Climate Risk Index for SMEs with High Energy Cost Intensity

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Summary

Introduction to the CLIMASAFE Project

Project Context and Rationale

The project CLIMASAFE – Management of Extreme Climate Events and Resilience: Strategies and Tools for Energy-Intensive SMEs was conceived with the objective of addressing an increasingly structural challenge for the cross-border productive system: the interaction between climate change, energy systems, and the vulnerability of energy-intensive SMEs.

In recent years, the intensification and increasing frequency of extreme climate events—heatwaves, intense precipitation, floods, and peaks in electricity demand—have highlighted the need to integrate climate risk into the ordinary management of businesses. In particular, SMEs with high energy cost intensity are exposed to significant operational and financial risks arising from their dependence on electricity continuity, the sensitivity of production processes to climate variations, and their limited capacity to absorb shocks.

CLIMASAFE addresses this scenario by developing an integrated methodological approach and operational tools aimed at:

- analyzing climate–energy risk at both territorial and company levels;
- supporting SMEs in understanding their exposure profile;
- strengthening energy resilience and adaptive capacity;
- promoting a replicable and transferable model within the cooperation area and beyond.

The project is structured along three main directions:

1. Development of an integrated knowledge base (territorial, climatic, and energy database);
2. Development of the Climate–Energy Risk Index (CERI);
3. Operational testing and development of digital decision-support tools.

The launch event covered in this report takes place in the final phase of WP1 and represents the public presentation of the CERI Index, as well as the transition toward the implementation phase foreseen in WP2.

The CLIMASAFE project is co-financed by the European Union under the Interreg VI-A Italy–Slovenia Programme.

The preparation of this deliverable involved the joint collaboration of the project partners together with the associated partners.

1. Methodology for the Calculation, Normalization, and Interpretation of the Climate–Energy Risk Index (CERI)

This section provides a systematic and detailed description of the methodology adopted for the construction, calculation, and interpretation of the Climate–Energy Risk Index (CERI), developed within the CLIMASAFE project as a synthetic tool for assessing the operational risk faced by energy-intensive SMEs in relation to the impacts of climate change.

The CERI is conceived as a composite index capable of integrating heterogeneous risk dimensions into a single normalized measure, while ensuring methodological transparency and traceability of the components contributing to the final value.

The methodological framework of CERI is based on the principle that climate–energy risk cannot be described solely in terms of physical hazard, but rather emerges from the interaction between the probability and intensity of extreme climate events, the structure of energy consumption, and the degree of dependence of firms on the continuity of energy supply, as well as their capacity to adapt and respond to such events.

In this sense, CERI lies at the intersection of climate risk analysis and energy vulnerability assessment, adopting an operational perspective oriented toward risk management and intervention planning.

1.1 Conceptual Structure of the CERI Index

The CERI is structured as a composite index combining three fundamental dimensions of risk: climate hazard, energy exposure, and adaptive capacity. These dimensions are formalized in a way that allows them to be quantified through measurable indicators and normalized on a common scale, enabling comparability across firms, sectors, and territories.

The climate hazard represents the external component of risk and describes the probability and intensity of extreme climate events relevant to the production system, with reference to specific territorial conditions.

The energy exposure describes the degree to which a company is exposed to the effects of such events, depending on the structure of energy consumption, the characteristics of the production process, and the dependence on the continuity of electricity supply.

The adaptive capacity represents the internal component of risk and measures the firm’s ability to prevent, absorb, and manage the impacts of climate events through technological, organizational, and infrastructural solutions.

1.2 Mathematical Formulation of CERI

Based on the conceptual structure described above, the CERI is formalized according to the following relationship:

$$\text{CERI}=\frac{RxE}{A}$$

where:

- **R** represents the level of **climate hazard**;
- **E** represents **energy exposure**;
- **A** represents **adaptive capacity**.

This formulation intuitively reflects the fact that risk increases with higher hazard and exposure, while it decreases as adaptive capacity increases.

The choice of a multiplicative and divisive formulation reflects the intention to assign adaptive capacity a central mitigation role in the overall risk assessment.

1.3 Definition and Normalization of the R Component – Climate Hazard

The R component is defined on the basis of a set of climate indicators selected according to their relevance for the productive activities analyzed.

These indicators include in particular:

- the frequency and intensity of heatwaves and cold waves;
- the probability of intense precipitation and flood events.

The data used derive from historical series and climate projections with a time horizon to 2050, developed on the basis of IPCC scenarios and georeferenced at the territorial scale.

Each climate indicator is normalized on a discrete scale, generally ranging from 1 to 5, where the minimum value corresponds to a very low hazard level and the maximum value corresponds to an extreme hazard level.

Normalization is carried out using thresholds defined on the basis of:

- the statistical distribution of climate data;
- the available scientific evidence (*IPCC AR6*);
- institutional sources (*Copernicus, regional environmental agencies*).

The final value of R for each enterprise or territorial cluster is obtained by aggregating the scores associated with the different types of climate hazard, according to a logic that takes into account their specific relevance for the sectors analyzed.

The base model includes the following climate hazards:

- heatwaves;
- cold waves;
- intense precipitation / flood events.

Quantitative climate indicators (for example number of days >35 °C per year or number of events >50 mm/24h) are converted into qualitative scores on a discrete scale from 1 to 5, according to predefined thresholds.

Hazard Scoring Scale

Level	Score	Interpretation
Very Low	1	Negligible risk
Low	2	Limited risk
Moderate	3	Medium risk
High	4	Significant risk
Extreme	5	Critical risk

Calculation of the R Score

The R score is calculated by aggregating the normalized values of the individual climate hazards relevant to the territory or production cluster considered, according to weighting criteria consistent with sectoral sensitivity and the expected impact on productive assets.

$$R=\frac{\sum_{i=1}^{n} R_i}{n}$$

where $\boldsymbol{R_i}$ represents the score associated with each climate hazard considered.

CASE STUDY – ITA

Energy-intensive manufacturing SME located in the Province of Venice, metallurgical sector (ATECO 24).

Climate indicators considered: *RCP 8.5 scenario, horizon 2036, anomaly 2021–2050 compared to 1990.*

Indicator	Observed Value	Qualitative Class	Score
SU30	15 days > 30 °C	Low	2
TAS	+1.2 °C	Low	2
CDDs	121	Low	2
HWDI	1 day	Low	2
R95pTOT	−2%	Low	2

$$R=\frac{2+2+2+2+2}{5}=2$$

R = 2

CASE STUDY – SI

Metallurgical company located in Ajdovščina – Goriška – Sector: metal processing / light metallurgy.

Scenario: *RCP 8.5, anomaly 2021–2050 compared to the period 1981–2010.*

Indicator	Observed Value	Qualitative Class	Score
SU30	Significant increase in days > 30 °C	High	4
TAS	Increase in average temperature: +1–2 °C	Moderate–High	4
CDDs	Reduction in consecutive dry days but increase in summer water stress	Moderate	3
HWDI	Increase in the frequency and duration of heatwaves	High	4

Indicator	Observed Value	Qualitative Class	Score
R95pTOT	Increase in intense precipitation events	High	4

$$R=\frac{4+4+3+4+4}{5}=3{,}8$$

R = 3.8

These trends highlight a future Slovenian climate characterized by a significant increase in temperatures and a greater intensity of extreme events.

1.4 Definition and Normalization of the E Component – Energy Exposure

The E component represents the energy exposure of the company and is calculated on the basis of indicators describing the intensity and structure of energy consumption, as well as the degree of dependence of production processes on the continuity of electricity supply.

Particular attention is given to electricity consumption, as it is the energy form most affected by extreme climate events and demand variability.

Energy exposure is expressed in terms of normalized energy intensity, for example through indicators such as electricity consumption per unit of surface area or per unit of production output. These indicators are subsequently weighted according to their relevance to operational risk, assigning higher weights to critical consumption components, such as summer cooling and motive power.

The value of E is normalized on a scale comparable to that used for the R component, in order to allow the integration of the two dimensions in the calculation of the CERI.

Energy Indicators Used

The indicators are **derived from Energy Audits** and are expressed in toe/m^2:

- **EnPI$_1$**: Total electricity consumption /m^2
- **EnPI$_2$**: Other energy carriers /m^2
- **EnPI$_3$**: Electricity consumption for summer cooling /m^2
- **EnPI$_4$**: Electricity consumption for lighting /m^2
- **EnPI$_5$**: Electricity consumption for motive power /m^2

Each **EnPI** is associated with a weighting coefficient **w_i**.

$$\sum w_i = 1$$

Example of Standard Weighting

Indicator	**Weight (w_i)**
$EnPI_1$	0,30
$EnPI_2$	0,20
$EnPI_3$	0,20
$EnPI_4$	0,10
$EnPI_5$	0,20

The distribution of weights reflects the greater importance assigned to overall electricity consumption and to the components directly linked to operational continuity (summer cooling and motive power).

Calcolo della componente E

The E component is calculated as the weighted sum of the normalized energy indicators:

$$E = \sum_{i=1}^{5} w_i * EnPI_i$$

Weights may be adapted according to the production sector, while maintaining the methodological structure.

CASE STUDY – ITA

SME in the metallurgy sector – Venice

- *Annual electricity consumption: 104,113 MWh*
- *Production area: 20,000 m²*
- *Toe conversion factor: 0.000187*

Conversion:
104,113 MWh = ***19.47 toe***

Estimated energy indicators (EnPI)

Indicator	Value (toe/m²)	Weight
EnPI$_1$ – Total electricity energy	0.448	0.30
EnPI$_2$ – Other energy carriers	0.120	0.20
EnPI$_3$ – Summer cooling	0.180	0.20
EnPI$_4$ – Lighting	0.070	0.10
EnPI$_5$ – Motive power	0.310	0.20

$$E = (0{,}30 \times 0{,}448) + (0{,}20 \times 0{,}120) + (0{,}20 \times 0{,}180) + (0{,}10 \times 0{,}070) + (0{,}20 \times 0{,}310)$$

$$E = 0{,}263\ \text{TEP}/m^2$$

CASE STUDY – SLO

Consumo annuo di energia elettrica dell'azienda metallurgica presso Ajdovscina.: 221.150 kWh/anno
Superficie produttiva: 10.000 m² (stima)
Fattore di conversione in toe: 0,000187

221.150 kWh = **41,35 toe**

Indicatori energetici stimati (EnPI)

Indicatore	Value (toe/m²)	Weight
EnPI$_1$ – Total electricity consumption	0,004135	0,30
EnPI$_2$ – Other energy carriers	0,001108	0,20
EnPI$_3$ – Summer cooling	0,001662	0,20
EnPI$_4$ – Lighting	0,000647	0,10
EnPI$_5$ – Motive power	0,001861	0,20

Calculation of the E Component

$$E = (0{,}30 \times 0{,}004135) + (0{,}20 \times 0{,}001108) + (0{,}20 \times 0{,}001662) + (0{,}10 \times 0{,}000647) + (0{,}20 \times 0{,}001861)$$

$$E = 0{,}00223\ \text{TEP}/m^2$$

E = 0.002

The resulting value represents the company's weighted energy intensity, expressed in toe/m², which forms the basis for the subsequent normalization of the E component for the calculation of the CERI.

1.5 Calculation of the E Component – Regulatory References

The methodology developed in this deliverable is embedded within a well-established European regulatory framework on energy efficiency and energy consumption monitoring, with particular reference to Directive 2012/27/EU on energy efficiency (Energy Efficiency Directive – EED) and its subsequent revisions and recasts, culminating in Directive (EU) 2023/1791.

This regulatory framework introduces and strengthens the requirement for periodic energy audits for large enterprises and energy-intensive companies, recognizing the energy audit as a fundamental tool for the structured understanding of consumption profiles and for identifying energy efficiency improvement measures.

In particular, Article 8 of Directive 2012/27/EU, as amended, establishes that energy audits must:

- be based on measured and traceable operational data;
- provide a detailed analysis of the energy consumption profiles of installations and production processes;
- adopt an approach that is proportionate and representative of the actual functioning of the company.

These requirements are further reinforced by the promotion of energy management systems compliant with the ISO 50001 standard, which may constitute an alternative to mandatory audits while sharing the same principle of systemic modelling of energy consumption and business processes.

The corporate energy model adopted for defining the E – Exposure component of the CERI is fully consistent with this regulatory framework, as it is based on:

- an analytical representation of machinery and production lines;
- the use of verifiable technical parameters;
- the reconstruction of temporal consumption profiles.

In this sense, the methodological approach does not merely meet the minimum regulatory requirements, but extends their applicability, allowing the results of energy audits to be leveraged for assessing climate exposure and the resilience of the production system.

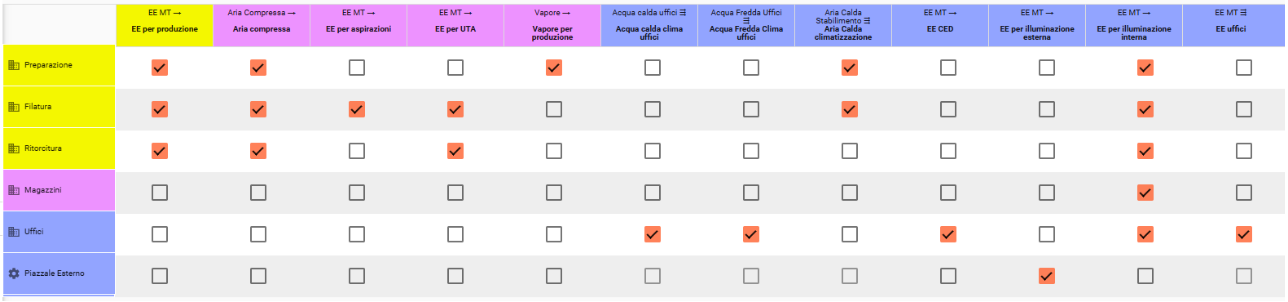
1.6 The Energy Model Underlying the Calculations

The construction of the E – Exposure component of the CERI is based on the use of a dedicated software platform for corporate energy profiling, designed to reconstruct in a coherent and verifiable way the energy consumption profiles of manufacturing and service companies.

The platform adopts a matrix-based approach that cross-references:

- the physical areas of the organization (site, building, department, functional area);
- the main energy uses.

This enables a structured and transparent representation of energy consumption and the related operational drivers, ensuring consistency between technical data, plant configuration, and production dynamics.



	EE MT → **EE per produzione**	Aria Compressa → **Aria compressa**	EE MT → **EE per aspirazioni**	EE MT → **EE per UTA**	Vapore → **Vapore per produzione**	Acqua calda uffici ☰ **Acqua calda clima uffici**	Acqua Fredda Uffici ☰ **Acqua Fredda Clima uffici**	Aria Calda Stabilimento ☰ **Aria Calda climatizzazione**	EE MT → **EE CED**	EE MT → **EE per illuminazione esterna**	EE MT → **EE per illuminazione interna**	EE MT ☰ **EE uffici**
Preparazione	☑	☑	☐	☐	☑	☐	☐	☑	☐	☐	☑	☐
Filatura	☑	☑	☑	☑	☐	☐	☐	☑	☐	☐	☑	☐
Ritorcitura	☑	☑	☐	☑	☐	☐	☐	☐	☐	☐	☑	☐
Magazzini	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☑	☐
Uffici	☐	☐	☐	☐	☐	☑	☑	☐	☑	☐	☑	☑
Piazzale Esterno	☐	☐	☐	☐	☐	☐	☐	☐	☐	☑	☐	☐

Figure 1 – Corporate energy model: matrix mapping of areas and energy consumption

Through the modeling of machinery and processes, based on essential technical parameters and on real or estimated operational data, the platform generates temporal consumption profiles for each area–use combination and for each energy carrier.

An energy balance reconciliation module ensures consistency between bottom-up estimates and the available top-down data (main meters, billing data), guaranteeing the closure of the overall energy balance at the site or company level.

The integration of this platform within the deliverable makes it possible to overcome purely aggregated approaches, providing a solid, replicable, and verifiable data basis for quantifying energy exposure. The resulting outputs directly feed the E component of the composite climate indicator, strengthening its methodological robustness, while at the same time enabling the valorization of data derived from energy audits and establishing an operational link with subsequent climate risk and adaptation analyses.

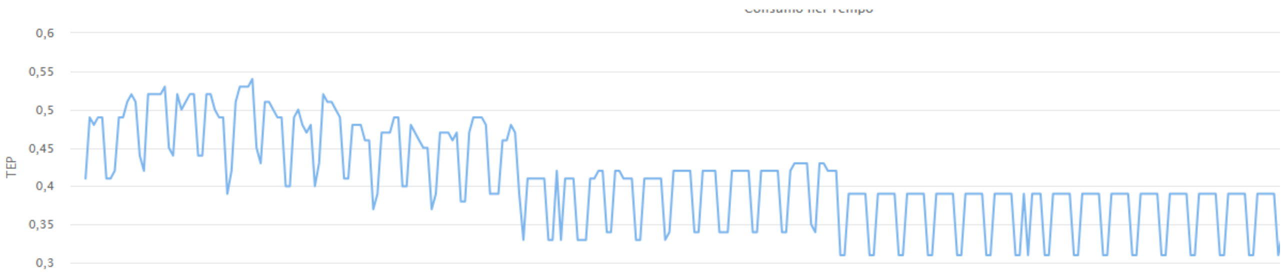


Figure 2 – Example of a reconstructed consumption profile for a manufacturing company

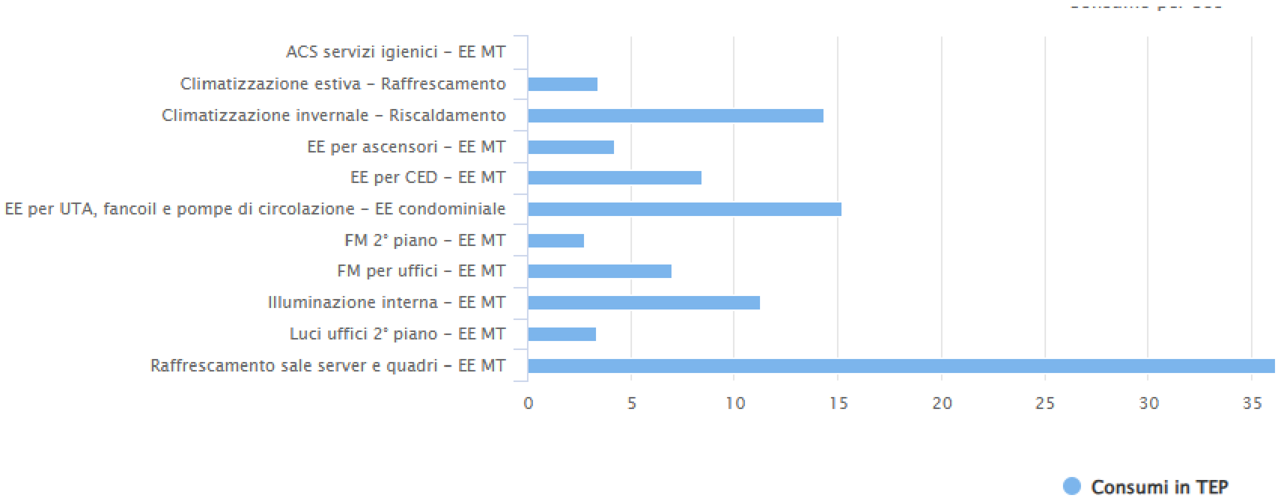


Figure 3 – Representation of total annual energy consumption for a service company

1.7 Derivable Indicators

The energy profiling platform makes it possible to derive a structured set of quantitative and normalized energy indicators, which can be used both to support energy audits and to feed the E – Exposure component of the composite climate indicator.

Thanks to the coherent reconstruction of consumption profiles by area, energy use, and energy carrier, indicators can be calculated on homogeneous bases and compared over time and across different contexts.

Among the main indicators is the share of energy self-production, expressed as the percentage of total demand covered by internal sources (for example photovoltaic systems or cogeneration), calculated both on an annual basis and on temporal profiles. This indicator is useful for assessing the degree of dependence on external energy supply and the exposure to energy shocks.

The platform also allows the estimation of energy intensity indicators, such as specific consumption per unit of surface area (kWh/m²) or per unit of output/service, normalizing consumption with respect to the physical and operational size of the organization.

Another set of indicators concerns the breakdown of consumption by energy use, with particular reference to HVAC systems (heating and cooling). In this case it is possible to quantify:

- the percentage share of total consumption attributable to HVAC uses;
- absolute consumption (kWh);
- normalized consumption.

This provides a direct measure of the company's sensitivity to external climatic conditions. Similar indicators can be calculated for other relevant uses (production processes, lighting, auxiliary services), enabling a granular interpretation of energy exposure.

1.8 Definition and Normalization of the A Component – Adaptive Capacity

The A component measures the adaptive capacity of the company and represents a key element of the CERI, as it allows differentiation between risk situations that may appear similar in terms of hazard and exposure, but are significantly different in terms of resilience.

Adaptive capacity is assessed through a set of indicators describing the presence of technological, organizational, and infrastructural solutions aimed at managing climate–energy risk.

These indicators include, for example:

- the energy efficiency level of buildings and plants;
- the presence of energy backup systems;
- the use of renewable energy sources;
- the existence of emergency plans and operational procedures for managing extreme events;
- the planning of adaptation investments.

As with the other components, the scores are normalized on a discrete scale, where higher values indicate greater adaptive capacity.

Evaluation Criteria and Scoring Scale

The assessment is based on:

- the presence of energy backup systems;
- the energy efficiency of buildings and plants;
- the use of renewable energy sources;
- emergency plans and operational procedures;
- planned adaptation investments.

Scoring Scale

Score	Level	Summary Criterion
1	Absent	No adaptation measures
2	Weak	Isolated and non-systemic measures
3	Basic	Minimum planned measures
4	Good	Measures integrated into processes
5	Comprehensive	Structural and managerial adaptation

CASE STUDY – ITA

Qualitative Assessment of the Company

Criterion	**Assessment**	**Score**
Energy backup systems	Absent	1
System/plant efficiency	Medium	3
Renewable energy sources	Absent	1
Emergency plans	Partial	2
Adaptation investments	Not planned	1

$$A = \frac{1+3+1+2+1}{5} = 1{,}6$$

A = 1.6

CASE STUDY – SLO

Qualitative Assessment of the Metallurgical Company in Ajdovščina

Criterion	**Assessment**	**Score**
Energy backup systems	Absent	1
System efficiency	Weak – aging rented building	2

Criterion	Assessment	Score
Renewable energy sources	Absent	1
Emergency plans	Absent	1
Adaptation investments	Basic – planned installation of a summer cooling system	3

$$A = \frac{1+2+1+1+3}{5} = 1{,}6$$

A = 1.6

1.9 Interpretation of CERI Values and Decision Thresholds

The final CERI value is expressed on a normalized scale that allows companies to be classified into increasing risk categories. Each category is associated with decision thresholds that guide the identification of intervention priorities and the definition of the most appropriate adaptation measures.

In this sense, CERI does not represent an end in itself, but rather an operational tool for risk management.

The final CERI value allows companies to be classified into the following risk categories:

Class	CERI (toe/m²)	Interpretation
Very Low	0–0.010	Negligible risk
Low	0.011–0.020	Limited risk
Medium	0.021–0.030	Significant risk
High	0.031–0.050	High exposure
Critical	>0.050	Severe risk

CASE STUDY – Risultati

SLO – Values obtained from the analysis

- **R = 3,8**
- **E = 0,002**
- **A = 1,6**

CERI=$\frac{RxE}{A}$

CERI=$\frac{3,8x0,002}{1,6} = 0,004$

CASE STUDY – Risultati

ITA – Values obtained from the analysis

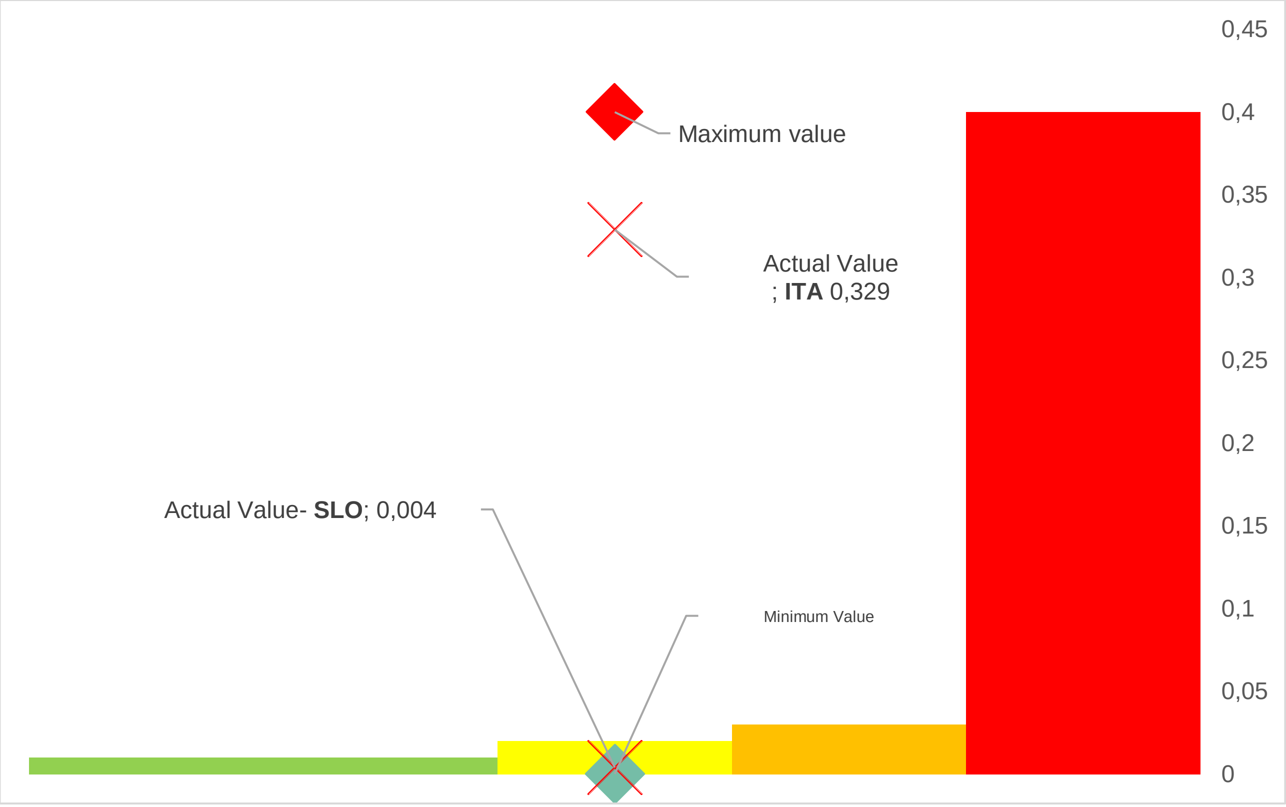
- **R = 2,0**
- **E = 0,263**
- **A = 1,6**

CERI=$\frac{RxE}{A}$

CERI=$\frac{2x0,263}{1,6} = 0,328$

Risk Classification

Case Study	Class	CERI Range	Interpretation
ITA	Critical	>0.050	Severe risk
SLO	Very Low	0–0.010	Negligible risk



The chart enables an integrated interpretation of the results of the Climate–Energy Risk Index (CERI) by linking the numerical value of the indicator to increasing risk classes and to the corresponding levels of intervention priority.

In the case study analyzed, concerning an energy-intensive manufacturing SME in the metallurgical sector located in the Province of Venice, the CERI value is 0.33, placing the company in the “Critical” risk class. This positioning is not attributable solely to the climate hazard of the territory, which in the period considered assumes moderate values (R = 2), but mainly results from the combination of high energy exposure of production processes (E = 0.263 toe/m²) and limited adaptive capacity (A = 1.6).

The chart highlights how, in the presence of significant energy consumption and a strong dependence on the continuity of electricity supply, even non-extreme levels of climate hazard can translate into high operational risk when resilience measures are insufficient. In this specific case, the significant share of electricity consumption related to motive power and summer cooling amplifies exposure to demand peaks associated with heatwaves, while the absence of energy backup systems, the limited integration of renewable energy sources, and the lack of structured emergency management plans reduce the company’s ability to absorb and manage potential disruptions or stress in the energy system.

The positioning in the “Critical” class therefore has a clear decision-making implication: the chart does not merely represent an abstract level of risk but signals the need for priority and structural interventions aimed both at reducing energy exposure (through efficiency measures, load optimization, and greater process flexibility) and at strengthening adaptive capacity (introduction of solutions for electricity continuity, improvement of building and plant performance, and formalization of procedures and response plans for extreme events).

In this sense, the case study demonstrates the central role of the index as a decision-support tool, highlighting how climate–energy risk for SMEs depends not only on external climatic conditions, but above all on the energy profile and the organizational and technological resilience of the company.

In the case of the metallurgical company in Ajdovščina, the Climate–Energy Risk Index (CERI) value is 0.004, placing the analysis in the “Very Low” class, corresponding to negligible risk. This result is mainly attributable to a favourable combination of factors: low energy exposure of production processes, limited dependence on energy-intensive consumption, and an adaptive capacity adequate to the climate events considered.

Under these conditions, even in the presence of potential climate variability, the expected operational impact on the production system remains limited and manageable, without the need for urgent structural interventions.

The positioning in the “Very Low” class therefore indicates a context characterized by good overall energy resilience, in which improvement actions may focus primarily on maintaining existing performance levels and on the adoption of incremental measures of efficiency and monitoring, rather than on priority or emergency interventions.

1.10 Application Cases and Use of CERI within the CLIMASAFE Project

The application of CERI to representative case studies allows the methodology to be validated and its operational usefulness to be demonstrated. Within the CLIMASAFE project, the index is applied to a sample of SMEs belonging to different sectors and located in various territorial contexts, highlighting how CERI values vary according to specific climatic, energy, and organizational conditions.

The application cases show how companies characterized by high energy exposure may present different levels of risk depending on their adaptive capacity, emphasizing the central role of investments in energy efficiency and resilience in reducing climate–energy risk.

2. Operational Applications, Pilot Actions, and Strategic Value of the Deliverable

The application of CERI is implemented through operational tools developed within the CLIMASAFE project, including a digital decision-support platform and a set of pilot actions targeting a representative sample of SMEs.

These applications make it possible to test the effectiveness of the index as an operational tool and to validate its usefulness in real-world contexts.

This deliverable therefore provides a solid and structured knowledge base for the management of climate–energy risk, contributing to strengthening the resilience of SMEs and supporting the development of integrated territorial policies in the Italy–Slovenia cross-border area.