Report on Climate Risk Analysis Related to Extreme Events for Energy-Intensive SMEs
D.1.1.1

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Summary

Project Context and Rationale

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

In recent years, the increasing intensity and frequency of extreme climate events—such as heatwaves, intense precipitation, floods, and peaks in electricity demand—have highlighted the need to integrate climate risk into routine business management. In particular, energy-intensive SMEs are exposed to significant operational and financial risks resulting from their dependence on electricity continuity, the sensitivity of production processes to climatic variations, and their limited capacity to absorb external shocks.

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

- analysing climate–energy risk at both territorial and company level;
- 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 around three main pillars:

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 described in this report takes place at the final stage of WP1 and represents the public presentation of the CERI Index, as well as the transition towards the application phase foreseen in WP2.

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

This deliverable has been developed through the joint contribution of the project partners, in collaboration with the associated partners.

1. Methodological Framework, Reference Context and Objectives of the Deliverable

This deliverable has been developed within the analytical and assessment activities foreseen by the CLIMASAFE project and represents the technical–scientific reference document for the characterisation of climate–energy risk affecting energy-intensive small and medium-sized enterprises (SMEs) operating in the cross-border area between Italy and Slovenia.

The document is conceived as a foundational tool for the development of the subsequent project phases, including the definition of pilot actions, the development of the digital decision-support platform, and the formulation of strategic recommendations supporting public policies and corporate adaptation strategies.

The general objective of the deliverable is to build an integrated knowledge framework capable of systematically explaining how climate change—through the intensification and increasing frequency of extreme events—interacts with energy systems and the productive structures of SMEs, generating new forms of operational risk.

In this context, the CERI – Climate–Energy Risk Index is adopted as the main methodological tool for the synthesis and interpretation of analytical results, enabling the translation of complex multidimensional information into a normalised and comparable indicator, suitable for supporting decision-making processes.

2. Territorial and Sectoral Scope of the Analysis

The analysis developed in this deliverable refers to the cross-border area identified by the CLIMASAFE project, characterised by strong economic and productive interconnections, but also by significant structural differences in terms of industrial organisation and energy resource management.

In particular, the focus is on the Italian province of Venice and the Friuli Venezia Giulia region, as well as on Slovenian municipalities with a high concentration of industrial activities, selected on the basis of energy consumption relevance and the presence of SMEs operating in energy-intensive sectors (*Primorsko-notranjska / Inner Carniola; Osrednjeslovenska / Central Slovenia; Gorenjska / Upper Carniola; Obalno-kraška / Coastal–Karst; Goriška / Gorizia Region*).

From a sectoral perspective, the analysis focuses on productive sectors that combine a high dependence on electricity with significant exposure to climate change impacts. These sectors include, in particular:

- agri-food industry,
- metallurgy,
- metal processing,
- mechanical engineering,
- furniture manufacturing.

The selection of these sectors allows the analysis of a diverse range of production processes, characterised by different energy consumption profiles and specific climate-related vulnerabilities, while ensuring comparability across different territorial contexts.

For the definition of energy-intensive enterprises, reference was made to the Italian regulatory framework, in which the concept of energy-intensive companies ("imprese energivore") plays a central role in characterising energy exposure.

According to the Ministerial Decree of 21 December 2017, as subsequently amended, companies are considered electricity-intensive when they have an average annual electricity consumption equal to or greater than 1 GWh and meet at least one of the following conditions:

(i) belonging to economic sectors identified as exposed to carbon leakage risk; or
(ii) having a ratio between electricity costs and Gross Value Added (GVA) equal to or greater than 20%.

For the purposes of the present analysis, the criteria relating to consumption above 1 GWh and carbon leakage classification are not applied. Companies are therefore considered energy-intensive when the ratio between total energy costs and Gross Value Added (GVA) is equal to or greater than 20%.

3. Mapping of Energy-Intensive SMEs and Identification of Territorial Clusters

The mapping of energy-intensive SMEs represents an essential preliminary phase of the climate–energy risk analysis, as it enables the identification of the spatial and sectoral distribution of production activities most exposed to the risks under investigation.

This activity was carried out through an integrated approach combining energy data analysis, sectoral classification of companies, and territorial analysis of production systems.

In the Italian context, the mapping is based on the analysis of Points of Delivery (POD) and the classification of economic activities according to ATECO codes.

Data on electricity consumption of non-domestic low-voltage users were obtained from the ARERA energy consumption portal, which provides information on the average consumption of productive activities supplied at low voltage.

In particular, electricity consumption data (expressed in kWh) aggregated on a monthly basis were used. These data can be consulted by region and province, with the possibility of disaggregation by:

- reference year,
- contractual power level,
- ATECO classification of economic activity.

The data—available both in graphical and tabular format in the "Attachments" section of the portal—derive from processing carried out by the Integrated Information System Manager (SII) on the basis of measurements provided by electricity distribution companies.

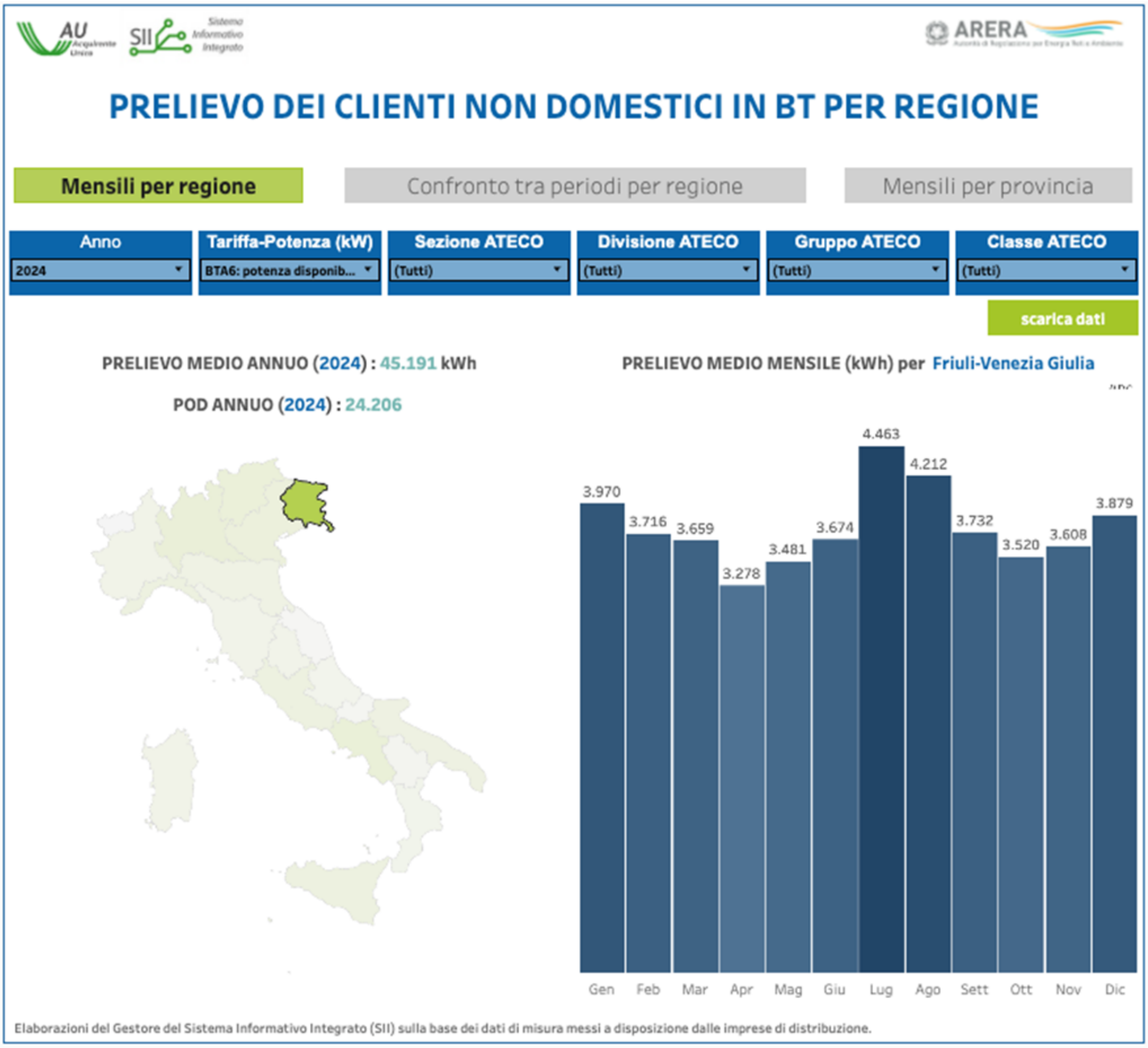


Figure 1 – Low-Voltage Electricity Withdrawals – Friuli Venezia Giulia

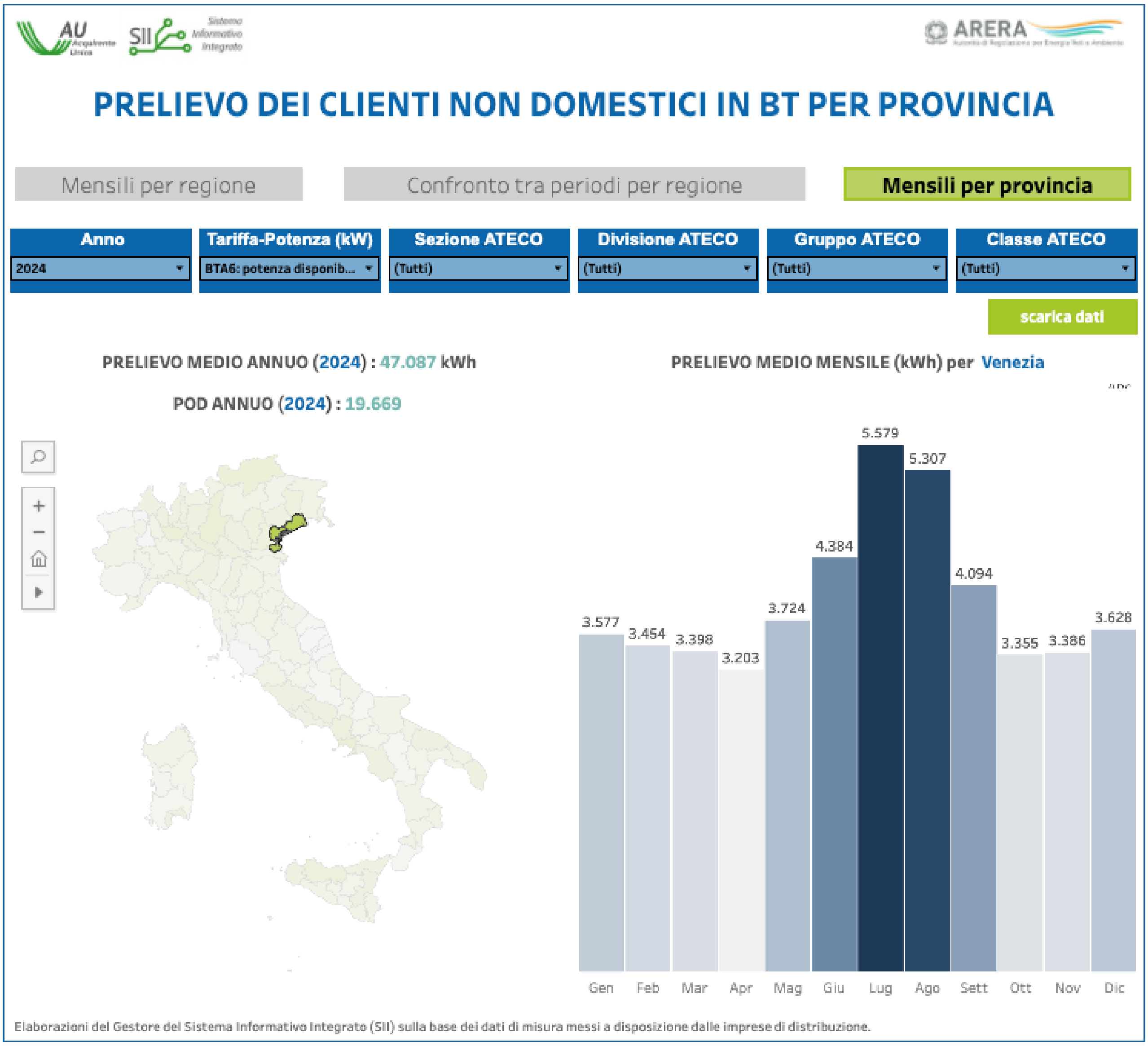
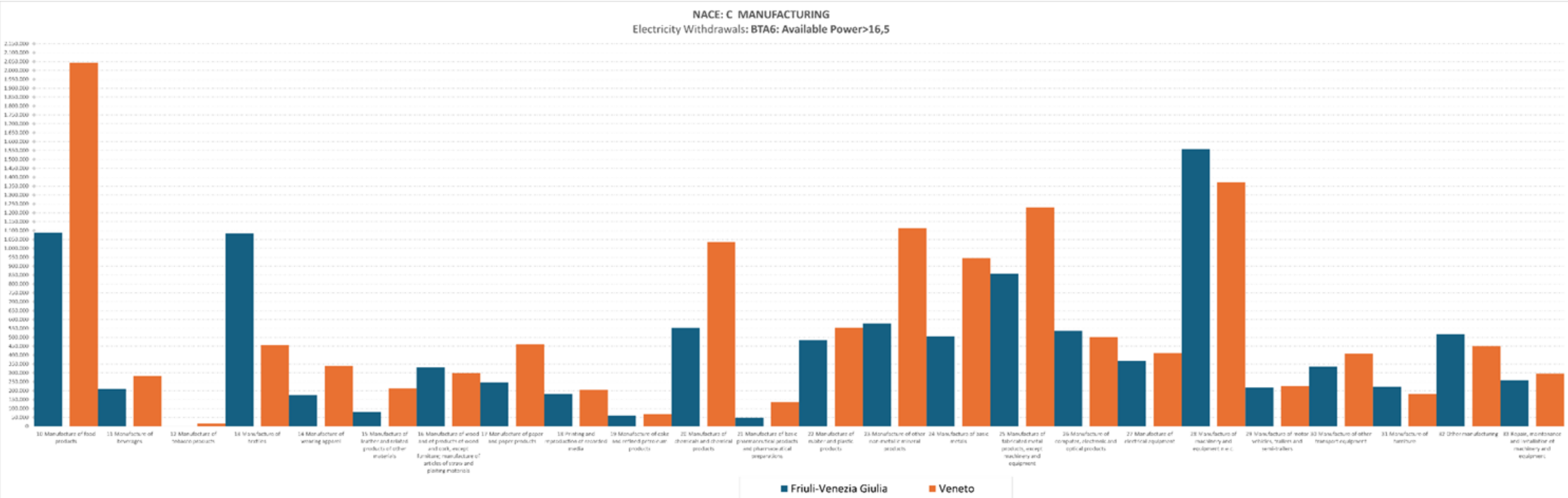


Figure 2 – Low-Voltage Electricity Withdrawals – Venice

Manufacturing Sector

Electricity Consumption (kWh) – Non-Domestic Low-Voltage Users

NACE Code	NACE Rev.2 Description	Friuli Venezia Giulia (kWh)	Veneto (kWh)
10	Manufacture of food products	1,087,011.00	2,042,453.00
11	Manufacture of beverages	210,069.00	281,668.00
12	Manufacture of tobacco products	0.00	15,257.00
13	Manufacture of textiles	1,084,849.00	455,235.00
14	Manufacture of wearing apparel	175,269.00	339,772.00
15	Manufacture of leather and related products	79,270.00	212,563.00
16	Manufacture of wood and of products of wood and cork (except furniture); manufacture of articles of straw and plaiting materials	331,838.00	299,586.00
17	Manufacture of paper and paper products	246,607.00	460,487.00
18	Printing and reproduction of recorded media	182,209.00	203,925.00
19	Manufacture of coke and refined petroleum products	60,805.00	69,178.00
20	Manufacture of chemicals and chemical products	552,521.00	1,036,499.00
21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	48,728.00	135,347.00
22	Manufacture of rubber and plastic products	483,070.00	554,488.00
23	Manufacture of other non-metallic mineral products	576,972.00	1,114,007.00
24	Manufacture of basic metals	504,557.00	944,563.00
25	Manufacture of fabricated metal products (except machinery and equipment)	856,778.00	1,231,211.00
26	Manufacture of computer, electronic and optical products	535,656.00	501,399.00
27	Manufacture of electrical equipment	366,879.00	410,271.00
28	Manufacture of machinery and equipment n.e.c.	1,557,108.00	1,371,769.00
29	Manufacture of motor vehicles, trailers and semi-trailers	217,186.00	226,457.00
30	Manufacture of other transport equipment	334,532.00	409,595.00
31	Manufacture of furniture	221,618.00	182,708.00
32	Other manufacturing	517,444.00	450,750.00
33	Repair and installation of machinery and equipment	258,146.00	296,420.00


NACE: C MANUFACTURING
Electricity Withdrawals: BTA6: Available Power>16,5
Friuli-Venezia Giulia
Veneto

The analysis highlights a highly fragmented production structure, characterised by a large number of SMEs with individually limited but collectively significant energy consumption.

This configuration results in a diffuse climate–energy risk, where exposure is not concentrated in a few critical nodes but rather distributed across a large number of potentially vulnerable enterprises. This reinforces the need for mitigation and adaptation policies calibrated at both territorial and sectoral levels.

In the Slovenian context, the analysis shows that the production system presents a highly polarised energy configuration.

Industrial electricity consumption is concentrated in a limited number of municipalities and, within them, in a small number of highly energy-intensive enterprises.

Territorial mapping allows the identification of industrial clusters in which energy dependence assumes a systemic dimension: exposure to extreme climate events (such as floods, heatwaves, or grid disruptions) or to infrastructural shocks can generate cascading effects across the entire local economic system.

In these contexts, climate–energy risk is not evenly distributed, but rather concentrated around “anchor” enterprises that account for a predominant share of municipal energy consumption.

The analysis of annual electricity consumption (kWh) highlights three structural elements:

- High municipal concentration of industrial energy consumption
- Presence of dominant large energy-intensive enterprises
- Formation of mono-sectoral or highly specialised territorial clusters

This configuration results in local systemic vulnerability: impacts affecting a single critical infrastructure or a large industrial plant may compromise employment, supply chains, and the production continuity of the entire territory.

Main Energy Clusters Identified

Municipality	Anchor Company/Companies	Annual Consumption (kWh)	Dominant Sector	Systemic Risk Profile
Kanal	Salonit Anhovo d.d.	1,041,551,777	Cement	Extreme
Ilirska Bistrica	Lesonit d.o.o.; Termoplasti-Plama	200,000,000; 13,649,607	Wood and plastics	High
Idrija	Kolektor Koling; Hidria d.o.o.	31,281,260; 27,035,549	Automotive / Mechanical engineering	Medium–high
Ajdovščina	Mlinotest; Fructal; Incom	28,760,870; 24,507,972; 20,087,300	Agri-food	Systemic
Pivka	Pivka Delamaris; RZ Pellets	18,995,580; 11,947,753	Food and biofuels	Significant
Cerkno	ETA d.o.o.	19,553,308	Electrical equipment	High

The mapping confirms that the Slovenian industrial system does not present a diffuse distribution of energy consumption, but rather a concentrated and cluster-based structure. This model:

- Amplifies territorial vulnerability;
- Increases dependence on individual grid infrastructures;
- Generates systemic economic risks in the event of climate or energy shocks.

The comparative analysis between the two contexts makes it possible to identify different types of territorial clusters and provides a solid basis for the application of the CERI, which considers not only the intensity of energy consumption, but also the structural configuration and spatial distribution of productive activities.

4. Development of the Integrated Territorial, Climate and Business Database

The development of an integrated database represents a key component of the activities carried out within the CLIMASAFE project, as it constitutes the information infrastructure on which the entire climate–energy risk analysis is based.

The database has been designed to integrate and harmonise data from heterogeneous sources, overcoming the methodological and statistical differences between the Italian and Slovenian national systems.

The database includes:

- energy data related to electricity consumption and, where available, thermal energy consumption of enterprises;
- territorial and socio-economic data;
- a structured set of climate indicators.

Climate data include both historical series and future projections up to the 2050 horizon, developed on the basis of IPCC scenarios and provided by institutional sources such as Copernicus and regional environmental agencies.

The integration of these datasets makes it possible to associate each enterprise or production cluster with a specific climate risk profile, consistent with the territorial and productive characteristics of the reference context.

The structure of the database has been designed to support integrated analyses and the calculation of the CERI, ensuring traceability of sources and reproducibility of results.

5. Analysis of Climate Risks, Energy Vulnerabilities and Operational Impacts

The analysis of climate risks and energy vulnerabilities represents the conceptual and methodological core of this deliverable, as it enables the transition from a static description of the territorial and productive context to a dynamic assessment of the potential effects of climate change on economic activities.

In line with the principles adopted in the main international climate risk assessment frameworks, risk is understood as the result of the interaction between:

- climate hazard,
- exposure of the production system,
- adaptive capacity of enterprises,

with particular attention to operational impacts and the continuity of energy services.

In the context of energy-intensive SMEs, this interaction is particularly relevant, since production processes depend heavily on the availability of electricity and are simultaneously sensitive to variations in climatic conditions.

Extreme climate events, even when of limited duration, may therefore generate disproportionate impacts compared to their physical intensity, leading to operational disruptions, economic losses and, in the most critical cases, a deterioration of corporate competitiveness.

5.1 Characterisation of Climate Hazards

The analysis of climate hazards focuses on events that, according to scientific evidence and available data, are most relevant for the productive system of the cross-border area considered.

Particular attention is therefore given to:

- heatwaves,
- cold waves,
- intense precipitation events, including floods and overflow events.

Italian Context

Heatwaves represent one of the most significant climate hazards for energy-intensive SMEs.

The analysis of historical time series and climate projections highlights an increase in both the frequency and intensity of these events.

In particular, climate indicators show a generalised increase in summer days (SU95p) and in the Warm Spell Duration Index (WSDI), with stronger intensification in areas characterised by high productive density.

In these contexts, high temperatures lead to increased electricity consumption related to the cooling of workplaces.

This phenomenon can be quantified through the increase in Cooling Degree Days (CDD), an indicator measuring the energy demand for summer air conditioning, which is expected to grow significantly, particularly in lowland and coastal areas.

This dynamic directly affects electricity loads, generating summer demand peaks that may exceed the capacity of existing infrastructures, thereby increasing the risk of blackouts and service interruptions precisely during periods of maximum grid stress.

Moreover, this effect is exacerbated by the urban heat island phenomenon, typical of densely built and highly impermeable areas, where average temperatures can be significantly higher than in surrounding rural areas.

Beyond energy consumption, heatwaves also affect labour productivity, increasing health and safety risks for workers (heatstroke, thermal stress), particularly for activities carried out outdoors or in non-air-conditioned industrial environments.

	Nord-ovest		Nord-est		Centro		Sud		Isole	
	Valore medio	±DS	Valore medio	±DS	Valore medio	±DS	Valore medio	±DS	Valore medio	±DS
TG (°C)	10,0	4,5	10,1	4,1	13,9	2,0	13,9	2,5	15,8	1,7
WD (giorni)	77	5	73	4	74	2	77	2	80	2
WW (giorni)	55	20	52	16	52	10	62	12	62	7
HDDS (GG)	3180	1448	3171	1293	1934	535	1925	669	1384	390
CDDS (GG)	78	81	97	97	157	91	164	128	225	155
PRCPTOT (mm)	912	277	922	288	897	246	667	227	561	121
R20 (giorni)	10	5	11	6	10	5	5	4	5	2
RX1DAY(mm)	50	12	51	15	51	13	35	16	39	10
SDII(mm)	10	2	10	2	10	2	8	2	8	1
PR99PRCTILE(mm)	46	11	46	12	46	11	34	13	39	8
CDD(giorni)	35	7	33	4	37	8	50	11	81	12
SPI3 classe siccità severa (%)	5	1	5	1	5	1	4	1	4	1
SPI3 classe siccità estrema (%)	3	1	3	1	3	1	2	1	2	1
SPI6 classe siccità severa (%)	4	1	5	1	5	1	4	1	5	1
SPI6 classe siccità estrema (%)	2	1	2	1	3	1	2	1	2	1
SPI12 classe siccità severa (%)	5	1	4	1	4	1	3	2	5	2
SPI12 classe siccità estrema (%)	2	1	2	1	3	1	2	1	2	1
SPI24 classe siccità severa (%)	6	2	4	2	4	1	3	2	4	2
SPI24 classe siccità estrema (%)	2	2	2	2	3	2	1	1	1	1
PET(mm)	650	138	658	130	757	68	750	88	806	72
CSDI(giorni)	6	2	5	2	5	1	6	1	5	1
FD(giorni)	93	63	98	56	34	22	23	26	3	7
WSDI(giorni)	7	1	8	2	8	1	6	2	5	1
HUMIDEX(giorni)	4	6	7	9	13	9	9	9	6	8
SU95P(giorni)	23	21	28	24	43	18	37	21	34	17
TR(giorni)	8	8	9	12	9	11	24	21	36	19

Figure 3 – Average Annual Values of Indicators by Geographic Area (Source: PNACC)

	Valori medi stagionali 1981-2010								
	DJF	±DS	MAM	±DS	JJA	±DS	SON	±DS	
Nord- Ovest	1,6	3,6	9,2	5,0	18,6	5,1	10,4	4,2	Temperatura media (°C)
	170	83	249	70	205	94	289	81	Precipitazione cumulata (mm)
Nord-Est	1,1	3,2	9,4	4,5	19,1	4,8	10,6	4,0	Temperatura media (°C)
	160	69	228	64	242	101	293	104	Precipitazione cumulata (mm)
Centro	6,3	2,0	12,4	1,9	22,1	1,9	14,8	2,1	Temperatura media (°C)
	247	75	217	61	118	41	314	87	Precipitazione cumulata (mm)
Sud	6,7	2,5	11,8	2,5	21,9	2,5	15,1	2,5	Temperatura media (°C)
	228	92	157	59	64	31	216	66	Precipitazione cumulata (mm)
Isole	9,2	1,5	13,4	1,8	23,1	1,9	17,3	1,7	Temperatura media (°C)
	216	36	129	46	23	11	194	33	Precipitazione cumulata (mm)

Figure 4 – Seasonal Average Values of Mean Temperature and Precipitation by Geographic Area (Source: PNACC)

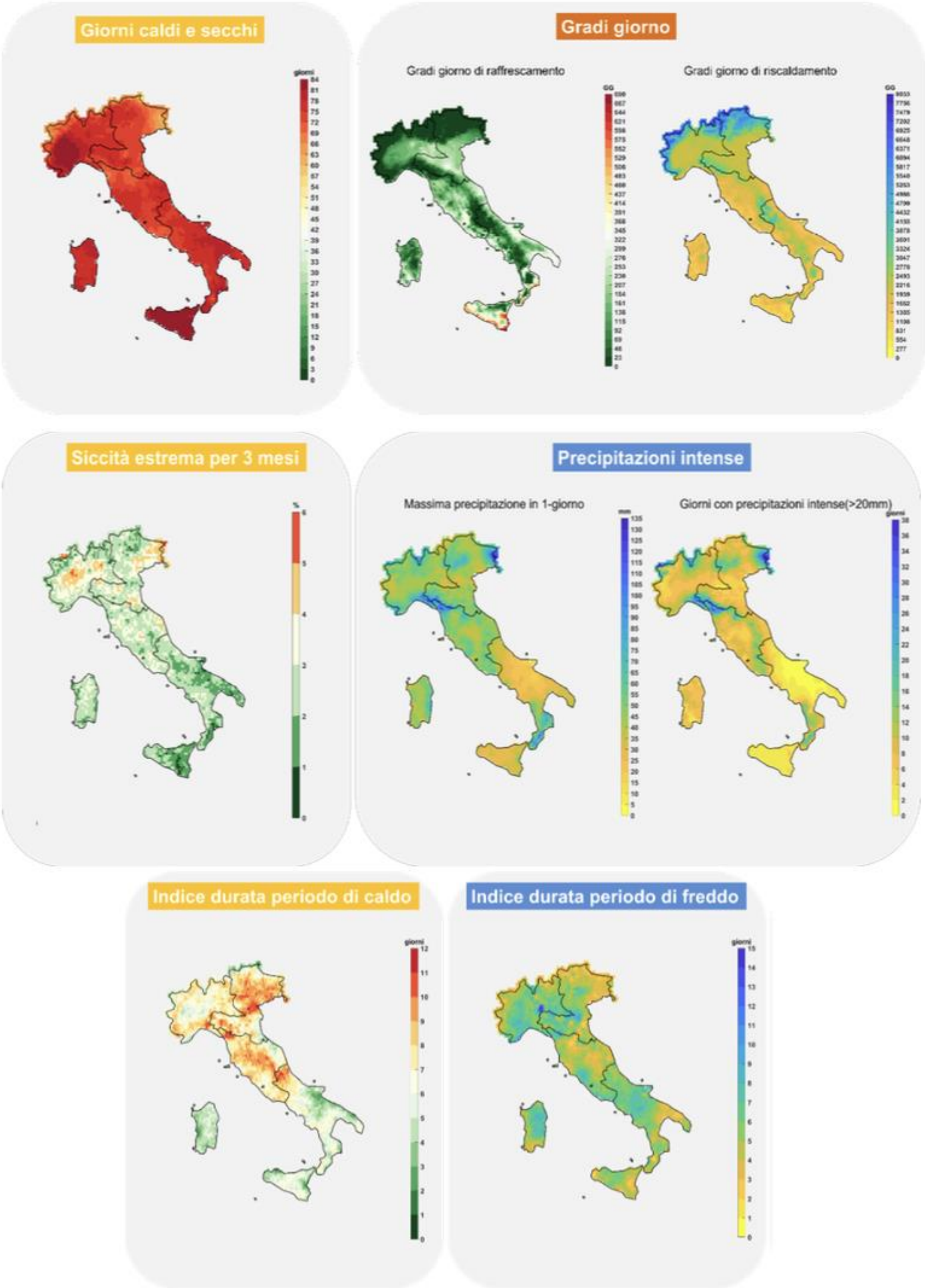


Figure 5 – Indicator Maps (Source: PNACC)

Cold waves, although showing a less pronounced trend compared to extreme heat events, continue to represent a hazard for certain types of enterprises.

Climate projections indicate a **general reduction in Heating Degree Days (HDD)** and in the number of **frost days (FD)**, suggesting a decrease in winter energy demand. However, episodes of **intense cold may still occur**, particularly affecting companies operating in **poorly insulated environments** or relying on **high-energy heating systems**.

In such cases, low temperatures may negatively affect **production efficiency** and generate **operational issues related to equipment performance** (for example, freezing of pipes or process fluids), as well as **worker safety concerns**, requiring extraordinary maintenance interventions or structural adjustments.

Intense precipitation events and floods represent another significant climate hazard.

Data show an **increasing trend in precipitation intensity**, monitored through indicators such as the **number of days with precipitation exceeding 20 mm (R20)** and the **95th percentile of daily precipitation (R95p)**, which indicate a concentration of rainfall in **short and intense events**.

These phenomena may generate **significant direct impacts on productive activities**, including:

Physical damage: flooding of production sites, warehouses and facilities (with particular vulnerability of **electrical machinery, pumps and compressors located at ground level or in underground spaces**).

Logistical disruption: blockage of access routes and logistics networks, preventing the **supply of raw materials and the distribution of finished products**.

NaTech risk (Natural triggering Technological disasters): for industries managing **hazardous substances**, natural events such as floods may trigger **technological accidents** (release of pollutants, fires, explosions), amplifying environmental and economic damage and posing **risks to public health**.

SMEs, often characterised by **limited financial and organisational resources**, are particularly vulnerable, especially when located in **urban areas where high levels of soil impermeabilisation reduce drainage capacity**, favouring **pluvial flooding even in the absence of major river overflow events**.

Slovenian Context

The analysis of climate hazards focuses on events that, based on **scientific evidence and available data**, are most relevant for the **territorial and productive system of Slovenia**. In this context, particular attention is given to **heatwaves**, the **reduction of cold waves**, and **intense precipitation events**, including floods.

Heatwaves represent one of the most significant hazards, with projections indicating an **increase in the average annual temperature in Slovenia between 1.3 °C and 4.1 °C by the end of the 21st century**, depending on the emission scenario considered.

Climate model analyses show an increase in both the **frequency and intensity of such events**. In particular, indicators reveal a general increase in the number of **"warm days" (maximum temperature above 25 °C)** and **"very warm days" (above 30 °C)**.

The latter, particularly in the **lowland areas of central, north-eastern and south-western regions**, may increase by **5–10 days in the near future and up to 60 days by the end of the century under the most pessimistic scenario**.

This trend directly affects **summer thermal loads**, resulting in **higher cooling demand in workplaces**.

The phenomenon can be further quantified through the increase in **"tropical nights" (minimum temperature not below 20 °C)**, the number of which could rise in lowland areas to **20–60 days per year**, preventing the **natural night-time cooling of infrastructure and the human body**. Such conditions increase **stress on the energy system and risks to workers' health and safety**.

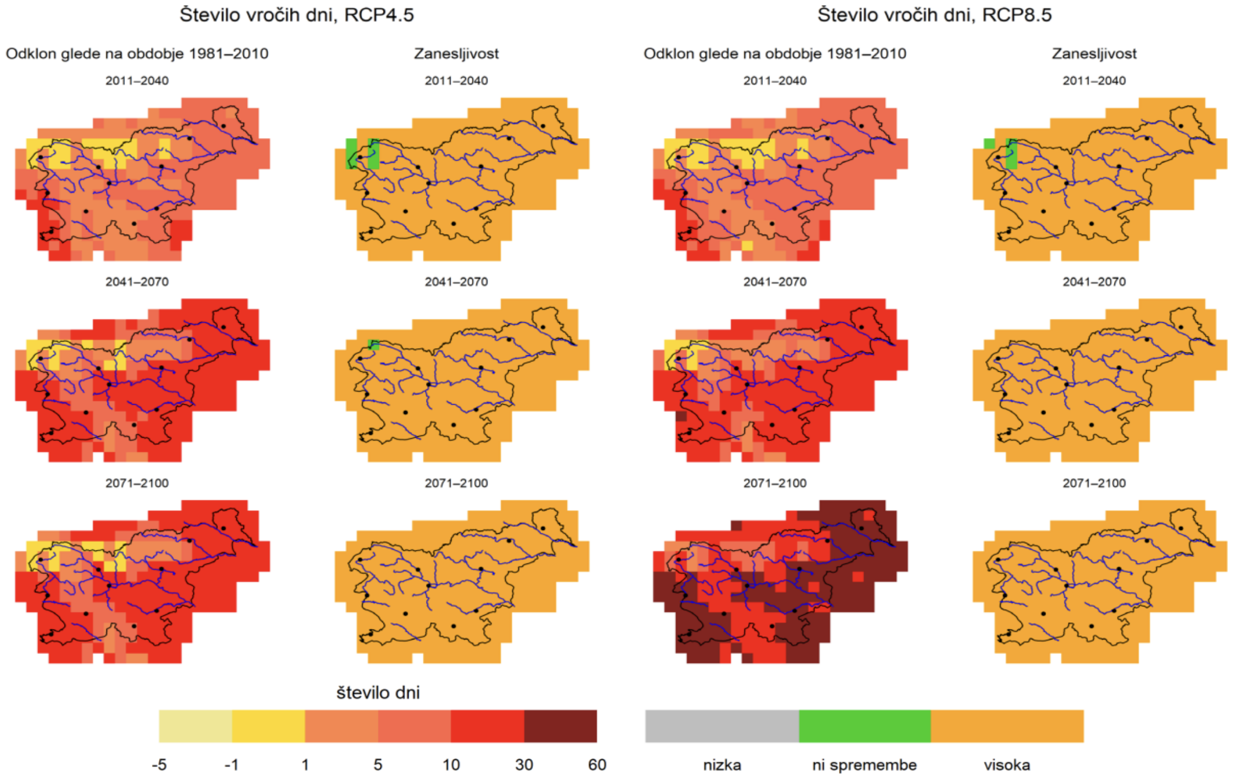
Regarding **cold waves**, sources indicate the opposite trend: the number of **cold days (minimum temperature below 0 °C)** and **ice days (maximum temperature below 0 °C)** is expected to gradually decrease.

By the end of the century, projections suggest a **reduction of approximately 20 cold days per year under the intermediate scenario and up to 40–60 days under the most pessimistic scenario**, with more pronounced effects in **high-altitude mountainous areas**.

Finally, **intense precipitation events and the resulting floods** represent a growing threat to **economic activities and infrastructure**.

Projections indicate an **increase in both the intensity and frequency of extreme precipitation**, particularly during **winter and spring periods**. The number of days with precipitation exceeding **20 mm** is expected to increase across the entire national territory.

This trend will translate into an **increase in flood discharges (average annual peak flows)** estimated on average between **20% and 30%**, with potential increases of **up to 40% at almost all monitoring stations by the end of the century**, thereby intensifying the **risk of river overflow events**.



igure 6 – Projected Change in the Number of Warm Days in Slovenia Across Three Future Periods, with Confidence Levels under the RCP4.5 Scenario (left) and RCP8.5 Scenario (right), Expressed as Deviations from the Reference Period 1981–2010 (Source: OPS Slovenia – *Climate Change Assessment in Slovenia*)

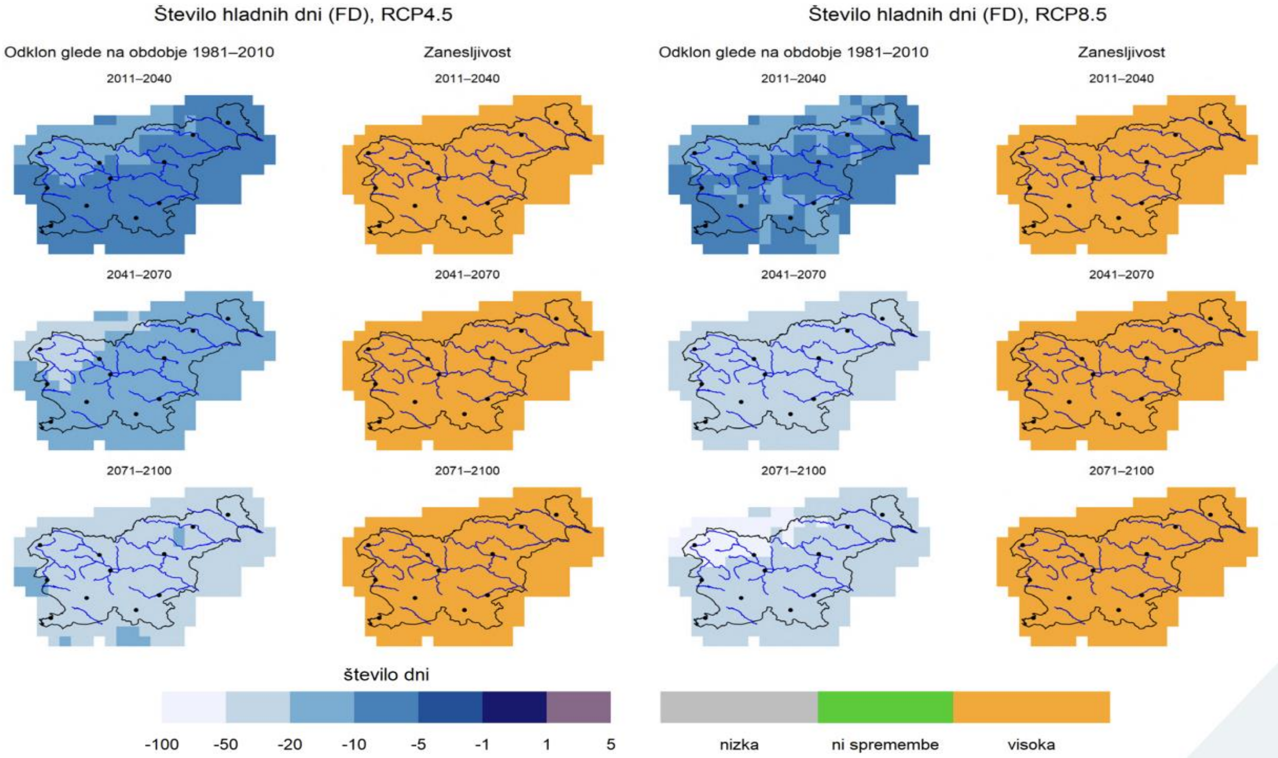


Figure 7 – Projected Change in the Number of Cold Days in Slovenia Across Three Future Periods, with Confidence Levels under the RCP4.5 Scenario (left) and RCP8.5 Scenario (right), Expressed as Deviations from the Reference Period 1981–2010 (Source: OPS Slovenia – *Climate Change Assessment in Slovenia*)

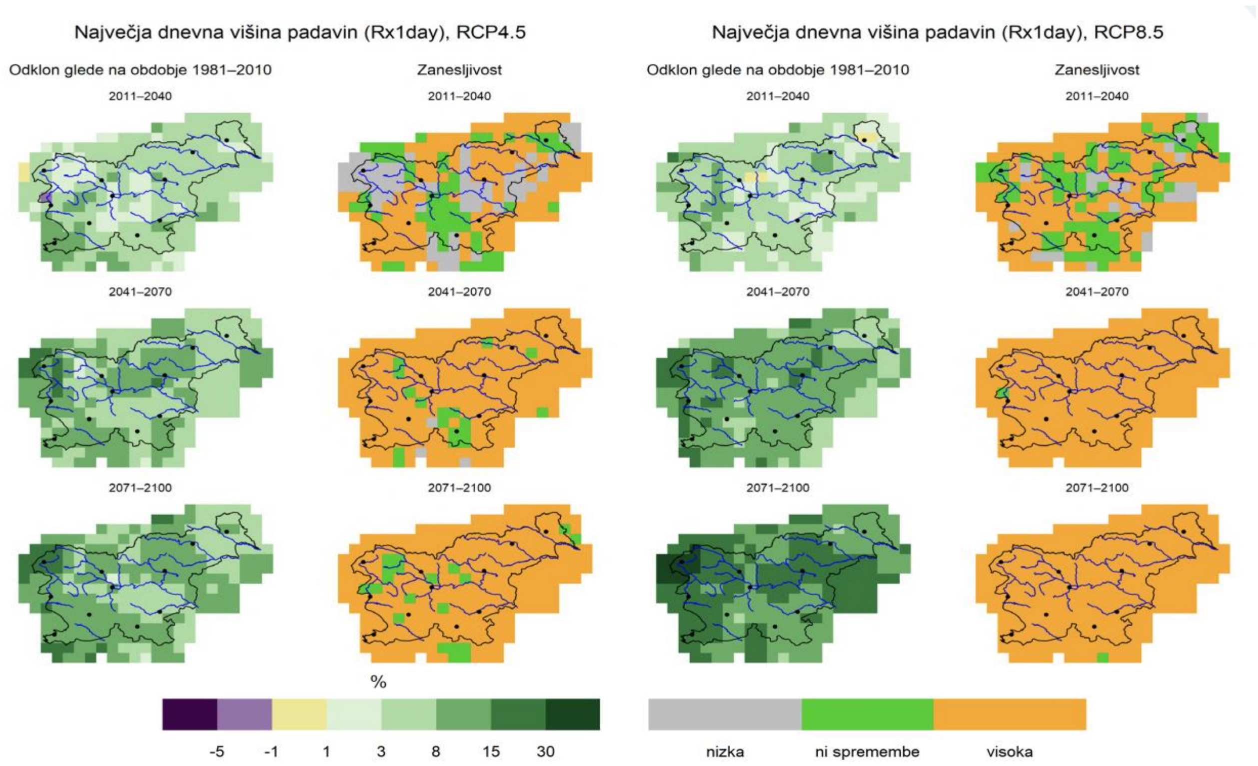


Figure 8 – Projected Change in Maximum Daily Precipitation Intensity in Slovenia Across Three Future Periods, with Confidence Levels under the RCP4.5 Scenario (left) and RCP8.5 Scenario (right), Expressed as Relative Deviations from the Reference Period 1981–2010 (Source: OPS Slovenia – *Climate Change Assessment in Slovenia*)

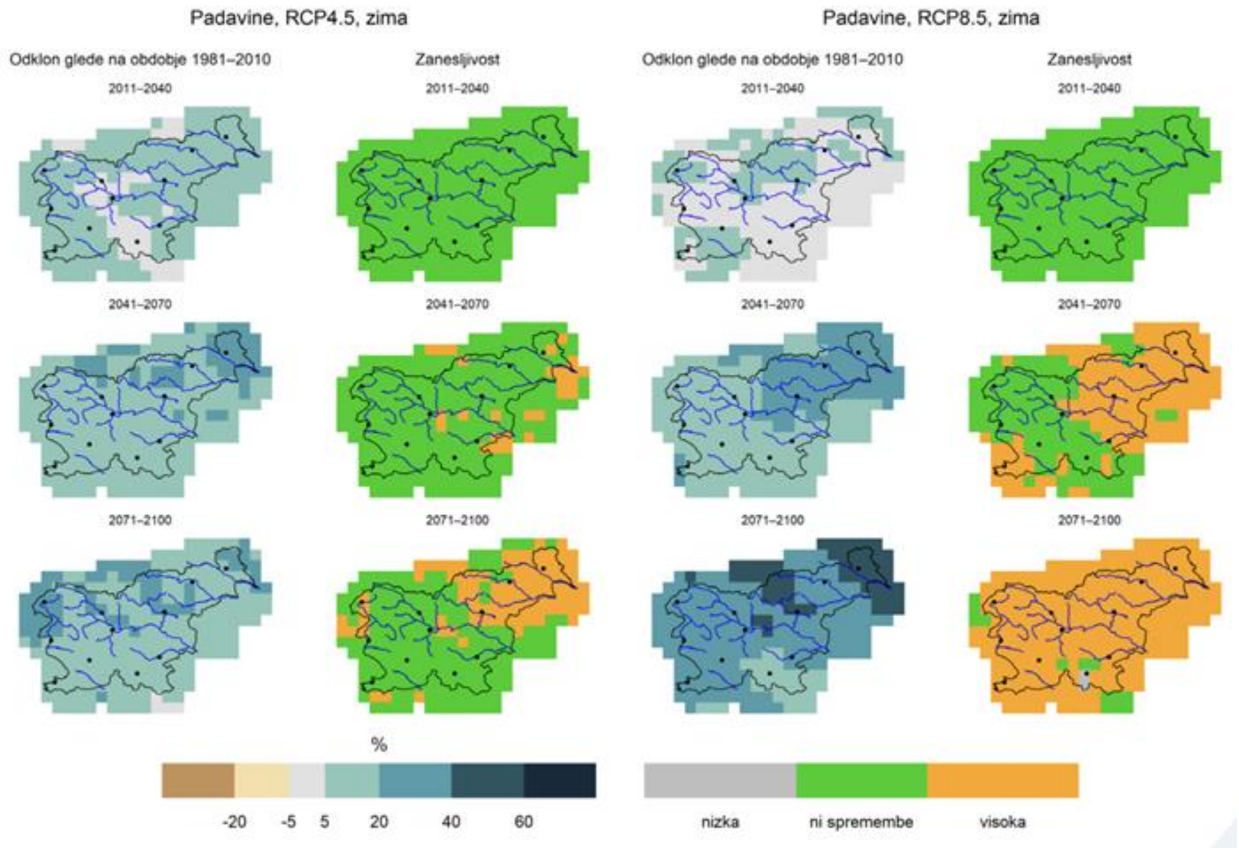


Figure 9 – Projected Change in Average Winter Precipitation in Slovenia Across Three Future Periods, with Confidence Levels under the RCP4.5 Scenario (left) and RCP8.5 Scenario (right), Expressed as Relative Deviations from the Reference Period 1981–2010 (Source: OPS Slovenia – *Climate Change Assessment in Slovenia*)

Cold waves, although showing a less pronounced trend compared to extreme heat events, continue to represent a risk for several types of enterprises. Climate projections indicate a general reduction in “cold days” (days with minimum temperature below 0 °C) and “ice days” (maximum temperature below 0 °C), suggesting a decrease in winter energy demand.

Under the moderate RCP4.5 scenario, the number of cold days is expected to decrease by approximately 10 days in the short term (up to 2040) and by around 20 days per year in the second half of the century.

However, episodes of intense cold may still occur, particularly affecting companies operating in non-insulated environments or relying on high-energy heating systems. In such cases, low temperatures may compromise production efficiency and generate operational issues related to plant performance and worker safety, requiring extraordinary maintenance interventions or structural adjustments.

Intense precipitation events and floods represent another significant climate hazard, with projections indicating an increase in both the intensity and frequency of extreme precipitation.

Data show a growing trend in precipitation intensity, monitored through indicators such as the number of days with rainfall exceeding 20 mm. According to the RCP8.5 scenario, the number of such days is expected to increase significantly across almost the entire national territory, indicating a concentration of precipitation in short and intense events. Moreover, extreme daily precipitation is projected to increase particularly during winter and spring periods.

These phenomena may generate significant direct impacts on productive activities:

Physical damage: the increase in river flood discharge (average annual peak flows) is estimated to range between 20% and 30% on average, with peaks potentially reaching 40% by the end of the century, aggravating the risk of flooding of production sites and warehouses. Even flood levels with a 100-year return period are expected to increase across almost the entire Slovenian territory.

Logistical disruption: the increase in winter precipitation (which in some areas could reach up to +60% by 2100 under the RCP8.5 scenario) and extreme events may disrupt access routes and logistics networks, preventing supply and distribution operations.

NaTech risk (Natural triggering Technological disasters): for industries managing hazardous substances, natural events such as floods may trigger technological accidents (release of pollutants, fires), amplifying environmental and economic damage and posing risks to public health.

5.2 Analysis of Energy Exposure

The energy exposure of energy-intensive SMEs is analysed in relation to consumption structure, energy use patterns, and the degree of dependence on the continuity of electricity supply.

In this context, electricity plays a central role, as it represents the main energy carrier for most of the production processes analysed.

The analysis highlights that energy exposure is not determined solely by the total volume of consumption, but also by its temporal distribution and the rigidity of demand.

Companies characterised by continuous processes or production cycles that are difficult to interrupt are particularly vulnerable to climate events that place stress on the electricity grid, since even short service interruptions may lead to significant losses in terms of production, product quality and plant safety.

Furthermore, the increasing incidence of summer cooling demand in electricity consumption amplifies the energy exposure of SMEs during periods of extreme heat, creating a strong correlation between climate hazard and energy demand.

This correlation represents one of the central elements of the analysis and constitutes one of the main motivations behind the development and application of the CERI.

5.3 Structural Vulnerability and Adaptive Capacity

The vulnerability of SMEs is analysed by considering both structural and organisational aspects.

From a structural perspective, factors such as building insulation, plant efficiency, the presence of outdated or oversized cooling and heating systems, and the absence of energy backup solutions contribute to increasing overall vulnerability.

From an organisational perspective, vulnerability is influenced by the ability of companies to plan and manage emergency situations, the availability of operational procedures for responding to extreme events, and the level of awareness regarding climate–energy risk.

In many cases, SMEs show limited adaptive capacity, due both to financial constraints and to a lack of information and specialised expertise.

5.4 Operational and Economic Impacts

The interaction between climate hazards, energy exposure and vulnerability translates into a series of operational and economic impacts that may compromise business continuity.

These impacts include plant shutdowns, product losses, increased energy costs, and reductions in production quality and competitiveness.

In particular, impacts associated with interruptions in electricity supply are of central relevance, as they may generate cascading effects along supply chains and negatively affect the entire territorial production system.

The analysis of these impacts provides essential inputs for the subsequent calculation of the CERI and for the identification of intervention priorities.

Annex A – Territorial Analysis of Energy Risk and Energy Concentration

This Annex provides a structured overview based on quantitative data of territorial energy concentration and risk within the CLIMASAFE cross-border area. It explicitly highlights the work of data collection and harmonisation carried out through the two project datasets:

- Slovenian LEK Industrial Energy Database (municipal industrial energy profiles)
- ATT1.1 Cross-Border Initial Data Collection & Mapping Dataset

These datasets constitute the quantitative basis for the development of the Territorial Energy Risk framework and for the future calibration of the CERI.

Part I – Industrial Energy Concentration in Slovenia (LEK Dataset)

Total industrial electricity consumption (analysed municipalities):
905,025,701 kWh/year

The analysis covers 18 municipalities and is based on industrial energy profiles at the level of individual enterprises.

Top 10 Municipalities by Industrial Electricity Consumption

Municipality	Industrial Electricity (kWh/year)	Share of Total (%)
Kanal	268,048,400	29.6
Ilirska Bistrica	154,966,900	17.1
Koper	131,859,200	14.6
Idrija	74,566,000	8.2
Pivka	50,822,600	5.6
Ajdovščina	40,206,250	4.4
Cerkno	37,717,150	4.2
Logatec	30,946,290	3.4
Tolmin	25,443,410	2.8
Divača	25,422,990	2.8

The top three municipalities account for 61.3% of the total industrial electricity demand, confirming a strongly concentrated territorial structure.

The Slovenian municipalities analysed in this Annex belong predominantly to the western Slovenian statistical regions (*Goriška, Primorsko-notranjska and Obalno-kraška*), corresponding to the CLIMASAFE cross-border cooperation area. The results therefore reflect the structural characteristics of this specific territorial cluster rather than the entire national territory.

Methodological Construction of the Indicators

Energy Concentration Index (ECI)

The **ECI** is derived directly from the **LEK dataset** by dividing the industrial electricity consumption of each municipality by the total consumption of the analysed area:

[
ECI_m = Industrial Electricit_*m/Total Industrial Electricity*_area
]

Example:

Kanal = 268,048,400/905,025,701} = approx 0.296

Energy Intensity per Capita (EIC)

The **EIC** combines LEK data on industrial consumption with **demographic information**:

EIC_m = Industrial Electricity_m/Population_m]

This indicator measures the **structural energy dependence of the territory**.

Territorial Energy Risk Score (TERS)

The **TERS** aggregates three classified components:

1. **ECI class**
2. **EIC class**
3. **Structural concentration level (CR3)**

TERS = Average of the three class scores
]

This simplified structure ensures **clear communication for SMEs while preserving analytical consistency**.

Part II – Energy Structure of the Italian Manufacturing Sector (ATT1.1 Dataset)

The Italian analysis derives from the **cross-border ATT1.1 dataset**, which integrates **low-voltage electricity withdrawals for non-domestic users disaggregated by NACE sector**.

Total manufacturing electricity consumption:

- **Friuli Venezia Giulia (FVG):** 10,230,147 kWh
- **Province of Venice:** 14,398,808 kWh

The Italian production structure shows **sectoral diversification rather than territorial concentration**, confirming a model of **diffuse exposure**.

Final Comparative Framework – Slovenia vs Italy

Dimension	Slovenia (LEK Dataset)	Italy – FVG & Venice (ATT1.1 Dataset)
Data granularity	Industrial energy profiles at enterprise level per municipality	Manufacturing electricity consumption by NACE sector
Total industrial electricity (sample)	905 GWh	FVG: 10.2 GWhVenice: 14.4 GWh
Structural model	Territorial concentration	Sectoral diversification
Top 3 share	61.3% of total consumption	No dominant territorial node
Type of energy risk	Territorial systemic amplification	Diffuse distributed exposure
Main risk driver	“Anchor” enterprises and dependence on local infrastructure	Cumulative SME demand and seasonal peaks
Policy implications	Infrastructure resilience and territorial coordination	Firm-level efficiency and sectoral adaptation

The comparative table highlights the value of cross-border data harmonisation activities.

The LEK dataset enables municipal-level concentration analysis for the Slovenian side, while the ATT1.1 dataset allows sectoral exposure mapping for the Italian side.

Taken together, these datasets provide a complementary territorial and sectoral perspective, necessary for the robust calibration of the CERI.

The integration of these datasets represents a key added value of the CLIMASAFE project, ensuring traceability, transparency and replicability of the climate–energy risk assessment.