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LCA analysis of a roof mounted PV system: A Romanian case study

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Methodology

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K2 Base is a **free** innovative **planning tool** that enables fast, safe and accurate planning of PV projects project for **pitched and flat roofs**.

https://base.k2-systems.com

- ✓ The design rules comply with the basic principles of structural design: SR EN 1990/NA: 2006.
- ✓ The snow loads are determined according to SR EN 1991-1-3/NA: 2017.
- ✓ The wind loads are determined according to SR EN 1991-1-4/NB: 2017.
- ✓ Service life is recognised according to 'Eurocode EN 1991 - Action on structures, Snow loads' and 'Eurocode EN 1991 - Actions on structures, Wind actions'.

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Scenario 1

East – West Oriented PV panels

Roof	Power	Quantity	Total power
Roof 1	550 Wp	80	44 kWp
Roof 2	550 Wp	36	19.8 kwp
Total		116	63.8 kWp

Scenario 2

South Oriented PV panels

Roof	Power	Quantity	Total power
Roof 1	550 Wp	72	39.6 kWp
Roof 2	550 Wp	36	19.8 kwp
Total		108	59.4 kWp

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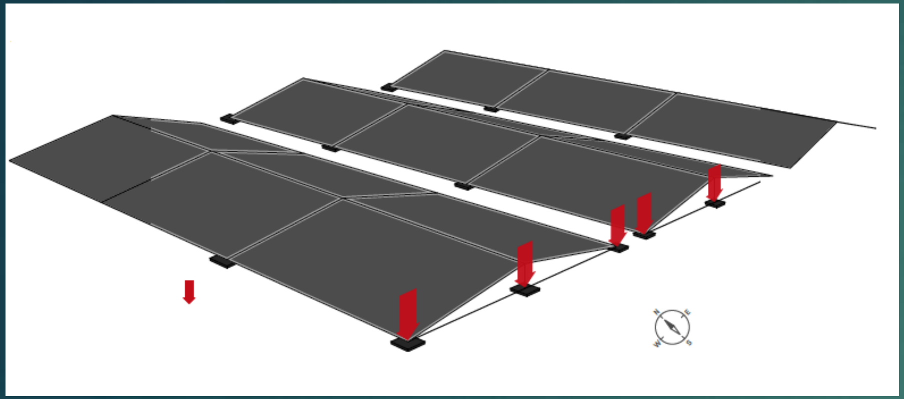
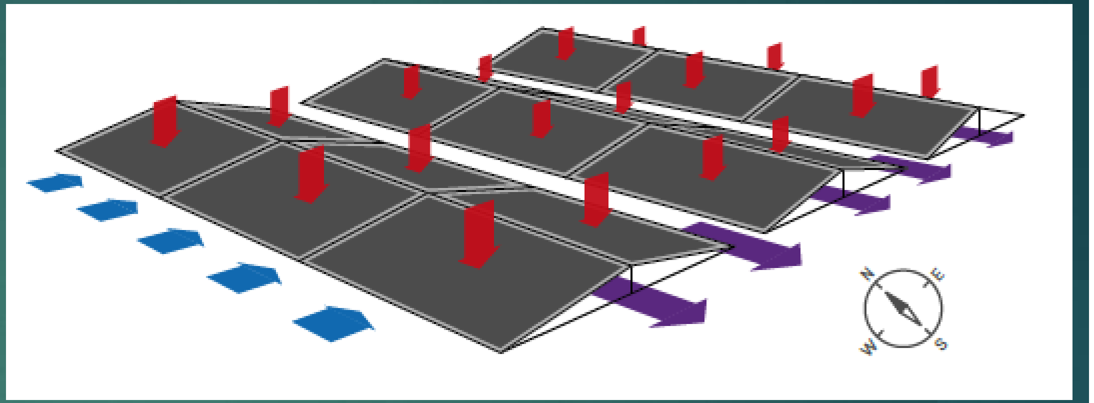
Structural analysis - Scenario 1

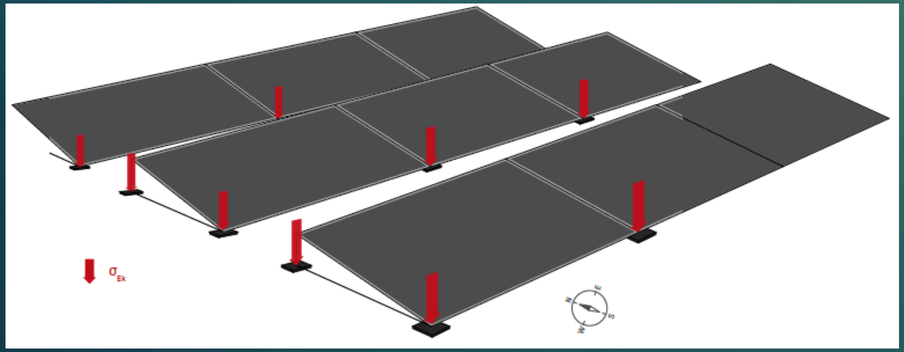
East – West Oriented PV panels

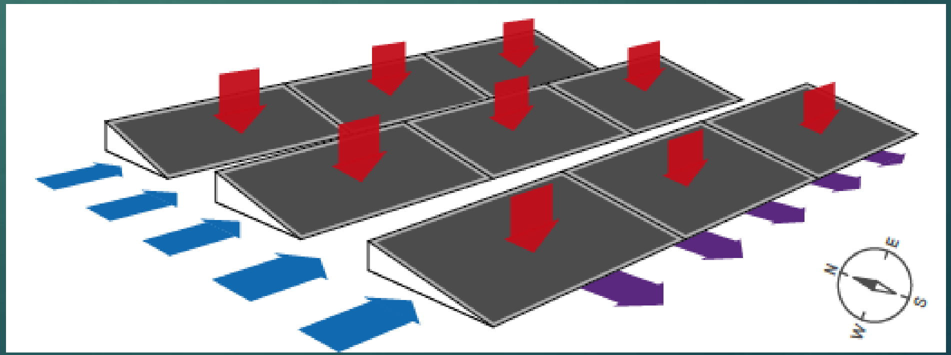




Structural analysis - Scenario 2

South Oriented PV panels





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Loads of the PV systems on the Artificial Intelligence Research Institute building

Orientation	Placement	Aluminium structure [kg]	Ballast [kg]	Total weight per roof [kg]	Total weight [kg]
South	Top roof	365.8	2561.0	2926.8	**7983.2**
	Bottom roof	697.4	4359.0	5056.4	
East-West	Top roof	192.4	258.0	450.4	**1900.5**
	Bottom roof	414.1	1036.0	1450.1	

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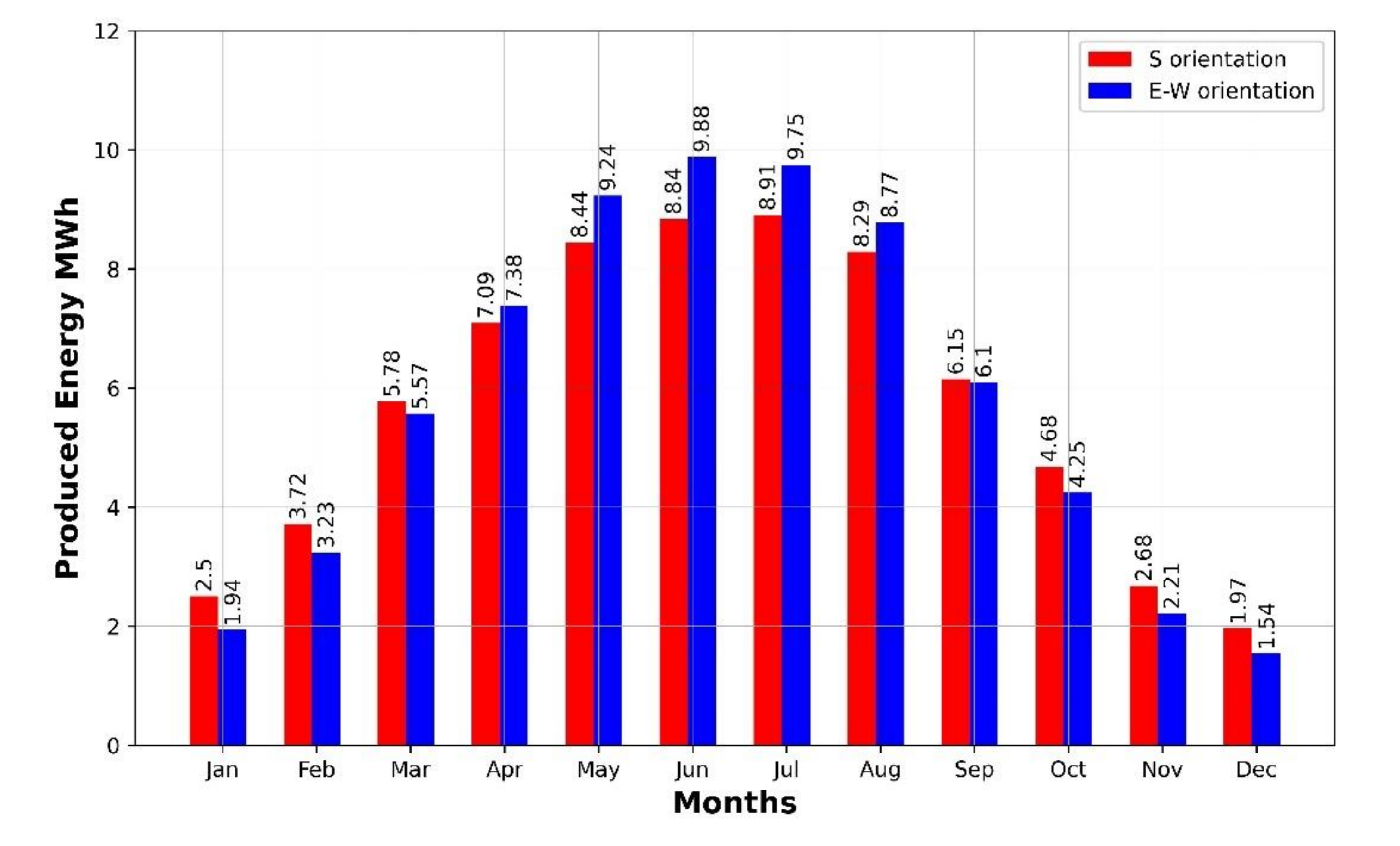
Energy production of the two scenarios



Scenario	PV modules	Specific production [KWh/kWp/year]	Produced energy [MWh/year]
East-West	116	1095	69.86
South	108	1162	69.04

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Life Cycle Assessment

Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle.

LCA covers a broad range of environmental issues (around twelve)

Climate change
Ozone depletion
Acidification
Eutrofication aquatic freshwater

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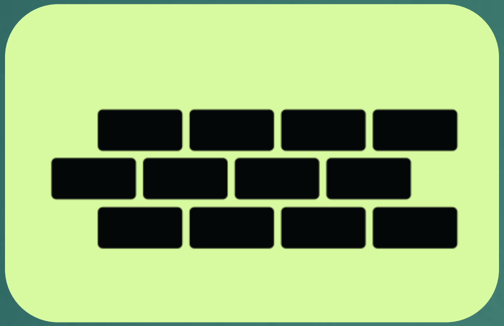
LCA methodology

ISO 14040:2006 Environmental management. Life cycle assessment. Principles and framework
ISO 14044:2006 Environmental management. Life cycle assessment. Requirements and guidelines

Definition of goal and scope



Inventory analysis

Life Cycle Impact assessment

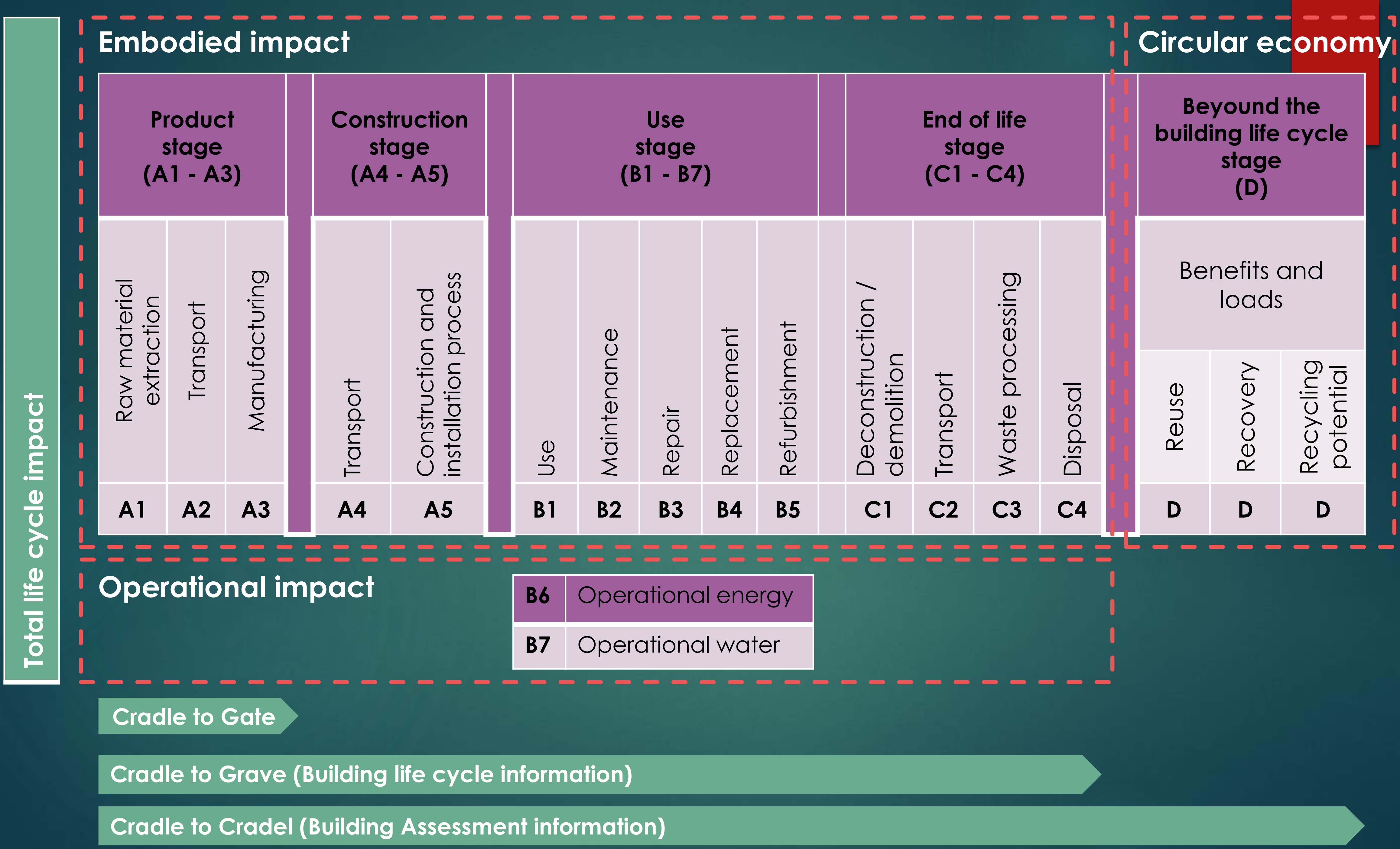
Interpretation

Intended application, reasons for carrying out the study, functions, system boundary

Data collection, calculating data, allocation

Classification, characterization, characterization model, normalization, ...

Interpretation of results, conclusions, limitations and recommendations



Total life cycle impact
Embodied impact
Circular economy
Product stage (A1 - A3)
Construction stage (A4 - A5)
Use stage (B1 - B7)
End of life stage (C1 - C4)
Beyound the building life cycle stage (D)
Raw material extraction
Transport
Manufacturing
Transport
Construction and installation process
Use
Maintenance
Repair
Replacement
Refurbishment
Deconstruction / demolition
Transport
Waste processing
Disposal
Benefits and loads
Reuse
Recovery
Recycling potential
A1
A2
A3
A4
A5
B1
B2
B3
B4
B5
C1
C2
C3
C4
D
D
D
Operational impact
B6
Operational energy
B7
Operational water
Cradle to Gate
Cradle to Grave (Building life cycle information)
Cradle to Cradel (Building Assessment information)

ABOUT ONE CLICK LCA

World-leading Carbon & Life-cycle Metrics Software.

MADE FOR CONSTRUCTION

Buildings and Renovation, Infrastructure, Product EPDs, CSR

COMPLIES WITH 40+ CERTIFICATIONS

BREEAM, LEED, DGNB, HQE/ E+C-, CEEQUAL, etc.

INTEGRATE WITH YOUR DESIGN TOOLS & 40+ DATABASE

Revit, BIM, IFC file. IESVE, other tools.

One Click LCA

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Easy to use tools for construction sustainability metrics and impact reduction

LIIFE CYCLE ASSESSMENT

LIFE CYCLE COSTING

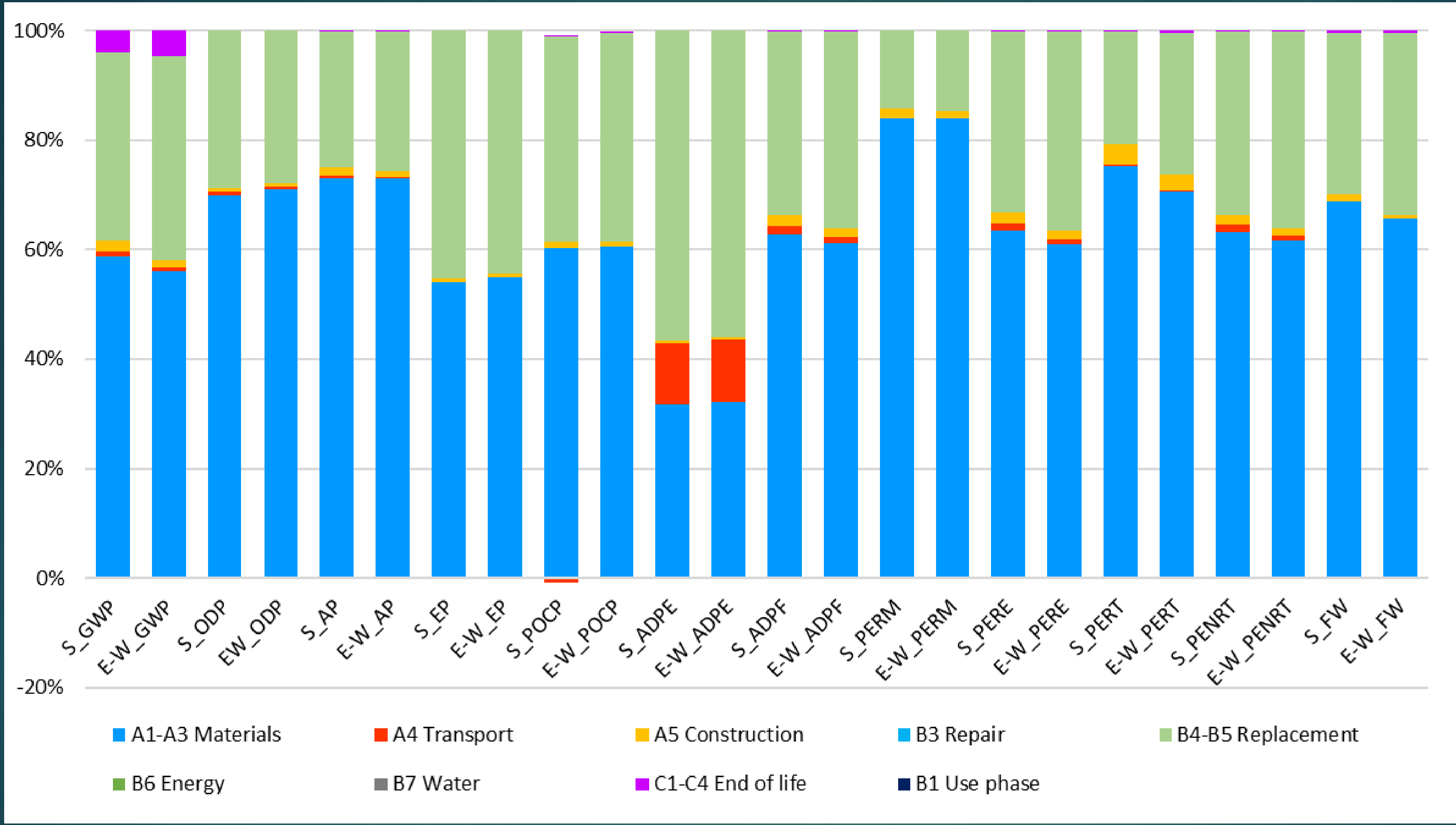
EMBODIED CARBON REDUCTION

EARLY DESIGN OPTIMIZATION

CIRCULARITY ASSESSMENT

EPDs GENERATION

Life cycle impacts by stage for South (S) and East-West (E-W) orientation



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Global Warming Potential (GWP); Acidification Potential (AP); Ozone Depletion Potential (ODP); Eutrophication Potential (EP); Photochemical Ozone Creation Potential (POCP); Abiotic Depletion Potential for Fossil Resources (ADPF); Abiotic Depletion Potential for Non-Fossil Resources (ADPE); Total Use of Renewable Primary Energy Resources (PERT); Total Use of Non-Renewable Primary Energy Resources (PENRT); Renewable Primary Energy Resources as Raw Materials (PERM); Renewable Primary Energy Resources excluding Raw Materials (PERE); Net Fresh Water (FW)

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LCA results for PV system

Category	Units	Orientation South	Orientation E-W
GWPtotal	kg CO2-eq	8.32E+04	7.98E+04
ODP	kg CFC11-eq	1.08E-02	1.11E-02
AP	kg SO2-eq	6.16E+02	6.12E+02
EP	kg PO4-eq	3.74E+02	3.80E+02
POCP	kg NMVOC	2.12E+02	2.14E+02
ADP-minerals and metals	kg Sb-eq	1.70E+01	1.72E+01
ADP-fossil	MJ	9.18E+05	8.86E+05
PERM	MJ	2.39E+03	2.37E+03
PERE	MJ	8.02E+05	7.35E+05
PERT	MJ	1.43E+05	1.23E+05
PENRT	MJ	1.07E+06	1.03E+06
FW	m3	2.46E+03	2.32E+03

Contribution of PV system's components to the environmental impact indicators for South (S) and East-West (E-W) orientation

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Energy PayBack Time (EPBT)

The **Energy PayBack Time (EPBT)** indicator serves as a valuable **tool for assessing the sustainability of a photovoltaic (PV) system**.

EPBT measures how long it takes for a PV system to **produce enough energy to offset the energy used** to create and install it, resulting in a net energy gain for the user. However, this indicator's calculation is **contingent on a multitude of influencing factors**, including:

1. Type of PV Module;
2. Efficiency of conversion;
3. Insolation;
4. Performance Ratio;
5. Installation Type;
6. Support Structure;
7. Application;
8. Grid efficiency.

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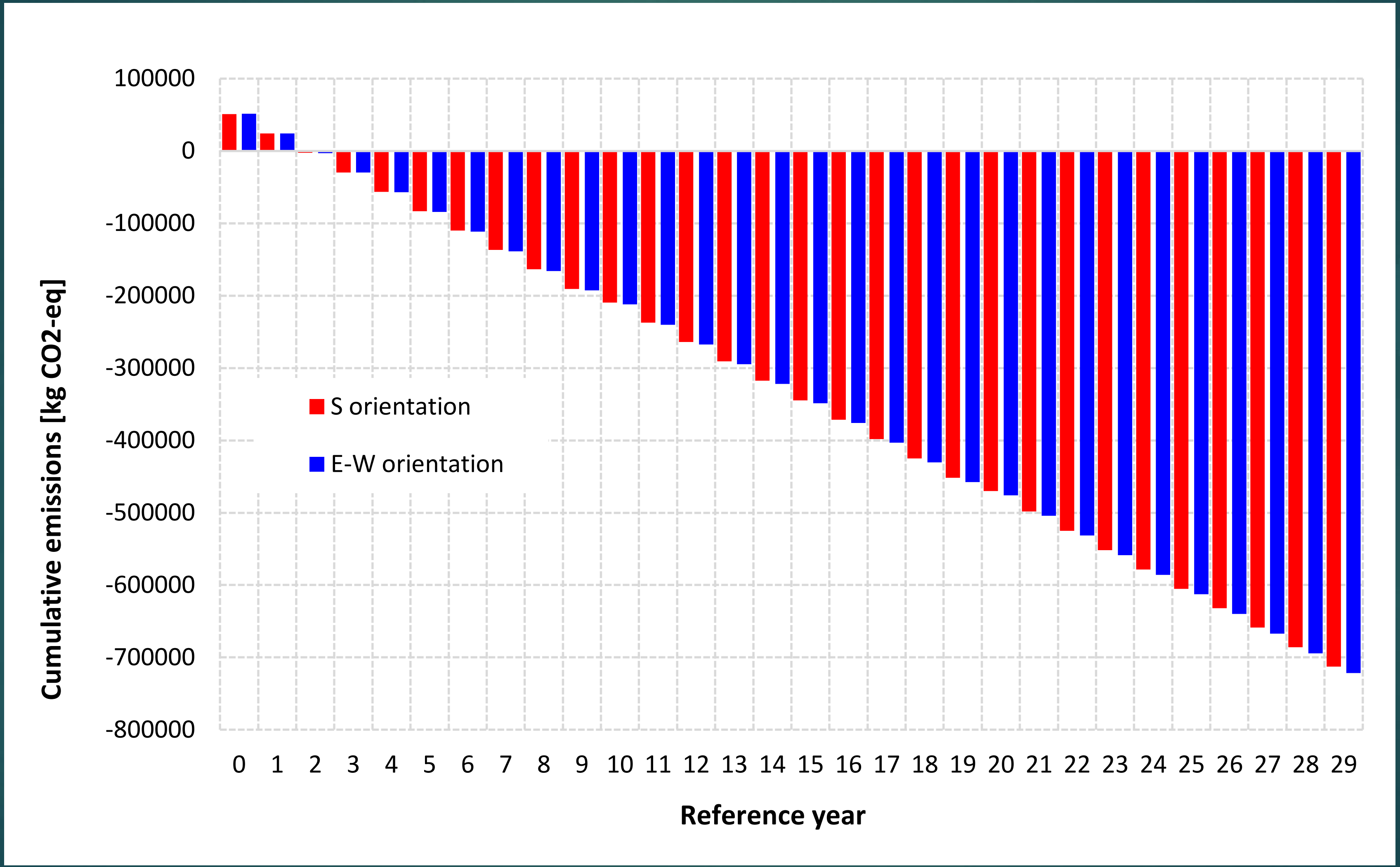
Energy PayBack Time (EPBT)

$$EPBT = (Emat + Emanuf + Etrans + Einst + E_{EOL})/((Eagen/\eta\_G) - E_{O\&M})$$

E_{mat} - energy to produce materials [MJ oil-eq]; E_{manuf} - energy to manufacture [MJ oil-eq]; E_{trans} - energy to transport materials used during the life cycle [MJ oil-eq]; E_{inst} - energy to install the system [MJ oil-eq]; E_{EOL} - energy for end-of-life management [MJ oil-eq]; $E_{O\&M}$ - annual energy for operation and maintenance [MJ oil-eq]; E_{agen} - annual electricity generation [kWh]; η_G - the grid efficiency [kWh electricity/ MJ oil-eq].

	Energy production [MWh]	EPBT (consumed directly) [years]	EPBT (injected) [years]
South	1913.72	2.54	6.36
East-West	1936.96	2.39	5.97

Yearly global warming and benefits of PV system for South (S) and East-West (E-W) orientation



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Conclusions

The **study examines two solar PV systems** – one with south-oriented panels and the other with east-west-oriented ones - and their potential and environmental impact. The outcomes obtained unveil:

(i) The aluminium structures for hosting the modules for **the E-W choice have a lower weight** (606.5 kg) than the South scenario (1063.2 kg);
(ii) The **ballast required** by the installation is **1294 kg and 6920 kg for the E-W and S** panels-oriented;
(iii) With a configuration of **116 modules the E-W scenario has higher annual energy production** (69.86MWh/year) compared to the South scenario (69.04 MWh/year for 108 modules);
(iv) The **E-W oriented PV system has lower emissions** because of the Aluminium structure (5100 and 9000 kg CO_2-eq) for E-W and South orientation respectively.

Selecting the right design configuration is crucial for photovoltaic systems, as it impacts the potential, environment, and performance of various orientations.

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THANK YOU

GRACIAS

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