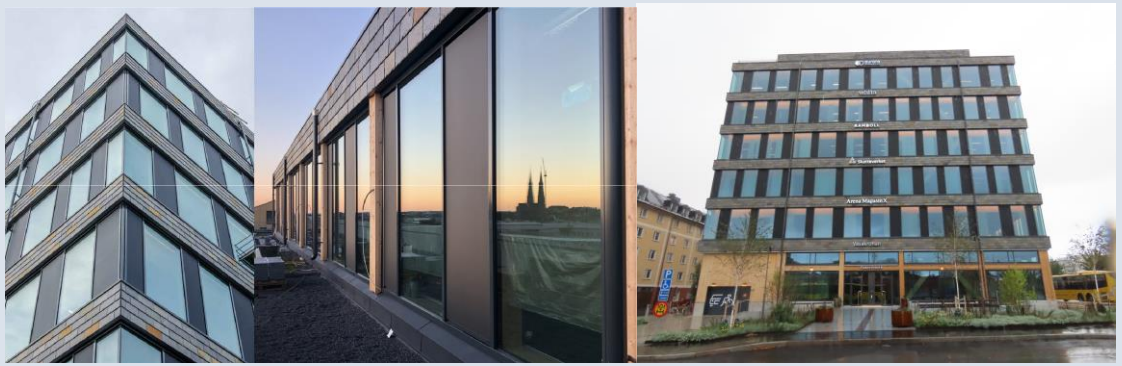


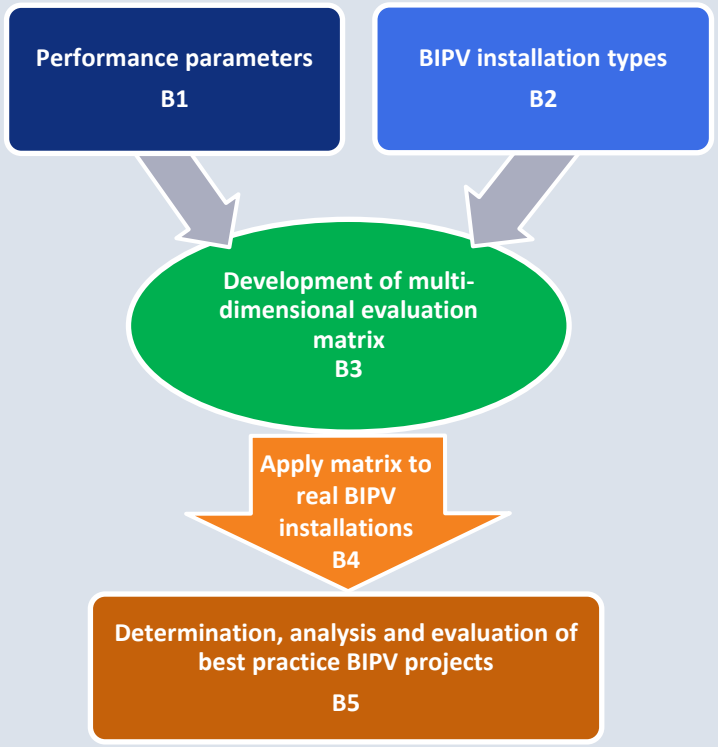
Magasin X; Vasakronan - Uppsala/S; White Architects; https://www.besmartproject.eu/magasin-x

# TASK 15 – “Enabling framework for the acceleration of BIPV”
# Subtask B: Cross-sectional Analysis of BIPV Installations

**Gabriele C. Eder,** Helen Rose Wilson, Nuria Martin Chivelet, Jennifer Adami, Markus Babin, Sune Thorsteinsson, Francesco Frontini, Pierluigi Bonomo, Karl Berger, Simon Boddaert, Rebecca Yang, Alessandra Scognamiglio, Rickard Nygren, Rolf Frischknecht, Antonia Galgiano, Roland Valckenborg, Lukas Gaisberger, Costa Kapsis and many more

# ACTIVITIES

- ✓B1: Definition of performance parameters/ indicators for the characterization of the electrical and building function of BIPV
- ✓B2: Identification of representative BIPV installation scenarios; Categorization of BIPV applications*
- ✓B3: Development of a multidimensional evaluation matrix
- ✓B4: Identify a set of real BIPV installations with available data
- B5: Determination, analysis and assessment of the multifunctional performance and dissemination of best practice results




*https://iea-pvps.org/key-topics/categorization-of-bipv-applications/

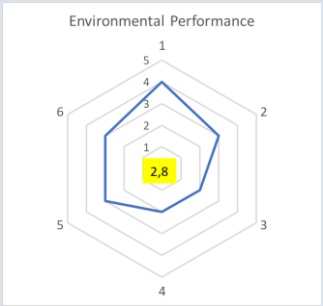
# MULTI-FUNCTIONAL EVALUATION MATRIX

General Information on
- installation site (geographical, climatic, orientation, inclination, shading);
- the PV Modules (datasheet): technical and constructive
- the BIPV installation (application and system category, sub-system, building type, total installed area and total nominal power of the BIPV building skin, fotos)

Performance Indicators (PI) in 4 categories (5-6 PIs for each category): numerical values;
- Energy-relevant
- economic
- environmental
- visual performance: evaluation via comparison: main objectives fulfilled: y/n

- ✓ defined possible range;  information taken from real installations (min. and max. values);
- ✓ define scale 1 → 5 for each PI => rating
- ✓ calculate the rated PI for each category
- ✓ mean value in the middle, but all individual PIs displayed in a “spider” diagram

| 5 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|

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# GENERAL INFORMATION

| | parameter | unit | BIPV project |
|---|---|---|---|
| **BIPV modules** | module area | $m^2$ | |
| from technical data sheet | module length, width | m x m | |
| | weight | kg | |
| | nominal power of module @STC (name plate) | Wp | |
| | PV technology; module efficiency | % | |
| | power density | $W/m^2$ | |
| | T-coefficient Power | %/K | |
| | solar transmittance (g-value= T/R)) | 0… 1 | |
| | thermal transmittance (U-Value) | $Wm^{-2}K^{-1}$ | |
| | visible transmittance (for semi-transparent PV) | 0… 1 | |
| **Site information** | average annual global radiation; horizontal | $kWh/m^2a$ | |
| | orientation (N=0°; E=90°; S=180°, W=270°) | ° | |
| | inclination (0 = horizontal , 90°= facade) | ° | |
| | annual solar radiation @ specific PV installation | $kWh/m^2$ | |
| | shading on BIPV (annual mean) | % | |
| **BIPV installation** | application category | IEC 63092-1:2020: Category A-E | |
| | system category (topology) * | roof, façade or ext. integrated device | |
| | sub-system (morphology) * | e.g. curtain wall, window, roofing.. | |
| | building type | | |
| | number of modules | N | |
| | total installed area BIPV building skin | $m^2$ | |
| | total nominal power BIPV building skin | Wp | |

*https://iea-pvps.org/key-topics/categorization-of-bipv-applications/

# DEFINITION OF PERFORMANCE INDICATORS
## for the characterization of the electrical and building functions of BIPV

| | Energy-relevant PIs | Economic PIs * | Environmental PIs | Visual PIs | |
|---|---|---|---|---|---|
| 1 | PV array energy yield (DC) | BIPV building element costs | Cumulative Energy Demand non-renewable | Recognizability | Evaluation: objective fulfilled: y/n |
| 2 | Final system yield (AC) | Material replacement value | Climate Change | Colour | |
| 3 | Area-specific AC final system yield (relative to total BIPV system area) | Effective levelized cost of electricity (eLCOE) | Resource Use, Minerals and Metals | Glare | |
| 4 | Performance Ratio (annual) | Standard LCOE | Particulate Matter | BIPV building in the urban environment | |
| 5 | Self-sufficiency index | Effective net present value (eNPV)/costs | Acidification | BIPV system in the building | |
| 6 | | Effective discounted payback period (eDPP) | Water use | PV module in the BIPV system | |

! here only the manufacturing phase is considered
→ extension to the End-of-Life phase is discussed

*A review of 45 non-domestic buildings 12 western countries; Weerasinghe, R.P.N.P.; Yang, R.J.; Renewable and Sustainable Energy Reviews 137 (2021) 110622

# EXAMPLE: ENERGY-RELEVANT PERFORMANCE INDICATORS

Energy-relevant PIs (refer to performance of installed BIPV system)* rating 1-5

| | Energy-relevant Pis | Unit | minimum values | maximum values | value / specific BIPV project | Rating / Energy relevant PIs |
|---|---|---|---|---|---|---|
| 1 | PV array energy yield | kWh/kWp | 0 | 1500 | 900 | 3 |
| 2 | AC final system yield | kWh/kWp | 0 | 1350 | 815 | 3 |
| 3 | Area-specific AC final system yield * | $kWh/m^2$ | 0 | 300 | 210 | 4 |
| 4 | Performance Ratio (annual) | % | 0 | 100 | 85 | 5 |
| 5 | self-sufficiency index | % | 0 | 100 | 89 | 5 |
| | * relative to the total BIPV system area | | | | **Mean** | **4.0** |

4

Proposed quantitative rating basis

| | Energy-relevant Pis | Unit | rating 1 | rating 2 | rating 3 | rating 4 | rating 5 |
|---|---|---|---|---|---|---|---|
| 1 | PV array energy yield (DC) | kWh/kWp | <550 | 550 - 825 | 825 - 1100 | 1100 - 1375 | > 1375 |
| 2 | AC final system yield | kWh/kWp | < 500 | 500 - 750 | 750 - 1000 | 1000 - 1250 | > 1250 |
| 3 | Area-specific AC final system yield * | $kWh/m^2$ | <100 | 100 - 150 | 150 - 200 | 200 - 250 | > 250 |
| 4 | Performance Ratio (annual) | % | < 50 | 50-60 | 60-70 | 70-80 | >80 |
| 5 | self-sufficiency index | % | <5 | 5-20 | 20-50 | 50-80 | >80 |
| | | | | | | | |
| | General information on PV modules | Unit | rating 1 | rating 2 | rating 3 | rating 4 | rating 5 |
| | module efficiency | % | <5 | 5-10. | 10-15. | 15-20 | >20 |
| | power densitiy | Wp/m2 | <50 | 50 - 100 | 100 -150 | 150 - 200 | >200 |

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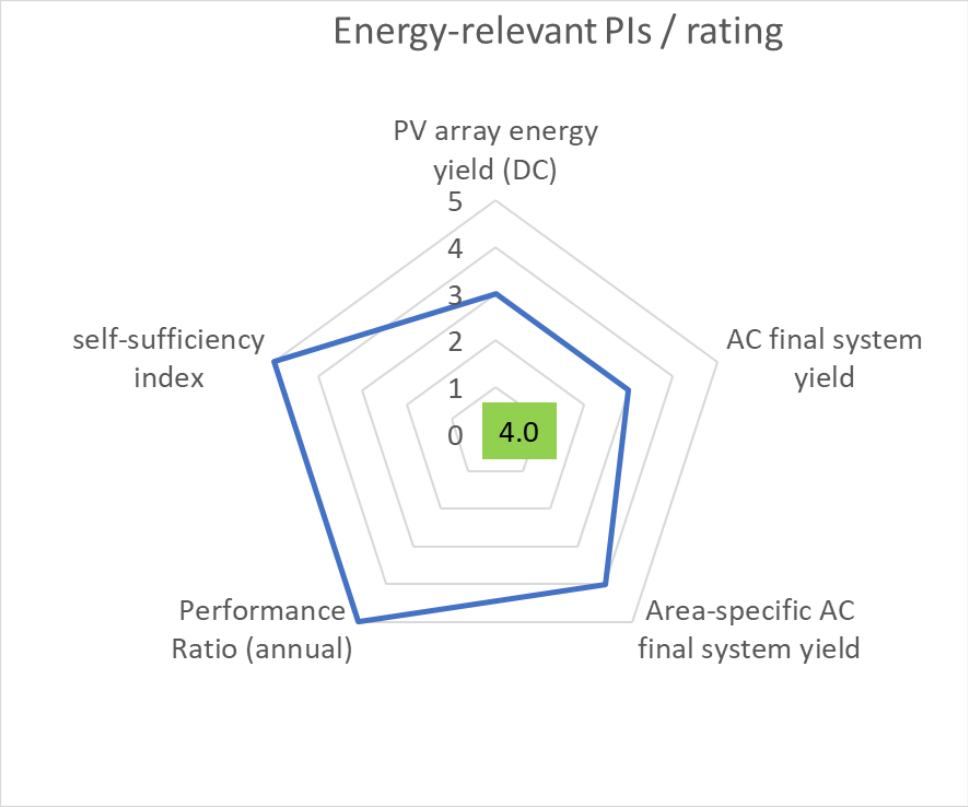
* Standard to refer to IEC 61724-1:2017

# EXAMPLE: SPIDER DIAGRAM



# ENVIRONMENTAL PERFORMANCE INDICATORS

Environmental PIs /example mono c-Si *

rating 1-5

| | Environmental PIs | Unit | minimum values | maximum values | value / specific BIPV project | Rating / Environmental PIs |
|---|---|---|---|---|---|---|
| 1 | Cumulative energy demand, non-renewable | MJ oil eq. / kWh | 0.22 | 1.25 | 0.54 | 4 |
| 2 | Climate change GHG | g $CO_2$ eq. / kWh | 15 | 88 | 42.5 | 3 |
| 3 | Resource use, minerals+metals | mg Sb eq. / kWh | 1.06 | 6.53 | 5.28 | 2 |
| 4 | Particulate matter | $10^{-9}$ disease incidence/kWh | 0.55 | 4.29 | 3.63 | 2 |
| 5 | Acidification | µmol H+ eq. /kWh | 104 | 563 | 360 | 3 |
| 6 | Water use | m³ world eq. /kWh | 2.2 | 13.9 | 7.49 | 3 |
| | | | | | **Mean:** | **2.8** |

2.8

Proposed quantitative rating basis

| | Environmental PIs | Unit | rating 1 | rating 2 | rating 3 | rating 4 | rating 5 |
|---|---|---|---|---|---|---|---|
| 1 | Cumulative energy demand, non-renewable | MJ oil eq. / kWh | > 1.25 | 1,25 -0,91 | 0,91 - 0,56 | 0,56 - 0,22 | < 0,22 |
| 2 | Climate change GHG | g $CO_2$ eq. / kWh | > 88 | 88 - 63,7 | 63,7 - 39,3 | 39,9 - 15 | < 15 |
| 3 | Resource use, minerals+metals | mg Sb eq. / kWh | > 6.53 | 6,53 - 4,71 | 4,71 - 2,88 | 2,88 - 1,06 | < 1,06 |
| 4 | Particulate matter | $10^{-9}$ disease incidence/kWh | > 4.29 | 4,29 - 3,04 | 3,04 - 1,80 | 1,80 - 0,55 | < 0,55 |
| 5 | Acidification | µmol H+ eq. /kWh | > 563 | 563 - 410 | 410 - 257 | 257 - 104 | < 104 |
| 6 | Water use | m³ world eq. /kWh | > 13.9 | 13,9 - 10 | 10 - 6,1 | 6,1 - 2,2 | < 2,2 |

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* Report IEA-PVPS T12-03:2020; Task 12 methodology guidelines, 4th edition and
Factsheet T12: https://iea-pvps.org/wp-content/uploads/2021/11/IEA-PVPS-Task12-LCA-PV-electricity-_-Fact-Sheet.pdf

# VISUAL PERFORMANCE INDICATORS

Visual PIs

rating 1-5

| | Visual PIs | main objective | fulfilled y/n | value / specific BIPV project | Rating / Visual PIs |
|---|---|---|---|---|---|
| 1 | Recognizability | | | partly fullfilled | 3 |
| 2 | Colour | | | 2 | 5 |
| 3 | Glare | | | 3 | 4 |
| 4 | BIPV building within the urban environment | | | Very good | 5 |
| 5 | BIPV system within the whole building | | | fullfilled | 3 |
| 6 | PV module within the BIPV System | | | well fullfilled | 4 |
| | | | | **Mean:** | **4.1** |

Proposed quantitative rating basis

| | Visual PIs | Main parameter | rating 1 | rating 2 | rating 3 | rating 4 | rating 5 |
|---|---|---|---|---|---|---|---|
| 1 | Recognizability | | | | | | |
| 2 | Colour (validation needed); | Spatial ΔC(A) and angular ΔC(θ) colour uniformity | ΔC(A) > 10 / --* | ΔC(A) < 10 /--* | ΔC(A) < 7 / --* | ΔC(A) < 4 / --* | ΔC(A) < 1 / --* |
| | | | ΔC(θ) > 10 / --* | ΔC(θ) < 10 / --* | ΔC(θ) < 7 / --* | ΔC(θ) < 4 / --* | ΔC(θ) < 1 / --* |
| 3 | Glare# (example calculations and validation needed) | Glare risk | Risk for flash blindness | Risk for flash blindness | Risk for dis-comfort glare | Risk for dis-comfort glare | Risk for dis-comfort glare |
| | | | >10 h/a | 1-10h /a | >10 h/ a | 1-10 h/ a | <1 h / a |
| 4 | BIPV building in the urban environment | | | | | | |
| 5 | BIPV system in the building | | | | | | |
| 6 | PV module in the BIPV system | | | | | | |

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*if desired

# Glare potential evaluation of structured PV glass based on gonioreflectometry; Markus Babin, Sune Thorsteinssonet all, IEEE PVPS 2022.

+ A Trans-Disciplinary Vocabulary for Assessing the Visual Performance of BIPV; Alessandra Scognamiglio; Sustainability 2021, 13, 5500. https://doi.org/10.3390/su13105500

# ECONOMIC PERFORMANCE INDICATORS

Economic PIs rating 1-5

| | Economic PIs | Unit | minimum values | maximum values | value / specific BIPV project | Rating / Economic PIs |
|---|---|---|---|---|---|---|
| 1 | BIPV element costs | €/m² | 130 | 1550 | 1000 | 3 |
| 2 | Material replacement value | €/m² | 0 | 460 | 300 | 5 |
| 3 | Eff.levelized cost of Electricity (eLCOE) | €/kWh | (-0.5) | 0.65 | 0.2 | 3 |
| 4 | Standard LCOE | €/kWh | -0.15 | 1.2 | 0,25 | 2 |
| 5 | Eff. Net Present Value (eNPV) | €/m² | (-9700) | 13700 | 9000 | 4 |
| 6 | Eff. Discounted Payback Period (eDPP) | a | 1 | 30 | 5 | 4 |
| | | | | | **Mean** | **3.5** |

4 3

3.5

Proposed quantitative rating basis

| | Economic PIs | Unit | rating 1 | rating 2 | rating 3 | rating 4 | rating 5 |
|---|---|---|---|---|---|---|---|
| 1 | BIPV element costs | €/m² | > 1400 | 1400 -1100 | 1100 - 700 | 700 - 300 | < 300 |
| 2 | Material replacement value | €/m² | < (-1000) | (-1000)- (-600) | (-600)- 0 | 0 - 200 | > 200 |
| 3 | Effective levelized cost of Electricity (LCOE) | €/kWh | > 0.4 | 0.4 – 0.24 | 0.24 - 0 | 0 - (-0.3) | < (-0.3) |
| 4 | Standard LCOE | | > 0.7 | 0.7 – 0.4 | 0.4 - 0.24 | 0.24 - 0 | < 0 |
| 5 | Effective Net Present Value (eNPV) | €/m² | < (-5000) | (-5000) - 0 | 0 - 5000 | 5000 - 10000 | > 10000 |
| 6 | Effective Discounted Payback Period (eDPP) | a | > 25 | 25 - 15 | 15 - 10 | 10 - 2 | < 2 |

*A review of 45 non-domestic buildings 12 western countries; Weerasinghe, R.P.N.P.; Yang, R.J.; Renewable and Sustainable Energy Reviews 137 (2021) 110622

# CROSS-SECTIONAL ANALYSIS OF BIPV INSTALLATIONS

Apply matrix to real BIPV installations…. first test runs…

Presentation of the outcome:

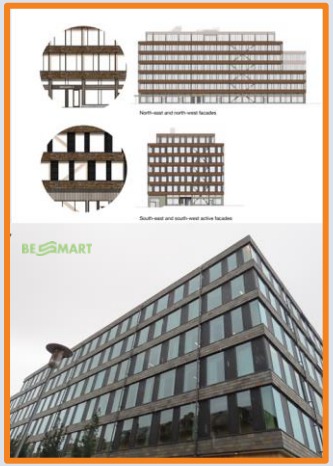
1. General Information as table

2. Photos and drawings (for illustration)

3. Results of the performance evaluation in 4 categories given as spider diagrams (with mean rating)

examples

| | parameter | unit | BIPV on windowblock | BIPV on parapet | PV on roof | |
|---|---|---|---|---|---|---|
| BIPV-modules from technical data sheet | module size | $m^2$ | 2,00 | 0,32 | Composite 0,80 | glass/glass 0,32 |
| | module length, width | m x m | 1.5 x 1.3 | 0.9 x 0.35 | 0.9 x 0.89 | 0.9 x 0.35 |
| | weight | kg | 40,0 | 3,4 | 4.8 | 3.4 |
| | nominal power of module @STC (name plate) | Wp | 318 | 47 | 92 | 47 |
| | PV-technology; module efficiency | % | m-Si; 15,9 | m-Si; 14,9 | 11.5 | m-Si; 14.9 |
| | power density | $W/m^2$ | 159,2 | 149,2 | 114.9 | 149.2 |
| | T-coefficient Power | %/K | -0,451 | | | |
| Site-Information | Average annual global radiation; horizontal | $kWh/m^2a$ | 1444 | | | |
| | Orientation (N=0°; E=90°; S=180°, W=270°) | ° | 109 and 289 | 109 and 289 | 109 and 289 | |
| | inclination (0 = horizontal , 90°= facade) | ° | 90 | 90 | 6 | |
| | annual solar radiation @ PV-installation | $kWh/m^2$ | 1005,5 | | | |
| | Shading on BIPV (annual mean) | % | 20 | 0 | 0 | |
| BIPV-Installation | Application category (A – E) | IEC 63092-1:2020 | C | E | Not integrated | |
| | System Category (Topology) | roof, façade or external int. device | façade | External int. device | | |
| | Sub-system (Morphology) | e.g. curtain wall, window,… | Rainscreen facade | parapet | | |
| | Building Type | | Residential, multi-family / Retrofit | | | |
| | module number | N | 12 (SE)+ 27 (NW) | 93 (SE)+ 102 (NW) | 36 (composite, SE facing) + 108 (glass-glass, NW facing) | |
| | total installed area BIPV building skin | $m^2$ | 202,2 | | | |
| | total nominal power BIPV building skin | Wp | 30000 | | | |





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# IDENTIFY REAL BIPV INSTALLATIONS WITH AVAILABLE DATA

- EURAC: multifamily dwelling unit (MDU);
  https://www.energymatching.eu/demo-sites/italian-demo-site/

- Fraunhofer ISE: Zentrum für höchst-effiziente Solarzellen (ZhS), Freiburg, DE

- Treeze: LCA of Buildings with active glass façades → for environmentals PIs
  https://treeze.ch/fileadmin/user_upload/downloads/Publications/Case_Studies/Energy/674-LCA-Active-Glass-Facades-v2.1.pdf

- Potentially: White architects: NCC headquarters and Magasin X;
  https://www.besmartproject.eu/


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# Example 1: Multi-family building - Campi Bisenzio, Florence, Italy

- Horizon 2020 EnergyMatching project
- Building retrofit (2021)
- BIPV parapets + BIPV window blocks + PV on roof
- SE and NW oriented surfaces
- Glass-glass (Onyx Solar) and composite (Tecnalia) modules with mono c-Si cells
- Click&go substructure (TULiPPS)
- Contact person: Jennifer Adami / eurac

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*This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement Nº 768766. The information reflects only the project's view and the Commission is not responsible for any use that may be made of the information it contains*

# Example 1: Multi-family building - Campi Bisenzio, Florence, Italy

## 3 types of BIPV

| | parameter | unit | BIPV I on windowblock | BIPV on parapet | PV on roof | |
|---|---|---|---|---|---|---|
| **BIPV modules** | module area | $m^2$ | 2.00 | 0.32 | Composite 0.80 | glass/glass 0.32 |
| from technical data sheet | module length, width | m x m | 1.5 x 1.3 | 0.9 x 0.35 | 0.9 x 0.89 | 0.9 x 0.35 |
| | weight | kg | 40.0 | 3.4 | 4.8 | 3.4 |
| | nominal power of module @STC (name plate) | Wp | 318 | 47 | 92 | 47 |
| | PV technology; module efficiency | % | m-Si; 15.9 | m-Si; 14.9 | 11.5 | m-Si; 14.9 |
| | power density | $W/m^2$ | 159.2 | 149.2 | 114.9 | 149.2 |
| | T-coefficient Power | %/K | -0.451 | | | |
| **Site information** | average annual global radiation; horizontal | $kWh/m^2a$ | 1444 | | | |
| | orientation (N=0°; E=90°; S=180°, W=270°) | ° | 109 and 289 | 109 and 289 | 109 and 289 | |
| | inclination (0 = horizontal , 90°= facade) | ° | 90 | 90 | 6 | |
| | annual solar radiation @ PV-installation | $kWh/m^2$ | 1005.5 | | | |
| | shading on BIPV (annual mean) | % | 20 | 0 | 0 | |
| **BIPV installation** | application category (A – E) | IEC 63092-1:2020 | C | E | Not integrated | |
| | system category (topology) | roof, façade or external int. device | façade | External int. device | | |
| | sub-system (morphology) | e.g. curtain wall, window,... | Rainscreen facade | parapet | | |
| | building type | | Residential, multi-family / Retrofit | | | |
| | number of modules | N | 12 (SE)+ 27 (NW) | 93 (SE)+ 102 (NW) | 36 (composite, SE facing) + 108 (glass-glass, NW facing) | |
| | total installed area BIPV building skin | $m^2$ | 202,2 | | | |
| | total nominal power BIPV building skin | Wp | 30000 | | | |




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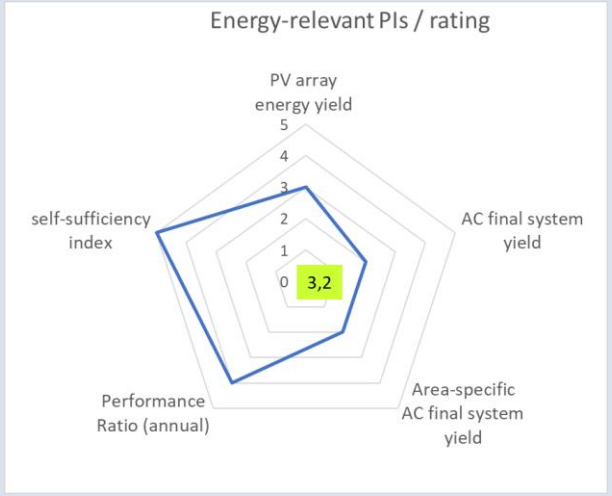
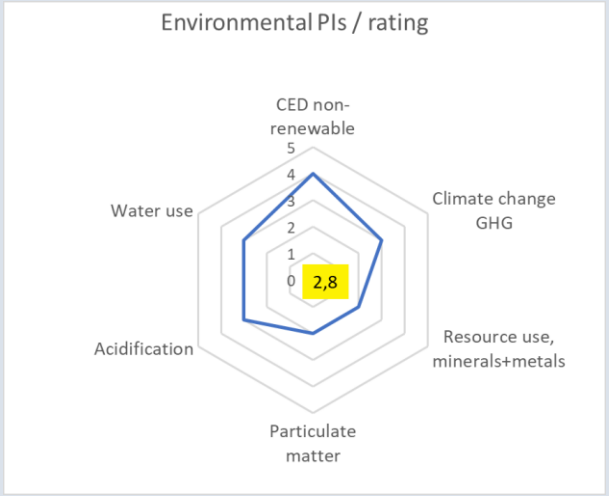
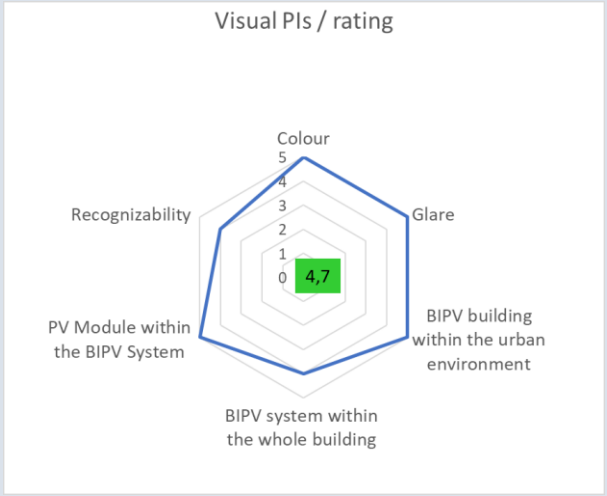
# Example 1: Multi-family building - Campi Bisenzio, Florence, Italy




Note: data provided are all results of simulations done in the preliminary phases of the retrofit project process

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# Example 2: active Glass facades /Comparison of Environmental PIs

## Life Cycle Assessment of Active Glass Façades, 2021

- Philippe Stolz[1], Luana Krebs[1], Rolf Frischknecht[1], Duglas Urena Hunziker[2], Urs Muntwyler[2]; [1] treeze Ltd.; [2] Bern University of Applied Sciences
- In this study, the environmental impacts of the active glass façades of five buildings and of the roof-integrated PV system of one building are analysed following a life cycle assessment approach

Fig. 3.1 Photographs of the selected buildings with integrated PV systems: 1) Grosspeter Tower, Basel[1]; 2) Flumroc, Flums (Flumroc 2015); 3) Viridén+Partner, Zurich[2]; 4) Solaris 416, Zurich[3]; 5) Setz, Möriken[4]; 6) Rudolf, Thun[5].

| | Grosspeter Tower | Flumroc | Viridén | Solaris 416 | Setz | Rudolf |
|---|---|---|---|---|---|---|
| **Location** | Grosspeterstrasse, Basel | Industriestrasse, Flums | Hofwiesen- / Rothstrasse, Zurich | Seestrasse, Zurich | Grabenweg, Möriken | Schubertstrasse, Thun |
| **Building type** | Commercial and office building | Office building | Residential building | Residential building | Residential building | Residential building |
| **Construction year** | 2017 | 2014 (refurbishment) | 2016 (refurbishment) | 2017 | 2019 | 2013 (refurbishment) |
| **Owner** | PSP Real Estate AG | Flumroc AG | EcoRenova AG | huggenbergerfries Architekten AG | Immo Treier AG | Thomas Rudolf |
| **Architect** | Burckhardt + Partner AG | Viridén + Partner AG | Viridén + Partner AG | huggenbergerfries Architekten AG | Setz Architektur | Architektur Atelier Adrian Christen |
| **PV system** | façade-integrated (440 kWp) rooftop, mounted (100 kWp; *not considered*) | façade-integrated (57.3 kWp) rooftop, mounted (71.3 kWp; *not considered*) | façade-integrated (159 kWp) rooftop, mounted (30 kWp; *not considered*) | façade-integrated (46.5 kWp) rooftop-integrated (25.2 kWp) | façade-integrated (3.57 kWp) rooftop, mounted (*not considered*) | rooftop-integrated (34.6 kWp) |
| **PV façade orientation** | South, East, West, North | South-East, South-West, North-East | South, East, West, North | South, East, West, North | South | - |
| **PV module manufacturer** | NICE Solar Energy GmbH | Solar Frontier | Kioto Photovoltaics GmbH | LOF Solar | Kioto Photovoltaics GmbH | Meyer Burger |
| **PV technology** | CIGS | CIS | monocrystalline silicon | monocrystalline silicon | monocrystalline silicon | monocrystalline silicon PERC |
| **PV module colour** | screen printing at the edges (black) | - | satin finish and digital ceramic printing (grey) | digital ceramic printing (red-brown) | - | - |
| **Substructure manufacturer** | Sto AG / Hevron SA | gft Fassaden AG | gft Fassaden AG | gft Fassaden AG | BE Netz AG | Meyer Burger |
| **LCIs displayed in** | Tab. A. 1; Tab. B. 1 | Tab. A. 2; Tab. B. 2 | Tab. A. 2; Tab. B. 3 | Tab. A. 2; Tab. B. 8 | Tab. A. 7; Tab. B. 7 | Tab. A. 6; Tab. B. 9 |

https://treeze.ch/fileadmin/user_upload/downloads/Publications/Case_Studies/Energy/674-LCA-Active-Glass-Facades-v2.1.pdf

functional units
active glass façade of selected buildings and façade constructions: 1 $m^2$;
electricity produced with the active glass façade of selected buildings: 1 kWh AC

Tab. Z. 1 Overview of the environmental impacts of the active glass façades of the six selected buildings per $m^2$ façade construction (gross: all impacts attributed to electricity production; net: impacts of front glass and substructure attributed to the building, remaining impacts attributed to electricity production).

| | | unit | Overall environmental impact | Cumu total |
|---|---|---|---|---|
| | | | UBP | kWh oil-eq |
| Grosspeter Tower | gross | $m^2$ | 583'000 | 683 |
| | net | $m^2$ | 526'000 | 461 |
| Flumroc | gross | $m^2$ | 804'000 | 1'050 |
| | net | $m^2$ | 741'000 | 802 |
| Solaris | gross | $m^2$ | 445'000 | 1'150 |
| | net | $m^2$ | 357'000 | 807 |
| Viridén | gross | $m^2$ | 409'000 | 1'080 |
| | net | $m^2$ | 344'000 | 824 |
| Setz | gross | $m^2$ | 611'000 | 1'420 |
| | net | $m^2$ | 526'000 | 1'050 |
| Rudolf roof | gross | $m^2$ | 256'000 | 693 |
| | net | $m^2$ | 212'000 | 551 |

Impacts of PV, glass and substructure considered

Tab. Z. 2 Overview of the gross environmental impacts of 1 kWh electricity caused by the active glass façades of the six buildings (gross: all impacts attributed to electricity production; net: impacts of front glass and substructure attributed to the building, remaining impacts attributed to electricity production).

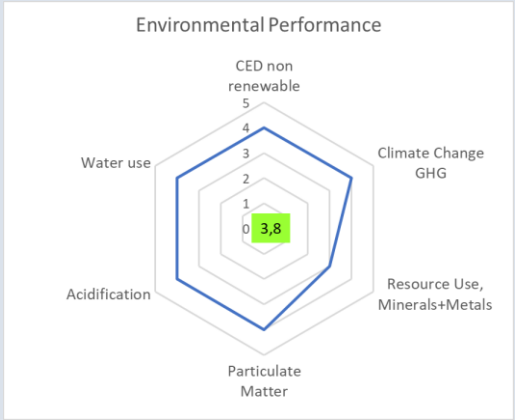
| | | unit | Overall environmental impact | Cumulative energy demand | | | Greenhouse gas emissions |
|---|---|---|---|---|---|---|---|
| | | | | total | non-renewable | renewable | |
| | | | UBP | kWh oil-eq | kWh oil-eq | kWh oil-eq | kg $CO_2$-eq |
| Grosspeter Tower | gross | kWh | 553 | 1.71 | 0.583 | 1.13 | 0.136 |
| | net | kWh | 499 | 1.50 | 0.402 | 1.10 | 0.093 |
| Flumroc | gross | kWh | 304 | 1.46 | 0.354 | 1.11 | 0.082 |
| | net | kWh | 280 | 1.37 | 0.273 | 1.10 | 0.063 |
| Solaris | gross | kWh | 347 | 1.97 | 0.815 | 1.15 | 0.226 |
| | net | kWh | 280 | 1.70 | 0.579 | 1.12 | 0.169 |
| Viridén | gross | kWh | 485 | 2.34 | 1.16 | 1.18 | 0.278 |
| | net | kWh | 408 | 2.04 | 0.900 | 1.14 | 0.215 |
| Setz | gross | kWh | 211 | 1.55 | 0.430 | 1.12 | 0.107 |
| | net | kWh | 182 | 1.43 | 0.324 | 1.10 | 0.083 |
| Rudolf roof | gross | kWh | 65.6 | 1.24 | 0.147 | 1.09 | 0.039 |
| | net | kWh | 55.0 | 1.20 | 0.120 | 1.08 | 0.032 |

PVPS

UBP eco-points
(German: Umweltbelastungspunkte)

# Example 2: Grosspeter Tower, Basel

Active glass façade
area: 4800 m²
power output: 440 kWp
annual electricity yield of 170,000 kWh/a
yield of 386.4 kWh/kWp.
frameless CIS glass-glass PV modules
weight of the module: 18.5 kg/m²

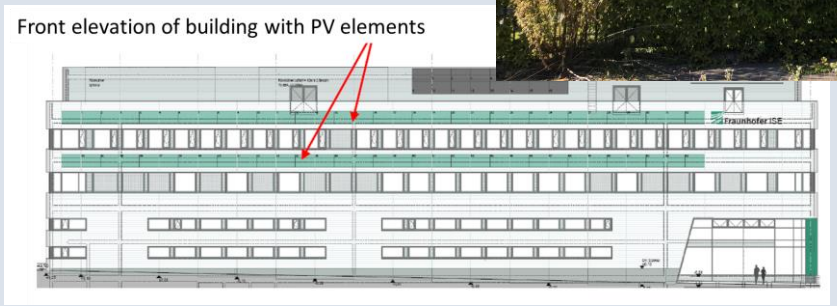



| | parameter | unit | BIPV I |
|---|---|---|---|
| **BIPV modules** from technical data sheet | module area | m² | 0.72 |
| | module length, width | m x m | 1.2 x 0.6 |
| | weight | kg | 13.3 |
| | nominal power of module @STC (name plate) | Wp | 102.5 |
| | PV technology; module efficiency | % | CIGS , 16 % |
| | power density | W/m² | 142.4 |
| | T-coefficient Power | %/K | -0.36 |
| **Site information** | average annual global radiation; horizontal | kWh/m²a | 1200 |
| | orientation (N=0°; E=90°; S=180°, W=270°) | ° | whole facade (91%) |
| | inclination (0 = horizontal , 90°= facade) | ° | 90 |
| | annual solar radiation @ specific PV-installation | kWh/m² | 994 |
| | shading on BIPV (annual mean) | % | 0 |
| **BIPV innstallation** | application category (A –E) | IEC 63092-1:2020: Category | C |
| | system category (topology) | roof, façade or ext. integrated device | facade |
| | sub-system (morphology) | e.g. curtain wall, window, roofing.. | |
| | building type | | high rise building; offices |
| | number of modules | N | |
| | total installed area BIPV building skin | m² | 4800 |
| | total nominal power BIPV building skin | Wp | 440000 |

only production of PV considered for environmental PIs

# Example 3a: Zentrum für höchsteffiziente Solarzellen at Fraunhofer ISE, DE (Clean rooms, laboratories, offices) for visual performance assessment

- South-east oriented facade
- Two PV strips, 66 m long, 1.2 m high in a rear-ventilated rainscreen
- Glass configuration and mounting in accordance with DIN 18008
- Glass-glass PV modules, c-Si, MorphoColor® coating
- Installed power ~18 kWp
- Installation to be completed in 2022
- Architects: BRECHENSBAUER WEINHART + PARTNER ARCHITEKTEN mbB
- Contact Person: Helen Rose Wilson / FH ISE

# Example 3b: Building N at Fraunhofer ISE, DE (workshops) – for energy-relevant, economic and possibly environmental assessment

- South-east oriented façade
- One PV strip, 27 m long, 1 m high in a rear-ventilated rainscreen
- Glass-glass PV modules with high-efficiency back-contact c-Si cells
- Anti-glare surface structure
- Installed power ~ 5.3 kWp
- Operating since 2016
- Contact person: Helen Rose Wilson / Fraunhofer ISE

# CROSS-SECTIONAL ANALYSIS OF BIPV INSTALLATIONS

Apply matrix to real BIPV installations….

**first test runs… already lessons learned…. several iterations needed**

- It is very difficult to get data on real BIPV installations
- Information is not available for all four PI categories for some BIPV installations

- For the environmental PIs:
  - in addition to the impact from the manufacturing phase, also material replacement effects (of the building materials) and End-of-Life phase (recycling, re-use of materials/components) can/should be taken into account
  - so far only PV was taken into account but not the substructure and glass

➢ close cooperation with the experts within Task 12 required

The application of the multidimensional evaluation matrix on realized BIPV projects (B4) allows for comparing the overall performance of a BIPV - installations and identify best-practice examples (B5) -> publication

PVPS

# Thank you for your interest and attention!
# Do you have any comments or questions?

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