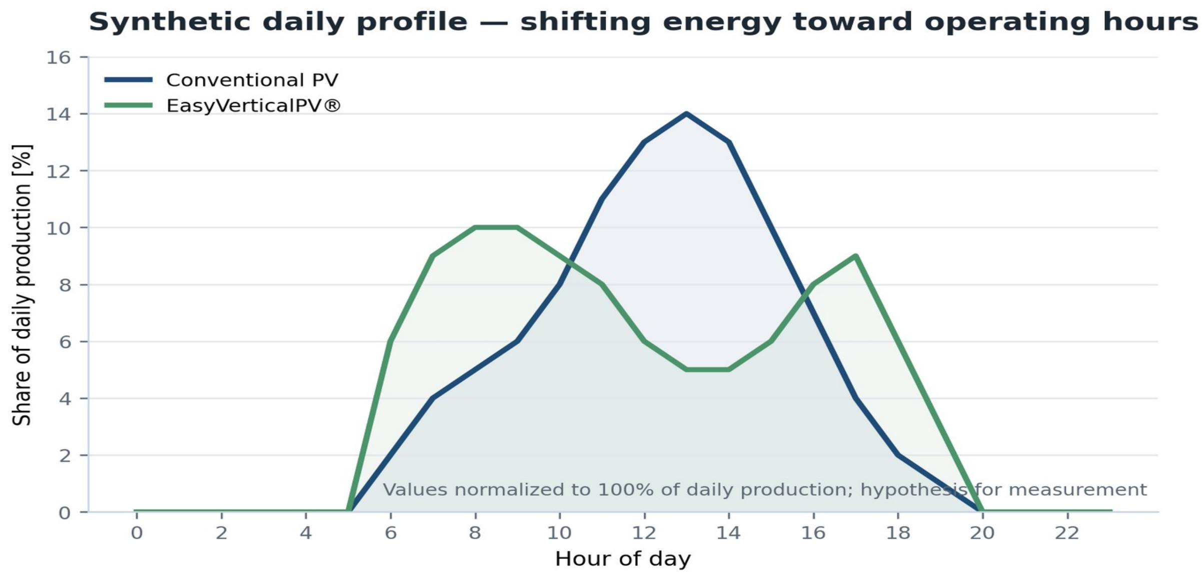


Figure 5. Normalized daily production profile; synthetic data illustrate a mechanism, not a particular weather day.

7.1. Why timing may matter more than the total

If the user load operates in the morning and afternoon—for example lighting, charging, pumps, ventilation or service equipment—the E–W profile increases the probability of generation and demand occurring simultaneously. This does not mean full energy self-sufficiency. Night-time demand still requires the grid or storage, and transient cloud cover can change the profile.

Temporal value can be measured in three ways: the share of energy consumed locally, reduced export during surplus hours, and the correlation between PV power and load. A 15-minute interval is recommended for a public pilot because hourly aggregation can hide instantaneous overloads and differences in simultaneity.

8. Sensitivity, uncertainty and risk

The base variant should not be read as a single forecast. Vertical bifacial PV output depends, among other things, on albedo, module height, clearance, spacing, shading from vegetation and adjacent elements, bifaciality, soiling and the method used to curtail power. Three planning scenarios were therefore introduced.

Scenario	Albedo	Production vs conventional	PV/year [kWh]	Self-consumption	Significance
Conservative	0.20	91% of conventional	9,182	60%	sensitivity test for low yield and

Scenario	Albedo	Production vs conventional	PV/year [kWh]	Self-consumption	Significance
					weaker simultaneity
Base	0.30	102.1% of conventional	10,300	66%	central scenario for communicating the model
Favorable	0.45	112% of conventional	11,301	72%	upper hypothesis range; not a guaranteed forecast

Table 8. Sensitivity scenarios for the vertical variant.

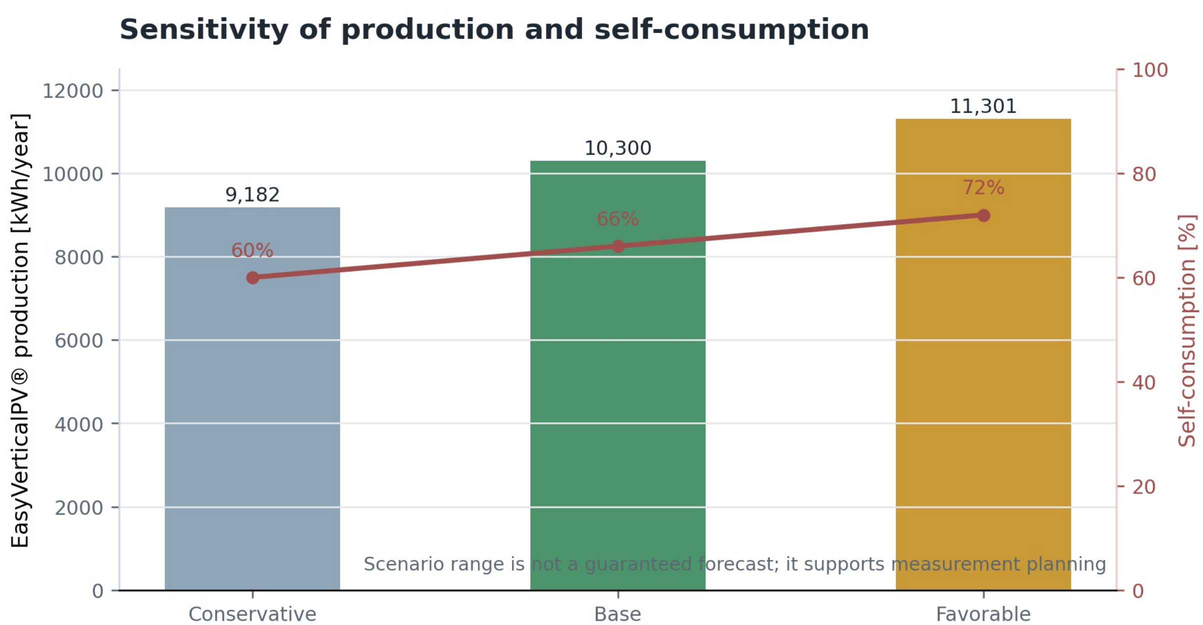


Figure 6. Sensitivity scenarios: annual production and self-consumption ratio.

8.1. Uncertainty register

Area	Uncertainty	Source	Reduction method
Geometry and shading	high	3D site data; spacing; horizon	local bifacial model + measurement
Albedo / rear-side reflection	high	surface changes seasonally	surface measurements and scenarios
Demand profile	high	synthetic load	15-minute meter
Structural loads	high	no site data	structural design and tests
Microclimate	medium	effect dependent on shade and vegetation	sensors + control zone
Relocation	medium	time and cost not measured	disassembly and reassembly protocol
Economics	high	variable tariffs and CAPEX	cost analysis after site selection

Area	Uncertainty	Source	Reduction method

Table 9. Uncertainty register; the assessment is intended to guide measurement, not replace it.

9. Environment, space and circularity

The environmental value of a system cannot be inferred solely from the fact that a module generates renewable energy. A full life-cycle balance should include transport, steel, modules, electronics, installation work, replacements and the end-of-life scenario. The Energy Performance of Buildings Directive directs attention to life-cycle global-warming potential, while ISO 20887 helps organize design for disassembly [5–6].

In the EasyClimate Spine® concept, the PV layout may work together with shade, vegetation and retention. These benefits are conditional: shade must be measured at defined hours and times of year; effects on surface temperature require sensors and a control zone; retention requires a balance of precipitation, runoff and use; biodiversity requires repeated observation, not a single photograph.

9.1. Relocation as a technical parameter

Relocatability should be described as a procedure, not an adjective. This study proposes measuring disassembly time, number of operations, mass of recovered elements, the share of elements suitable for reuse, damage after disassembly and site condition after restoration. Every trial should have a safety record and acceptance by an authorized person.

Dimension	What to document	Metric
Time	installation / disassembly / reassembly	minutes per module or node
Material	component mass and identifier	kg, batch number, source
Recovery	undamaged elements	% of mass and number of items
Site	surface and vegetation condition	checklist + geotagged photographs
Safety	deviations, damage, incidents	acceptance record

Table 10. Minimum evidence package for relocatability.

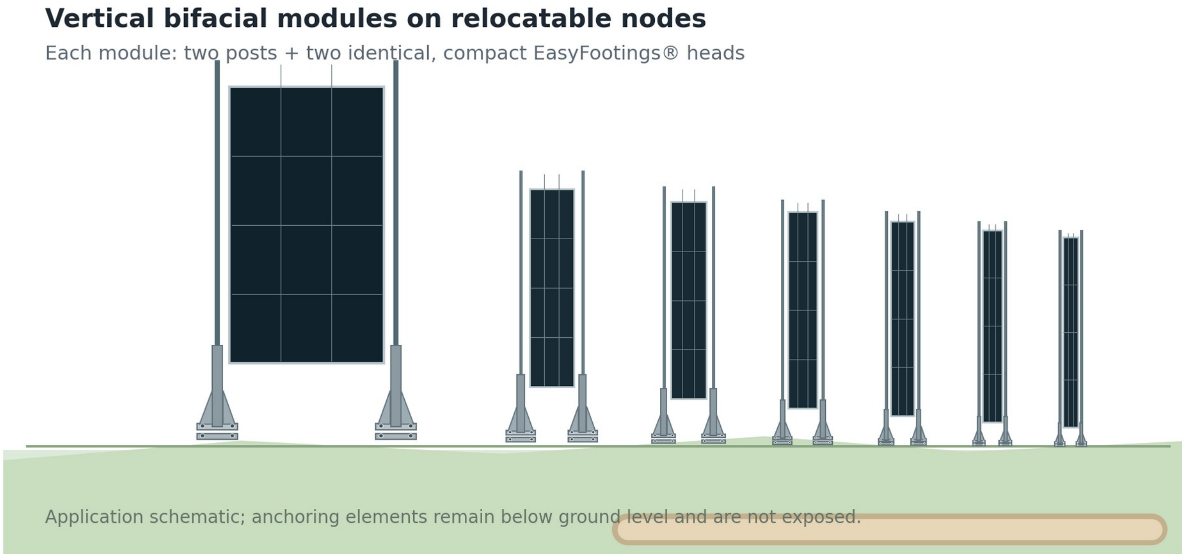


Figure 7. Application schematic: vertical bifacial modules on two posts and two identical, proportional EasyFootings® heads in a green corridor.

Figure 7a. Photorealistic conceptual visualization of an EasyClimate Spine® application with vertical bifacial PV modules in public space.

10. Pilot protocol and validation

The most credible next step is a comparative pilot at one site, with boundary conditions controlled. If two layouts cannot be installed side by side, a reference model should be built for the same meteorological period and calibrated against measurements.

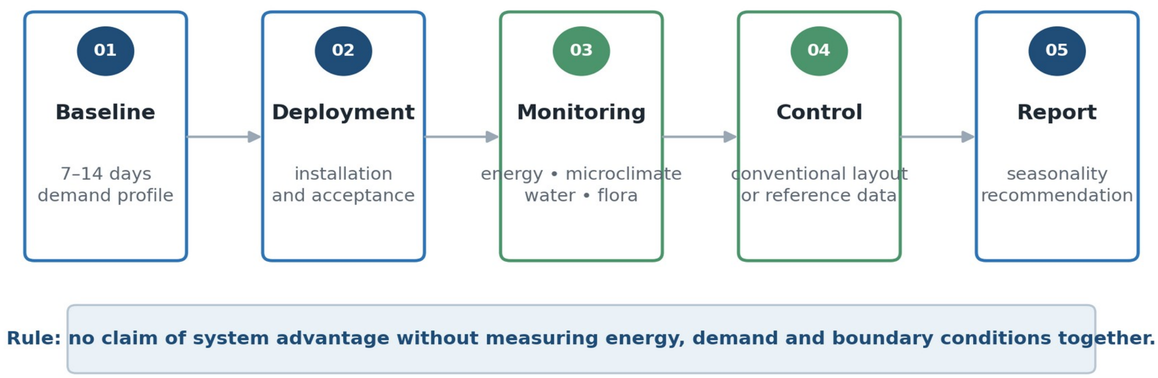


Figure 8. Minimum pilot flow: baseline, deployment, monitoring, control and report.

10.1. Measurement plan

Stream	Parameters	Interval	Quality condition	Units
DC/AC energy	power, voltage, current, energy	1–15 min	meter of suitable class; time synchronization	kWh, kW
Demand	load profile and instantaneous power	1–15 min	separate node meter	kWh, kW
PV conditions	front/rear irradiance, module temperature	1–5 min	calibrated sensors; geometry and shading	W/m², °C
Microclimate	surface and air temperature, RH	5–15 min	under-module zone + control	°C, %
Water	precipitation, runoff, retention, use	event-based / daily	water balance for the specific layout	mm, l
Flora/fauna	survival, coverage, observations	monthly / seasonally	same method and observation points	% / count
Relocation	time, mass, damage, site condition	after operation	acceptance protocol	min, kg, %

Table 11. Proposed pilot measurement package.

For bifacial modules, measurement quality requires control of rear-side conditions, irradiance non-uniformity, background reflectance and geometry. IEC TS 60904-1-2:2024 is an appropriate reference for bifacial I–V characteristics, while open bifacial-modeling tools can account for module layout, albedo, obstructions and mutual shading [7–8].

10.2. Pilot success criteria

- energy and demand data completeness ≥ 95% at a 15-minute interval
- transparent model calibration to at least one complete heating and cooling season

- reporting of median, quartiles and uncertainty interval, not only the annual average
- separate summary of climate, water and biological layers with a control point
- documented disassembly operation or at least a 1:1 node-scale test
- versioning of all data and metadata in the ARW+ Relation Passport

11. ARW+ Relation Passport

The ARW+ Relation Passport is a proposed data schema that describes not only a component, but also its relations with the site, conditions, user, measurement and decision. Unlike an ordinary product card, the record should answer the question: “What happened to this module at this site, and what were the consequences?”

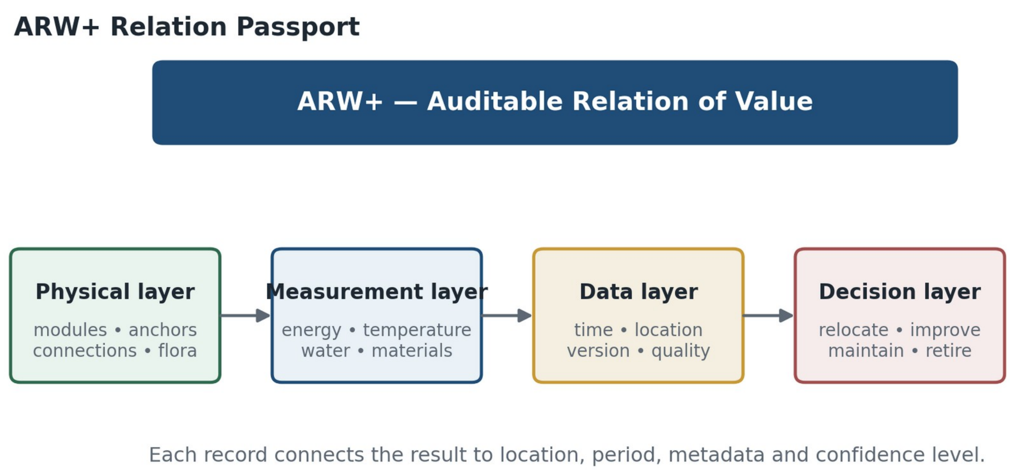


Figure 9. Conceptual ARW+ Relation Passport flow: from component and site to operational decision.

11.1. Minimum record

Block	Example fields	Status
identity	component ID, manufacturer, model, serial number, batch	M
place	location, orientation, height, spacing, surface	A/M
time	installation date, measurement window, time zone, data version	M
energy	DC, AC, demand, self-consumption, export, quality	M
climate	temperature, shade, RH, wind, precipitation	M
material	mass, steel, module, GWP footprint, repair, recovery	A/M
decision	maintain, improve, relocate, retire; author and date	M
evidence	source, method, uncertainty, attachment, file hash	M/W

Table 12. Minimum ARW+ record architecture for a data prototype.

ARW+ should be interoperable and machine-readable. In practice, work can start with CSV/JSON and an unambiguous vocabulary, and only later map records to a BIM system or future digital product passport. The pilot version should have explicit identifiers, quality metadata and the ability to reproduce calculations.

12. Implementation: from a single node to a corridor

Implementation should proceed in stages. The first node should serve learning, not maximum scale. Only after collecting data on production, demand, microclimate and relocation operations can it be determined whether the solution is worth repeating along a street, path, parking area, sports facility or post-industrial site.

Stage	Action	Transition evidence
0. Site definition	problem, function, constraints, approvals	site card + conflict map
1. Test node	1–2 modules, sensors, control	seasonal data and node test
2. Demonstrator	module row with a user function	common acceptance protocol
3. Corridor	integration of energy, water, shade and data	ARW+ for each node
4. Site portfolio	data-driven relocation	comparison of sites and decisions

Table 13. Proposed scaling pathway.

12.1. Decisions required before the pilot

1. Select the site and define the energy-use scenario.
2. Select the specific bifacial module, inverter, protection devices and structural geometry.
3. Verify the geotechnical and structural suitability of the EasyFootings® element for site conditions.
4. Set the load profile, measurement interval and data-retention policy.
5. Approve the method for observing shade, water, vegetation and user impacts.
6. Agree on criteria for ending, relocating or extending the test before measurements begin.

13. Discussion

The model confirms the design intuition while disciplining it. If only annual production is assessed, the advantage of the vertical variant is small in the base scenario. If energy is analyzed over time, the difference becomes useful: the vertical layout supplies a larger share of energy in two daily windows that may correspond to user loads. The site and demand determine whether the effect becomes value or merely an interesting geometry.

The greatest communication risk is mixing simulated results with measurements and transferring a result from one site to every other site. This publication addresses that risk through three rules: transparent assumptions, sensitivity scenarios and a measurement protocol. As a result, even a negative result—for example lower production in a shaded corridor—can be valuable information about the limits of application.

A second risk is overpromising an environmental effect. Shade, retention and biodiversity are not automatic consequences of placing a panel vertically. They become credible results only when they have a defined baseline, measurement period, control point and analysis method. In this publication they are therefore recorded as layers to be validated, not as certified benefits.

13.1. Implications for the EasyFootings® project

If relocatability is to be a real advantage, it must be designed together with the operation: service access, disconnection sequence, component identification, cable protection, packing and renewed acceptance. A future specification should add to each node a “disassembly without loss of value” card describing tools, time, mass, risks and site condition after the operation.

This directs development from a single structural solution toward a system that can learn from successive locations. From a product-development perspective, this is important: pilot data can improve not only the PV-selection algorithm, but also frame geometry, shading method, retention and the relocation standard.

14. Final conclusions and recommendations

The model comparison does not show a universal advantage of vertical bifacial PV in kWh/year. It does show a conditional temporal and system advantage: potentially higher self-consumption, less energy exported to the grid, less conflict with the function of a continuous corridor, and the ability to connect energy with climate and material data.

- Base variant: 10,300 kWh/year for EasyVerticalPV® versus 10,090 kWh/year for conventional PV; the +2.1% difference is small and should not be communicated as a guaranteed advantage.
- Modeled self-consumption: 6,773.5 kWh/year versus 5,466.9 kWh/year; the increase of 1,306.6 kWh/year and +11.58 percentage points in the self-consumption ratio is the most important use-related result.
- Daily profile: a synthetic 61% of production in the morning and afternoon windows versus 31% in the conventional layout; this hypothesis requires 15-minute data.
- Space: the −5% planning-area assumption is a design hypothesis requiring GIS measurement and a site-function test.
- Relocatability: it should be treated as a measurable process involving time, safety, material recovery and site condition, not merely as a catalogue feature.
- ARW+: it is worth creating a relation-passport prototype in the first pilot so that the energy result remains permanently connected to site and evidence quality.

Next 90 days

1. Select a site and define the energy-use scenario.
2. Replace the proxy with a local PVGIS model and a separate bifacial model.
3. Prepare the structural and geotechnical design of the EasyFootings® node.
4. Commission baseline measurements: demand, temperature, shade, precipitation and vegetation condition.
5. Launch the ARW+ register and publish a zero report before installation.

The final value of this concept will be determined not by the attractiveness of a single visualization, but by the quality of repeatable evidence. The strongest development scenario is a small, well-instrumented pilot that can be safely relocated, compared and described in an open report.

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Appendix A. Full model input data

Month	Conventional PV	Vertical PV	Demand	Conventional SC	Vertical SC	Conventional export	Vertical export
January	270	300	1,200	215.8	235.6	54.2	64.4
February	430	470	1,100	322.2	360.4	107.8	109.6
March	800	820	1,000	495.5	598.1	304.5	221.9
April	1,120	1,050	900	615.3	706.9	504.7	343.1
May	1,270	1,190	800	634.3	767.8	635.7	422.2
June	1,320	1,220	750	646.1	752.9	673.9	467.1
July	1,350	1,250	700	633.8	736.4	716.2	513.6

Month	Conventional PV	Vertical PV	Demand	Conventional SC	Vertical SC	Conventional export	Vertical export
August	1,250	1,210	750	599.4	724.1	650.6	485.9
September	1,000	1,080	900	499.5	666.5	500.5	413.5
October	690	820	1,050	386.0	552.1	304.0	267.9
November	360	560	1,200	244.5	413.7	115.5	146.3
December	230	330	1,300	174.6	259.2	55.4	70.8
TOTAL	10,090	10,300	11,650	5,466.9	6,773.5	4,623.1	3,526.5

Table 7. Full monthly model dataset [kWh]; SC = locally consumed energy.

A.1. Daily profile

Hour	Conventional PV	EasyVerticalPV®
00:00	0.0%	0.0%
01:00	0.0%	0.0%
02:00	0.0%	0.0%
03:00	0.0%	0.0%
04:00	0.0%	0.0%
05:00	0.0%	0.0%
06:00	2.0%	6.0%
07:00	4.0%	9.0%
08:00	5.0%	10.0%
09:00	6.0%	10.0%
10:00	8.0%	9.0%
11:00	11.0%	8.0%
12:00	13.0%	6.0%
13:00	14.0%	5.0%
14:00	13.0%	5.0%
15:00	10.0%	6.0%
16:00	7.0%	8.0%
17:00	4.0%	9.0%
18:00	2.0%	6.0%
19:00	1.0%	3.0%

Hour	Conventional PV	EasyVerticalPV®
20:00	0.0%	0.0%
21:00	0.0%	0.0%
22:00	0.0%	0.0%
23:00	0.0%	0.0%

Table 14. Normalized daily profile of the model; each variant sums to 100%.

Appendix B. Variable set and reproduction method

The model can be reproduced in any spreadsheet if the following series and rules are retained. Numbers are written with decimal commas in the Polish text, but CSV implementation should use a comma or semicolon separator and explicit UTF-8 encoding.

```
months = [Jan, Feb, Mar, Apr, May, Jun, Jul, Aug, Sep, Oct, Nov, Dec]
classic_pv_kwh = [270, 430, 800, 1120, 1270, 1320, 1350, 1250, 1000, 690, 360, 230]
vertical_pv_kwh = [300, 470, 820, 1050, 1190, 1220, 1250, 1210, 1080, 820, 560, 330]
load_kwh = [1200, 1100, 1000, 900, 800, 750, 700, 750, 900, 1050, 1200, 1300]
classic_self_consumption_kwh = classic_pv_kwh * monthly_rate_classic, normalized to 5466.9
vertical_self_consumption_kwh = vertical_pv_kwh * monthly_rate_vertical, normalized to 6773.5
export_kwh = pv_kwh - self_consumption_kwh
self_consumption_ratio = sum(self_consumption_kwh) / sum(pv_kwh)
load_coverage = sum(self_consumption_kwh) / sum(load_kwh)
```

Table 15. Pseudocode / variable definitions enabling reproduction of the model.

Appendix C. Publication evidence matrix

Area	Status	What it means
Field measurements	missing	to be completed in the pilot
Conventional production model	S/A	transparent monthly series; proxy location
Bifacial production model	S/A	derived scenario; requires a local model
Self-consumption	S/A	synthetic demand and allocation rule
Microclimate / water / flora	P	metric and protocol concept
Relocatability	P	list of parameters for a 1:1 test
ARW+	P	authored proposal for a data schema
Certification	missing	no certification of the entire system has been declared

Table 16. Evidence matrix: what the publication demonstrates and what it does not yet resolve.

Appendix D. Note for online publication

Recommended sharing description: "An authored comparative study of vertical bifacial PV and a conventional photovoltaic installation. The publication presents a data model, hypotheses for EasyClimate Spine® and a pilot protocol. Results are scenario-based and require local validation."

For online publication, it is useful to attach separately: a spreadsheet with data and assumptions, a PDF version with metadata, the version number and access date. Conceptual illustrations should be labelled as visualizations, and charts as model results—this prevents an image from being confused with as-built documentation.