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Disclaimer

1. Executive summary

The objective of this second deliverable of WP2 is to update D2.1 and ensure the continuation of the different tasks included in the WP.
The main scope of WP2 is to assure the update of the RE-SKIN context and its different features (energy, regulatory and economic issues, technological application etc.) during the development and realization of the whole project. In this respect, the objective of this work package is to continuously monitor the geographic, energy, regulatory, technological, and social contexts relevant to the RE-SKIN project, along with all boundary conditions, including economic and regulatory factors. This ensures that any changes or developments in policies, standards, technological advancements, and other contextual factors are promptly integrated into the development process of the project's components and overall package, maintaining their effectiveness and ensuring the achievement of intended impacts. Additionally, the deliverable aims to present a comprehensive overview of the site risk assessment, going beyond a mere summary of the results. It strives to include multi-hazard and multi-risk assessment maps, providing a visual representation of the various hazards and risks associated with each target country within the application context. Moreover, it provides a comprehensive overview of the hazards, mitigation, adaptation and resilience strategies of the systems within RE-SKIN project.

The WP2 is divided in to five tasks as follows:
T2.1 Buildings retrofit market.
T2.2 Economic and regulatory context and Smart Grids interaction rules.
T2.3 Compatibility and synergy continuous review
T2.4 Technological and performance benchmarking process.
T2.6 Site risk assessment.

2. Building Retrofit Market

The task delves into the advancement of residential building energy retrofits in the target countries, aiming to analyze the progress achieved in enhancing the energy efficiency of existing residential buildings. To accomplish this, data has been meticulously collected from a variety of sources, including official government websites, comprehensive European databases, and authoritative international reports.

This extensive data collection enables a thorough evaluation of retrofit initiatives and their effectiveness in reducing energy consumption. The insights and findings derived from this task are instrumental in assessing the impact of energy retrofit policies and strategies implemented in the target countries. By understanding these dynamics, the study contributes to the broader discourse on sustainable building practices and energy conservation, highlighting areas of success and opportunities for further improvement.

This study is divided into four main sections, each devoted to a specific country: France, Spain, Italy, and Bulgaria.

For each country, we have structured the data found according to the following subsections:

- **The residential building stock**: An overview of the building stock, the distribution of final energy consumption, the total housing stock, new housing constructions, and the distribution of the urban and rural population.
- **Energy consumption by the residential sector**: Final energy consumption by the residential sector and by use, the main drivers of variation in household energy consumption, heating and cooling days, greenhouse gas emissions from energy use in buildings, as well as energy production and consumption.
- **The retrofit market**: Building systems for energy efficiency, overall energy efficiency, classification of building energy consumption, and the cost of renovations.

Through this comprehensive analysis, we aim to provide valuable insights and recommendations for future energy retrofit initiatives.

2.1. Building Retrofit Market in France

2.1.1. Residential building stock

2.1.1.1. High-level overview of the building stock

Table 1 presents the diversity of dwellings in France as of 2021, showcasing a notable distribution between single-family and multi-family units.[1]

The data reveals a substantial number of single-family units at 20,714.250, comprising 55.4% of the total housing stock. Multi-family units represent 16,673.300 units, making up the remaining 44.6%. The total number of units amounts to 37,387.550. This distribution indicates a significant presence of both single-family and multi-family dwellings in France.

Table 1: Diverse dwellings in France, 2021

Dwelling type	Number of Units	Percentage of Total
Single-family	20,714,250	55.4
Multi-family	16,673,300	44.6
Total	37,387,550	

Table 2 illustrates the distribution of dwellings in France by usage as of 2021.[1]

This distribution underscores the varied usage of dwellings across France. Owner-occupied homes represent the largest segment at 47.1% of the total housing stock. Private rentals and social housing follow with 20.4% and 14.4%, respectively. Secondary residences, including holiday homes, make up 9.8% of the total, while vacant dwellings account for 8.3%.

Table 2: Dwellings in France by usage, 2021

Dwelling usage	Number of Units	Percentage of Total
Owner-occupier	17,598.490	47.1
Private rental	7,629.980	2.,4
Social rental	5,393.240	14.4
Secondary residences (e.g., holiday homes)	3,666.250	9.8
Vacant dwellings	3,099.590	8.3
Total	37,387.550	

2.1.1.2. Residential building stock by final energy consumption source

Energy consumption in residential buildings is pivotal for environmental sustainability and efficient resource management. [2]

In France, residential building energy consumption in 2022 (Table 3) is largely dominated by oil and petroleum products, comprising 38.87% of the total consumption. Electricity follows closely at 26.87%, with natural gas contributing 18.61%. Renewables and biofuels account for 11.74% of the energy mix, while solid fossil fuels and other fuels have minimal shares. Heat represents 3% of the total consumption. This distribution highlights a continued dependence on fossil fuels, despite ongoing efforts to shift towards more sustainable energy sources such as renewables and electricity generated by renewable energy sources.

Table 3: Residential building stock by final energy consumption source in France, 2022

Solid fossil fuels	Natural gas	Oil and petroleum	Renewables and biofuels	Electricity	Heat	Other fuels n.e.c.*
0.53	18.61	38.87	11.74	26.87	3.0	0.39

***Other fuels n.e.c :** Other fuels not elsewhere classified

Comparing these figures with the Eurozone averages (Table 4), several trends emerge. France exhibits a higher reliance on oil and petroleum products (38.87% compared to the Eurozone's 36.78%) and electricity (26.87% compared to 22.98%). Conversely, France uses less natural gas (18.61% vs. 20.47%) and renewables and biofuels (11.74% vs. 12.23%) compared to the Eurozone average. Additionally, France has a significantly lower reliance on solid fossil fuels (0.53% vs. 1.81%) and other fuels not elsewhere classified (0.39% vs. 1.08%).[2]

Table 4: Residential Building Stock by Final Energy Consumption Source in the Eurozone, 2022

Solid fossil fuels	Natural gas	Oil and petroleum	Renewables and biofuels	Electricity	Heat	Other fuels n.e.c.
1.81	20.47	36.78	12.23	22.98	4.65	1.08

2.1.1.3. The total stock of dwellings

The following Tables illustrate the total stock of dwellings in France over recent years. It's essential to distinguish between the **'Number of Buildings'** and the **'Total Stock of Dwellings'**. The former reflects the count of physical structures, while the latter indicates the number of housing units available for residents.

- **Number of Buildings**

Table 5 provides an analysis of residential buildings in France as of 2020, categorized by their construction period and current usage, distinguishing between buildings owned by occupants and those rented by tenants. [3]
Starting from 1945, earlier periods showed a predominance of owner-occupied buildings, followed by relative stability with slight variations in the subsequent decades until the 2000s. The 1990s saw a significant decline in both owner-occupied and tenant-occupied properties.
The 2000s exhibited a slight recovery before another decrease in the 2010s, illustrating fluctuations in the French real estate market over time.

Table 5: Residential Buildings in France, by Construction Period and Tenure

Construction Period	0-1945	1946-1969	1970-1979	1980-1989	1990-1999	2000-2010	2011-2020
Owners	2,348,584	1,639,747	1,753,972	1,744,764	1,082,119	1,711,046	1,154,227
Tenants	1,734,084	1,093,799	1,153,260	1,193,740	778.436	1,161,711	758.16

- **Total Stock of Dwellings**

Table 6 provides an overview of the total stock of dwellings in France from 2011 to 2023, illustrating trends in housing supply over this period.
The data reveals a consistent growth in the number of dwellings each year, highlighting a sustained expansion of the housing market in France. From 2011 to 2023, the total stock has steadily risen from 32,860 dwellings in 2011 to 37,818 dwellings in 2023. This growth indicates ongoing efforts to meet housing demand and accommodate population growth or shifting residential preferences across the country. [4]

Table 6: Total stock of dwellings in France

2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
32,860	34,038	34,415	34,800	35,182	35,535	36,221	36,221	36,556	36,883	37,180	37,497	37,818

- **Distribution of population by dwelling type**

Table 7 depicts the distribution of different types of dwelling in France in 2023. Detached houses account for 12.1%, semi-detached houses for 6.4%, flats for 24.3%, flats in buildings with less than ten dwellings for 4.8%, flats in buildings with ten or more dwellings for 19.5%, and other types of dwellings for 0.2%. This data shows the relative prevalence of each housing type across the country.[5]

Table 7: Distribution of population (%) by dwelling type in France, 2023

House	Detached house	Semi-detached house	Flat	Flat in a building with less than ten dwellings	Flat in a building with ten or more dwellings	Others
12.1	6.4	5.7	24.3	4.8	19.5	0.2

- **Average Household Size**

The average household size in France for the years 2022 and 2023 is recorded at 2.2 individuals per household.[6]

- **New construction of dwellings**

Table 8 presents data on the annual additions of new dwellings in France from 2016 to 2021, showcasing the yearly construction activities within the housing sector. [7]

The data reveals a fluctuation in the annual addition of new dwellings in France from 2016 to 2021. There was a progressive increase from 2016 to 2019, peaking at 390,000 new constructions in 2019, followed by a slight decrease in 2020 with 357,300 new dwellings, and a recovery in 2021 with 386,600 constructions.

Table 8: Annual new dwelling additions in France

2016	2017	2018	2019	2020	2021
345,500	346,900	360,400	390,000	357,300	386,600

2.1.1.4. Share of the urban and rural populations in the total population

Table 9 presents data on the share of urban and rural populations in France from 2005 to 2022, highlighting the distribution between urban and rural areas over time.

The data indicates a consistent trend of urbanization in France from 2005 to 2022, with the urban population growing from 77.13% in 2005 to 81.51% in 2022, while the rural population declined from 22.87% to 18.49% over the same period. This steady increase highlights the shift towards urban living over the years. [8]

Table 9: Share of urban and rural populations (%) in France

France	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Urban	77.13	77.38	77.62	77.87	78.12	78.37	78.62	78.88	79.14	79.39	79.66	79.92	80.18	80.44	80.71	80.87	81.24	81.51
Rural	22.87	22.62	22.38	22.13	21.88	21.63	21.38	21.12	20.86	20.61	20.34	20.08	19.82	19.56	19.29	19.13	18.76	18.49

2.1.2. Energy consumption by the residential sector

2.1.2.1. Final energy consumption by the residential sector and by use

- **Energy consumption by end-use**

Table 10 presents per capita energy consumption in terajoules for various end-uses in France in 2022. Space heating constitutes the largest portion at 1,047,493.373 terajoules (38.86%), reflecting the significant energy demand for heating in residential buildings. Water heating follows with 159,866.833 terajoules (5.93%), indicating substantial energy usage for water heating. Cooking accounts for 76,403.395 terajoules (2.84%), demonstrating the energy consumed for culinary purposes. Space cooling shows a relatively lower consumption at 9,776.369 terajoules (0.36%), suggesting lesser demand compared to heating. The category "Lighting and electrical appliances" accounts for 262,907.119 terajoules (9.76%), while "Other end use" represents the highest consumption at 1,556,447.089 terajoules (57.24%), encompassing various miscellaneous energy uses in residential settings.[9]

Table 10: Residential energy consumption by end-use, per capita basis in terajoules and percentages in France, 2022

Space heating	Space cooling	Water heating	Cooking	Lighting and electrical appliances	Other end use

1,047,493.373	9,776.369	159,866.833	76,403.395	262,907.119	1,556,44.089
33.65%	0.31%	5.14%	2.45%	8.45%	50.00%

- **Percentage of households unable to keep their home adequately warm**

In 2022, 10.7% of households in France are unable to adequately heat their homes. This figure highlights a persistent challenge in terms of access to sufficient warmth for a significant portion of the population, despite advancements in energy efficiency and supportive policies. [10]

- **Final energy consumption by sector**

Final energy consumption in France slightly decreased from 138,965.296 TJ in 2021 to 132,682.3 TJ in 2022 under normal climate conditions.[11]

- **Disaggregated Final Energy Consumption in Households**

Disaggregated final energy consumption in households in France decreased from 1,766,066.837 terajoules in 2021 to 1,556,447.089 terajoules in 2022.[12]

2.1.2.2. Main drivers of the energy consumption variation of households

The data shown in Table 11 indicates that total energy consumption increased from 40.5 to 42.3 Mtoe* from the year 2000 to 2021. Several factors contributed to this variation, including climate fluctuations (+1.6 Mtoe), an increase in the number of dwellings (+8.8 Mtoe), more appliances per dwelling (+5.3 Mtoe), and larger homes (+1 Mtoe). However, these increases were partially offset by energy savings (-17 Mtoe) and other factors (+2 Mtoe).[13]

***Mtoe:** Million tons of oil equivalent

Table 11: Energy consumption changes (Units) in France (2000 vs. 2021)

Consumption 2000	Climate	More dwellings	More appliances per dwelling	Larger homes	Energy savings	Others	Consumption 2021
40.5	1.6	8.8	5.3	1	-17	2	42.3

2.1.2.3. Heating & cooling degree days

France experienced 2045 heating degree days (HDD) and 87 cooling degree days (CDD), reflecting the extent of heating and cooling needs due to temperature variations throughout the year.[14]

2.1.2.4. Greenhouse gas emissions from energy use in buildings

Table 12 outlines greenhouse gas emissions from building energy use in France, showing percentage changes from 2005 to 2021, and projected changes for 2030 under existing and additional measures.

From 2005 to 2021, emissions decreased by 33%. Projections for 2030 suggest a further reduction of 46% with both existing and additional measures, emphasizing the country's commitment to mitigating environmental impact through effective practices in the building sector.[15]

Table 12: Greenhouse gas emissions from building energy use in France

	2005-2021 percentage change	2005-2030 further projected change with existing measures	2005-2030 further projected change with additional measures
France	-33	-46	-46

2.1.2.5. Energy Production and Consumption

Table 13 highlights France's electricity production capacities in 2020, totaling 1,215.45 billion kWh.[16] Nuclear power dominates with 830.53 billion kWh, followed by hydroelectric power at 142.07 billion kWh. Fossil fuels contribute 97.14 billion kWh. Wind power, solar, biomass, and tidal energy add 88.64, 30.36, 24.28, and 2.43 billion kWh, respectively. This diverse energy mix underscores France's efforts to enhance energy security and reduce carbon emissions, aligning with environmental sustainability goals.

Table 13: France electricity production capacities, 2020 (billion kWh)

Type	Nuclear	Hydro	Fossil fuel	Wind power	Solar	Biomass	Tidal	Total
Amount	830.53	142.07	97.14	88.64	30.36	24.28	2.43	1,215.45

Table 14 provides an overview of electricity production in France. In 2020, France produced 553.71 billion kWh of electricity, slightly exceeding its domestic consumption of 472.70 billion kWh. The country exported 64.43 and imported 19.61 billion kWh, demonstrating its strong capability in managing its energy needs and participating in the European electricity market. [16]

Table 14: France electricity production overview, 2020 (billion kWh)

Category	Consumption	Production	Import	Export
Amount	472.70	553.71	19.61	64.43

Table 15 presents data on natural gas in France. In 2020, France exhibited a significant reliance on natural gas imports to meet its domestic consumption, with very limited domestic production amounting to just 0.01 billion m^3. Exports total 9.10 billion m^3, indicating a strong position as a net consumer of natural gas, albeit with lower exports compared to imports. [16]

Table 15: Natural gas in France, 2020 (billion m^3)

Category	Consumption	Production	Import	Export
Amount	38.19	0.01	46.11	9.10

The crude oil statistics in barrels per day are shown in Table 16. In France, daily consumption of crude oil amounts to 1,690,000 barrels per day, while domestic production stands at only 81.5 barrels per day. The country imports 161.6 barrels per day and exports 1,060,000 barrels per day, primarily in the form of refined petroleum products rather than crude oil itself. This highlights

France's heavy reliance on crude oil imports to meet its high consumption, with domestic production covering only a small fraction of its needs. [16]

Table 16: Crude oil statistics in France, 2020 (barrels per day)

Category	Consumption	Production	Import	Export
Amount	1,690,000	81.5	161.6	1,060,000

The total CO_2 emissions in France, amounted to 267.15 million tons. [16]

2.1.3. Retrofit market

2.1.3.1. Building systems for energy efficiency

Various building systems and technologies promote energy efficiency in the context of France [17]. Understanding these systems allows stakeholders to assess the most effective retrofitting approaches.

The H1, H2, and H3 zones in France correspond to specific climate classifications. H1 represents regions with a mild to moderate climate, where buildings primarily utilize External Thermal Insulation (ITE), Internal Thermal Insulation (ITI), and roof insulation to optimize energy efficiency. In contrast, H2 covers colder regions than H1, necessitating more robust insulation solutions such as attic insulation, in addition to ITE and ITI. H3, on the other hand, pertains to the coldest climate regions, focusing heavily on attic insulation, as well as the use of ITE and ITI to address significant heat loss challenges.

The following Tables provide information on the number of available and stocked dwellings that utilize the system, along with their respective percentages in each of France's zones, and the distribution of building types. For each system, the available types are listed with their corresponding percentages of use in the various climatic zones across France.

In Zone H1, single-family buildings predominantly use External Thermal Insulation (ITE) and Internal Thermal Insulation (ITI), while multi-family buildings favor roof insulation. In contrast, in Zone H3, attic insulation is more commonly used for single-family buildings (Table 17). [18]

Table 17: Building insulation analysis: Distribution by zone, building type, and insulation methods, 2020

Zone	Number of data	Total insulation	Type of building		Insulation post				
			Single-Family	Multi-Family	Low Floor	Attic Lost	Rampants	ITE	ITI
H1	2461	62.6%	93.3%	6.7%	5.6%	27.4%	21.9%	26.3 %	18.8%
H2	1430	36.4%	99.8%	0.2%	9.0%	45.3%	11.2%	19.1 %	15.4%
H3	38	1.0%	89.2%	10.8%	9.1%	42.4%	21.2%	15.2 %	12.1%

The table indicates a higher adoption of double-flow systems in multi-family buildings compared to single-flow systems and hygro B and A systems, which are more common in single-family homes. This suggests an adaptation of ventilation technologies based on specific building characteristics and ventilation needs in each zone.

Table 18: Ventilation analysis: Exploring building types and ventilation methods by zones, 2020

Zone	Number of data	Total ventilation	Type of building		Type of ventilation			
			Single-Family	Multi-Family	Simple flux	Hygro B	Hygro A	Double flux
H1	2461	65.2%	94.6%	5.4%	30.6%	40.3%	15.3%	13.9%
H2	1430	34.1%	100.0%	0.0%	19.0%	68.6%	7.6%	4.8%
H3	38	0.7%	100.0%	0.0%	0.0%	40.0%	60.0%	0.0%

The analysis (Table 19) focuses on heating sources and generator types before and after renovations, by building type and zone. There is a shift towards more efficient heating sources like gas and electricity post-renovation, with prevalent use of condensing boilers and wood stoves in some cases.

Table 19: Heating: Investigating building types, heating sources, and generator types by zones, 2020

Zone	Number of data	Total heating	Type of building		Heating source before renovation					Heating source after renovation				
			Single-Family	Multi-Family	Wood	Electricity	Oil	Gas	Other	Wood	Electricity	Oil	Gas	Other
H1	1132	43.4%	92.6%	7.4%	10.4 %	20.8%	30.4 %	35.8 %	2.5 %	46.4 %	9.2%	8.5 %	35.9 %	0.0 %
H2	1424	54.6%	99.8%	0.2%	3.8 %	61.5%	11.5 %	15.4 %	7.7 %	78.2 %	5.5%	0.8 %	15.5 %	0.0 %
H3	50	1.9%	93.9%	6.1%	0.0 %	64.3%	14.3 %	21.4 %	0.0 %	84.0 %	10.0%	0.0 %	6.0 %	0.0 %

The distribution of heating generators as shown in Table 20 is dominated by stoves, which account for nearly half of the total at 49.9%. Boilers are the second most prevalent type, comprising 38.2% of the distribution. Heat pumps, referred to as Pac, are used to a lesser extent, representing 10.4% of the total. Other types of heating generators make up a small fraction, at just 1.4%. This distribution suggests a strong preference for stoves and boilers, which together account for the vast majority of heating systems in use. The relatively lower adoption of heat pumps indicates they are less common, possibly due to higher initial costs or specific installation requirements. The minimal percentage of other heating generators highlights their limited presence in the market.

Table 20: Distribution of heating generators

Type of heating generator	Percentage
Boiler	38.2%
Stove	49.9%
Pac	10.4%
Other	1.4%

Within the category of boilers (Table 21), condensation boilers are overwhelmingly the most common type, making up 63% of all boilers. These boilers are known for their high efficiency and environmental benefits, which likely contribute to their widespread use. Air-water boilers and air-air boilers are also significant, representing 12.1% and 9.7% respectively, indicating a notable preference for boilers that utilize air systems. High-Performance Energy (HPE) boilers account for

5.6%, showcasing a focus on energy-efficient options. Standard boilers have the lowest share among the specified types at 4.50%, reflecting a shift towards more advanced and efficient technologies. Other types of boilers constitute 5.10%, suggesting a variety of less common boiler technologies in use. This breakdown reveals a clear trend towards high-efficiency and advanced boiler systems.

Table 21: Distribution of heating generator types

Type of boiler generator	Percentage
Standard	4.5%
In condensation	63%
Air-Water	12.1%
Air-Air	9.7%
HPE	5.6%
Other	5.1%

Table 22 explores different types of domestic hot water systems used by building type and zone. It shows significant variability in the adoption of solar hot water systems (CETI and CESI) and conventional systems, with a marked prevalence of Combined Solar Systems (SSC) in certain zones to meet domestic hot water needs.

Table 22: Domestic hot water analysis: Exploring building types and domestic hot water types by zones, 2020

Zone	Number of data	Total heating	Type of domestic hot water			
			Classic	CETI	CESI	SSC
H1	74	19.9%	1.4%	21.1%	68.4%	9.1%
H2	291	78.4%				
H3	6	1.6%				

2.1.3.2. Energy efficiency

Table 23 presents data on final energy consumption, which reflects the energy used by end-users in various sectors such as residential, commercial, industrial, and transportation.

On the other hand, the information on primary energy consumption is also provided, which encompasses the total energy extracted from nature to meet the demands of society, including energy losses during extraction, transportation, and transformation processes.

Final energy consumption in France decreased from 143.23 Mtoe in 2021 to 138.25 Mtoe in 2022, while primary energy consumption declined from 222.82 Mtoe to 204.96 Mtoe over the same period.

These figures reflect potential changes in energy efficiency and consumption patterns within the country.[19]

Table 23: Final and primary energy consumption in France

	2021	2022
Final energy consumption	143.23	138.25
Primary energy consumption	222.82	204.96

2.1.3.3. Classification of building energy consumption

The energy class of a dwelling is determined by its energy consumption, measured in (kWh/m²/year). Dwellings are classified based on their energy performance, with specific thresholds for each class.

This classification enables the assessment of building energy efficiency and identifies opportunities for improving performance. As shown in Table 24, the classes range from A to G, representing the highest to lowest levels of energy efficiency respectively. In 2020, the most common classifications were D (30.4%), E (25.7%), and C (14.2%), indicating a significant prevalence of buildings that may benefit from energy efficiency improvements. Classes A (5.6%) and B (7.8%) also show a presence, though smaller, of highly energy-efficient buildings. Classes F (11.6%) and G (4.7%) represent the lowest levels of energy efficiency.[18]

Table 24: France's energy classification of 2020

Energy Classification	Consumption (kWh/m²/year)	Percentage
A	<70	5.6%
B	70≤Consumption<110	7.8%
C	110≤Consumption<180	14.2%
D	180≤Consumption<250	30.4%
E	250≤Consumption<330	25.7%
F	330≤Consumption<420	11.6%
G	≥420	4.7%

Table 25 compares France's energy performance diagnosis (DPE) classifications for 2018 and 2022 among main residences, secondary residences, and vacant dwellings. It shows changes in energy efficiency over time, including increases in class C and decreases in classes A, B, and F across different types of dwellings. [20]

Table 25: France's energy performance diagnosis (DPE) classification of 2018 and 2022 for different types of dwellings

DPE Class	2018 Main Residences	2018 Main Residences	2022 Main Residences	2022 Main Residences	2022 Secondary Residences	2022 Secondary Residences	2022 Vacant Dwellings	2022 Vacant Dwellings	2022 All Dwellings	2022 All Dwellings
A	520	1.8%	502	1.7%	22	0.6%	10	0.3%	534	1.5%
B	1 370	4.8%	961	3.2%	62	1.7%	52	1.7%	1 075	2.9%
C	5 161	18.0%	7 039	23.5%	506	13.8%	508	16.9%	8 052	22.0%
D	9 791	34.2%	9 708	32.4%	961	26.2%	896	29.8%	11 564	31.5%
E	6 993	24.4%	6 586	22.0%	948	25.8%	748	24.8%	8 283	22.6%
F	3 076	10.7%	3 154	10.5%	601	16.4%	414	13.8%	4 169	11.4%
G	1 709	6.0%	2 032	6.8%	573	15.6%	383	12.7%	2 989	8.2%

2.1.3.4. Cost of renovation

The following Tables 26-28 provide a detailed cost analysis of building retrofitting for energy systems in France. It outlines the investments required for various energy-efficient upgrades including windows, doors, facade, roof, attic, basement, ground plate, and solar shading. Costs are differentiated between fixed and variable costs, offering a comprehensive overview of expenses associated with each type of energy improvement.

Additionally, it examines cooling systems, photovoltaics, space heaters, other heat emitters, radiators, ventilation, domestic hot water systems, and lighting, detailing average costs per respective unit of measurement.[18]

Table 26: Cost analysis of building retrofitting: Evaluating Energy Systems Investment in France

Windows (Base = 2015)					Doors (Base = 2015)	Facade (Base = 2014)		Roof		Attic		Basement		Ground plate	Solar shading (Base = 2015)
Single glazing	Double glazing	Double glazing with solar protection	Triple glazing	Triple glazing with solar protection	Average	Fixed costs	Variable costs	Fixed costs	Variable costs	Fixed costs	Variable costs	Fixed costs	Variable costs	Fixed costs	Average costs
EUR/m²	EUR/m²	EUR/m²	EUR/m²	EUR/m²	EUR/m²	EUR/m²	EUR/m²cm	EUR/m²	EUR/m²cm	EUR/m²	EUR/m²cm	EUR/m²	EUR/m²cm	EUR/m²	EUR/m²
195	283	308	350	469	1 087	71	1.64	142	1.47	21	1.56	34	1.23	33.56	765

Table 27: Costs of Cooling Systems and Photovoltaic Installations in France

Cooling systems (Base = 2018)						Photovoltaics (Base = 2018)			
Centralised chiller (whole building, replacement)	Centralised chillers (whole building, new installation)	Centralised multi-split system (whole building)	Centralised multi-split system (for appartment)	Mounted single-split/window AC	Movable AC systems	0-10 kWp	10-15 kWp	15-20 kWp	>20 kWp
EUR	EUR	EUR	EUR	EUR	EUR	EUR	EUR	EUR	EUR
72 530	574 329	28 607	9 214	1 809	379	2 356	2 385	2 413	2 442

Table 28: Average Costs of Space Heaters, Other Heat Emitters, and Related Systems (Base Year = 2015) in France

Space heaters (base = 2015)	Other heat emitters than radiators	Radiators	Ventilation		Domestic hot water systems		Lighting
Average	Average	Average	Central	Local	Central	Decentral	Average
EUR	EUR/m²	EUR	EUR/m²	EUR	EUR	EUR	EUR/m²
9 074	34	392	37	1 989	3 332	1 084	16

2.2. Building Retrofit Market in Spain

2.2.1. Residential building stock

2.2.1.1. High-level overview of the building stock

As shown in Table 29, main residence units account for the majority of the housing stock in Spain, with 19,536.469 units constituting 75.2% of the total. Among these, single-family units amount to

6,622.863, representing 25.5%, while multi-family units make up 12,913.606, comprising 49.7%. The total number of units is 25,976.305.
This data indicates a substantial number of primary residence units, accompanied by a notable presence of both single-family and multi-family dwellings.

Table 29: Diverse dwellings in Spain 2021

Dwelling type	Number of Units	Percentage of Total
Main residence	19,536.469	75.2
Single-family	6,622.863	25.5
Multi-family	12,913.606	49.7
Total	25,976.305	

2.2.1.2. Residential building stock by final energy consumption source

In Spain, energy consumption in residential buildings in 2022 (Table 30) shows a strong dependence on oil and petroleum products, which account for 49.47% of total consumption. Natural gas follows at 16.02%, with electricity contributing significantly at 24.77%. Renewables and biofuels represent 8.82% of the energy mix, while solid fossil fuels and other fuels have minimal shares.[2]

Table 30: Residential building stock by final energy consumption source in Spain in 2022

Solid fossil fuels	Natural gas	Oil and petroleum	Renewables and biofuels	Electricity	Heat	Other fuels n.e.c.*
0,49	16.02	49.47	8.82	24.77	0	0.42

2.2.1.3. The total stock of dwellings

- **Number of Buildings**

Across all periods (Table 31), the number of buildings owned by occupants significantly outnumbers those rented or with unknown ownership status, reflecting a strong culture of homeownership in Spain. The highest growth in building construction for owners was between 2000-2010, with a significant increase to 1,584,622 units. From 2011-2020, there is a noticeable drop in new constructions compared to previous decades.[3]

Table 31: Comparative analysis of building construction trends across Spain

Construction Period	0-1945	1946-1969	1970-1979	1980-1989	1990-1999	2000-2010	2011-2020
Owners	1,178,617	1,290,563	1,160,054	1,120,505	1,187,219	1,584,622	419,624
Tenants	383,07	353,06	274,803	359,238	384,424	491,42	109,065
Unknown	987	302	51	247	269	402	6

- **Total Stock of Dwellings**

Table 32 presents the total stock of dwellings in Spain from 2011 to 2022. A continuous increase in the number of dwellings is observed, rising from 25,249 in 2011 to 26,068 in 2022. This growth reflects a stable yet slow expansion of the housing market in Spain.[21]

Table 32: Total stock of dwellings in Spain

2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
25,249	25,382	25,441	25,492	25,541	25,586	25,645	25,712	25,793	25,882	25,976	26,068

- **Distribution of population by dwelling type**

The table presents the distribution of different types of dwellings in Spain in 2023. Detached houses represent 8.9%, semi-detached houses account for 3.8%, and flats (or apartments) dominate significantly at 45.5%. The flats are further detailed based on whether they are located in buildings with less than ten dwellings (9.7%) or in buildings with ten or more dwellings (35.8%). Other types of dwellings represent 0.1%. These figures illustrate the relative prevalence of each housing type across the country.[5]

Table 33: Distribution of population by dwelling type in Spain, 2023

House	Detached house	Semi-detached house	Flat	Flat in a building with less than ten dwellings	Flat in a building with ten or more dwellings	Others
8.9	3.8	5.1	45.5	9.7	35.8	0.1

- **Average Household Size**

The average household size in Spain was stable at 2.5 persons per household for both the years 2022 and 2023. [6]

2.2.1.4. New construction of dwellings

The number of new dwellings constructed each year shows a consistent upward trajectory, starting at 45,000 in 2016 and steadily increasing to 91,000 in 2021 (Table 34). This indicates a period of growth in residential construction activity in Spain during these years. This analysis underscores the evolution of new dwelling constructions in Spain, reflecting a progressive rise in construction activity and a response to the growing demand for housing in the country. [7]

Table 34: Annual new dwelling additions in Spain (2016-2021)

2016	2017	2018	2019	2020	2020
45,000	54,000	64,000	78,000	87,000	91,000

2.2.1.5. Share of the urban and rural populations in the total population

The above table presents the distribution of urban and rural populations in Spain from 2005 to 2022. Over the years, there has been a noticeable trend towards urbanization, marked by a consistent increase in the proportion of the population living in urban areas. In 2005, the urban population accounted for 77.26% of the total, while the rural population was 22.74%. [8]
This trend has intensified over time, reaching 81.3% for the urban population and 18.7% for the rural population in 2022.

Table 35: Share of urban and rural populations in Spain

Spain	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Urban	77.26	77.5	77.74	77.98	78.21	78.44	78.67	78.9	79.13	79.37	79.6	79.84	80.08	80.32	80.57	80.81	81.06	81.3
Rural	22.74	22.5	22.26	22.02	21.79	21.56	21.33	21.1	20.87	20.63	20.4	20.16	19.92	19.68	19.43	19.19	18.94	18.7

2.2.2. Energy consumption by the residential sector

2.2.2.1. Final energy consumption by the residential sector and by use

- **Energy consumption by end-use**

Residential energy consumption in Spain in 2022 (Table 36) is primarily driven by "other end uses," totaling 597,849.125 terajoules. Space heating follows with 235,990.174 terajoules, followed by water heating at 114,285.729 terajoules. Space cooling and cooking consume 6,173.501 terajoules and 46,900.868 terajoules, respectively. Lighting and electrical appliances account for 194,497.837 terajoules. [9]

Table 36: Residential energy consumption by end-use, per capita basis in terajoules and Percentages in Spain, 2022

Space heating	Space cooling	Water heating	Cooking	Lighting and electrical appliances	Other end use
235,990.174	6,173.501	114,285.729	46,900.868	194,497.837	597,849.125
19.74%	0.52%	9.56%	3.92%	16.27%	50.00%

- **Percentage of households unable to keep their home adequately warm**

In 2022, 17.1% of households in Spain reported being unable to adequately heat their homes, which increased to 20.8% in 2023.[10]

- **Final energy consumption by sector**

Final energy consumption in Spain across all sectors experienced a slight decrease from 78,607.539 terajoules in 2021 to 77,873.473 terajoules in 2022.[11]

- **Disaggregated Final Energy Consumption in Households**

Within households, disaggregated final energy consumption decreased from 617,240.001 terajoules in 2021 to 597,849.125 terajoules in 2022.[12]

2.2.2.2. Main drivers of the energy consumption variation of households

In 2000, household energy consumption stood at 12.1 Mtoe . Climate impact accounted for a slight decrease of 0.7 Mtoe. The construction of new dwellings contributed significantly to an increase of 5.3 Mtoe, highlighting the impact of housing expansion. Larger homes added 0.6 Mtoe to consumption, reflecting the increased energy demand of larger living spaces. Efficiency improvements led to a notable reduction of 6.5 Mtoe. Other unspecified factors contributed to an increase of 3.7 Mtoe in consumption. By 2021, household energy consumption totaled 14.6 Mtoe . [22]

Table 37: Energy consumption changes in Spain (2000 vs. 2021)

Consumption 2000	Climate	More dwellings	Larger homes	Energy savings	Others	Consumption 2021
12.1	-0.7	5.3	0.6	-6.5	3.7	14.6

2.2.2.3. Heating & cooling degree days

In 2023, Spain recorded approximately 1482 heating degree days and 338 cooling degree days. [14]

2.2.2.4. Greenhouse gas emissions from energy use in buildings

Table 38 presents the percentage changes in greenhouse gas emissions from building energy use in Spain from 2005 to 2021, showing a decrease of 16%. It also projects further reductions by 2030 with existing measures -34% and with additional measures -46%. [15]

Table 38: Greenhouse gas emissions from building energy use in Spain

Countries	2005-2021 percentage change	2005-2030 further projected change with existing measures	2005-2030 further projected change with additional measures
Spain	-16	-34	-46

2.2.2.5. Energy Production and Consumption

Table 39 presents data on Spain's electricity production capacities for the year 2020, categorized by various types of energy sources. It indicates the capacities for each energy source: fossil fuels at 328.77, wind power at 224.26, nuclear power at 222.23, hydroelectric power at 132.93, solar power at 82.19, and biomass at 26.38. The total electricity production capacity in Spain for that year was 1,016.76. This data underscores Spain's energy diversification strategy, with significant contributions from both conventional sources like fossil fuels and nuclear power, as well as renewable sources such as wind, hydro, solar, and biomass.[23]

Table 39: Spain electricity production capacities, 2020 (billion kWh)

Type	Fossil fuel	Wind power	Nuclear	Hydro	Solar	Biomass	Total
Amount	328.77	224.26	222.23	132.93	82.19	26.38	1,016.76

In 2020, Spain consumed 233.27 of electricity and produced 253.99 various energy sources (Table 40). The country imported 17.93 to supplement its domestic production and meet demand, while exporting 14.65, highlighting its role as a net exporter of electricity that year.[23]

Table 40: Spain electricity production overview, 2020 (billion kWh)

Category	Consumption	Production	Import	Export
Amount	233.27	253.99	17.93	14.65

As shown in Table 41, natural gas consumption in Spain amounted to 32.03 billion m^3, reflecting the total quantity of natural gas used in the country for the year 2020. Conversely, domestic production was minimal, standing at just 0.01. Consequently, Spain heavily relied on natural gas imports, which totaled 32.49 to meet its domestic consumption needs.

The country also exported 1.19 m^3 of natural gas, demonstrating a level of export capacity despite its significant dependency on imports to satisfy its natural gas energy requirements.[23]

Table 41: Natural gas in Spain, 2020 (billion m^3)

Category	Consumption	Production	Import	Export
Amount	32.03	0.01	32.49	1.19

Crude oil statistics for Spain in 2020 reveal significant figures: daily consumption stands at 1,330,000 barrels, whereas domestic production is a modest 47.2 barrels per day. The country's reliance on crude oil imports is stark, with imports totaling 1,360,000 barrels per day, slightly exceeding its domestic consumption.

This underscores Spain's heavy dependence on imports to meet its crude oil needs, despite having limited domestic production capacity. [23]

Table 42: Crude oil statistics in Spain, 2020 (barrels per day)

Category	Consumption	Production	Import
Amount	1,330,000	47,2	1,360,000

Spain's total CO_2 emissions were reported at 262.71 million tons in 2024.[23]

2.2.3. Retrofit market

2.2.3.1. Energy efficiency

For the year 2021, Spain recorded a final energy consumption of 80.33 Mtoe, which slightly increased to 81.23 Mtoe in 2022. Regarding primary energy consumption, Spain consumed 111.46 Mtoe in 2021, which then rose to 113.23 Mtoe in 2022 (Table 43).

These figures indicate a slight uptick in both final and primary energy consumption from 2021 to 2022.[19]

Table 43: Final and primary energy consumption in Spain

	2021	2022
Final energy consumption	80.33	81.23
Primary energy consumption	111.46	113.23

2.2.3.2. Classification of building energy consumption

The energy classification in Spain for 2021 highlights a concentration of buildings in the middle to lower energy classes, particularly classes D, E, and F (Table 44).

In 2021, no buildings were classified in category A, (1%) were in category B, (4%) in category C, (11%) in category D, (52%) in category E, (11%) in category F, and (21%) in category G. This distribution highlights a significant predominance of buildings in categories E and G, indicating potential for improving energy efficiency in Spain's building sector.

Table 44: Spain energy classification, 2021

Energy Classification	Percentage
A	0.00%
B	1.00%
C	4.00%
D	11.00%
E	52.00%
F	11.00%
G	21.00%

2.2.3.3. Cost of renovation

Table 44 offers a comprehensive analysis of the financial aspects of building retrofitting in Spain, covering investment costs for energy systems such as windows, doors, facades, roofs, attics, basements, ground plates, solar shading, cooling systems, space heaters, and additional heating solutions.[18]

Table 45: Cost analysis of building retrofitting: Evaluating Energy Systems Investment in Spain

Windows (Base = 2015)					Doors (Base = 2015)	Facade (Base = 2014)		Roof		Attic		Basement	Ground plate		Solar shading (Base = 2015)
Single glazing	**Double glazing**	**Double glazing with solar protection**	**Triple glazing**	**Triple glazing with solar protection**	**Average**	**Fixed costs**	**Variable costs**	**Fixed costs**	**Variable costs**	**Fixed costs**	**Variable costs**	**Fixed costs**	**Variable costs**	**Fixed costs**	**Average costs**
EUR/ m²	EUR/ m²	EUR/m²	EUR/ m²	EUR/m²	EUR/m²	EUR/ m²	EUR/ m²cm	EUR/ m²	EUR/ m²cm	EUR/ m²	EUR/ m²cm	EUR/ m²	EUR/ m²cm	EUR/ m²	EUR/m²
137	211	231	273	370	675	44	1	88	1	13	1	21	1	21	475

Table 46: Costs of Cooling Systems and Photovoltaic Installations in Spain

Cooling systems (Base = 2018_						Photovoltaics (Base = 2018)			
Centralised chiller (whole building, replacement)	Centralised chillers (whole building, new installation)	Centralised multi-split system (whole building)	Centralised multi-split system (for appartment)	Mounted single-split/window AC	Movable AC systems	0-10 kWp	10-15 kWp	15-20 kWp	>20 kWp
EUR	EUR	EUR	EUR	EUR	EUR	EUR	EUR	EUR	EUR
85,386	640,393	29,650	9,287	1,512	398	2,176	2,249	2,322	2,394

Table 47: Average Costs of Space Heaters, Other Heat Emitters, and Related Systems (Base Year = 2015) in Spain

Space heaters (base = 2015)	Other heat emitters than radiators	Radiators	Ventilation		Domestic hot water systems		Lighting
Average	Average	Average	Central	Local	Central	Decentral	Average
EUR	EUR/m²	EUR	EUR/m²	EUR	EUR	EUR	EUR/m²
5,289	21	137	23	291	1,525	287	10

2.3. Building Retrofit Market in Italy

2.3.1. Residential building stock

2.3.1.1. High-level overview of the building stock

As shown in Table 48, occupied units represent the majority of the housing stock in Italy, with 25,690,057 units constituting 72.8% of the total. Among these, single-family units amount to 12,048,637, representing 34.2%, while multi-family units make up 13,641,420, comprising 38.7%. The total number of units is 35,271,829. [24]

This distribution highlights a significant proportion of occupied units alongside a substantial presence of both single-family and multi-family dwellings.

Table 48: Diverse dwellings in Italy, 2021

Dwelling Type	Number of Units	Percentage of Total
Occupied	25,690.057	72.8
Single-family	12,048.637	34.2
Multi-family	13,641.420	38.7
Total	35,271.829	

2.3.1.2. Residential building stock by final energy consumption source

In Italy, energy consumption in residential buildings in 2022 is primarily dominated by oil and petroleum products, accounting for 37.01% of total consumption. Natural gas follows closely at 28.5%, with electricity contributing significantly at 22.28% (Table 49).

Renewables and biofuels make up 10.24% of the energy mix, while solid fossil fuels and other fuels have negligible shares. Heat represents 1.35% of the total consumption.[2]

Table 49: Residential building stock by final energy consumption source in Italy (%), 2022

Solid fossil fuels	Natural gas	Oil and petroleum	Renewables and biofuels	Electricity	Heat	Other fuels n.e.c.*
0.28	28.5	37.01	10.24	22.28	1.35	0.35

2.3.1.3. The total stock of dwellings

- **Number of Buildings**

Table 50 provides a comparative analysis of building construction trends across Italy, categorized by ownership status from pre-1945 to 2020. It reveals a steady decline in owner-occupied buildings, dropping from 2,259,851 pre-1945 to 1,137,168 in the 2011-2020 period. Tenant-occupied buildings also decreased, albeit more gradually, from 882,604 to 436,675 over the same timeframe. [3]

Table 50: Residential Buildings in Italy, by Construction Period and Tenure

Construction Period	0-1945	1946-1969	1970-1979	1980-1989	1990-1999	2000-2010	2011-2020
Owners	2,259,851	1,700,027	1,593,645	1,520,189	1,183,691	1,183,883	1,137,168
Tenants	882,604	646,294	605,999	577,673	457,696	464,348	436,675
Unknown	5,374	3,845	2,373	2,594	1,058	1,384	1,498

- **Total Stock of Dwellings**

Table 51 presents the total stock of dwellings (in million) in Italy from 2006 to 2017. It shows a steady increase in the number of dwellings over the years, rising from 28,344 in 2006 to 34,996 in 2017. This continuous growth reflects the expansion of the Italian housing market during this period. Notably, there was a significant acceleration between 2007 and 2010, with an increase of nearly 4 million dwellings in just three years.[25]

Table 51: Total stock of dwellings in Italy

2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
28,344	28,597	31,997	32,484	32,905	33,429	34,435	34,608	34,721	34,802	34,882	34,996

- **Distribution of population by dwelling type**

Table 52 outlines the distribution of different types of housing in Italy in 2023. Detached houses represent 7.2%, semi-detached houses account for 3.6%, and flats (or apartments) make up 28.2%. The flats are further categorized based on whether they are located in buildings with less than ten dwellings (11%) or in buildings with ten or more dwellings (17.2%). Other types of housing constitute 0.1%. These percentages illustrate the relative prevalence of each housing type across Italy.[5]

Table 52: Distribution of population by dwelling type in Italy, 2023

House	Detached house	Semi-detached house	Flat	Flat in a building with less than ten dwellings

7.2	3.6	3.5	28.2	11

- **Average Household Size**

The average household size in Italy for the years 2022 and 2023 is 2.2 persons per household.[6]

2.3.1.4. New construction of dwellings

Table 53 provides annual data on new dwelling constructions from 2016 to 2021. In 2016, there were 81,600 new dwellings constructed, slightly fewer than the 80,600 units built in 2017. This number increased to 83,100 in 2018 and continued to rise to 86,500 in 2019. Despite a slight decrease to 82,500 in 2020, the trend reversed with 87,300 new constructions recorded in 2021. [7]

Table 53: Annual new dwelling additions in Italy (2016-2021)

2016	2017	2018	2019	2020	2021
81,600	80,600	83,100	86,500	82,500	87,300

2.3.1.5. Share of the urban and rural populations in the total population

Table 54 presents the share of urban and rural populations in Italy from 2005 to 2022.
Over these years, there has been a consistent trend towards urbanization, with the urban population steadily increasing from 67.74% in 2005 to 71.66% in 2022.
In contrast, the rural population has gradually declined from 32.26% in 2005 to 28.34% in 2022.[8]

Table 54: Share of urban and rural populations in Italy

Italy	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Urban	67.74	67.86	67.97	68.09	68.21	68.33	68.44	68.68	68.98	69.27	69.56	69.86	70.14	70.44	70.74	71.04	71.35	71.66
Rural	32.26	32.14	32.03	31.91	31.79	31.67	31.56	31.32	31.02	30.73	30.44	30.14	29.86	29.56	29.26	28.96	28.65	28.34

2.3.2. Energy consumption by the residential sector

2.3.2.1. Final energy consumption by the residential sector and by use

- **Energy consumption by end-use**

Table 55 presents energy consumption in Italy for the year 2022, categorized by different end uses. Space heating dominates with 845,848.537 TJ, underscoring its significance during cold periods. Space cooling follows with 25,939.805 TJ, indicating reliance on air conditioning during warmer months. Water heating reaches 131,724.174 TJ, crucial for domestic hot water needs. Cooking consumes 94,152.949 TJ, while other end uses, encompassing various energy needs, total 125,106.167 TJ.[9]

Table 55: *Residential energy consumption by end-use, per capita basis in terajoules and percentages in Italy, 2022*

Space heating	Space cooling	Water heating	Cooking	Lighting and electrical appliances	Other end use
845,848.537	25,939.805	131,724.174	94,152.949	141,280.191	125,106.167
62.01%	1.90%	9.66%	6.90%	10.36%	9.17%

- **Percentage of households unable to keep their home adequately warm**

The percentage of households in Italy unable to maintain adequate warmth in their homes was reported at 8.8% for the year 2022. [10]

- **Final energy consumption by sector**

In 2021, the final energy consumption was recorded at 114,724.702 TJ, which decreased to 110,777.728 in 2022. This data indicates a reduction in overall final energy consumption across various sectors in Italy from one year to the next. [11]

- **Disaggregated Final Energy Consumption in Households**

The disaggregated final energy consumption in households in Italy for the years 2021 and 2022 indicates a decrease from 1,340,889.679 TJ in 2021 to 1,256,106.167 TJ in 2022. [12]

2.3.2.2. Main drivers of the energy consumption variation of households

Table 56 compares changes in household energy consumption in Italy between 2000 and 2021. In 2000, energy consumption was 27.6 Mtoe, with contributions including 0.7 Mtoe due to climate, 5.6 Mtoe from new housing construction, and 4.2 Mtoe from increased appliances per dwelling. Larger homes added 0.8 Mtoe to consumption. Energy savings initiatives reduced consumption by 5.2 Mtoe. Other unspecified factors marginally contributed to consumption. By 2021, household energy consumption in Italy increased to 32 Mtoe, highlighting overall growth influenced by housing dynamics, technological advancements, and consumption patterns over two decades.[26]

Table 56: Energy consumption changes (in units) in Italy (2000 vs. 2021)

Consumption 2000	Climate	More dwellings	More appliances per dwelling	Larger homes	Energy savings	Others	Consumption 2021
27.6	0.7	5.6	4.2	-0.8	-5.2	-0.2	32

2.3.2.3. Heating & cooling degree days

In 2023, Italy experienced 1689 heating degree days (HDD) and 301 cooling degree days (CDD), reflecting the extent of heating and cooling requirements due to temperature variations.[14]

Below is a comprehensive analysis of climate zones and degree days distribution in Italy, presented through both a table and a graphical representation. Table 57 provides detailed insights into the number of municipalities categorized by climate zone and corresponding degree days, while the Figure 1 visually depicts these zones across the Italian territory.

Based on the provided data, Italy's municipalities are classified into different climate zones based on their degree days (DD) ranges:

- *Zone A includes municipalities with DD values ≤ 600, representing 0.04% of the total resident population across two municipalities.*
- *Zone B comprises municipalities with DD values ranging from 601 to 900, encompassing 5.33% of the resident population across 157 municipalities.*
- *Zone C consists of municipalities with DD values ranging from 901 to 1400, covering 21.25% of the resident population across 989 municipalities.*
- *Zone D includes municipalities with DD values ranging from 1401 to 2100, representing 25.13% of the resident population across 1611 municipalities.*
- *Zone E encompasses municipalities with DD values ranging from 2101 to 3000, covering the highest proportion of the resident population at 45.53% across 4271 municipalities.*
- Zone F includes municipalities with DD values exceeding 3000, representing 2.72% of the resident population across 1071 municipalities.[27]

Figure 1: Map of climate zones in Italy

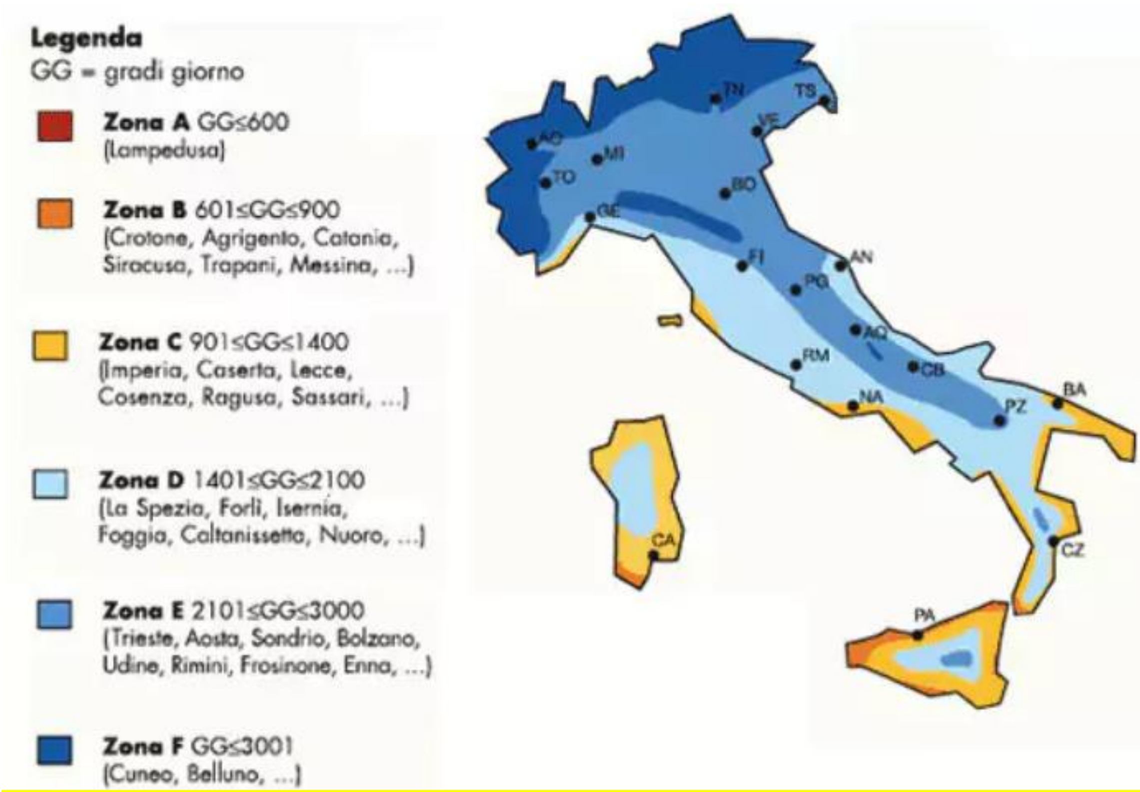

Table 57: Number of Italian municipalities by climate zone and heating degree days

Climate zone	DEGREE DAY (DD)	NUMBER OF MUNICIPALITIES	RESIDENT POPULATION	% RESIDENT POPULATION
A	DD ≤ 600	2	22989	0,04
B	600 < DD ≤ 900	157	3176382	5,33
C	900 < DD ≤ 1 400	989	12657407	21,25
D	1 400 < DD ≤ 2 100	1611	14970952	25,13
E	2 100 < DD ≤ 3 000	4271	27123848	45,53
F	DD > 3 000	1071	1619003	2,72

2.3.2.4. Greenhouse gas emissions from energy use in buildings

Table 58 shows a 13% reduction in greenhouse gas (GHG) emissions from building energy use in Italy from 2005 to 2021. Projections for 2030 indicate that emissions could decrease by 26% compared to 2005 levels with existing policies and also with additional measures. This highlights progress made through effective policies while emphasizing the potential for even greater reductions with further actions.[15]

Table 58: Greenhouse gas emissions from building energy use in Italy

Countries	2005-2021 percentage change	2005-2030 further projected change with existing measures	2005-2030 further projected change with additional measures
Italy	-13	-26	-26

2.3.3. Retrofit market

2.3.3.1. Energy efficiency

Table 59 presents Italy's final and primary energy consumption for the years 2021 and 2022. Final energy consumption decreased slightly from 114.2 Mtoe in 2021 to 112.04 Mtoe in 2022, indicating potential improvements in energy efficiency efforts. Similarly, primary energy consumption decreased from 145.56 Mtoe in 2021 to 139.25 Mtoe in 2022, reflecting more efficient use of overall energy resources.[19]

Table 59: Final and primary energy consumption in Italy

	2021	2022
Final energy consumption	114.2	112.04
Primary energy consumption	145.56	139.25

2.3.3.2. Classification of building energy consumption

In 2021, the majority of residential buildings in Italy were in the less efficient categories as shown in table 60, with (29.6%) of buildings classified as category F and (23.5%) as category G. The higher energy classifications (A1 to A4) represented a small percentage, totaling around (5.1%).

Table 60: Italy's energy classification of 2021

Energy Classification	Percentage
A1	2.2%
A2	1.4%
A3	1.2%
A4	0.3%
B	1.4%
C	2.3%
D	14.0%
E	24.0%
F	29.6%
G	23.5%

2.3.3.3. Cost of renovation

Tables 61-63 provide an in-depth examination of the costs associated with retrofitting buildings in Italy, evaluating expenditures on energy systems, including windows, doors, facades, roofs, attics, basements, ground plates, solar shading, cooling systems, space heaters, and various other heating systems.[18]

Table 61: Cost analysis of building retrofitting: Evaluating Energy Systems Investment in Italy

Windows (Base = 2015)					Doors (Base = 2015)	Facade (Base= 2014)		Roof		Attic		Basement		Ground plate	Solar shading (Base= 2015)
Single glazing	Double glazing	Double glazing with solar protection	Triple glazing	Triple glazing with solar protection	Average	Fixed costs	Variable costs	Fixed costs	Variable costs	Fixed costs	Variable costs	Fixed costs	Variable costs	Fixed costs	Average costs
EUR/m^2	EUR/m^2	EUR/m^2	EUR/m^2	EUR/m^2	EUR/m^2	EUR/m^2	EUR/m^2cm	EUR/m^2	EUR/m^2cm	EUR/m^2	EUR/m^2cm	EUR/m^2	EUR/m^2cm	EUR/m^2	EUR/m^2
164	246	268	311	420	696	46	1,05	91	0,94	14	1,00	21	0,79	21,50	490

Table 62: Costs of Cooling Systems and Photovoltaic Installations in Italy

Cooling systems (Base = 2018_						Photovoltaics (Base = 2018)			
Centralised chiller (whole building, replacement)	Centralised chillers (whole building, new installation)	Centralised multi-split system (whole building)	Centralised multi-split system (for appartment)	Mounted single-split/window AC	Movable AC systems	0-10 kWp	10-15 kWp	15-20 kWp	>20 kWp
EUR	EUR	EUR	EUR	EUR	EUR	EUR	EUR	EUR	EUR
76,486	573,644	31,053	9,721	1,575	417	2,273	2,350	2,427	2,504

Table 63: Average Costs of Space Heaters, Other Heat Emitters, and Related Systems (Base Year = 2015) in Italy

Space heaters (base = 2015)	Other heat emitters than radiators	Radiators	Ventilation	Domestic hot water systems	Lighting

Average	Average	Average	Central	Local	Central	Decentral	Average
EUR	EUR/m²	EUR	EUR/m²	EUR	EUR	EUR	EUR/m²
4,968	22	229	23	288	1,364	165	10

2.4. Building Retrofit Market in Bulgaria

2.4.1. Residential building stock

2.4.1.1. High-level overview of the building stock

The data (Table 64) indicates a total of 4,261,454 dwellings in Bulgaria, with single-family units numbering 1,858.596 representing 43.6% and multi-family units totaling 2,402.858 representing 56.4%. This highlights a predominance of multi-family housing compared to single-family residences in the country. [28]

Table 64: Diverse dwellings in Bulgaria, 2021

Dwelling type	Number of Housing Units	Percentage of Total
Single-family	1,858.596	43.6
Multi-family	2,402.858	56.4
Total	4,261.454	

2.4.1.2. Residential building stock by final energy consumption source

In Bulgaria, energy consumption in residential buildings in 2022 exhibits a significantly lower reliance on solid fossil fuels, natural gas, and oil compared to other examined countries.
As shown in Table 65, only 2.69% of domestic energy needs are sourced from these fuels, indicating a relatively low dependency. Bulgaria also demonstrates higher utilization of renewable energy sources, which account for 14.98% of its residential energy mix. Electricity and heat have substantial shares at 26.80% and 5.64% respectively, suggesting potential for further enhancing energy efficiency and sustainability. [2]

Table 65: Residential building stock by final energy consumption source in Bulgaria, 2022

Solid fossil fuels	Natural gas	Oil and petroleum	Renewables and biofuels	Electricity	Heat	Other fuels n.e.c.*
2.69	11.24	37.94	14.98	26.8	5.64	0.71

2.4.1.3. The total stock of dwellings

- **Number of Buildings**

Table 66 provides a detailed analysis of building construction trends in Bulgaria, categorized by construction periods and ownership types.

Before 1945, the majority of the 764,643 buildings were owner-occupied, with 149,002 occupied by tenants and 1,027 of unknown status. Subsequent periods up to 2020 show variations in ownership, with an increasing number of buildings owned by proprietors, although the proportion occupied by tenants also rises in more recent constructions.[3]

Table 66: Residential Buildings in Bulgaria, by Construction Period and Tenure

Construction Period	0-1945	1946-1969	1970-1979	1980-1989	1990-1999	2000-2010	2011-2020
Owners	764,643	851,981	476,286	433,866	277,592	304,189	195,998
Tenants	149,002	167,271	93,336	85,651	57,594	60,742	39,256
Unknown	1,027	873	454	485	252	309	265

- **Total Stock of Dwellings**

Table 67 presents the total stock of dwellings in Bulgaria from 2011 to 2022. In 2011, the total stock was 3,899 thousand dwellings, which increased steadily each subsequent year. By 2022, the total stock reached 4,282 thousand dwellings, indicating a consistent upward trend in the number of dwellings in Bulgaria over this period.[29]

Table 67: Total stock of dwellings in Bulgaria

2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
3,899	3,909	3,918	3,927	3,935	3,943	3,951	3,959	3,970	3,985	4,001	4,282

- **Distribution of population by dwelling type**

Table 68 shows the distribution of various types of housing in Bulgaria in 2023. Detached houses represent 8%, semi-detached houses account for 5.4%, and flats (or apartments) make up 36.5%. The distribution of flats further specifies those in buildings with less than ten dwellings (4.5%) and those in buildings with ten or more dwellings (31.9%). Other types of housing constitute 0.2%. These figures provide insights into the proportion of each housing type relative to the total housing stock in Bulgaria.[5]

Table 68: Distribution of population by dwelling type in Bulgaria, 2023

House	Detached house	Semi-detached house	Flat	Flat in a building with less than ten dwellings	Flat in a building with ten or more dwellings	Others
8	5.4	2.6	36.5	4.5	31.9	0.2

- **Average Household Size**

The average household size in Bulgaria remained stable at 2.3 persons per household for both the years 2022 and 2023.[6]

This statistic indicates the average number of individuals living in a typical Bulgarian household during these years, reflecting stability in household composition over the period.

2.4.1.4. New construction of dwellings

Table 69 shows the annual additions of new housing units in Bulgaria from 2016 to 2021. The figures show a general upward trend, from 9,342 new housing units in 2016 to a peak of 17,868 in 2021. [30]

Table 69: Annual new dwelling additions in Bulgaria (2016-2021)

2016	2017	2018	2019	2020	2021
9,342	8,384	8,136	12,105	15,415	17,868

2.4.1.5. Share of the urban and rural populations in the total population

In 2005, the urban population accounted for 70.58% of the total population, while the rural population was 29.42%.

Over the years (Table 70), there has been a consistent trend towards urbanization, with the share of the urban population gradually increasing each year.

By 2022, the urban population had risen to 76.36%, indicating a significant shift towards urban areas, while the rural population decreased to 23.64%.[8]

This data highlights Bulgaria's ongoing urbanization process, reflecting global trends where populations increasingly concentrate in urban centers.

Table 70: Share of urban and rural populations in Bulgaria

Bulgaria	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Urban	70.58	70.93	71.8	71.62	71.96	72.3	72.64	72.97	73.31	73.65	73.99	74.33	74.67	75.01	75.35	75.69	76.03	76.36
Rural	29.42	29.07	28.72	28.38	28.04	27.7	27.36	27.03	26.69	26.35	26.01	25.67	25.33	24.99	24.65	24.31	23.97	23.64

2.4.2. Energy consumption by the residential sector

2.4.2.1. Final energy consumption by the residential sector and by use

- **Energy consumption by end-use**

Table 71 provides a detailed breakdown of energy consumption for various end-uses in Bulgaria in 2022. The data reveals that space heating accounts for the largest share of energy consumption at 41,205.698 terajoules per person. Additionally, significant energy is allocated to other essential activities such as water heating 17,236.583 and general household use 87,729.596. These figures highlight the substantial energy demand for maintaining household comfort and functionality. The relatively lower consumption for space cooling 474.948 and cooking 8,130.422 suggests seasonal variations and efficiency in these areas.[9]

Table 71: Residential energy consumption by end-use, per capita basis in terajoules and percentages in Bulgaria, 2022

Space heating	Space cooling	Water heating	Cooking	Lighting and electrical appliances	Other end use
41,205.698	474.948	17,236.583	8,130.422	20,681.946	87,729.596
23.48	0.27	9.82	4.63	11.79	50.00

- **Percentage of households unable to keep their home adequately warm**

In 2022, 22.5% of households in Bulgaria were unable to keep their homes warm enough.
In 2023, this percentage decreased to 20.07%. This means that there is an improvement in the ability of households to heat their homes from one year to the next.[10]

- **Final energy consumption by sector**

In 2021, the final energy consumption by sector in Bulgaria was 10,164.447 terajoules. In 2022, this consumption decreased to 9,854.067 terajoules. This indicates a reduction in final energy consumption in different economic sectors of Bulgaria from year to year.[11]

- **Disaggregated Final Energy Consumption in Households**

The disaggregated final energy consumption in Bulgarian households was 83,120.649 terajoules in 2021. In 2022, this consumption increased to reach 87,729.596 terajoules. This shows an increase in energy consumption in households.[12]

2.4.2.2. Main drivers of the energy consumption variation of households

As shown in Table 72, in 2000, energy consumption in Bulgaria was 2.1 Mtoe. Factors influencing variations include climate (+0.01), more housing (+0.02), larger housing (+0.33), energy savings (-0.25) and other factors (+0.19). In 2021, consumption increased to 2.4 Mtoe. This shows a slight increase in energy consumption.[31]

Table 72: Energy consumption changes in Bulgaria (2000 vs. 2021)

Consumption 2000	Climate	More dwellings	Larger homes	Energy savings	Others	Consumption 2021
2.1	0.01	0.02	0.33	-0.25	0.19	2.4

2.4.2.3. Heating & cooling degree days

In 2023, Bulgaria recorded 2,081 heating-degree days and 248.43 cooling-degree days.[14] This data shows the energy requirement for heating and cooling buildings based on annual climate variations, indicating a climate requiring more heating than cooling.

2.4.2.4. Greenhouse gas emissions from energy use in buildings

Between 2005 and 2021, greenhouse gas emissions from the energy use of buildings in Bulgaria decreased by 1% (Table 73).

Projections to 2030 indicate a further reduction of 3% with existing measures, and a more significant reduction of 28% with additional measures.[15]

This highlights the potential impact of stricter environmental policies and energy efficiency initiatives to reduce greenhouse gas emissions in the building sector.

Table 73: Greenhouse gas emissions from building energy use in Bulgaria

Countries	2005-2021 percentage change	2005-2030 further projected change with existing measures	2005-2030 further projected change with additional measures
Bulgaria	-1	-3	-28

2.4.3. Retrofit market

2.4.3.1. Energy efficiency

As shown in Table 74, in 2021, the final energy consumption in Bulgaria was 10.2 Mtoe. In 2022, this consumption decreased slightly to 9.92 Mtoe. This decrease indicates a slight improvement in energy efficiency.

In 2021, primary energy consumption in Bulgaria was 18.55 Mtoe. In 2022, this consumption increased to 18.93 Mtoe.[19]

Table 74: Final and primary energy consumption in Bulgaria

	2021	2022
Final energy consumption	10.2	9.92
Primary energy consumption	18.55	18.93

2.4.3.2. Classification of building energy consumption

The majority of buildings in Bulgaria in 2010 had low energy classifications, with 39% of buildings classified as category E and 34% as category F. Very few buildings were well classified, with only 1% in category C and none in categories A or B. This indicates a need for improvements in energy efficiency, especially in buildings classified as less energy efficient. [32]

Table 75: Bulgaria energy classification of 2010

GHG Classification	Percentage
A	0%
B	0%
C	1%
D	8%
E	39%
F	34%
G	18%

2.4.3.3. Cost of renovation

Tables 76-78 presents a detailed cost analysis of building retrofitting in Bulgaria, focusing on investments in energy systems such as windows, doors, facades, roofs, attics, basements, ground plates, solar shading, cooling systems, space heaters, and other heat emitters.[18]

Table 76: Cost analysis of building retrofitting: Evaluating Energy Systems Investment in Bulgaria

Windows (Base = 2015)					Doors (Base = 2015)	Facade (Base = 2014)		Roof		Attic		Basement		Ground plate	Solar shading (Base = 2015)
Single glazing	Double glazing	Double glazing with solar protection	Triple glazing	Triple glazing with solar protection	Average	Fixed costs	Variable costs	Fixed costs	Variable costs	Fixed costs	Variable costs	Fixed costs	Variable costs	Fixed costs	Average costs
EUR/m²	EUR/m²	EUR/m²	EUR/m²	EUR/m²	EUR/m²	EUR/m²	EUR/m²cm	EUR/m²	EUR/m²cm	EUR/m²	EUR/m²cm	EUR/m²	EUR/m²cm	EUR/m²	EUR/m²
60	117	130	171	241	379	25	0,57	49	0,51	7	0,54	12	0,43	11,70	267

Table 77: Costs of Cooling Systems and Photovoltaic Installations in Bulgaria

Cooling systems (Base = 2018)						Photovoltaics (Base = 2018)			
Centralised chiller (whole building, replacement)	Centralised chillers (whole building, new installation)	Centralised multi-split system (whole building)	Centralised multi-split system (for appartment)	Mounted single-split/window AC	Movable AC systems	0-10 kWp	10-15 kWp	15-20 kWp	>20 kWp
EUR	EUR	EUR	EUR	EUR	EUR	EUR	EUR	EUR	EUR
60,755	537,560	28,019	8,626	1,221	379	1,904	1,997	2,091	2,184

Table 78: Average Costs of Space Heaters, Other Heat Emitters, and Related Systems (Base Year = 2015) in Bulgaria

Space heaters (base = 2015)	Other heat emitters than radiators	Radiators	Ventilation		Domestic hot water systems		Lighting
Average	Average	Average	Central	Local	Central	Decentral	Average
EUR	EUR/m²	EUR	EUR/m²	EUR	EUR	EUR	EUR/m²
4,232	12	154	13	557	2,206	821	6

3. Economic and Regulatory Context and Smart Grids Interaction Rules

This task serves as a continuous review and update of current guidelines, incentives, and opportunities related to energy retrofit practices, smart grids, and the electricity market within the European Union and the four project target countries. The main objective is to keep current with regulations and changes throughout the project's duration. This version presents an update on building retrofit-related regulations, economic aspects, smart grid initiatives, and strategies at both the EU and the four target countries. The Updates include the recent regulations published at the end of 2023 until June 2024. Smart grid interaction rules, electricity interchange information, analyses, identification of gaps, and areas of alignment for countries and EU-level regulatory frameworks will be presented in future deliverables.

3.1. Retrofit Practices Guidelines and Regulations

Globally, the building sector accounts for over 30% of final energy consumption and around 40% of energy-related emissions.[33] Older buildings presenting the largest share of the existing building stock, and being less efficient than new ones require energy retrofit practices to significantly improve their performance, reduce consumption, increase comfort, save costs, and lower operational greenhouse gas emissions.[34–36] Comprehensive guidelines and regulations are set globally at international and national levels to govern building retrofit practices. These regulations ensure compliance with energy performance standards, environmental assessments, and safety protocols, often providing incentives for adopting sustainable solutions. Compliance with these guidelines reduces energy consumption and operational costs and contributes to achieving broader climate goals and improving the buildings' resilience. Recent energy retrofit projects benefit from technological advancements, innovative building techniques, and cost-effective renovation practices incorporating energy-efficient solutions and renewable energy sources. For instance, the "REZBUILD" project, initiated in 2017 under the EU's Horizon 2020 program, developed a renovation decision-making platform. This platform integrates market technologies such as PV panels, energy-efficient glazing, and advanced insulation materials to achieve deep Near Zero Energy Buildings renovations.[37] Project demonstrations took place in Italy, Spain, and Norway, showcasing significant energy savings and reduced installation times.[38] Following the REZBUILD project, the "HEART project" (Holistic Energy and Architectural Retrofit Toolkit), also launched at the end of 2017, developed a multifunctional retrofit toolkit. This toolkit aims to transform existing buildings into smart buildings by integrating renewable energy sources, improving energy efficiency, and enhancing overall building performance through recent technologies like prefabricated façade systems, photovoltaic tiles, and smart energy management systems. Demonstrations for this project are being conducted in Italy and France.[39] In 2021, the "TripleSEC initiative" was launched in Ireland to promote sustainable practices in urban communities such as CABRA, Dublin. This initiative focuses on home renovation and the integration of solar PV systems to achieve significant energy savings.[40] In 2023, the "Schools Energy Retrofit Pathfinder Programme" in Ireland targeted energy use and CO2 emission reductions in schools. This program implemented deep retrofits and low-carbon heating solutions across multiple school buildings to improve energy efficiency and create a scalable model for future projects.[41] Additionally, the RESKIN project is an important example of comprehensive systems integration due to its Holistic Technological toolkit, which includes advanced technologies and energy-efficient solutions. This project demonstrates the significant savings that can be achieved, paving the way for future retrofit projects. As policies evolve, staying informed about the latest regulations and directives amendment is crucial for RESKIN project stakeholders to successfully implement the designed effective retrofit measures and provide the required information on the project solution effectiveness.

3.1.1. Guidelines and regulations at the European level

At the European Union level, energy retrofit practices are governed by a comprehensive framework of guidelines and regulations aimed at improving energy efficiency, meeting the EU's commitment to climate change mitigation, and reducing the environmental impact of the building sector.[42]

The following is the latest update on the main directives and regulations guiding energy-building retrofit practices at the EU level:

Energy Performance of Buildings Directive (EPBD): is the key element of the EU strategy to improve the energy efficiency of buildings. The EPBD recast, which entered into force in May 2024, indicates significant revisions aimed at decarbonizing the EU building sector as part of the broader "Fit for 55" package[43]. The following table presents the key measures of the new recast and binding targets for some measures[33]:

Table 79. Key measures of EPBD 2024 recast

Measure	Content
New Buildings	Member States shall ensure that new buildings are ZEBs: (a) as of 1 January 2028, new buildings owned by public bodies (b) as of 1 January 2030, all new buildings.
Renovation Targets	Deep renovation requirements in line with the energy efficiency first principle which focuses on the main building elements: (a) before 1 January 2030, into a NZEB; (b) as of 1 January 2030, into a ZEB;
Life-Cycle Emission Calculations	Starting in 2028, large new buildings must calculate their life-cycle Global Warming Potential (GWP), expanding to all new buildings by 2030. This includes emissions from manufacturing, construction, use, and end-of-life stages.

E-Mobility and Smart Readiness	New provisions require pre-cabling for electric vehicle charging in new and renovated buildings, and improvements to the Smart Readiness Indicator to enhance energy performance transparency and comparability across the EU.
Solar Energy	Deployment of solar systems if technically suitable and economically and functionally feasible, considering structural integrity, green roofs, and attic and roof insulation, where appropriate.
Indoor Air Quality Requirement	The directive mandates member states to set requirements for the implementation of adequate indoor environmental quality standards in new and existing buildings to maintain a healthy indoor climate. Non-residential ZEBs are required to be equipped with measuring and control devices for the monitoring and regulation of indoor air quality.
Energy Certificates	Member States may define an A+ energy performance class corresponding to buildings with a maximum threshold for energy demand which is at least 20% < the maximum threshold for ZEBs, and which generates more renewable energy on-site annually than its total annual primary energy demand.
Financial Incentives, Skills and Market Barriers	Member States shall provide appropriate financing, support measures, and other instruments able to address market barriers to deliver the necessary investments identified in their national building renovation plan to transform their building stock into zero-emission buildings by 2050.

- **Energy Efficiency Directive (EED):** The EED recast was published in **September 2023**, to reinforce the EU's commitment to enhancing energy efficiency across all sectors, with a particular emphasis on building energy renovation. The recast introduces more stringent targets and measures to ensure that buildings contribute significantly to the EU's energy efficiency and climate goals[43]. The directive mandates a higher annual energy savings target of 1.7% for member states, emphasizing the renovation of existing buildings as a critical pathway to achieving these savings. It requires member states to establish long-term renovation strategies that prioritize the deep renovation of the worst-performing buildings, aiming to address energy poverty and improve living conditions. Public sector buildings are given special attention, with a requirement to renovate at least 3% of the total floor area annually to exemplary energy performance standards (i.e., NZEB or ZEB); though member states can choose to provide a special exemption to the public housing sector, given that the savings from utility bills are not always sufficient to compensate for the costs of renovations. The recast also promotes the use of advanced energy management systems, digital technologies, and energy audits to drive continuous improvements in energy performance[44].
- **Renewable Energy Directive (RED):** RED new recast entered into force on **November 2023** sets a higher target for the share of renewable energy in EU gross final consumption of at least 42.5% by 2030. This directive mandates increased integration of renewable energy sources in buildings, particularly through renewable heating and cooling systems. New constructions and major renovations are required to achieve higher levels of renewable energy usage, thereby reducing reliance on fossil fuels and enhancing energy efficiency. The directive also supports the

development of renewable energy communities and simplifies administrative procedures to facilitate the adoption of renewable technologies in building projects. The recast aims to attend EU's climate commitment by promoting the use of solar panels, heat pumps, and other renewable technologies in the renovation of existing buildings[45]. In order to better achieve the results of the Directive, by 21 May 2025, Member States shall carry out a mapping exercise during which potential areas of Renewable Energy deployment are identified to achieve their 2030 Renewable Energy goal

- **The Eco-design for Sustainable Products Regulation (ESPR):** This regulation aims to enhance energy retrofit practices by setting rigorous standards for the energy performance and resource efficiency of a wide array of products. This regulation, approved by the European Council in **June 2024**, extends the previous Eco-design Directive to include almost all physical goods, thereby promoting more sustainable and circular product designs. By mandating requirements for product durability, upgradability, and reparability, the ESPR facilitates energy savings throughout a product's lifecycle. Furthermore, the Digital Product Passport introduced by the ESPR offers comprehensive information on a product's energy efficiency and environmental impact, aiding consumers and businesses in making environmentally responsible choices.[46]
- **F-Gas Regulation**: Which entered into force in **March 2024**, it introduces stricter measures to limit emissions of fluorinated greenhouse gases (F-gases) such as hydrofluorocarbons (HFCs), commonly used in refrigeration, air conditioning, and heat pumps. The regulation includes an ambitious binding target for HFCs, with a goal of full phase-out by 2050, with interim targets to steadily reduce their market availability. The regulation update directly promotes the adoption of more energy-efficient and environmentally sustainable equipment by enforcing the reduction in HFC quotas and expanding the scope to include more equipment and gases . Additionally, the regulation's emphasis on digital monitoring and stricter rules for preventing emissions during the lifecycle of equipment.[47] In the case of retrofit projects, this will also ensure that retrofitting efforts are aligned with broader EU sustainability goals.
- **Construction Product Regulation (CPR):** Adopted by the European Parliament in **April 2024**, incorporates the requirements of the European Sustainability Performance of Products Regulation (ESPR). Key features of this regulation include the introduction of digital product passports and lifecycle assessment information, which provide detailed data on the energy performance and environmental impact of materials used in construction projects. By streamlining standardization processes and simplifying documentation, the CPR reduces administrative burdens, making it easier for manufacturers and builders to comply with environmental sustainability standards[48].
- **Ambient Air Quality Directive (AAQD):** approved by EU institutions in February 2024 and adopted by the European Parliament in **April 2024**, the revised directive sets stricter air quality standards for pollutants such as particulate matter ($PM_{2.5}$, PM_{10}), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2), aiming to align more closely with World Health Organization (WHO) guidelines by 2030. [49,50] This directive mandates enhanced monitoring and reporting systems

and introduces stringent enforcement measures, including penalties for non-compliance and the creation of low-emission zones.[51] These updates are related to the EU's Climate action plan, targeting zero air pollution by 2050, and are expected to reduce the health impacts of air pollution, which currently causes approximately 300,000 premature deaths annually in Europe.[49] The approval of this directive encourages building retrofits to reduce their emissions and improve air quality through upgrading HVAC systems, improving insulation, and adopting cleaner energy sources, all of which follow AAQD standards.

For most EU directives provisions, there will be an 18-month period to transpose them into national law, only provisions related to permitting renewable will have a shorter deadline of July 2024.[45]

3.1.2. Guidelines and Regulations at Target Countries Level

Country-level regulations and guidelines are crucial in promoting energy efficiency across the EU, addressing environmental, architectural, and socioeconomic aspects in each member state. Local entities ensure energy retrofit practices adhere to these regulations, aligning with the directives and ambitious energy transition targets set by the EU. These national-level efforts bring these objectives to life and make a meaningful impact. Within the context of the RE-SKIN project, this part presents a summary of regulations and guidelines specific to energy retrofit practices in Italy, Bulgaria, France, and Spain in the following sections.

3.1.2.1. Guidelines and Regulations in Italy

Italy's framework is established for enhancing energy efficiency in the building sector at both national and municipality levels, driven by national policies and regulations that complement EU directives. The key element of Italy's strategy is the **National Energy Strategy (Strategia Energetica Nazionale or SEN)**, introduced in 2017. This strategy outlines ambitious goals to reduce overall energy consumption by 30%, improve energy efficiency by 10% in the building sector increase the share of renewable energy to 28% of total energy usage and 55% of electricity usage by 2030.[52]

In addition to the SEN, Italy has implemented specific regulations to promote energy efficiency in buildings. **Legislative Decree 192/2005**, subsequently amended by **Legislative Decree 311/2006**, establishes the minimum energy performance requirements for new and existing buildings undergoing significant renovations. This legislation also mandates the certification of energy performance for buildings, which must be provided at renting or selling properties, ensuring transparency and promoting energy-efficient choices among consumers.[53]

At the municipality level, **regulations such** as the **Regolamento Edilizio** in Milan provide detailed guidelines for energy retrofitting. These regulations specify requirements for building permits, including the integration of energy-efficient materials and technologies. They also mandate the **Certificato di Idoneità Statica** for buildings over 50 years old, ensuring their structural integrity and safety.[53-54]

3.1.2.2. Guidelines and regulations in France

France has established a comprehensive regulatory framework for building energy retrofits, marked by several key regulations and codes. The following is the key remarkable regulations.

The **RT 2012** (Réglementation Thermique 2012), effective since 2012, aims to enhance energy performance in new buildings but also influences retrofit projects by setting high benchmarks for energy efficiency and reducing greenhouse gas emissions.[55]

This was followed by the **RE 2020** (Réglementation Environnementale 2020), which replaced RT 2012, coming into effect in 2020. RE 2020 emphasizes further reductions in energy consumption and carbon footprint, including life cycle analysis of buildings and promoting energy sobriety and renewable energy use.[56]

The **Energy Transition for Green Growth Act** (Loi de Transition Énergétique pour la Croissance Verte, LTECV), enacted in 2015, sets ambitious goals for reducing greenhouse gas emissions, increasing renewable energy usage, and improving overall energy efficiency. It includes a target of renovating 500,000 homes annually, prioritizing energy-poor households.[57]

Energy Performance Certificates (DPE - Diagnostic de Performance Énergétique), mandatory since 2006 for selling or renting properties, rate a building's energy efficiency on a scale from A to G, with recommendations for improvement.[58]

The **Energy Renovation Passport** (Passeport Efficacité Énergétique), introduced as a voluntary scheme, aids homeowners in planning and managing energy renovation projects by providing a detailed roadmap of recommended improvements and potential energy savings.[59]

Professional standards are upheld by the **RGE** (Reconnu Garant de l'Environnement) certification, a label for professionals and companies specializing in energy renovation, ensuring quality and compliance.[60]

Local regulations, such as **Local Climate Plans** (Plans Climat Air Énergie Territoriaux, PCAET), developed by local authorities to address climate change and energy transition, and **Low Emission Zones** (Zones à Faibles Émissions, ZFE), designed to reduce urban air pollution, further enhance the regulatory landscape.[61-62]

3.1.2.3. Guidelines and regulations in Spain

Spain's regulatory framework for building energy retrofits is aligned with EU directives and aims to enhance energy efficiency in the building sector. The key guidelines and regulations are presented in the following:

The **Technical Building Code** (Código Técnico de la Edificación, CTE), established in 2006 and updated multiple times, sets detailed standards for building safety and energy efficiency. It includes requirements for thermal insulation, energy-saving installations, and the integration of renewable energy sources.[63]

Regulation on Energy Performance of Buildings (Reglamento sobre la Eficiencia Energética en Edificios) introduced in 2013, mandates for energy performance improvements for both new constructions and retrofits, emphasizing reduced energy consumption and greenhouse gas emissions.[63]

Energy Performance Certificates (Certificado de Eficiencia Energética, CEE) have been mandatory since 2007 for selling or renting properties. These certificates rate buildings on a scale from A to G based on energy consumption and CO2 emissions, providing recommendations for improvements .[63-64]

The **Long-Term Strategy for Energy Rehabilitation in the Building Sector** (Estrategia a Largo Plazo para la Rehabilitación Energética en el Sector de la Edificación en España, ERESEE), updated in 2020, outlines Spain's plan to decarbonize its building stock by 2050, emphasizing the need for deep energy renovations and the adoption of renewable energy sources.[64]

Local regulations, such as **Municipal Energy Plans** (Planes Energéticos Municipales), developed by local authorities, address energy efficiency and sustainability at the municipal level, promoting tailored solutions for urban and rural areas.[65-66]

3.1.2.4. Guidelines and Regulations in Bulgaria

Bulgaria has established a comprehensive regulatory framework for building energy retrofits, focusing on enhancing energy efficiency and aligning with European Union directives. The first key element of this framework is the implementation of the Energy Performance of Buildings Directive (EPBD) to align national regulations to the EU level. The second key element is the **Energy Efficiency Act**, introduced in 2004 and updated multiple times. This Act mandates energy audits, certifications such as **Energy Performance Certifications** (EPCs) also mandated by EPBD, and performance improvements for buildings, emphasizing the reduction of energy consumption and greenhouse gas emissions.[67-68] Additionally, Bulgaria's **Recovery and Resilience Plan** outlines significant investments in renewable energy and infrastructure improvements, including installing renewable energy sources and energy storage solutions. This plan provides guidelines for retrofitting existing buildings to integrate these new technologies, thereby enhancing their energy profiles.[69-70] For historic buildings, Bulgaria has developed retrofit guidelines that balance energy efficiency improvements with the preservation of historical integrity, demonstrating best practices for maintaining architectural and cultural values during energy upgrades.[69]

3.2. Economic Retrofit Subsidies and Grants

Retrofit subsidies and grants play a crucial role in enhancing energy efficiency within the building sector. These financial incentives make it economically feasible for homeowners and businesses to undertake significant upgrades that reduce energy consumption. Common measures supported by these subsidies include the installation of energy-efficient windows, improved insulation, advanced heating and cooling systems, and the integration of renewable energy sources like solar panels. By lowering the upfront costs of these technologies, subsidies, and grants encourage wider adoption and accelerate the transition to more sustainable building practices. Additionally, these programs often provide technical support and information, helping building owners make informed decisions about the most effective energy-saving measures. This not only reduces greenhouse gas emissions but also leads to substantial savings on energy bills, enhancing overall economic resilience. Governments and organizations that provide these subsidies and grants contribute significantly to national and global energy efficiency targets, ultimately fostering a more sustainable and energy-secure future.

3.2.1. Retrofit Subsidies and Grants at the EU Level

The European Union (EU) provides various financial mechanisms to support retrofitting projects to improve energy efficiency, reduce greenhouse gas emissions, and promote renewable energy use. These initiatives are part of the EU's broader strategies such as the European Green Deal and the Renovation Wave.[71],[72] The following table is an overview of the main EU-level programs, including descriptions, funding amounts, eligibility criteria, and key deadlines.

Table 80. Key programs and initiatives for retrofits practices and energy efficiency measures at EU level

Program/Initiative	Description	Funding Amount	Eligibility	Due Dates
Recovery and Resilience Facility (RRF)	Part of the NextGenerationEU recovery plan, providing substantial funding for member states to support economic recovery post-COVID-19 with a significant portion allocated to green investments, including building renovations	€723.8 billion	Member States must submit national recovery plans	Plans by 2024, implementation by 2026
European Regional Development Fund (ERDF)	Supports regional development across the EU, with a strong focus on sustainable development, co-financing projects that include energy-efficient retrofits of buildings	€200 billion for 2021-2027	Projects focused on regional development, including energy-efficient building renovations	Managed by regional authorities
Cohesion Fund	Finances projects in environmental and transport sectors, including building energy efficiency improvements, targeting member states with a GNI per	€42.6 billion for 2021-2027	Member States with GNI per inhabitant below 90% of the EU average	Annual or multi-annual calls

	inhabitant below 90% of the EU average			
Horizon Europe	The EU's research and innovation framework program funds projects that advance energy efficiency technologies and innovative retrofitting solutions	€95.5 billion for 2021-2027	Research and innovation projects focused on energy efficiency and retrofit technologies	Multiple annual calls
European Investment Bank (EIB)	Provides loans and financial instruments to support energy efficiency investments, collaborating with various stakeholders to finance large-scale retrofit projects across the EU	€70 billion annually for climate action	Public and private sector projects meeting sustainability criteria	Rolling applications
Social climate Fund	Supports EU citizens most affected or at risk of energy or mobility poverty, providing funds for energy efficiency, building renovations, and clean heating, and cooling solutions	Up to €65 billion for 2026-2032 (rising to €86bn when member state co-financing is included)	Vulnerable citizens and small businesses affected by energy or mobility poverty	Yet to begin

3.2.2. Retrofit Subsidies and Grants at Target Countries Level

Retrofit subsidies and grants are crucial for supporting energy efficiency measures at the national level, aligning with EU strategies like the European Green Deal. They lower cost barriers, enabling comprehensive retrofitting projects and thereby contributing to the EU's climate and economic goals.

3.2.2.1. Incentives, Subsidies, and Grants in Italy

Italy offers several national-level subsidies and grants to support building retrofits, focusing on improving energy efficiency and reducing emissions. The following table presents some of the main programs:

Table 81. Key programs and initiatives for retrofits practices and energy efficiency measures in Italy

Program/Initiative	**Description**	**Funding Amount**	**Eligibility**	**Due Dates**
Conto Termico[73]	Provides incentives for increasing energy efficiency and the production of thermal energy from renewable sources, targeting public and private entities.	€400 million yearly for public entities' projects and €500 million yearly for	Public administrations, businesses, and private individuals implementing	Ongoing

		private individuals' projects.	thermal energy systems and energy-efficient measures	
White Certificate (Certificati Bianchi)[3773]	Tradable securities issued by the Energy Market Manager certifying the achievement of end-use energy savings through energy efficiency measures and projects.	Varies by project	Energy distributors, energy service companies, public and private entities with a certified energy management system	Ongoing
Central Public Administration Energy Requalification Program (PREPAC) [73]	Aimed at improving the energy efficiency of public buildings by at least 3% each year. The incentive can cover up to 100% of the planned expense	Up to 100% of the planned expense	Public buildings owned and used by the public administration	Proposals by July 15 each year
Ecobonus[74]	Provides tax deductions for energy efficiency improvements, including insulation, window replacement, and heating systems. The deduction rate can be up to 65% of the expenses.	Up to 65% of eligible expenses	Homeowners, tenants, and businesses undertaking energy-efficient upgrades	Ongoing
SuperBonus 70%[74]	Offers a tax deduction for expenses related to specific energy efficiency and seismic risk reduction interventions. The rate is 70% for 2024, decreasing to 65% in 2025.	70% of eligible expenses	Apartment buildings undertaking major renovations to meet energy improvement criteria	Ends 31 December 2024
Charging bonuses for businesses and professionals[75]	Supports the purchase and installation of electric vehicle charging infrastructure by businesses and professionals.	Up to 40% of eligible expenses.	Companies of any size ,and professionals	20 June 2024
Sismabonus[74]	Offers tax deductions for seismic retrofitting, which can be combined with energy efficiency improvements under the Ecobonus and Superbonus programs.	Up to 85% of eligible expenses	Property owners in seismic zones 1, 2, and 3	Ongoing
Renovation Bonus[74]	Provides tax deductions for building renovations, including ordinary and extraordinary maintenance.	50% of eligible expenses	Homeowners, businesses, and local public administration	Ongoing

Furniture and Appliances Bonus[74]	Offers tax deductions for purchasing furniture and appliances in properties undergoing renovation	50% of eligible expenses.	Homeowners, businesses, and local public administration	Ongoing
Architectural Barrier Bonus[74]	Provides tax deductions for works aimed at reducing architectural barriers in existing buildings, including stairs, ramps, and elevators.	75% of eligible expenses	Property owners undertaking accessibility improvements	Ends 31 December 2025
Green Bonus[74]	Supports initiatives aimed at improving outdoor residential spaces, including the installation of irrigation systems and creation of roof gardens.	36% of eligible expenses	Homeowners enhancing their outdoor residential spaces	Ongoing
Bonus Facciate[76]	Provides tax deductions for the renovation of building facades, aiming to improve aesthetic and energy efficiency aspects.	90% of eligible expenses	Homeowners and businesses renovating building facades	Ends 31 December 2024

3.2.2.2. Incentives, Subsidies, and Grants in France

France provides a variety of subsidies and grants to support energy-efficient building retrofits. The following table presents the key programs and initiatives available in France:

Table 82. Key programs and initiatives for retrofits practices and energy efficiency measures in France

Program/Initiative	Description	Funding Amount	Eligibility	Due Dates
MaPrimeRénov'[77]	Offers financial support for energy-efficient home renovations, with the grant amount based on household income and energy savings achieved.	Up to €20,000 per project	Homeowners and landlords, including single-family homes and apartments	Ongoing
Éco-Prêt à Taux Zéro (Eco-PTZ)[78]	Interest-free loan for financing energy renovation works, repayable over 10 to 15 years.	Up to €50,000 per home	Homeowners and landlords for primary residences, and co-ownerships	Ongoing
CEE (Certificats d'Économies d'Énergie)[79]	Energy savings certificates that provide grants for energy efficiency projects. These are offered by energy companies as part of their obligations under the Energy Efficiency Directive.	Varies by project	Homeowners, businesses, and public entities	Ongoing

Bonus Sortie de Passoire Thermique[80]	Additional grant for properties that improve from an energy rating of F or G to E or better through renovations	Additional 10% on eligible expenses	Homeowners undertaking comprehensive energy renovations	Ongoing
Crédit d'Impôt pour la Transition Énergétique (CITE)[81]	Tax credit for energy efficiency improvements, phased out and replaced by MaPrimeRénov' but still available for some higher-income households	30% of eligible expenses	Higher-income households not eligible for MaPrimeRénov'	Ongoing
Fonds Air Bois[82]	Provides financial assistance for replacing old wood-burning heating systems with new, efficient, and low-emission wood heaters.	Up to €2,400	Homeowners replacing old wood heating systems in eligible regions	Ongoing
Chèque Énergie[83]	Financial assistance for low-income households to help pay for energy bills, also usable for energy-efficiency renovation works.	Up to €277 annually	Low-income households	Ongoing
Prime Coup de Pouce Chauffage[84]	Financial incentive for replacing old, inefficient heating systems with new, efficient options like heat pumps or biomass boilers	Up to €4,000	Homeowners replacing old heating systems	Ongoing

3.2.2.3. Incentives, Subsidies, and Grants in Spain

Spain offers several subsidies and grants to support energy-efficient building retrofits. The following table presents some key ongoing programs and initiatives.

Table 83. Key programs and initiatives for retrofits practices and energy efficiency measures in Spain

Program/Initiative	Description	Funding Amount	Eligibility	Due Dates
IDAE's Building Energy Renovation Programs[85]	Includes various grants for improving energy efficiency in buildings, focusing on thermal insulation, HVAC system upgrades, and renewable energy	Varies by project	Homeowners, businesses, and public entities	Ongoing
PREE 5000 (Programa de Rehabilitación	It aims to support energy renovation in buildings located in municipalities facing	€300 millions	Homeowners, communities of	31 July 2024

Energética de Edificios)[86]	demographic challenges, focusing on reducing energy consumption and CO2 emissions.		property owners, and companies	
National Energy Efficiency Fund (NFEE)[87-88]	Co-financed by the EU, this fund invests in projects that reduce energy consumption across various sectors including buildings, transport, industry, and services.	€350 million annually	Public and private entities in sectors such as residential and non-residential buildings, transport, industry, and agriculture	Ongoing
Grandes Instalaciones Térmicas (GIT)[89-90]	Provides financing for large thermal installations using renewable energy sources such as biomass, solar thermal, and geothermal energies in the building sector.	Up to 80% of the investment value	Qualified firms in the building sector	Ongoing
Biomcasa[89-90]	Offers incentives for biomass thermal projects in buildings, promoting the use of biomass for heating.	Maximum €350,000 per individual project	Homeowners, businesses, and public entities	Ongoing
SOLCASA[89-90]	Provides financial support for solar thermal energy projects, promoting the use of solar energy for heating.	Maximum €250,000 PER individual project	Homeowners, communities of property owners, and companies	Ongoing
GEOCASA[89-90]	Supports geothermal energy projects, aiming to enhance the use of geothermal energy in building heating and cooling systems.	Maximum €350,000 PER individual project	Homeowners, communities of property owners, and companies	Ongoing
Third-Party Finance (FPT)[91]	A financing mechanism available for energy-saving and efficiency projects as well as energy generation projects using various sources, including renewable energies.	Varies by project	Public and private entities	Ongoing
IRPF Deductions for Sustainable Renovations[92]	Allows for tax deductions on the IRPF for sustainable	20% to 60% of the energy efficiency measures costs	Homeowners undertaking	Ongoing

	renovations that improve energy efficiency.		sustainable renovations	
Grants for Heat Pumps[93]-[94]	Subsidies for the installation of heat pumps, supporting the transition to low-carbon heating solutions.	€2,070/kW and up to 70% of the investment	Homeowners and businesses installing heat pumps	31 December 2026
Aid program for actions to improve energy efficiency in homes[95]	Finances energy efficiency improvements in primary residences, aiming for at least a 7% reduction in heating and cooling demand and a 30% reduction in non-renewable primary energy consumption	40% of the cost, up to €3,000 per residence	Homeowners, usufructuaries, and tenants of primary residences	30 June 2026

3.2.2.4. Incentives, Subsidies, and Grants in Bulgaria

Bulgaria offers various subsidies and grants to support energy-efficient building retrofits. The following table presents the key ongoing programs and initiative in Bulgaria s:

Table 84. Key programs and initiatives for retrofits practices and energy efficiency measures in Bulgaria

Program/Initiative	Description	Funding Amount	Eligibility	Due Dates
Program for Energy Efficiency of Multi-Family Residential Buildings[96]	Provides grants for energy efficiency measures such as insulation, window replacement, and heating system upgrades in multi-family residential buildings.	Up to 100% of the eligible costs	Homeowners' associations of multi-family residential buildings	19 September 2024
Operational Program "Regions in Growth"[97]	Focuses on improving the energy efficiency of public and residential buildings in urban areas to foster sustainable urban development	Varies by project	Municipalities, public entities, and private owners	Ongoing
Rural Development Program (RDP)[98]	Provides funding for energy efficiency projects in rural areas, including building renovations and renewable energy installations.	€2.9 billion from 2014 to 2020	Projects in rural areas, including agriculture, tourism, and renewable energy sectors	Ongoing
Energy Efficiency and Renewable Sources Fund (EERSF) [99-100]	Offers loans and guarantees for projects aimed at improving energy efficiency and incorporating renewable energy sources in buildings.	Varies by project	Municipalities, private companies, and individuals	Ongoing

Energy Renovation of Bulgarian Homes (ERBH)[99]	Provides funding for energy efficiency measures such as window replacement, insulation, and solar hot water systems in residential buildings.	Up to 50% of project costs	Individual homeowners and associations of flat owners in eligible towns	Ongoing
Energy Efficiency and Green Economy Programme (EEGMunicipal Energy Efficiency Projects Fund) [99]	Supports SMEs in implementing energy-saving and renewable energy technologies, including solar heating and cooling.	Up to 50% of project costs, max. €1 million	Small and medium Companies	Ongoing

3.3. Smart grids Initiatives and Strategies

Smart grid initiatives and strategies play a crucial role in modernizing grid infrastructure and driving the development of innovative energy projects. These efforts focus on integrating renewable energy sources, enhancing grid reliability, and improving energy efficiency. By implementing advanced technologies such as smart meters, grid automation, and real-time data management, these initiatives facilitate a more resilient, flexible, and sustainable energy system. Additionally, they support decarbonization goals, optimize energy consumption, and enable better demand response, contributing to overall energy security and environmental sustainability.

3.3.1 Smart grids Initiatives and Strategies at the EU Level

The European Union (EU) supports smart grid development through policies and funding mechanisms aimed at enhancing grid reliability, integrating renewable energy sources, and improving energy efficiency. The following table presents the key initiatives and strategies:

Table 85. Smart grids key initiatives and strategies at the EU level

Initiative / Strategy	Description	Investment Amount
Horizon Europe[72]	EU's research and innovation program focuses on smart grid technologies, energy storage, and grid integration of renewable energy.	€95.5 billion for 2021-2027 (though only a fraction of this will support smart grids)
Innovation Fund	The Innovation Fund is a key funding instrument for delivering the EU's economy-wide commitments under the Paris Agreement, with a strong focus on renewable energy grids and battery storage.	Up to €40 billion will be invested in the 2020-2030, with funds coming from the EU Emission Trading System (ETS)

Connecting Europe Facility (CEF)[101]	Funding for trans-European energy infrastructure projects, including smart grids to enhance energy security and integration of renewable energy.	€5,84 billion for 2021-2027
BRIDGE Initiative[102]	Combines Horizon 2020 and Horizon Europe projects to address cross-cutting issues in smart grid, energy storage, and digital projects.	Coordinated funding from multiple projects
Digitalization of Energy Action Plan[103]	Promotes investments in digital solutions, data exchange, and efficient infrastructure planning.	Part of broader energy investment
Trans-European Networks for Energy (TEN-E)[104]-[105]	Supports smart grid projects that benefit at least two EU countries, focusing on integrating renewables and enhancing grid capacity.	Varies by project
Smart Grids Task Force[106]	Provides policy and regulatory guidance for smart grid deployment in Europe, focusing on standards, cybersecurity, and demand-side flexibility.	Advisory role, no direct funding
Projects of Common Interest (PCIs)[107]	Strategic projects that enhance grid infrastructure, integrating renewables, and ensuring energy security across multiple EU countries.	Part of TEN-E and CEF funding
Clean Energy Technology Observatory (CETO)[108]	Monitors and supports the development of smart grid technologies through data collection and analysis.	Research and monitoring
ETIP SNET R&I Implementation Plan 2025+[109]	Identifies research and innovation priorities for transforming the energy system, focusing on smart grids, sector coupling, and storage.	€954 million for 2025-2028

3.3.2 Smart grids Initiatives and strategies at the target countries' level

National initiatives and strategies for smart grids align with EU-level efforts to create a unified, resilient, and sustainable energy system. These national programs help integrate renewable energy, enhance grid efficiency, and improve energy security, mirroring the broader objectives of the EU's Green Deal and Horizon Europe.

3.3.2.1 Smart grids Initiatives and Strategies in Italy

Italy has several smart grid initiatives focusing on modernizing the energy infrastructure, integrating renewable sources, and improving energy efficiency. The following table presents the key initiatives

Table 86. Smart grids key initiatives and strategies in Italy

Initiative / Strategy	Description	Investment Amount
Enel's Smart Grid Projects[110]	Enel, Italy's largest power company, has numerous projects aimed at deploying smart grid technologies, including smart meters and automated systems.	Varies by project

Terna's Investment Plan 2024-2028[111]	Terna plans to invest €16,5 billion in grid modernization, including €2 billion for digitalization and innovation	€16,5 billion from 2024 to 2028
Piano Nazionale Integrato per l'Energia e il Clima (PNIEC)[112]	National Integrated Energy and Climate Plan focusing on smart grids and the integration of renewable energy sources.	Varies by project
Smart Grid Pilot Projects[113]	Government-supported pilot projects to test and implement smart grid technologies across different regions.	Varies by project

3.3.2.2 Smart Grids Initiatives and Strategies in France

France has several ongoing smart grid initiatives and strategies focusing on enhancing grid resilience, integrating renewable energy, and improving energy efficiency. Below are the key initiatives, programs and projects empowering Smart Grids integration in France.

Table 87. Smart grids key initiatives and strategies in France

Initiative / Strategy	Description	Investment Amount
Linky Smart Meter Program[114]	The country's rollout of smart meters by Enedis to improve energy management and efficiency.	€4,5 billion
Flexgrid Project[115]	A regional project in Provence-Alpes-Côte d'Azur focused on creating a large-scale smart grid demonstration area.	€150 million
Nice Grid[116]	First experimental minigrid project in an interconnected area, testing all minigrid use cases.	€30 million
MILLENER Project[117]	Aims to reduce electricity consumption and better integrate intermittent renewables in island networks.	€35 million
ODRI Project[118]	Studies, designs, and tests smart grid solutions to facilitate the insertion of renewable energy and storage on electricity distribution networks.	Varies by project
ADEME's Intelligent Electrical systems[119]	Optimizes the distribution of electricity and facilitates the integration of renewable energies in rural areas.	Varies by project
French Energy Regulation Commission (CRE) Initiatives[115]	Supports R&D in smart grid projects, including demand response, energy storage, and integration of renewable energy.	Varies by project
InterFlex Project[120]	Focuses on the flexibility of energy grids through advanced storage solutions and grid automation.	€22,8 million
GreenLys Project[121]	Pilot project in Lyon and Grenoble to test the entire smart grid system from generation to consumption.	€43 million

SOGRID[115]	Aims to develop and test a new generation of smart grid technologies, focusing on interoperability and real-time data management.	€27 million
SMILE (Smart Ideas to Link Energies)[122]-[123]	Demonstration of smart grids and integration of renewable energy sources in Western France.	€262 million

3.3.2.3 Smart Grids Initiatives and Strategies in Spain

Spain focuses on integrating renewable energy sources, improving energy efficiency, and enhancing grid reliability through smart grid initiatives. The following table presents initiatives and strategies supported by Spain, the private sector and EU programs for Smart grid integration:

Table 88. Smart grids key initiatives and strategies in Spain

Initiative / Strategy	Description	Investment Amount
EIB and Iberdrola Green Loan[124]	Expansion of Iberdrola's electricity-distribution grid to integrate more renewable energy sources and enhance efficiency and resilience. This includes support for heat pumps and electric vehicles.	€700 million green loan from EIB, total project cost €1.44 billion (remaining €740 million from Iberdrola)
Red Eléctrica de España (REE)[125]	Implementation of advanced grid technologies to manage renewable integration and improve grid reliability.	Varies by project
National Energy and Climate Plan (NECP) 2021-2030[126]	Framework for Spain's energy and climate policies, focusing on increasing renewable energy, energy efficiency, electrification, and renewable hydrogen to achieve climate neutrality by 2050. Includes a target of 42% renewables in energy use by 2030.	Total anticipated investment of €241 billion, with 80% from the private sector
The 2021-2026 Electricity Transmission Grid Planning [127]	Government strategy to promote the development of smart grids as part of Spain's broader energy transition efforts.	€7 million investment
Iberdrola Strategic Plan 2024-2026[128]	Focuses on decarbonizing energy supply, enhancing grid reliability, and expanding renewable energy capacity with a significant focus on smart grids.	Total of €41 billion investment with €21,5 billion in grids and €15,5 billion in renewables
BARCELONA Smart City[129]	Smart city strategy integrating smart grids, IoT, and sustainable energy solutions to enhance urban living and energy efficiency.	Varies by project
Andalusian Sustainable Energy A+ Programme[130]	Incentive program within Andalusian Sustainable Energy Development, focusing on smart grids, energy supply infrastructure, and decarbonization of transport systems.	€27 million
Endesa Smart Grid Investment[131]	Endesa secured €250 million from the European Investment Bank to modernize and expand Spain's distribution networks with smart technologies.	€2,9 billion from 2022 to 2024

3.3.2.4 Smart Grids Initiatives and Strategies in Bulgaria

Bulgaria is working on modernizing its energy infrastructure with a focus on smart grids to improve efficiency and integrate renewable energy sources. The following table presents Some key initiatives, projects, and national strategies promoting the integration of smart grids and the improvement of energy infrastructure in Bulgaria.

Table 89. Smart grids key initiatives and strategies in Bulgaria

Initiative / Strategy	Description	Investment Amount
Grid Development Plan[132]	Bulgaria aims to integrate 4.1 GW of wind and solar power by 2030, although national targets are more ambitious at 11 GW.	Not specified for the case of Bulgaria
Izgrei Energy Cooperative[133,134]	Bulgaria's first energy cooperative, founded by the Georgiev brothers, allows community members to invest in solar panels and sell surplus electricity to the grid. The project aims to promote local renewable energy production and community involvement.	Initial investment: €7,500
ADD Bulgaria Smart Metering[135]	It provides intelligent systems for digitalizing and modernizing grid infrastructures, including smart metering, street lighting management, and cybersecurity solutions. These systems help reduce non-technical losses and optimize energy use.	Not specified
STRIDE Project[136]	The STRIDE project focuses on integrating smart grid concepts in the Danube Region, including training local policymakers and sharing good practices. The project aims to enhance smart grid technology adoption and policy alignment across municipalities.	Overall € 1 million
Electricity System Operator (ESO) Investment[69]	ESO is finalizing its investment program to ensure the grid connection of new power plants with a total installed capacity of 4,500 MW, primarily renewables. This includes significant investments in grid digitalization.	Over €25 million for digitalization

4. Compatibility and Synergy Continuous Review

In order to ensure and to maintain RE-SKIN's open connotation throughout the duration of the project, market technological solutions with potential compatibility with RE-SKIN's technologies are reviewed on a regular base. Compatible technologies with RE-SKIN, available on the market and including the most relevant innovations will be listed along the project.

This task is divided into three main steps that will be detailed in the next phase of the project:

Phase 1: Market Research and Identification of Potential Products

- Research existing technologies and products that could integrate with RE-SKIN.

Phase 2: Establish a criteria for assessing compatibility

- Assess technical compatibility with the RE-SKIN system (interfaces, protocols, physical dimensions).
- Develop KPIs to assess compatibility of systems together.

Phase 3: Database Development

- Develop a database to store technical details, compatibility KPIs, integration status, synergy potential, and market data.

Compatible technologies include market technologies and innovative technologies that can improve RE-SKIN that can substitute one or more utilized/investigated technologies. The output of this activity will be an online database including available technologies, new innovative technologies and near to market technologies.

5. Technological and Performance Benchmarking Process

This task's objective was to establish a comparative analysis of the expected technological characteristics and key energy performance parameters of the proposed retrofit package, both with standard retrofit solutions and with future retrofit best practice. This data will then be compared with the controlled data from the demonstration cases, to assess the real cost-effectiveness of the RE-SKIN renovation package.

3.1 State-of-the-art in building integrated energy systems based on literature review

3.1.1 Solar photovoltaic systems

Photovoltaic (PV) systems are crucial for renewable energy, with Grid-Tied, Off-Grid, and Hybrid PV Systems being the most common types, each suited to different needs. Additionally, Photovoltaic Thermal (PVT) systems are notable for combining the benefits of photovoltaic cells and solar thermal collectors into a single system, producing both thermal and electrical energy more cost-effectively than separate systems.

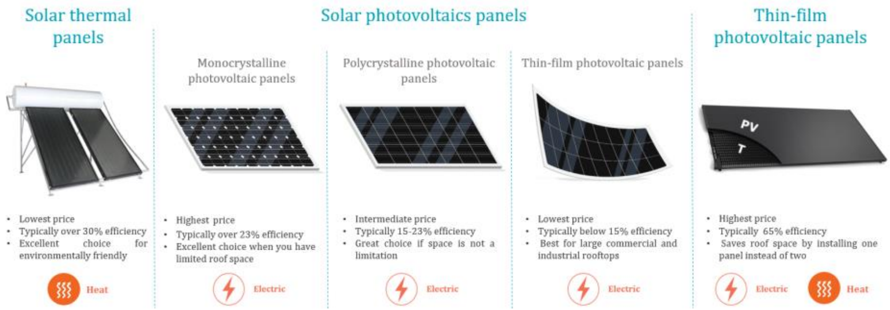

Figure 2. Different types of solar systems

PVT systems are used in district heating, drying, desalination, and building energy generation. They are especially valuable in standalone solar energy systems with seasonal energy storage for areas without grid connections or where energy sales are not financially competitive. This analysis evaluates these systems based on key performance indicators (KPIs) such as reliability, energy efficiency, cost, environmental impact, and flexibility [137]. Grid-connected PV Systems enhance grid efficiency and offer cost benefits but depend on grid stability. Off-Grid PV Systems provide independence and reduce fossil fuel use but require higher initial costs. Hybrid PV Systems combine the benefits of both, optimizing energy use and offering adaptability [138].

Table 90. Key Performance Indicators (KPIs) of solar systems

KPIs	**Grid-Tied PV Systems**	**Off-Grid PV Systems**	**Hybrid PV Systems**
System Efficiency	EER: 12-16	EER: 10-14	COP: 3-5
	15-20%	10-15%	12-18%
Efficiency Loss Over Time	0.5-0.7% per year	0.4-0.6% per year	0.45-0.65% per year
Cycle Life	4000-6000 cycles	3000-5000 cycles	3500-5500 cycles
Response Time	<1 second		
Energy Capacity	4-6 kWh/kWp	3-5 kWh/kWp	4-6 kWh/kWp
Power Output	90-120 W/m²	70-100 W/m²	80-110 W/m²
Energy Production	Performance Ratio		
Energy Independence	Total kWh Generated		
Safety	Risk of Thermal Runaway: Low		
System Reliability	Percentage of electricity supplied by PV system	Full self-sufficiency	Partial self-sufficiency
	During peak hours		
Environmental Impact	CO_2 Emissions Avoided: 5-10 tons/year	CO_2 Emissions Avoided: 3-7 tons/year	CO_2 Emissions Avoided: 4-9 tons/year
	System Availability		
Cost Effectiveness	ROI: 15-20%	ROI: 12-18%	ROI: 14-22%
	Payback Period: 5-7 years	Payback Period: 6-8 years	Payback Period: 5-7 years
	Levelized Cost of Electricity		
Maintenance Requirements	Payback Period		
	1-2% of system cost	1.5-2.5% of system cost	1-2% of system cost
Scalability and Adaptability	Frequency and Cost of Maintenance		
	Component Lifespan		
	Scalability Potential		
	Adaptability to changing energy demands		

3.1.2 Solar-assisted DC Heat Pump

One approach to harness solar energy for building heating and cooling involves integrating heat pumps with photovoltaic systems. This entails converting the photovoltaic-generated direct current to alternating current using a Direct/Alternating Current converter, typically part of the photovoltaic setup. Subsequently, another converter within the heat pump modulates the power for efficient operation. While some direct current-powered vapor-compression systems are available, they often have limited capacity and architectural considerations, as outdoor installation of the air heat exchanger can impact aesthetics and acoustics. Direct Expansion (DE) Solar-Air Heat Pump Systems offer a solution, directly integrating solar energy into the heat pump cycle.

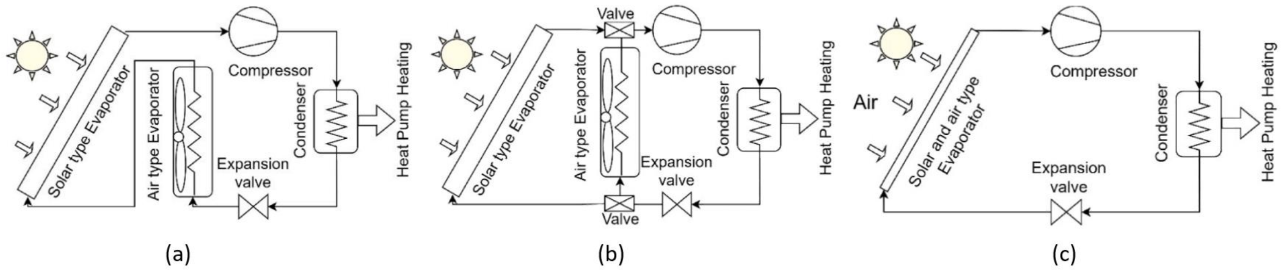

Figure 3. Illustration of solar-assisted direct expansion heat pump types; (a) direct expansion solar-air serial heat pump, (b) direct expansion solar-air dual source heat pump and (c) direct expansion solar-air parallel heat pump.

They are available in three configurations: Serial, Dual Source, and Parallel. Serial systems precondition refrigerant with solar energy for enhanced efficiency in sunny conditions, while Dual Source dynamically combines solar and air inputs for adaptable performance across climates. Parallel systems operate both sources concurrently, offering reliability in moderate resource environments. Evaluated by KPIs such as System Efficiency, Energy Independence, Cost Effectiveness, and Environmental Impact, each configuration presents distinct advantages and challenges [139]. Ultimately, DE Solar-Air Heat Pump Systems are instrumental in reducing operational costs and carbon emissions, thereby contributing significantly to sustainable energy solutions.

Table 91. Various Key Performance Indicators (KPIs) of solar Solar-assisted DC Heat Pump

KPI	DE Solar-Air Serial Heat Pump	DE Solar-Air Dual Source Heat Pump	DE Solar-Air Parallel Heat Pump
System Efficiency (%)	80% - 85%	85% - 90%	75% - 80%
Efficiency Loss Over Time (%)	1% - 2% per year	1% - 1.5% per year	1.5% - 2.5% per year
Cycle Life (Years)	15 - 20 years	20 - 25 years	15 - 20 years
Response Time (Minutes)	5 - 10 minutes	3 - 7 minutes	4 - 8 minutes

Energy Capacity (kWh)	N/A (dependent on integrated storage, if any)		
Power Output (kW)	3 - 10 kW	4 - 12 kW	3 - 9 kW
Energy Production (kWh/year)	1,500 - 3,000 kWh	2,000 - 4,000 kWh	1,200 - 2,500 kWh
Energy Independence (%)	30% - 40%	40% - 50%	25% - 35%
Safety	High (Standard)	Very High (Enhanced due to dual sources)	High (Standard)
System Reliability	95% uptime	97% uptime	93% uptime
Environmental Impact	Moderate impact reduction	High impact reduction	Moderate impact reduction
Cost Effectiveness	Moderate (Mid-range costs, good savings)	High (Higher costs, excellent savings)	Moderate (Lower costs, moderate savings)
Maintenance Requirements	Low to Moderate (Annual check-ups)	Low (Due to advanced systems, less frequent)	Moderate (Bi-annual check-ups)
Scalability and Adaptability	Moderate (Depends on design)	High (Flexible and adaptive to various conditions)	Moderate (Some limitations in scalability)

3.1.3 Battery storage systems

One of the main challenges of renewable energy is matching supply with demand, as the sun doesn't always shine during peak electricity needs. Electrochemical batteries can stabilize the power grid by storing energy and allowing buildings to shift consumption from day to night, reducing peak consumption and lowering electricity tariffs.

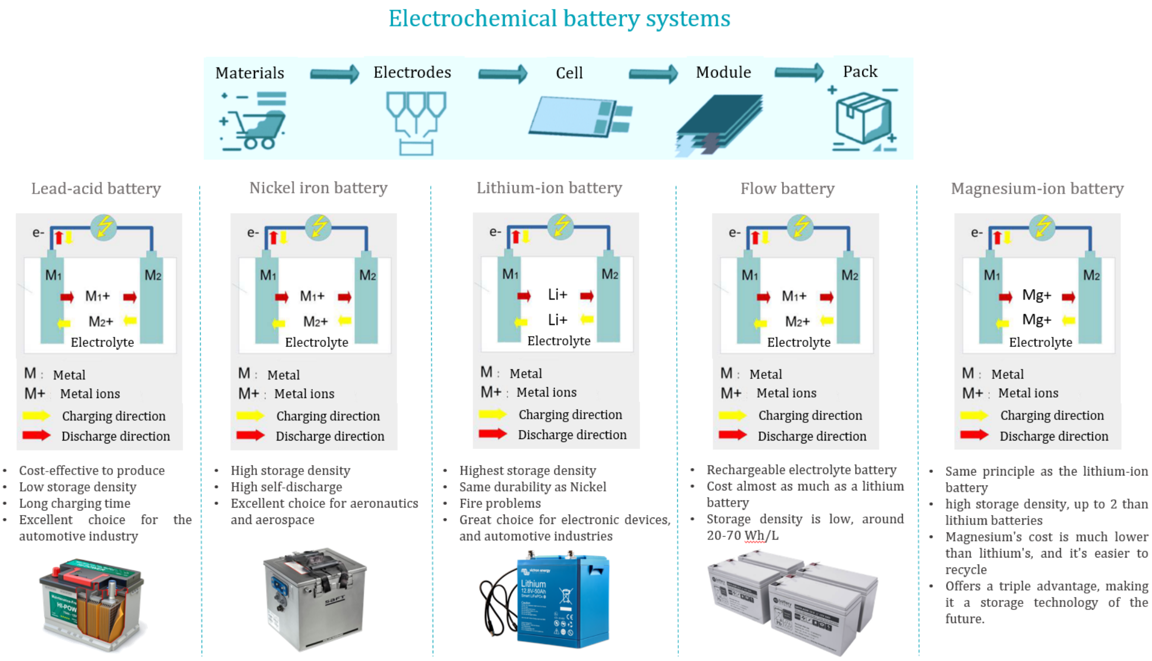

Figure 4. Various electrochemical batteries systems

Common battery technologies include Lead-Acid, Lithium-Ion, and Flow Batteries, each with unique advantages and limitations [140]. These are evaluated based on KPIs such as Energy Density, Cycle Life, Efficiency, Cost-effectiveness, and Environmental Impact. Lithium-Ion Batteries are preferred for their high energy density, extended cycle life, and superior efficiency, despite higher initial costs and environmental considerations [141].

Table 92. Key Performance Indicators (KPIs) of Battery storage systems

KPIs	Lead-Acid Batteries	Lithium-Ion Batteries	Flow Batteries
Energy Efficiency	Round-Trip Efficiency: 75-85%	Round-Trip Efficiency: 85-95%	Round-Trip Efficiency: 70-80%
	Discharge Efficiency: 85-95%	Discharge Efficiency: 95-99%	Discharge Efficiency: 70-80%
Energy Capacity	Total Energy Storage: 100-150 Wh/kg	Total Energy Storage: 150-250 Wh/kg	Total Energy Storage: 20-40 Wh/kg
	Energy Density: 30-50 Wh/L	Energy Density: 100-200 Wh/L	Energy Density: 10-20 Wh/L
Power Output	Maximum Power Output: 200-400 W/kg		Maximum Power Output: 100-200 W/kg
	Power Density: 50-100 W/L	Power Density: 200-300 W/L	Power Density: 50-100 W/L
Cycle Life	Number of Cycles: 1000-2000	Number of Cycles: 2000-5000	
	Cycle Life Expectancy: 5-7 years	Cycle Life Expectancy: 7-10 years	

Efficiency Loss Over Time	Degradation Rate: 2-3%/ year	Degradation Rate: 1-2% per year
	Capacity Fade Rate: 2-3%/ year	Capacity Fade Rate: 1-2% per year
Response Time	Response Time to Charge/Discharge Commands: <5 ms	
Environmental Impact	Environmental Impact of Manufacturing: Moderate	
	Recyclability: Highly Recyclable	
Safety	Safety Features: Overcharge Protection, Thermal Management	
	Risk of Thermal Runaway: Low	
Cost Effectiveness	Initial Cost: Moderate	Initial Cost: High
	Total Cost of Ownership: Moderate	
Scalability and Adaptability	Scalability Potential: High	
	Compatibility with Various Applications: Versatile	

3.1.4 HVAC systems

Heating, Ventilation, and Air Conditioning (HVAC) systems ensure good air quality, healthy air flows, and occupant comfort by managing air circulation within buildings. The choice of HVAC systems significantly impacts energy efficiency and budget considerations.

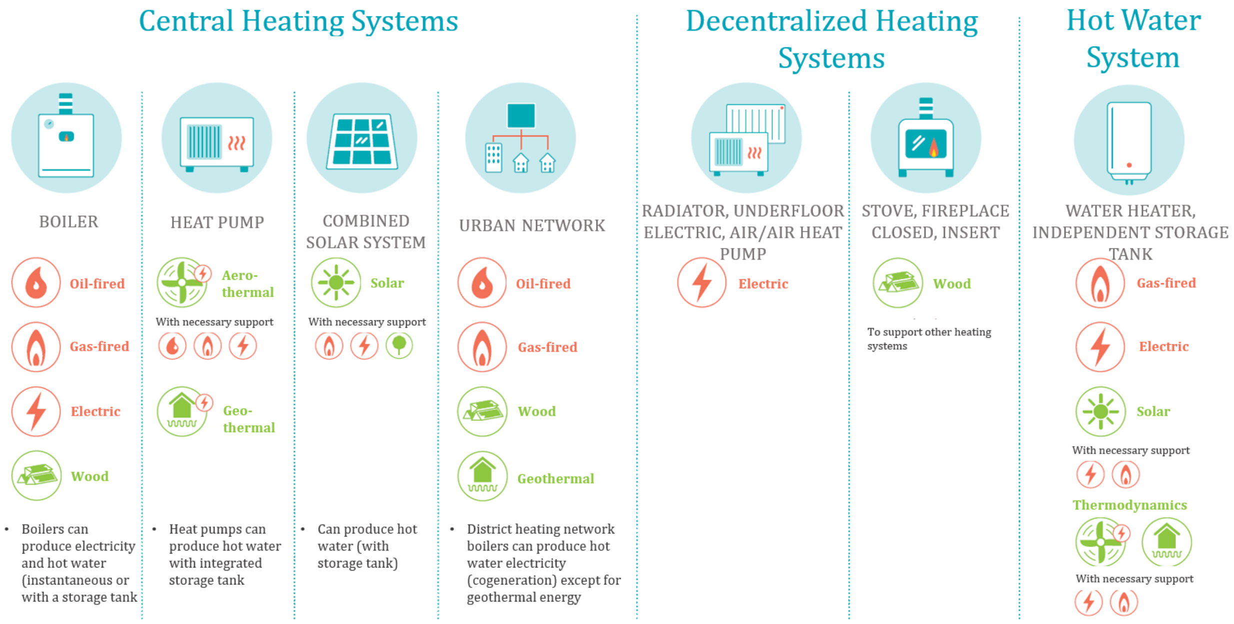

Figure 5. Different heating and water heating systems

Centralized, Decentralized, and Variable Refrigerant Flow (VRF) systems each offer unique advantages. Evaluated based on Key Performance Indicators (KPIs) such as Energy Efficiency, Comfort and Indoor Air Quality, Flexibility, Installation and Maintenance Costs, and Value Proposition, Centralized systems excel in energy efficiency and consistent temperature control for large buildings. Decentralized systems provide zoned control and localized comfort, ideal for flexible layouts. VRF systems offer top-tier energy efficiency, precise temperature control, and adaptability, suitable for diverse occupancy patterns. Each system type is tailored to specific building needs, optimizing performance and occupant satisfaction [142].

Table 93. Key Performance Indicators (KPIs) of HVAC system types

<table>
<tr><th>KPIs</th><th>Centralized HVAC Systems</th><th>Decentralized HVAC Systems</th><th>Variable Refrigerant Flow (VRF) Systems</th></tr>
<tr><td rowspan="3">Energy Efficiency</td><td>EER: 10-14</td><td colspan="2">EER: 12-16</td></tr>
<tr><td colspan="2">COP: 3-5</td><td>COP: 4-6</td></tr>
<tr><td>Energy Savings: 20-30%</td><td>Energy Savings: 25-35%</td><td>Energy Savings: 15-25%</td></tr>
<tr><td rowspan="3">Operational Efficiency</td><td>System Downtime: <2%</td><td colspan="2">System Downtime: <1%</td></tr>
<tr><td colspan="3">Response Time: <15 minutes</td></tr>
<tr><td colspan="3">Fault Detection Accuracy</td></tr>
<tr><td rowspan="3">Comfort</td><td colspan="3">Temperature Control Accuracy</td></tr>
<tr><td colspan="3">Humidity Control Accuracy</td></tr>
<tr><td colspan="3">Airflow Distribution</td></tr>
<tr><td rowspan="3">Maintenance Requirements</td><td>Planned Maintenance Completion Rate: >90%</td><td colspan="2">Planned Maintenance Completion Rate: >95%</td></tr>
<tr><td>Mean Time Between Failures: 10-15 years</td><td colspan="2">Mean Time Between Failures: 8-12 years</td></tr>
<tr><td>Mean Time to Repair (MTTR): <4 hours</td><td colspan="2">Mean Time to Repair (MTTR): <2 hours</td></tr>
<tr><td rowspan="2">Environmental Impact</td><td>CO2 Emissions Reduction: 5-10%</td><td colspan="2">CO2 Emissions Reduction: 10-15%</td></tr>
<tr><td colspan="3">Environmental Footprint</td></tr>
<tr><td rowspan="2">Cost Effectiveness</td><td>Payback Period: 5-7 years</td><td colspan="2">Payback Period: 4-6 years</td></tr>
<tr><td>ROI: 15-20%</td><td colspan="2">ROI: 18-22%</td></tr>
<tr><td rowspan="2">Scalability and Adaptability</td><td colspan="3">Scalability Potential</td></tr>
<tr><td colspan="3">Adaptability to Building Changes</td></tr>
</table>

3.1.5 Building automation systems

Building Automation and Control Systems (BACS) encompass products, software, and engineering services necessary for energy-efficient, cost-effective, and safe operation of building services. They utilize automatic controls and facilitate manual management of building systems, serving as centralized control systems for technical systems. Building Automation Systems (BAS) are essential for modern building management, providing centralized control and monitoring of HVAC, Lighting Control, and Security & Access Control systems.

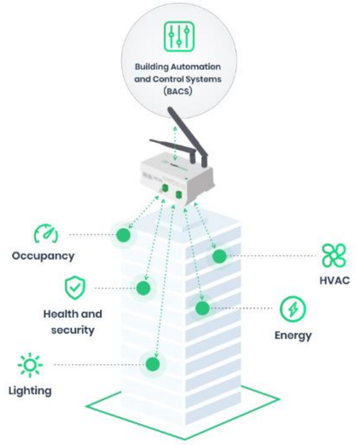

Figure 6. Building automation and control systems (BACS)

These BAS types optimize building operations, enhancing performance, energy efficiency, occupant comfort, and safety. The analysis aims to identify the most suitable BAS type based on Key Performance Indicators (KPIs) such as Energy Efficiency, Comfort and Occupant Satisfaction, Safety and Security, Integration and Interoperability, Cost-effectiveness, and Value Proposition [143]. HVAC BAS optimizes energy consumption and operational costs while ensuring comfort and safety. Lighting Control BAS customizes lighting levels for efficiency, comfort, and security, integrating with occupancy sensors. Security & Access Control BAS manages access and integrates with surveillance for safety. Each BAS type offers unique benefits tailored to specific building needs, ensuring optimal performance and value [144].

Table 94. Various Key Performance Indicators (KPIs) of Building Automation and Control Systems

KPIs	HVAC BAS	Lighting Control BAS	Security & Access Control BAS
Energy Efficiency	Energy Savings: 15-30%	Energy Savings: 20-50%	Energy Savings: 10-25%
	HVAC Energy Consumption	Lighting Energy Consumption	Security System Energy Consumption
	HVAC Efficiency	Lighting Efficiency	Security System Efficiency
Operational Efficiency	System Downtime: <2%	System Downtime: <1%	
	Response Time: <15 minutes	Response Time: <5 minutes	
	Fault Detection Accuracy		
Occupant Comfort	Temperature Control Accuracy	Lighting Levels Consistency	Access Control Effectiveness
	Humidity Control Accuracy	Occupant Comfort Surveys	Security System Reliability
	Indoor Air Quality (IAQ)	Dimming and Color Tuning	Intrusion Detection Rate
Maintenance Requirements	Planned Maintenance Completion Rate: >90%	Planned Maintenance Completion Rate: >95%	

	Mean Time Between Failures: 10-15 years	Mean Time Between Failures: 8-12 years
	Mean Time to Repair (MTTR): <4 hours	Mean Time to Repair (MTTR): <2 hours
Environmental Impact	CO_2 Emissions Reduction: 5-10%	
	Environmental Footprint	
Cost Effectiveness	Payback Period: 5-7 years	Payback Period: 4-6 years
	ROI: 15-20%	ROI: 18-22%
Scalability and Adaptability	Scalability Potential	
	Integration with Other Systems	
	Adaptability to Building Changes	

3.2 Comparison with the state of the art: standard renovation solutions and the upcoming best retrofit practices

Hybrid PV Systems excel due to their balanced energy efficiency, reliability, cost-effectiveness, and environmental impact, making them ideal for diverse energy needs and grid stability. Choosing the right PV system should consider specific needs, location, and budget for optimal performance. For Solar-assisted DC Heat Pump systems, Serial Systems are best for sunny, cost-conscious regions, Dual Source Systems offer high efficiency for varied climates, and Parallel Systems provide reliable performance in moderate resource environments [145]. Lithium-Ion Batteries, with high energy density, long cycle life, and efficiency, are the top battery choice despite higher initial costs. Variable Refrigerant Flow (VRF) Systems are optimal for modern buildings, balancing energy efficiency, comfort, flexibility, and cost-effectiveness, while Building Automation Systems (BAS) should focus on Lighting Control for energy efficiency and cost-effectiveness, Security & Access Control for safety, and HVAC for comfort and air quality. The final choice in all cases should consider specific needs, budget constraints, and long-term sustainability goals.

Table 95. Comparison of state-of-the-art with standard renovation solutions

Solar photovoltaic systems		
Grid-Tied PV Systems	Off-Grid PV Systems	Hybrid PV Systems
High efficiency with minimal losses over time. Dependent on the grid, vulnerable to outages. Low initial cost, good ROI, and short payback period.	Moderate efficiency with slightly better longevity in efficiency. High resilience and independence from the grid. High initial cost, moderate ROI, and longer payback period.	Balanced efficiency with reasonable loss over time. Combines the reliability of grid-tied with the resilience of off-grid systems.

Significant CO2 emissions reduction. Limited adaptability to changing energy demands. Low maintenance requirements and costs.	Lower CO2 emissions reduction, but better overall environmental footprint. High adaptability to energy demands and better integration with local systems. Moderate maintenance needs and costs.	Moderate initial cost, best ROI, and short payback period. Moderate to high CO2 emissions reduction with a balanced environmental footprint. High adaptability and scalability with excellent integration potential. Low to moderate maintenance needs and costs.
	Solar-assisted DC Heat Pump	
Serial Heat Pump	Dual Source Heat Pump	Parallel Heat Pump
Moderate to high; pre-conditions refrigerant. Good savings; mid-range initial costs, residential use. Low to moderate; annual check-ups required. Moderate; specific to regions with consistent sunlight.	Highest; dynamic use of both solar and air sources. High; higher initial costs with significant long-term savings. Low; infrequent due to advanced technology. High; adaptable to various climates and applications.	Moderate; balances solar and air inputs simultaneously. Moderate; lower initial costs, balanced performance. Moderate; bi-annual check-ups needed. Moderate; suitable for moderate solar and air resources.
	Battery storage systems	
Lead-Acid Batteries	Lead-Acid Batteries	Lead-Acid Batteries
Low upfront cost, widely available.	High energy density, long cycle life, high efficiency, and relatively moderate environmental impact.	Very long cycle life, moderate efficiency, low environmental impact.
	HVAC systems	
Centralized HVAC Systems	Decentralized HVAC Systems	Variable Refrigerant Flow (VRF) Systems
Best suited for large-scale commercial buildings. High energy efficiency and consistent temperature control. Higher initial installation cost but moderate maintenance requirements and long-term reliability	Enhanced energy efficiency through zoned control. Flexibility in localized comfort adjustments and building layout adaptations. Moderate installation costs and high maintenance efficiency.	Superior energy efficiency and precise temperature control. High adaptability to diverse occupancy patterns. High installation costs but excellent scalability and adaptability, making them suitable for versatile building applications.
	Building automation systems	

HVAC BAS	Lighting Control BAS	Security & Access Control BAS
Significant energy savings in HVAC operations. High satisfaction due to improved temperature, humidity control, and indoor air quality. High potential for integration with other BAS components. Good ROI with moderate payback period. Moderate maintenance requirements with long MTBF.	Greatest potential for energy savings, especially with occupancy sensors and dimming controls. High satisfaction from optimal lighting levels. Enhances security through controlled lighting. Best ROI and shortest payback period. Lower maintenance costs and shorter MTTR.	Moderate energy savings. High potential for integration with other BAS systems. Moderate ROI with a good payback period. Moderate maintenance needs with long MTBF.

6. Site Risk Assessment

This section outlines the site risk assessment process for the RE-SKIN project, focusing on four target countries and their respective case studies. The assessment begins with an evaluation that includes both multi-hazard and multi-risk aspects, producing detailed risk maps for each target country. This comprehensive analysis provides a foundational understanding of the various threats that could impact the RE-SKIN systems. Subsequently, preliminary data on the vulnerabilities of these systems are collected, considering both natural and technological hazards during their installation and use. A detailed hazard assessment follows, evaluating the resilience and maintainability strategies of RE-SKIN systems. This involves gathering in-depth data on system vulnerabilities and assessing their capacity to withstand stress and function effectively amidst climate change. Additionally, strategies are explored to ensure the systems' reliability and performance over time. Finally, specific resilience strategies tailored to the target countries are developed, and Key Performance Indicators (KPIs) are defined to measure the effectiveness of these strategies against climate change, with a particular focus on the performance of renovated buildings.

6.1 State-of-the-art on multi-hazard and multi-risk assessment

The analytical methodology proposed to assess the territorial risks and protection factors in target countries has been developed by the research group of Milan Politecnico in the context of prior consultancy experiences (in 2019 and 2021) to assess the environmental risks of data centers in the Metropolitan area of Milan, considering both multihazard and multirisk conditions and for the potential impact of Climate Change.[146] The proposed analytical methodology adopts a territorial perspective considering both i) local site-level risks due to extreme weather events or phenomena that may lead to a prolonged change in site conditions, and ii) territorial (regional/provincial) risks that are not directly related to the site, but which may nevertheless have important impacts on the availability of supplies, services and/or personnel. The core elements of the methodological framework are synthesized in Figure *7*. The joint consideration of threats, vulnerabilities, potential impacts, and possible countermeasures takes inspiration from the Dow method, adopted for analysing risk in hazardous industrial[147], as each risk is balanced against the mitigation measures that may be enforced.

First step of the methodology is the analysis of hazard factors, namely: i) natural, health and man-made hazards; and ii) Climate Change as both a hazard per se (inducing for example heat waves) and a stressor of other hazards (such as fires, droughts and storms) (as depicted in the first two boxes in the upper left part of Figure *7*). Then, the vulnerability to multiple hazards of single assets is considered (second box in the first line). The third box in the first line accounts instead for the vulnerabilities to multiple hazards of the territory in which plant is located. In facts, the proposed methodology accounts for both physical and systemic vulnerabilities: the former regards the physical integrity of the facilities, the second represents a second-order factor regarding damage to lifelines or vital services, affecting the business continuity due to power or telecommunication outages, or impeding the workforce from reaching the site for ordinary or extraordinary operations particularly in case of extreme events.

The physical damage scenario derives from the combination of hazards, the physical vulnerability of the building and of its territorial context (first box in the second line). Systemic vulnerability depicts the response capacity (or lack of) to the physical damage that has occurred to one or more components of the building or to systems it depends on for its functioning, as depicted in the second box in the second line. Systemic damage, due, for example, to the disruption of transportation or power system in the area, is derived from the combination of physical damage and systemic vulnerability as depicted in the box in the last line.

The assessment of physical and systemic vulnerability is followed by the identification of appropriate protection measures that either exist or can be implemented. Mitigation strategies are aimed at contrasting the systemic damage and the various components of both physical and systemic damage scenarios. Such measures are aimed at reducing the hazard potential, making the plants more robust structurally and less dependent on external services, and increasing the response capacity and the resilience of the territory and critical services. As shown in Figure *7*, mitigation measures are aimed at reducing the potential of systemic failure but also recovering from it, using all resources that can be put in place both internally to the plants and in collaboration with civil protection and rescue organizations.

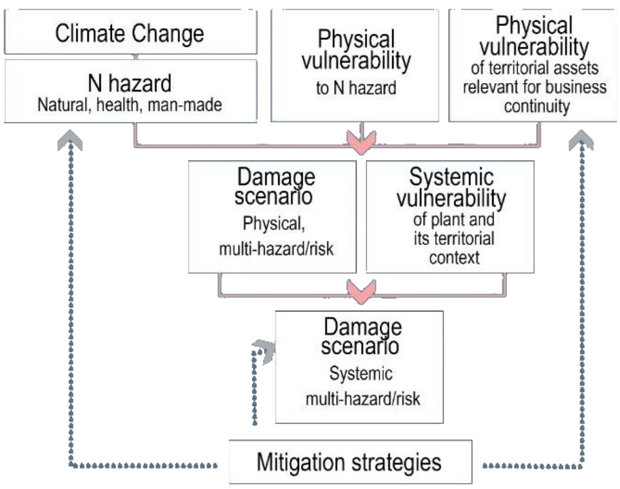

Figure 7. Conceptual scheme about analytical methodology proposed for supporting multi-risk assessment in territorial perspective.[146]

6.2 Mapping and Multi-risk assessment In Target Countries

6.2.1 Multi-hazard and multi-risk assessment in Italy

The Italian pilot case study is located in via Amenta in the west quadrant of the Metropolitan area of Milan, in in the district of Baggio (20152). Site is accessible by the ring road A50, the highways A4 Turin-Trieste, A8 Milan-Varese, A7 Milan-Genoa (Figure 8) .

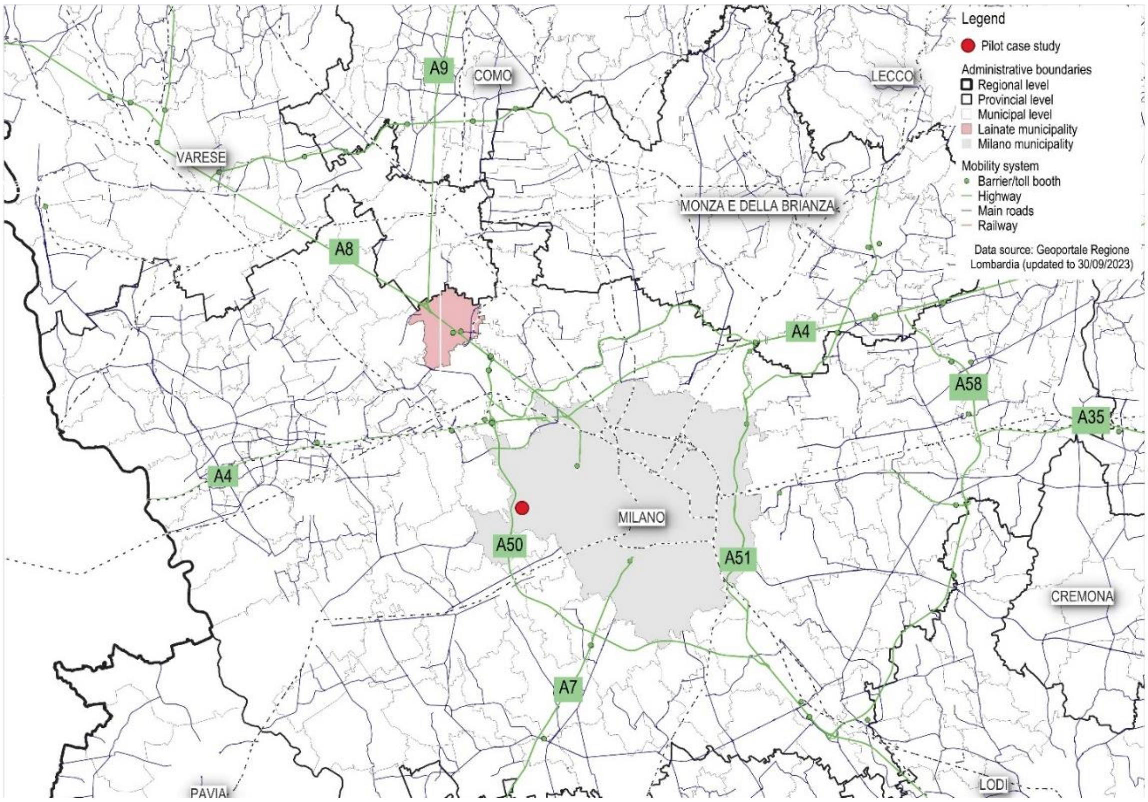

Figure 8. Territorial framework and accessibility of the Italian pilot case study in Milan

<u>Analysis of risk factors at site level</u>

Among all the risks that can determine potential impacts on building, territorial networks and personnel in a consequence of both multihazard and multirisk conditions and for the effect of Climate Change, relevant local site-level risks due to extreme weather events or phenomena (natural, health, and man-made hazards) that may lead to a prolonged change in site conditions are summarized in Table 101.

a. Forest fire risk

Considering the Integrated Regional Risk Mitigation Program of Lombardia Region (PRIM), the pilot case study is located in an area at high forest fire risk (Risk index: 2.77) (Figure 9). Moreover, prolonged periods of drought and the proximity of green/forest areas (as represented in the Corine Land Cover map in Figure 10 should not be overlooked as possible causes of fire ignition.

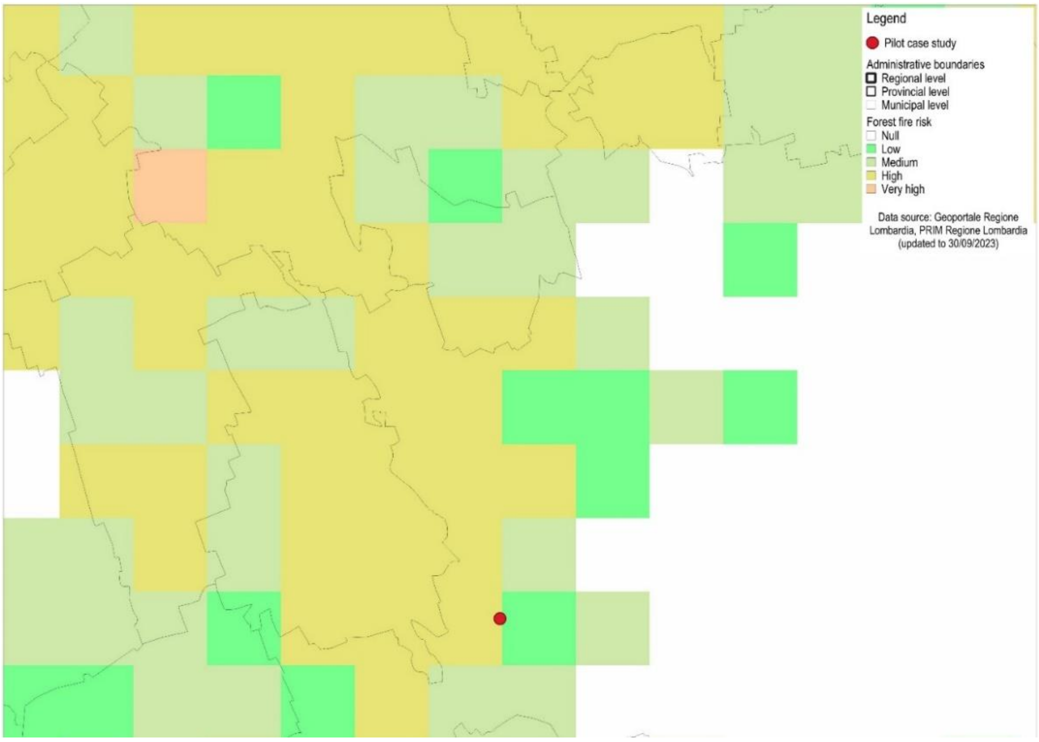

Figure 9. Forest Fire Risk Map

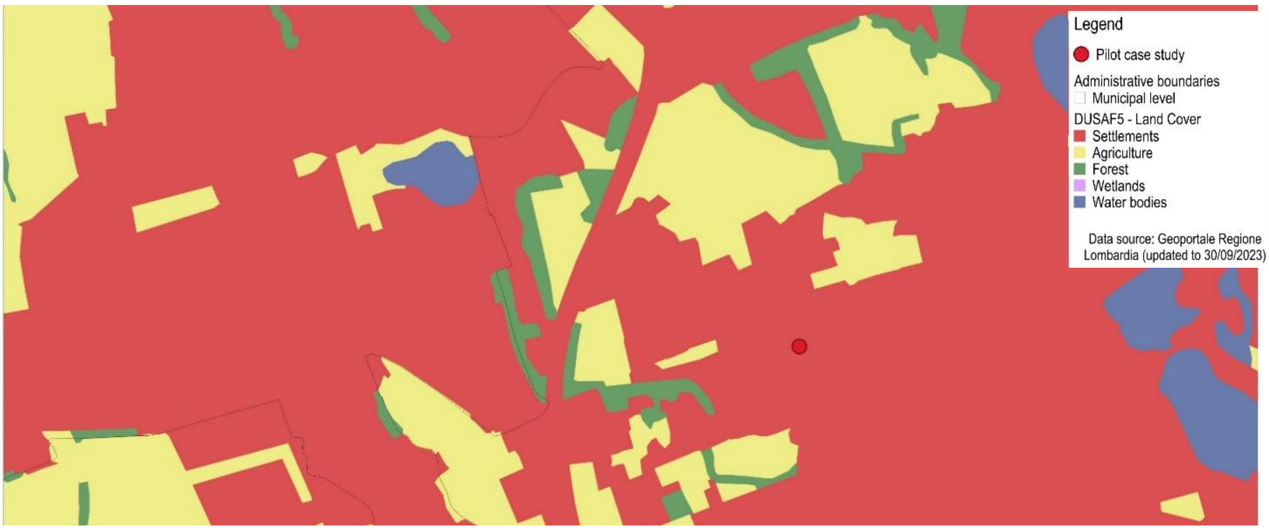

Figure 10. Corine Land Cover Map

b. Proximity to major accident risk installations

Considering the National list of major accident risk plants [148] such as industrial facilities that handle one or more hazardous substances and lead to a serious danger to workers, the public or the environment in case of major emissions, fires or explosions (regulated by the norms contained in the Legislative Decree 26 June 2015, n. 105 according to the EU Directive 2012/18/EU), several hazardous installations are located in the metropolitan area of Milan. The most relevant installation to be considered is BISI LOGISTICA SRL located in via Cusago (Milan) (distance: ~1,5km) (Figure 11);

it provides technical-organizational support for issues related to the management of product flows and their stocks (logistics). The location of such installation should be considered to assess their potential impacts (direct and indirect) on pilot case study, territorial networks and personnel in case of fires or explosions and subsequent emissions of toxic substances. To maintain appropriate safety distances, areas at major accident risk are identified for each plant by their External Emergency Plan (PEE) drawn up on the basis of the guidelines prepared by the Department of Civil Protection .[149] There are three zones: i) zone I of “IMPACT”: area characterized by serious and irreversible health effects as located in close proximity to the installation at major accident risk; ii) zone II of “DAMAGE”: area where the consequences of the accident are still serious, especially for certain categories of people (children, elderly, pregnant women, etc.); iii) zone III of "ATTENTION": area where the consequences of the accident are minor and reversible.

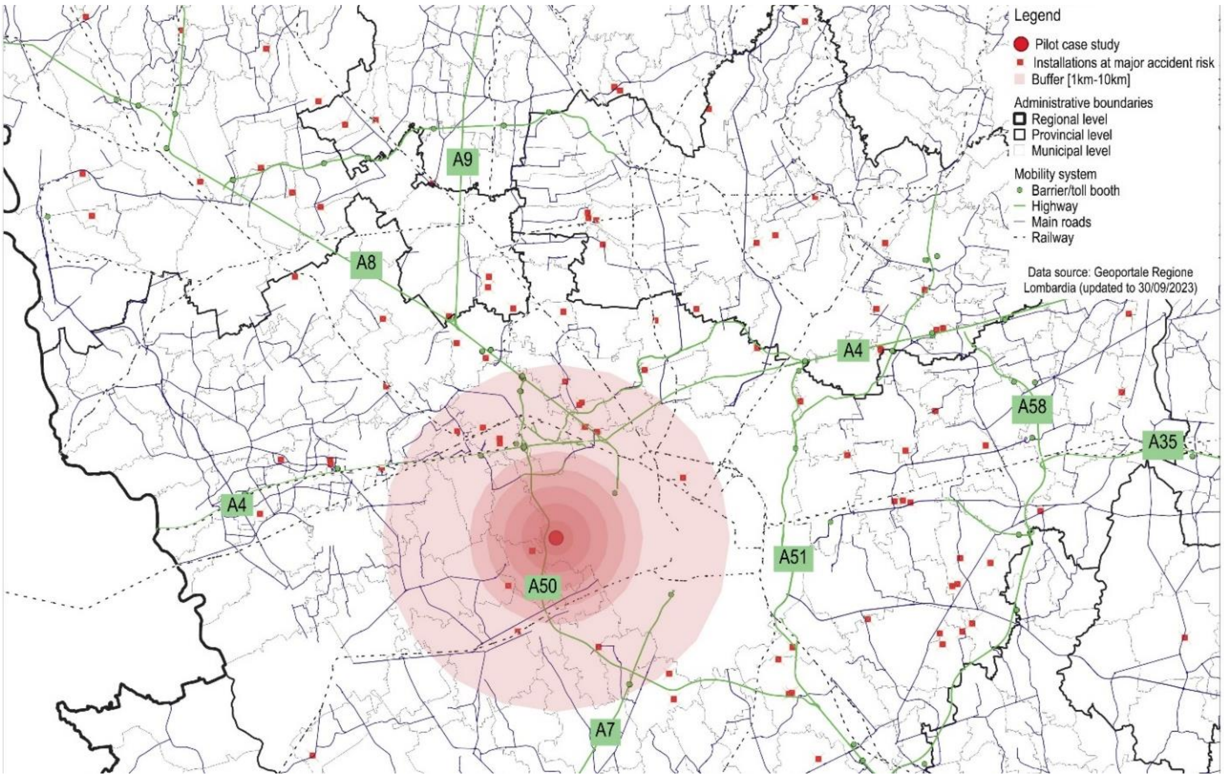

Figure 11. Presence of installations at major risk of accident in the territorial context where the Italian pilot case study is located in Milan

In Table 96, safety distances are defined with regard to the major accident risk installation relevant in the environmental context where the Italian pilot case study is located. The high level of proximity to the BISI plant could be responsible for direct impacts with particular regard to the mobility system (ring road A50); in case of major accident, a possible traffic disruption may be, limiting the accessibility of the area. No installations at major risk of accident are located in the flood risk area (Na-tech risk such as natural hazard-induced technological risk).

Table 96. Safety distances and areas at major accident risk in the environmental context where the Italian pilot case study is located.[150]

	Zone I of "IMPACT"	Zone II of "DAMAGE":	Zone III of "ATTENTION"
BISI LOGISTICA SRL	<10-42 mt	<10-62 mt	22-75 mt

* Distance changes according to the specific harmful substance released by installation at major risk of accident.

c. Road accident risk

Road accident risk must be assessed both for the potential impacts to the plant (for example in case of explosions/fires and consequent dispersion of harmful substances/fumes) and to the potential interruption of the vehicular circulation and limitation of the accessibility to the area where the Italian pilot case study is located. The Risk Prediction and Prevention Program of Milan Province (2013) describes the accident risk level of all main arterial roads in the metropolitan area, classifying the A4 and A8 highways as belonging to the R4 class (high risk) and the A50 ring road to the R3 class (medium risk). Moreover, the Regional Risk Mitigation Program of Lombardia Region (PRIM) highlights - by different colours – not only the medium/high level of road accident risk for A50 ring road, but also the high level of risk characterizing the Amenta street, the access way to the pilot case study (Figure 12).

Figure 12. Road accident risk Map

d. Transport of dangerous substances risk

In a territory, dangerous substances (flammable liquid material-ADR3) are transported by road and rail networks, as well as through special underground pipelines (oil and gas pipelines). The Risk Prediction and Prevention Program of Milan Province [151] describes the related risk level for all of the different transport categories, defining different classes of risk. With regard to the road system, highway A4 (Turin-Trieste) and the A50 ring road are classified as belonging to the R4 class (high risk, 250-1000 daily transits), and highway A8 (Milan-Varese) in the R2 class (moderate risk, 50-100 daily transits). The Milan-Turin railway is classified in R3 (medium risk, 100,000–150,000 tons/year). Moreover, the Emergency Plan of the Lainate municipality (2016) defines some risk scenarios about transport of dangerous substances along the A8 motorway crossing the municipality of Lainate. Similarly to installations at major accident risk, to maintain appropriate safety distances, some at-risk areas are defined (Table 97).

Table 97. Safety distances defined by risk scenario about transport of dangerous substances along the highway A8. Source: Emergency Plan of the municipality of Lainate (2016)

	Zone of "LETHALITY"	Zone II of "IRREVERSIBLE DAMAGE"
Transport of chlorine	110 mt	500 mt
Transport of gasoline	35 mt	60 mt
Transport of GPL	70 mt	160 mt

Considering the medium/high risk level defined above and the proximity of the pilot cases study to the mobility system, direct impacts could be on transport infrastructures, particularly in the case of explosions/fires and the consequent dispersion of harmful substances/ fumes and indirectly on territorial networks/personnel as a consequence of the potential disruption of vehicle traffic and the limitation of accessibility to the site.

Analysis of risk factors at territorial level

Among all the risks that can determine potential impacts on plants, territorial networks and personnel in consequence of both multihazard and multirisk conditions and for the effect of Climate Change, relevant territorial (regional/provincial) risks that are not directly related to the site, but which may nevertheless have important impacts on the availability of supplies, services and/or personnel are summarized in Table 101.

a. Hydraulic risk

Considering the Flood Risk Management Plan (PGRA)[152] (Figure 13), the pilot case study is not located in at risk area, but mobility system (Highway A4) could be impacted in case of a flood event, so accessibility to site could be consequently compromised.

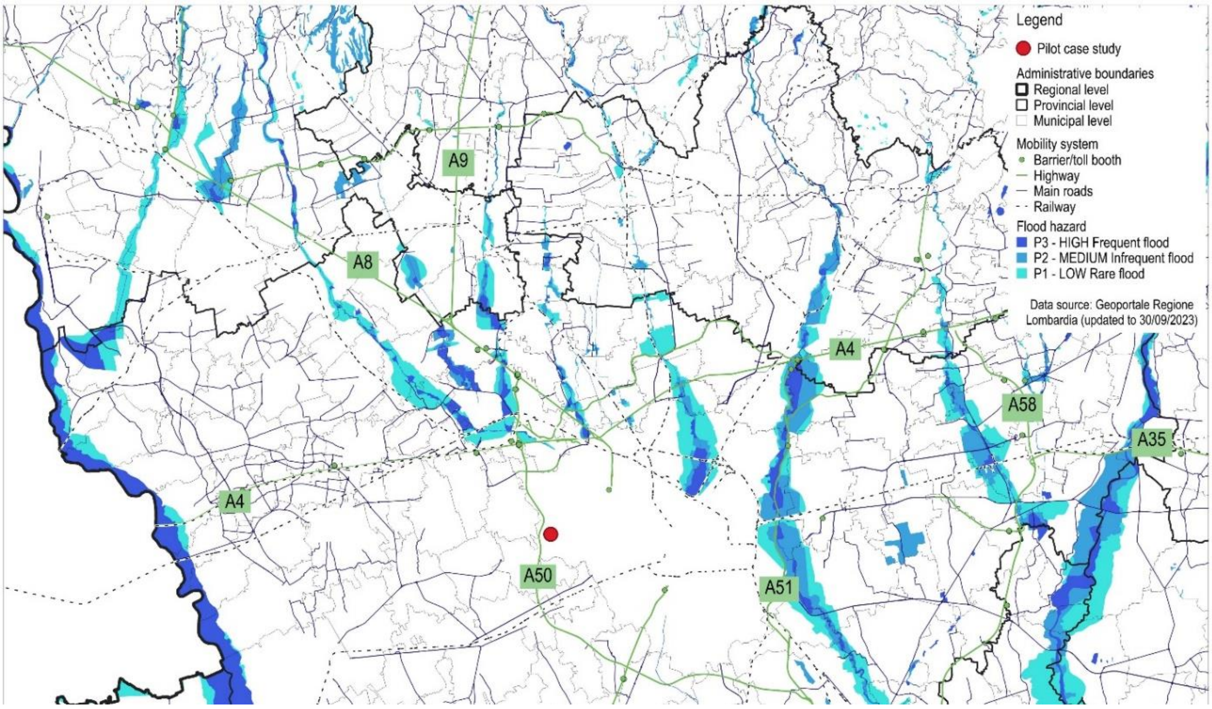

Figure 13. Flood risk areas potentially impacting the territorial context where the Italian pilot case study is in Milan

b. Seismic risk

All the Metropolitan area of Milan (where the Italian pilot case study is located) is classified in seismic zone 3 (Medium probability) (Figure 14).

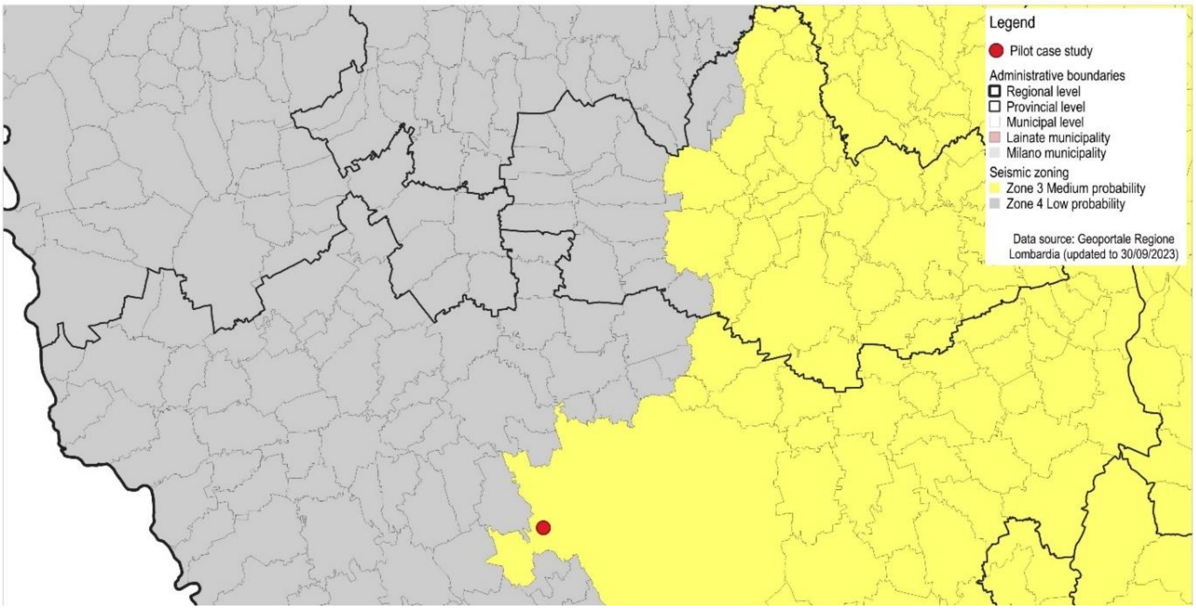

Figure 14. Seismic classification Map

c. Heat wave

Data provided by Regional Agency for Environmental Protection (ARPA) of Lombardia Region [153] can be used to assess the trend in the global warming [°C] recorded by one of the nearest available sensor to the environmental context where Italian pilot case study is located (in Piazza Zavattari, Milan) in the last 35 years (from 1989 to 2023) (Table 98). It has been observed that in recent years (differently from the past years), temperature peaks above 30/35ºC have been more frequent than temperature peaks below 0ºC. In periods of heat waves, a major problem concerns the supply of electricity which could be at risk due to overload for excessive energy demand for conditioning. So, an increasing number of power outages (both short and long) could be experienced. Then, telecommunications cables could degrade and produce malfunctions as they are vulnerable to very high temperatures.

Table 98. Trend in temperature peaks [°C] recorded in Milan (Piazza Zavattari) from 1989 to 2023.[153]

Year	Frequency [n° of days]			N° of recorded days	Year	Frequency [n° of days]			N° of recorded days
	T<0°C	T>30°C	T>35°C			T<0°C	T>30°C	T>35°C	
2023*	4	82	22	319 out of 365	**2005**	43	43	1	320 out of 365
2022	13	96	22	365 out of 365	**2004**	23	29	0	344 out of 366
2021	13	73	6	359 out of 365	**2003**	33	76	11	362 out of 365
2020	9	61	4	366 out of 366	**2002**	25	11	0	357 out of 365
2019	23	68	13	365 out of 365	**2001**	30	29	0	359 out of 365
2018	20	57	0	353 out of 365	**2000**	27	12	0	361 out of 366
2017	40	66	4	362 out of 365	**1999**	37	15	0	346 out of 365
2016	22	47	0	366 out of 366	**1998**	30	22	0	356 out of 365
2015	21	55	16	360 out of 365	**1997**	13	7	0	363 out of 365
2014	7	13	1	341 out of 365	**1996**	19	14	0	366 out of 366
2013	32	0	0	195 out of 365	**1995**	21	30	0	365 out of 365
2012	44	50	1	355 out of 366	**1994**	11	56	4	364 out of 365
2011	30	39	5	353 out of 365	**1993**	16	40	2	359 out of 365
2010	44	39	0	352 out of 365	**1992**	25	36	0	346 out of 366
2009	34	39	0	332 out of 365	**1991**	53	48	1	346 out of 365
2008	21	24	0	322 out of 366	**1990**	18	7	0	263 out of 365
2007	18	5	0	173 out of 365	**1989**	0	0	0	45 out of 365
2006	26	27	2	217 out of 365					

* Data recorded from 01.01.2023 to 15.11.2023

d. Heavy rainfall/ Drought

Data provided by Regional Agency for Environmental Protection (ARPA) of Lombardia Region[153] can be used to assess the trend of daily cumulative precipitation values (mm) recorded by one of the nearest available sensor to the environmental context where Italian pilot case study is located (in Piazza Zavattari, Milan) in the last 20 years (from 2004 to 2023) (Table 99). It can be observed that in the territory considered in the last years the rainy events have been less frequent but of greater intensity. Heavy rainfall can cause not only flooding but - in simultaneous conditions of strong winds - trees to fall on the traffic arteries, affecting the accessibility to the sites. Moreover, water infiltrations in the plant can be recorded in case of extreme weather events, mainly on the roof.

Table 99. Trend in daily cumulative precipitation values [mm] recorded in Milan (Piazza Zavattari) from 2004 to 2023.[153]

Year	Daily cumulative precipitation values [n° of days]			N° of recorded days
	10-50 mm	50-100 mm	>100 m	
2023*	24	1	0	315 out of 365
2022	17	0	0	365 out of 365
2021	23	0	0	365 out of 365
2020	27	4	0	363 out of 366
2019	35	2	0	365 out of 365
2018	25	0	0	354 out of 365
2017	19	1	0	365 out of 365
2016	34	0	0	337 out of 366
2015	27	0	1	364 out of 365
2014	27	3	0	283 out of 365
2013	11	0	0	93 out of 365
2012	28	1	0	353 out of 366
2011	18	0	0	346 out of 365
2010	44	4	0	341 out of 365
2009	34	3	0	353 out of 365
2008	41	1	0	349 out of 366
2007	18	2	0	333 out of 365
2006	18	0	0	347 out of 365
2005	23	2	0	360 out of 365
2004**	3	0	0	38 out of 366

* Data recorded from 01.01.2023 to 15.11.2023 - ** Data recorded from 22.11.2004 to 31.12.2004

e. Wind storm

Italian territory is divided by national legislation (UNI 10349:1994)[154] in 5 regions of windiness (A, B, C, D, E) and then there is a subdivision into 4 zones characterized by an increasing influence of the wind (1,2,3,4). The Province of Milan falls in Region A, wind zone 1 where the situation of greatest danger arises when intense northern currents invest and cross the Alps. Moreover, data provided by Regional Agency for Environmental Protection (ARPA) of Lombardia Region[153] can be used to assess the trend in daily maximum gusts of wind [km/h] recorded by one of the nearest available sensor to the environmental context where Italian pilot case study is located (in Piazza Zavattari, Milan) in the last 7 years (from 2013 to 2019) (Table 100). Increasing frequency of daily wind peaks is observed. Damage caused by this type of event can be attributed to damage to structures (i.e. uncovering the roofs of buildings) and the uprooting of trees and pylons. As result of the fall of branches and/or trees, risk scenario can also lead to electrical blackouts and malfunction of the mobile telephone network, as well as damage to other technological equipment. Road traffic may also be disrupted.

Table 100. Trend in daily maximum gust of wind [km/h] recorded in Milan (Piazza Zavattari) from 2013 to 2019. [153]

Year	Daily maximum gust of wind [km/h]			N° of recorded days
	Strong wind [50-61 km/h]	**Wind storm** [62-74 km/h]	**Strong wind storm** [75-88 km/h]	

2019	6	0	1	358 out of 365
2018	0	0	0	354 out of 365
2017	6	0	0	362 out of 365
2016	3	1	0	366 out of 366
2015	4	2	0	365 out of 365
2014	2	1	0	343 out of 365
2013*	0	0	0	99 out of 365

* Data recorded from 23.11.2013 to 31.12.2013

f. Lightening

The Regional Risk Mitigation Program of Lombardia Region (PRIM)[155] provides the lightening risk map representing the annual lightning rate per square kilometer (Figure 15). The case study is located in a low risk, but - on the basis of past events data analysis - it's evident that the consequences of Climate Change are increasingly being felt in the Metropolitan area of Milan, such as the increasing average temperature, more frequent extreme climatic conditions due to both the increasing of winds and precipitation, and the reduction in annual average rainfall precipitation. While the direct impact on plants/servers/IT equipment is potentially low, the indirect impact on the power grid and telecommunication systems (responsible for widespread outages at the level of the metropolitan area of Milan) and on the accessibility of sites (limited in the case of trees falling on the roads) is expected to be higher.

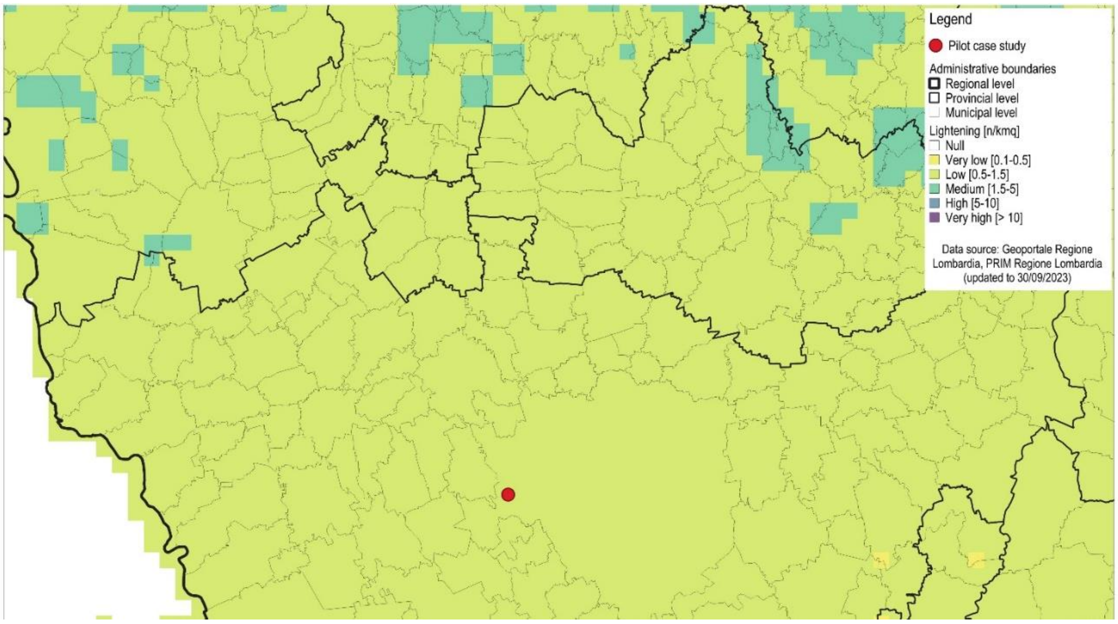

Figure 15. Lightening risk map

g. Epidemic/Pandemic risk

With regard to pandemic risk, it is a territorial risk potentially impacting a whole region. In particular, it could have a direct impact on the health of workers and/or limit their movement by emergency measures aimed at containing the spread of infection for instance minimizing the presence of the workers and encouraging smart working. Measures must be defined and diversified considering the evolution of pandemic peaks. A pandemic plan must provide including all the interventions.

h. Distance from airports

In the environmental context where pilot case study is located, the airports closer to it are: Milano Bresso (distance: ~12 km), Milano Linate (distance: ~15 km) and Milano Malpensa (distance: ~33 km).

Table 101. Risk factors and direct/indirect impact assessment

Risk	Hazard & Climate Change	Multi-hazard/risk	Potential impacts assessment (☒ Direct impact on plant, ◎ Indirect impact on territorial networks/personnel)
Seismic	Pilot case study is located in seismic zone 3 (Medium probability)	-	◎ Medium impact on the mobility networks
Hydraulic	Pilot case study is not located in at risk area	⌘ Heavy rainfall	☒ Null ◎ Medium impact on mobility system (highways A4/A8) compromising the accessibility to the site
Heavy rainfall	⭱ Rainy events have been less frequent but more intense in the last 20 years	⌘ Flooding Wind storm	☒ Medium/Low impact on the plant ◎ Medium impact on power and mobility networks (highways A4/A8, ring road A50) compromising the accessibility to the site
Heat wave	⭱ In recent years, temperature peaks (~ 30/35 ºC) have been more frequent	-	☒ Low impact on the plant as it is not located in a heat island ◎ Medium impact in case power system outages
Drought	⭱ Rainy events have been less frequent but more intense in the last 20 years	-	☒ Low impact on the plant ◎ Medium impact on the water network
Wind storm	⭱ Increasing frequency of wind phenomena daily peaks	⌘ Heavy rainfall	☒ Low impact on the plant ◎ Medium/low impact on power and mobility networks (highways A4/A8, ring road A50) compromising the accessibility to the site in case of trees falling
Lightening	⭱ Pilot case study is located in a low risk	-	☒ Low impact ◎ Medium/Low in case of power failures and accessibility disruption
Forest fire	⭱ Pilot case study is located in a high forest fire risk area	-	☒ High considering the presence of green areas close to the plant ◎ Medium/High in case of power failures and accessibility disruption
Pandemic	Even if localized contamination can be predicted, the pandemic is clearly a territorial risk potentially impacting the whole Lombardia Region	-	☒ Low impact on the plant ◎ Medium impact in case of failure in the provision of local services and on the availability of the staff
Installations at major accident risk	Pilot case study is close to an installation at major accident risk	-	☒ Medium/High impact on the plant ◎ Medium impact for closing roads adjacent to the facilities
Transport of dangerous substances	Road Proximity to A4 and A50 classified in R4 class (high risk), A8 in R2 class (moderate risk)	-	☒ Medium impact for release of hazardous substances on the highway A50 ◎ Medium/High impact in case of highway/ring road closure in consequence of road accident and release of harmful substances
	Railway Proximity to railway Milan-Turin classified in R3 (medium risk)	-	☒ Low impact distance to railway system: ~5km to Milan-Novara-Turin and Milan-Varese lines ◎ Medium/Low impact in case of vehicle circulation interruption
	Pipelines No proximity	-	☒ Null ◎ Low impact in case of fire and release of harmful substances into soil/groundwater contamination
Road accident	A4 and A8 classified in R4 class (high risk), A50 in R3 class (medium risk)	-	☒ Medium/high impact for local access road (via Amenta) ◎ Medium/High impact in case of closure of the highways/ring road

⤒ Climate Change impact: increase of hazard frequency/severity; ⌘ Multi-risk conditions

Protection factors and mitigation measures

With regard to the different factors of risk defined in the previous paragraphs, some protection factors and mitigation measures must be considered at site level (⊠) and/or at territorial level (◎) (Table 102).

Table 102. Protection factors and mitigation measures

Risk	Protection factors & mitigation measures (⊠ plant, ◎ territorial networks/personnel)
Seismic	⊠ Earthquake-resistant structures, installations anchored to walls
	◎ Organisation of alternative roads in emergency plans (road system redundancy), power generators
Hydraulic	⊠ Lift the installations with respect to level "0"
	◎ Organization of alternative roads system
Heavy rainfall	⊠ Resistant structures (roofs) and sealed openings
	◎ Emergency generators, power grid redundancy, alternative traffic
Heat wave	⊠ The plant must be equipped with autonomous generators and UPS uninterruptible power supply to ensure a 48-hour autonomy in case of lack of external energy supply
	◎ Redundancy and efficiency of electrical equipment, telecommunications network connections, and site accessibility. Internal procedures and emergency management systems are becoming fundamental to carrying out all of the necessary operations for business continuity, in addition to the availability and accessibility of territorial resources such as the Regional Fire Department and the Prefecture and Regional Directorate of Civil Protection
Drought	◎ Redundancy of air conditioning systems
Wind storm	⊠ Roof dust sealing
	◎ Power supply medium voltage redundancy
Lightening	⊠ Lightning protection
	◎ Emergency generators, power system redundancy, civil protection plans, cooperation with firefighters
Forest fire	⊠ Vegetation maintenance and on-site fire protection systems, mainly in summer
	◎ Civil protection plans, cooperation with firefighters
Pandemic	⊠◎ plant must provide a pandemic plan, including all the interventions aimed at containing the spread of infection for instance minimizing the presence of the workers and encouraging smart working. Measures must be defined and diversified in consideration of the evolution of pandemic peaks.
Installations at major accident risk	⊠ Air circulation systems
	◎ Alternative road systems, civil protection plans, cooperation with firefighters
Transport of dangerous substances	⊠ Air circulation systems
	◎ Interruption of the vehicular circulation with difficulty in accessibility of the area -> road system redundancy
Road accident	⊠ Resistant structures, dedicated access
	◎ Interruption of the highways or closure of the ring road junctions -> road system redundancy

Proximity to fire stations

In addition to the defined protection and mitigation measures (Table 102), it is important to consider the proximity to the firefighters departments (Figure 16). Considering the proximity to the Italian pilot case study in Milan, the most relevant fire departments to be considered are the following ones:

- *Fire department in via Sardegna, 8 (Milan): ~6,5 km, ~16 minutes.*
- *Fire department in via Darwin, 5 (Milan): ~10 km, ~20 minutes.*
- *Fire department in via Messina, 35 (Milan): ~11 km, ~23 minutes.*

- *Fire department in via Sandro Pertini, 1 (municipality of Rho): ~13 km, ~16 minutes.*

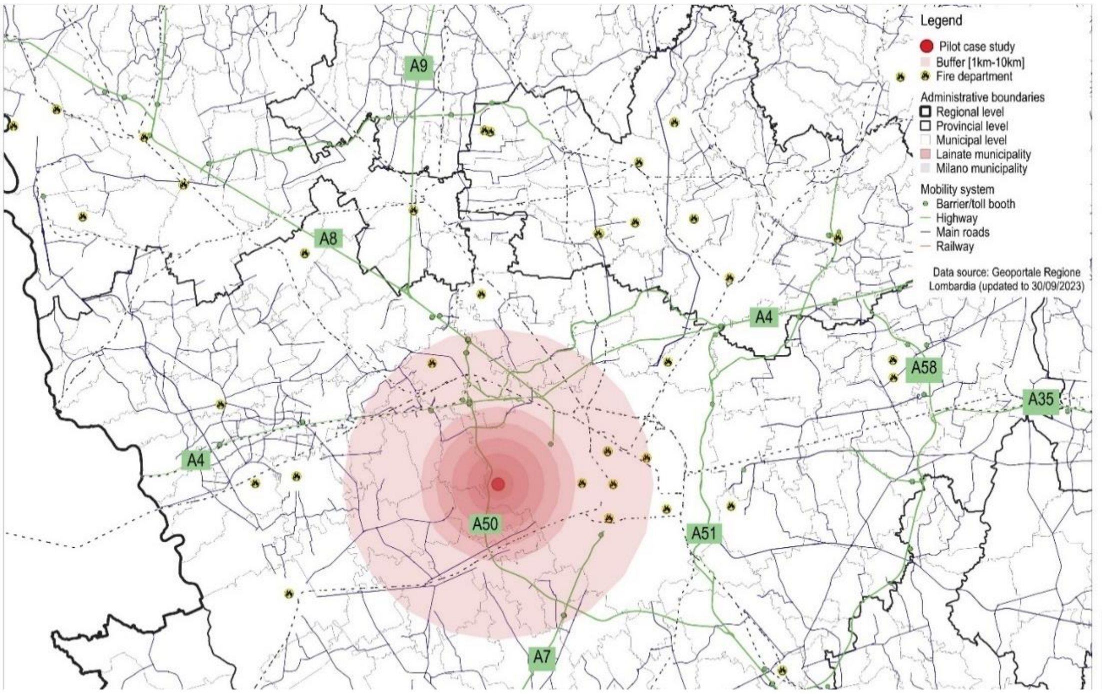

Figure 16. Map of fire departments in the surrounding of the Italian pilot case

6.2.2 Multi-hazard and multi-risk assessment in France

The French pilot case study is located in Rue D'Artois in Pérenchies (59840) in the Northwest part of the Métropole Européenne de Lille. Site is accessible by the highways A25 and A22, and the ring road Nord-Ouest (Figure 17).

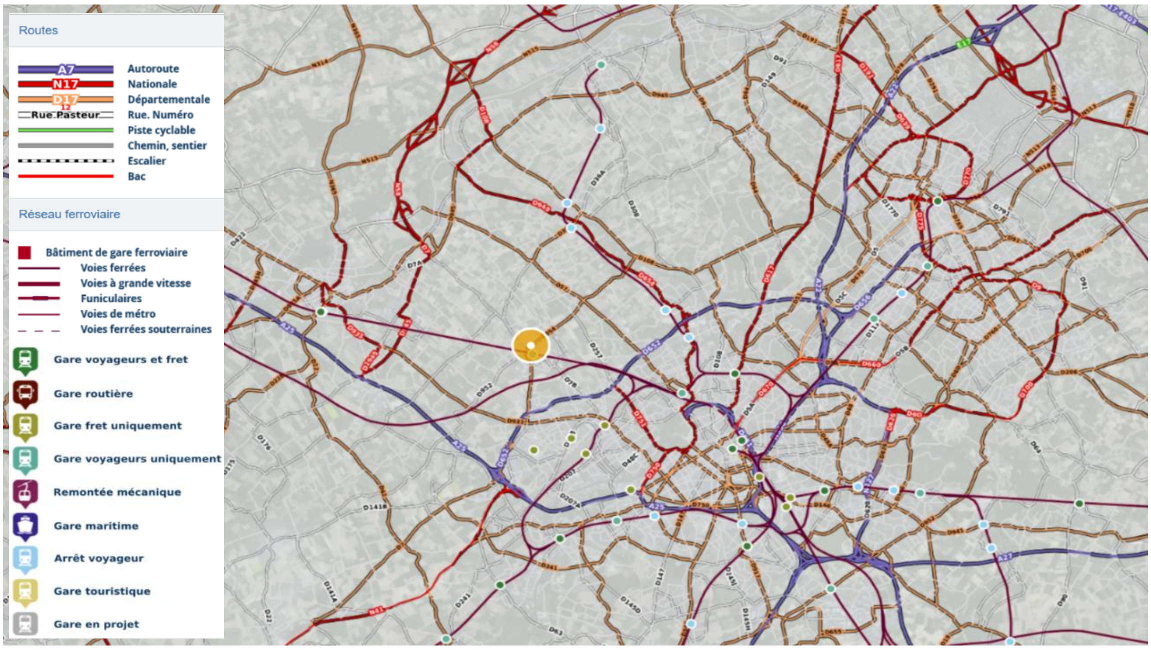

Figure 17. Territorial framework and accessibility of the French case study. Source: geoportail.gouv.fr

Analysis of risk factors at site level

a. Geological risk

Soils composed by clay swell in the presence of water (during rainy season) and settle in dry season. These movements of the ground can damage buildings (cracking). Detached houses that have not been designed to withstand the movements of clay soils can be significantly damaged. In the site, the geological risk is medium (Figure 18).

Figure 18. Carte de l'exposition au retrait-gonflement des argiles en France.[156]

b. Transport of dangerous substances

In the surrounding of the French case study (~ 500 meters), there are pipelines used for the long-distance transport of natural gas (gas pipelines) are buried at least 80 cm in deep (Figure 9).

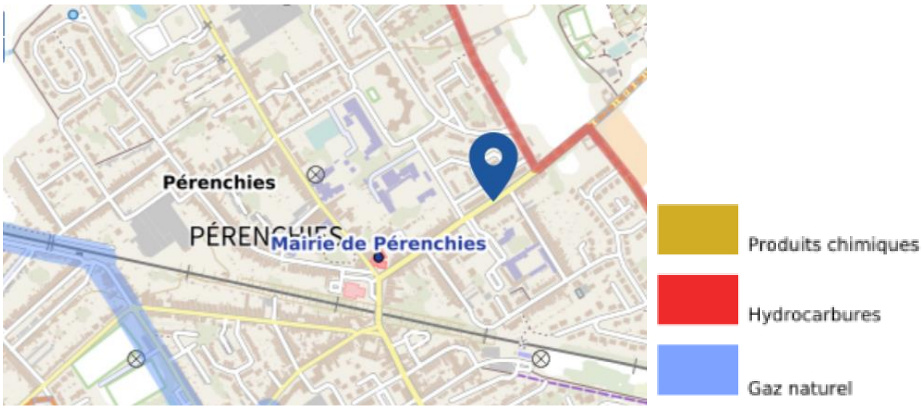

Figure 19. Proximity to gas pipelines. [156]

c. Risk of soil pollution

Because of old deposits of waste or infiltration of polluting substances, a polluted site presents a risk for people health and for environmental conditions. In the surrounding of the French case study (~ 500 meters), there are 7 potentially polluting industrial sites. So, the risk of soil pollution is high (Figure 20).

Figure 20. Proximity to potentially polluting industrial sites. [156]

Analysis of risk factors at territorial level

a. Seismic risk

The seismic zoning of France[157] defines 5 seismicity zones: 1 - Very low, 2 - Low, 3 - Moderate, 4 - Medium, 5 – High. The pilot case study is located in seismic zone 2 (Low risk or *Sismicité faible*) (**Figure 21**).

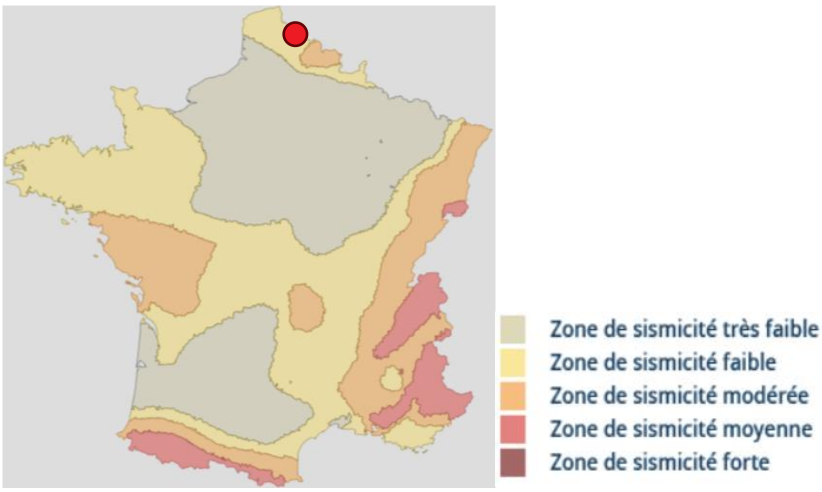

Figure 21. Seismic zoning of France.[158]

b. Hydraulic risk

The municipality of Lille benefits from a Flood Prevention Action Programme .[159] The territory at high risk of flooding of Lille has been identified as TRI with regard to its exposure to the overflows of the rivers of the Lys, the Deûle and the Marque. Pérenchies is not part of TRI (Figure 22).

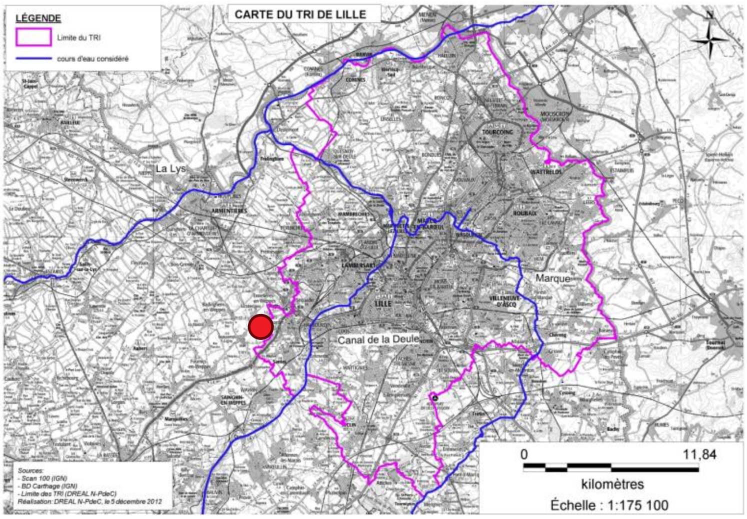

Figure 22. Directive inondation TRI de Lille. Source : Préfet de la Région Hauts-de-France

c. Distance from airports

The Lille airport is close to the case study (distance: ~14 km).

Protection factors and mitigation measures

a. Proximity to fire stations

Mainly in case of emergency, it is fundamental to consider the high proximity to the firefighter departments; the most relevant fire departments to be considered are mapped in Figure 23.

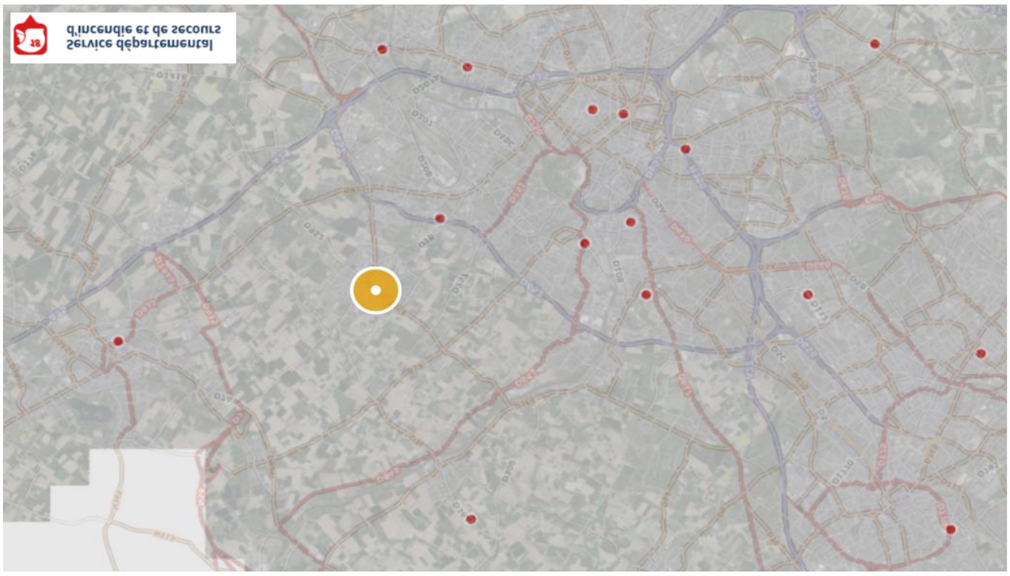

Figure 23. Map of fire departments in the surrounding of the French pilot case.[160]

6.2.3 Multi-hazard and multi-risk assessment in Bulgaria

About this case study, several data and information are collected to carry out the risk assessment. For example, about risks related to extreme heat/cold/rain, drought, storms, landslides, forest fires, etc. [161,162,163] .The process of translating all the Bulgarian documents will be started soon.

6.2.4 Multi-hazard and multi-risk assessment in Spain

The Spanish case study is located is located in Calle de la Bolera in Langreo (33900), part of the Principado de Asturias in Spain.

<u>Analysis of risk factors at local level</u>

a. Geological risk

To evaluate the hydro-geodynamic hazards, Principado de Asturias provides a "*Sistema de Información Territorial e Infraestructura de Datos Espaciales de Asturias (SITPA-IDEAS)".*[164] The pilot case study site is characterized by a medium/high geo-hazard (landslide, large mass movements, falling rocks) (Figure 24).

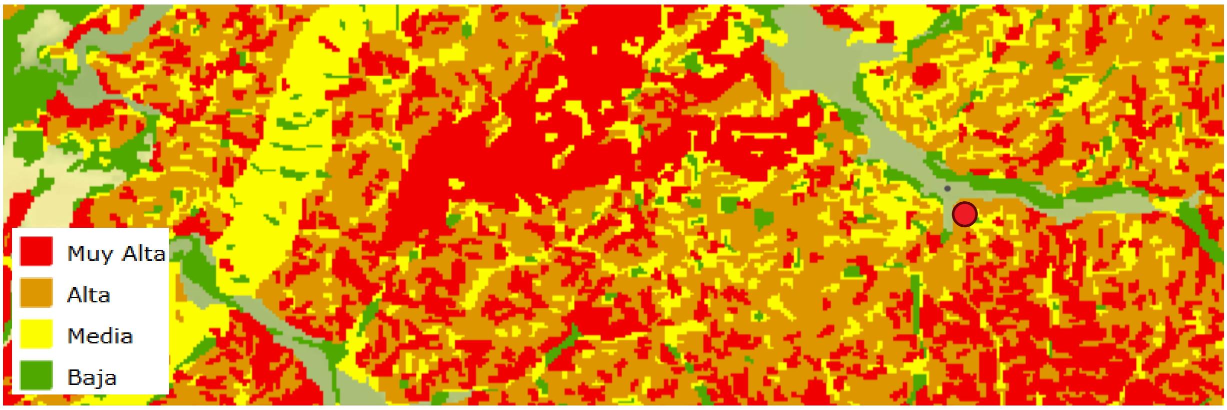

Figure 24. Map of level of geo-risk.[164]

<u>Analysis of risk factors at territorial level</u>

a. Seismic risk

The National Geographic Institute (IGN) periodically publishes the Seismic Hazard Maps of Spain. These maps are produced on the basis of different criteria, such as intensity or seismic acceleration. The Principado de Asturias is characterized by lowest seismic value in Spain (Figure 25).

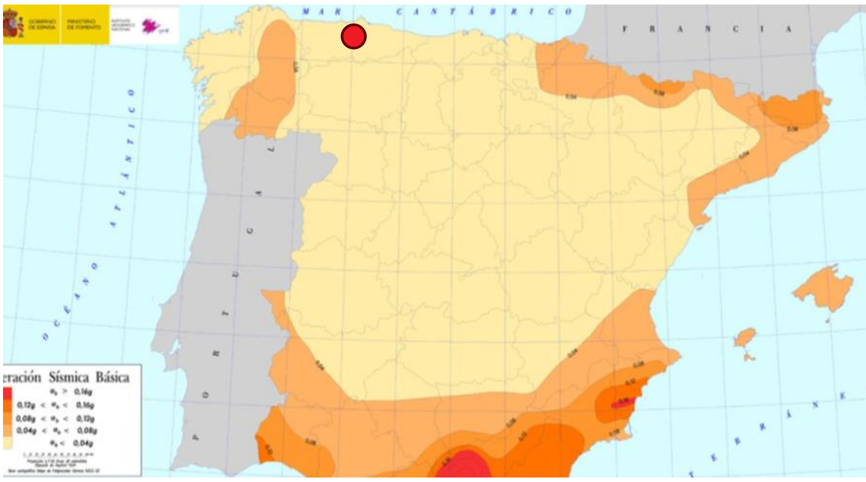

Figure 25. Seismic hazard map of Spain.[165]

b. Hydraulic risk

The Ministerio para la Transición Ecológica y Reto Demográfico provides flood risk mapping of Spain with regard to 3 scenarios: 1) Low probability of flooding (extreme events or return period greater than or equal to 500 years), 2) Medium probability of flooding (return period of 100 years or more), 3) High probability of flooding (return period greater or equal to 10 years). Considering the flood risk mapping (Figure 26), the pilot case study is not located in at risk area, but mobility system could be impacted in case of a flood event, so accessibility to site could be consequently compromised.

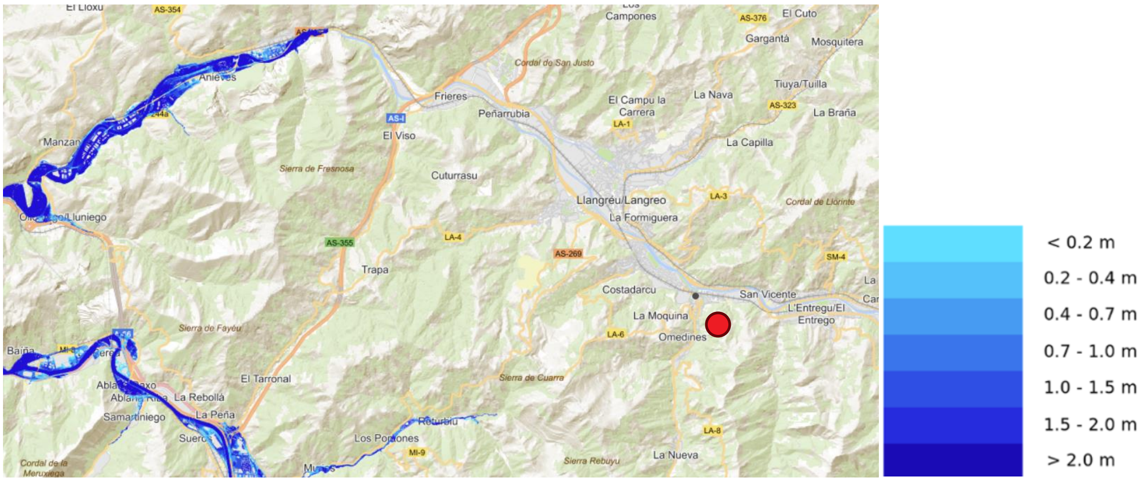

Figure 26. Flood risk mapping in the surrounding of Spanish case study. [164]

c. Forest fire risk

The Plan Especial de Protección Civil de Emergencias por Incendios Forestales del Principado de Asturias [166] provides forest fire risk map (**Figure 27**). The pilot case study is not located in at risk area, but there are several high-risk areas in its surrounding; so in case of fire, accessibility could be highly compromised.

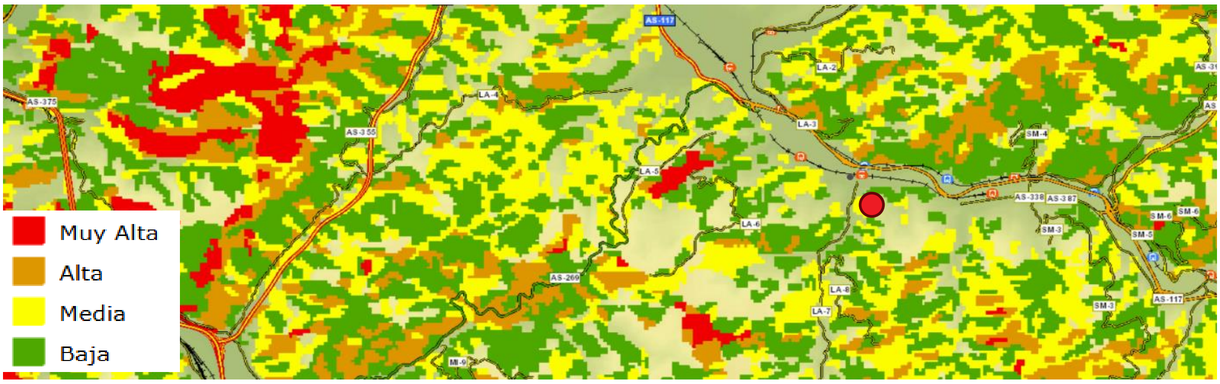

Figure 27. Map of forest fire risk.[164]

6.3 Risk Assessment of RE-SKIN Components

To identify the risks associated with RE-SKIN components, a thorough analysis was conducted to evaluate their vulnerabilities to various hazards. This analysis aimed to enhance the security, reliability, and efficiency of the systems by identifying both direct and indirect impacts of potential hazards on the systems and their subcomponents. By understanding these vulnerabilities and implementing appropriate measures, the RE-SKIN systems can become more resilient, better prepared to withstand potential impacts, and more capable of minimizing damages or disruptions. This approach facilitates the development of effective risk mitigation strategies, ultimately improving overall service provision. The following diagram provides an overview of the different levels of risks considered in the RE-SKIN systems (Figure 28).

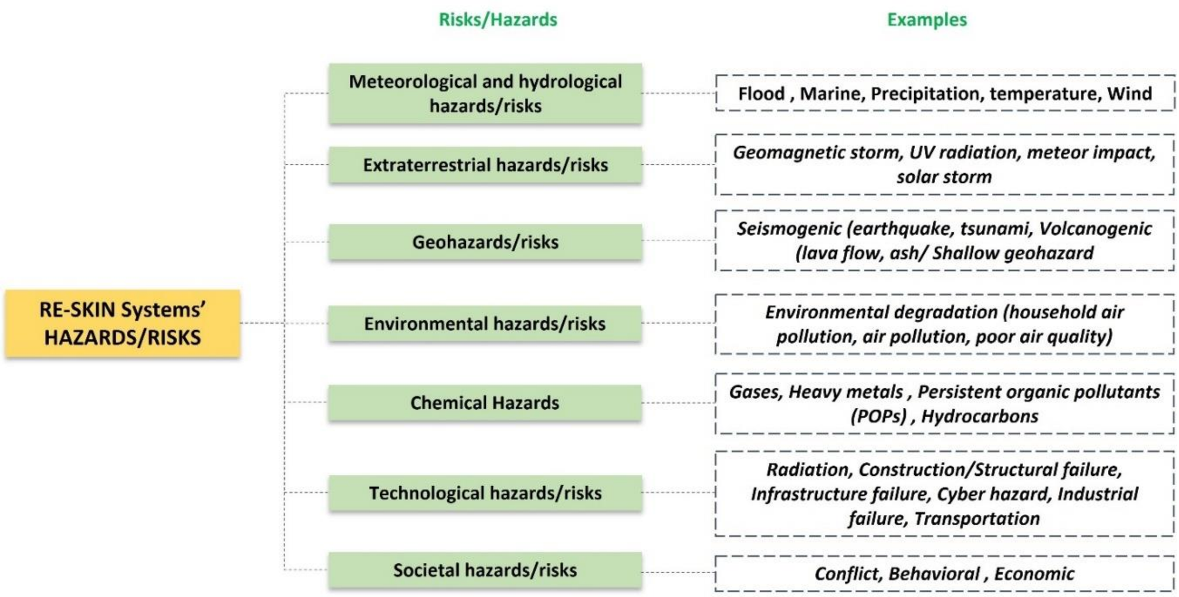

Figure 28. RE-SKIN Systems Possible Hazards

6.3.1 Hazards, Mitigation and Resilience Measures of RE-SKIN Systems

The initial phase of RE-SKIN project focused on gathering preliminary data to assess the vulnerability of systems and their subcomponents to various hazards. Vulnerability was defined as the likelihood of damage, fragility, or susceptibility to impacts from natural and technological events. This phase adopted a comprehensive multi-hazard and multi-risk perspective, examining both direct and indirect consequences of potential threats. The analysis aimed not only to identify these vulnerabilities but also to explore mitigation strategies that could be implemented to enhance security, reliability, and efficiency.

Building on this, the subsequent phase provided an in-depth assessment of RE-SKIN components, focusing on detailed hazard evaluations during both the installation and operational phases. This phase aimed to collect extensive data on system vulnerabilities and assess strategies to ensure resilience and maintainability. Resilience was characterized by the system's capacity to absorb stresses and continue functioning amid climate change, while maintainability involved systematic approaches to sustain reliability and optimal performance. The assessment also considered the effects of various hazards, applying a multi-hazard and multi-risk lens to uncover potential risks and identify protective measures. These insights helped develop effective risk mitigation strategies, ensuring higher levels of physical, logical, and operational security, thereby improving the overall reliability and service efficiency of the systems.

The following table identifies the potential hazards that may occur during both the installation and operational phases of the project. It involves collecting detailed information on various aspects: the specific hazards involved, the relevant phase of the project, the subsystems within the overall system that could be impacted, the type of physical damage that might occur, and the protective measures implemented to mitigate such damage. By comprehensively understanding these elements, the project can better address risks, ensuring safety, resilience, and continuity throughout its lifecycle.

Table 103. Hazards and Mitigation Measures of the RE-SKIN systems

System	Hazard Type	Phase	Impacted Subsystem	Physical Damage	Mitigation Measures
Hydronic Air-to-Water DC Heat Pump	Geohazard (High Humidity)	Usage	Indoor heat exchanger unit	Frost formation on heat exchanger surface	Defrost mode operation
	Geohazard (Earthquake)	Installation	Compressor, blower motor, connections	Oil and refrigerant leaks, blade breakage, liquid leaks	Proper securing of refrigerant lines and connections
	Meteorological (Flood)	Usage	Electrical components, heat exchangers	Malfunction due to water exposure, contamination	Elevated platform, flood barriers

	Technological (Infrastructure Failure)	Usage	Compressor, coils	Overheating, freezing and cracking of coils	Backup power source (e.g., generator)
	Chemical Hazards (Refrigerant Leaks)	Installation/ Usage	Refrigerant system	Refrigerant leaks	Leak testing before transportation
BIPVT Roof System	Meteorological (Flood)	Installation/ Usage	Electrical cables and connectors	Water penetration leading to electrical shorts	Not specified
	Hailstorm	Usage	Glazed surface	Glass breakage	Use of high-quality glass
	Strong Winds	Usage	Structure	Structural failure	Tightness checks, proper installation practices
Electrical Storage – Batteries	Meteorological (Flood)	Installation/ Usage	Lithium battery cells, electricals	Short circuit, fire, H2 production	Install in dry weather, IP66 cabinet, prevent water entry
	Temperature Extremes (Low/High)	Usage	Battery cells	Loss of charging capacity, cell damage	Heaters for cold, fans for heat management
	Fire Hazard	Usage	Battery system	Fire outbreak	Proper storage and placement
	Wind-Related Hazards	Usage	Cabinet	Cabinet toppling	Securely bolt to a cement base
	Hailstorm	Usage	Cabinet	Loss of sealing	Post-hailstorm maintenance checks
	Construction and Installation Hazards	Installation	Battery system	Short circuit, fire	Assembly by trained engineers
	Societal Risks (Vandalism)	Usage	Battery system	Vandalism	Steel cabinet with keyed access, secure placement
	Transportation	Installation	Battery system	Damage during shipment	Follow transportation guidelines for hazardous materials
	Power Outage	Usage	Battery pack	Deep discharge below recoverable limit	BMS programming, MIMO controls
Building Envelope - Façade Cladding	Meteorological (Precipitation)	Installation/ Usage	Outer layer, mounting system	Corrosion, water penetration	Proper installation of sealings, regular cleaning
	Meteorological (Flood)	Installation/ Usage	Existing wall, mounting system	Water penetration, mold growth	Testing and controlling internal drainage channels
	Wind-Related Hazards	Installation/ Usage	Sandwich panel, substructure	Wind uplift, system failure	Secure fastening, regular maintenance, wind-resistant materials

	UV Radiation	Usage	Outer layer	Material degradation	UV-resistant materials and coatings, regular maintenance
	Geohazard (Earthquake)	Installation	Substructure	Structural deformation, detachment	Proper anchoring
	Air Pollution	Usage	Outer layer	Material degradation over time	Regular cleaning, weather-resistant materials
	Societal Risks (Vandalism)	Usage	Outer layer	Damage from vandalism, falling objects	Impact-resistant materials, protective barriers
Building Envelope – Windows	Behavioral Violence	Usage	Glazing	Glass breakage	Using strong glass with protection
	Meteorological (Flood)	Installation/Usage	Internal areas	Water penetration	Testing and controlling internal drainage channels
	Temperature-Related Hazards	Usage	Insulation	Loss of insulating capacity, increased energy consumption	Regular testing and control of resilience
Multi-Input/Multi-Output Converter (MIMO)	Meteorological Hazards	Installation	AC-DC converter, DC-DC converter, PV optimizers	Delays in manufacturing	Early acquisition of parts, testing all possible scenarios
	Technological Hazards	Installation	AC-DC converter, DC-DC converter, PV optimizers	Delays due to manufacturing issues	Early acquisition of parts, prototype testing
Smart Control System	Technological (Infrastructure Failure)	Usage	Storage, network	Data loss, critical system errors	Cloud storage, design software to avoid dependencies
	Technological (Cyber Hazard)	Usage	Entire system	Data breaches, control loss	VPN protection, software upgrades, remote control measures
Monitoring Platform	Technological (Cyber Hazard)	Usage	Cloud-based monitoring system	Unauthorized data access	Enhanced cyber security measures

To visualize the relationships between the systems, hazards, and maintenance strategies within RE-SKIN project, the figure below illustrates how each system interacts with different types of hazards and the corresponding maintenance strategies (Figure 29). This diagram provides a comprehensive overview of the preventive and corrective measures designed to ensure the resilience and longevity of the project components under various adverse conditions.

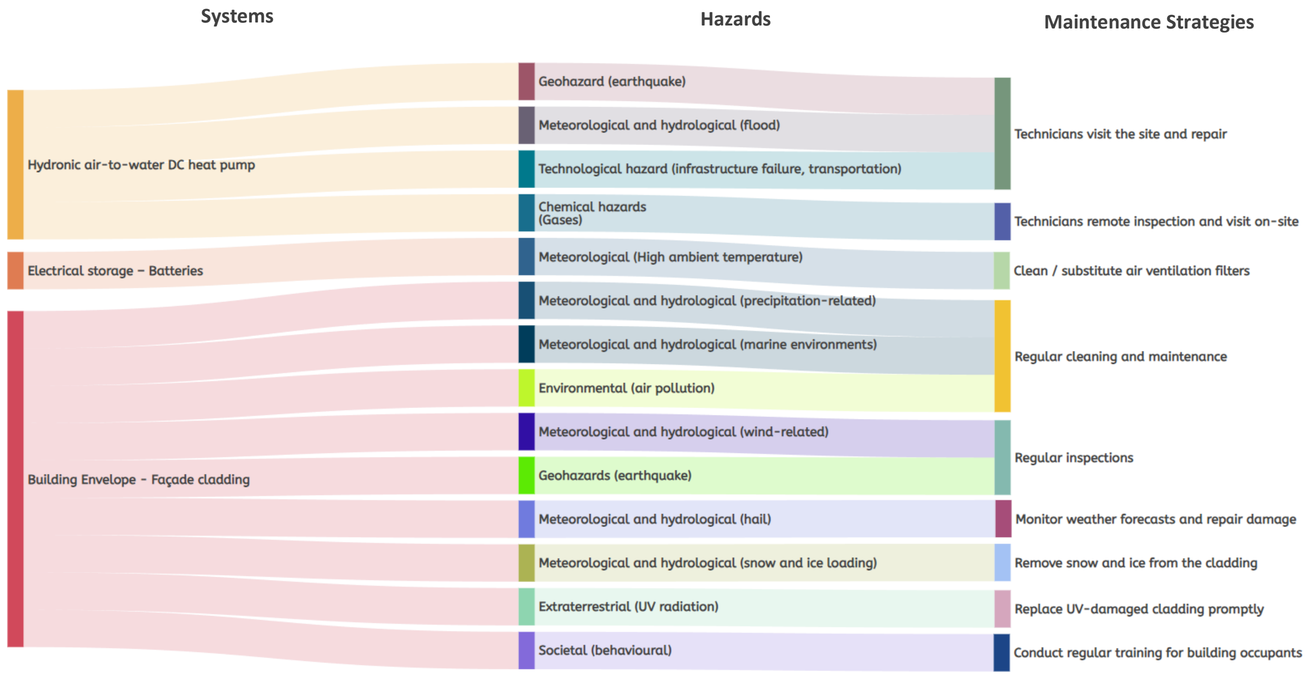

Figure 29.RE-SKIN Systems' Maintenance Strategy

A further analysis has been done on the maintenance and resilience strategies for each system in the project considering the identified hazards in Table 104.

Table 104. Maintenance and resilience strategy in RE-SKIN Project

System	Hazard Type	Maintenance Strategy	Resilience Strategy
Hydronic Air-to-Water DC Heat Pump	**Geohazard (Earthquake)**	Technicians visit the site and repair.	Educate users about the safety guide for heat pump usage.
	Meteorological and Hydrological (Flood)	Technicians visit the site and repair.	Educate users about the safety guide for heat pump usage.
	Technological Hazard (Infrastructure Failure)	Technicians visit the site and fill lubricant oil in the heat pump.	Educate drivers and installers about the safety guide for installation.
	Chemical Hazards (Gases)	Remote inspection and site visits for repairs or part replacements where leaks occur.	Conduct thorough leak testing before transportation.
Electrical Storage - Batteries	**Meteorological**	Check the cabinet's condition to ensure water and dust isolation. Perform extraordinary maintenance after hailstorms.	Maintain water-resistant paint integrity; replace air ventilation filters regularly.
	High Ambient Temperature	Regularly clean or substitute the air ventilation filters.	Ensure cabinet conditions maintain functionality and perform additional checks post-hailstorms.
Building Envelope - Façade Cladding	**Meteorological and Hydrological (Precipitation)**	Regular cleaning and maintenance to remove dirt and debris.	Use corrosion-resistant materials; design to prevent galvanic corrosion and ensure long-term durability.

Meteorological and Hydrological (Marine Environments)	Regular cleaning and maintenance to remove salt deposits and corrosion.	Use corrosion-resistant materials; design to prevent galvanic corrosion and apply protective coatings.
Meteorological and Hydrological (Wind-Related)	Regular inspections to secure loose panels, fasteners, or sealants.	Use high-strength materials and proper installation anchoring to withstand high winds.
Meteorological and Hydrological (Hail)	Monitor weather forecasts and repair hail damage promptly.	Design cladding to withstand hail impacts using robust materials like structural and thicker steel.
Meteorological and Hydrological (Snow and Ice Loading)	Prompt removal of snow and ice from the cladding.	Install drainage systems to prevent pooling from snowmelt.
Extraterrestrial (UV Radiation)	Replace UV-damaged cladding promptly.	Use UV-resistant materials such as SSAB GREENCOAT.
Geohazards (Earthquake)	Regularly inspect for signs of damage or loose panels/fasteners.	Ensure proper anchoring during installation.
Environmental (Air Pollution)	Regular cleaning to remove pollutants.	Use corrosion-resistant coatings like SSAB GREENCOAT.
Societal (Behavioral)	Conduct regular training for occupants and visitors on proper usage.	Train occupants and visitors regularly; use scratch-resistant coatings.

6.3.2 Summary of Potential Risks in RE-SKIN Systems

When considering the implementation of the systems in the project, it is crucial to recognize and prepare for various additional risks beyond the immediate scope. These risks can significantly affect the success and performance of the building envelope, storage systems, MIMO and smart control systems, and its associated subsystems. Here are some critical risk factors to be aware of:

Building Envelope – Façade:

- **Stakeholder Engagement**: Lack of commitment and trust from end-users and difficulty in convincing stakeholders of the project's benefits can hamper progress and acceptance.
- **Supply Chain and Licensing**: Global shortages in supplies and materials, transportation strikes, delays in obtaining necessary licenses, and a shortage of skilled labour for installation can lead to project delays and increased costs.
- **Technical and Compliance Issues**: Problems in material adherence during manufacturing, unanticipated technical or integration issues, noncompliance with fire safety regulations, inadequate insulation performance, and excessive façade flexing can compromise the integrity and functionality of the façade system.
- **Operational Risks**: Vandalism, accidents, inappropriate installation, and misuse of the façade system pose significant threats. These risks could result in project delays, increased costs, and reduced safety and performance.

- **Environmental and Mechanical Damage:** Risks include corrosion of mountings and brackets due to road salt, descaling of façade panel coatings from lawn mowing debris, and general wear and tear from environmental factors.

Storage System:

- **Temperature Extremes**: Persistent high temperatures can cause batteries to operate near their limits, accelerating aging. Extremely low temperatures could prevent recharging, posing significant operational risks to battery systems.

MIMO (Multiple Input Multiple Output):

- **Supply Chain Vulnerabilities**: Issues in the supply chain, such as shortages, stocking problems, and shipping delays for electronic components, could impact the development and deployment of the MIMO converter.
- **Global Instabilities**: Wars and hostilities could disrupt manufacturing facilities, increase costs, or extend lead times for components.
- **Development Risks**: As a newly designed device, the MIMO converter may encounter unforeseen failures in its initial unit.

Smart Control System:

- **Technological Hazards**: Software malfunctions, including bugs and transient instability issues, could impact the functionality and reliability of the system's technological components.

These considerations highlight the complexities involved in integrating advanced systems and underscore the importance of comprehensive risk management strategies to ensure the project's success and sustainability.

6.3.3 Overall risks associated with RE-SKIN Systems

A risk assessment matrix map of various hazards is developed to categorize the primary and secondary systems affected in RE-SKIN buildings (Figure 30). It categorizes hazards into geohazards, meteorological, technological, marine, societal, extraterrestrial, and environmental, showing their impacts on systems like electrical components, HVAC, building facades, and advanced control systems. Key observations include the vulnerability of electrical systems to floods and infrastructure failures, the susceptibility of building envelopes to environmental factors, and the specific impacts on hydronic systems and smart components by geohazards and temperature-related events. This matrix also helps identify critical points for improving resilience and preparedness against diverse hazards.

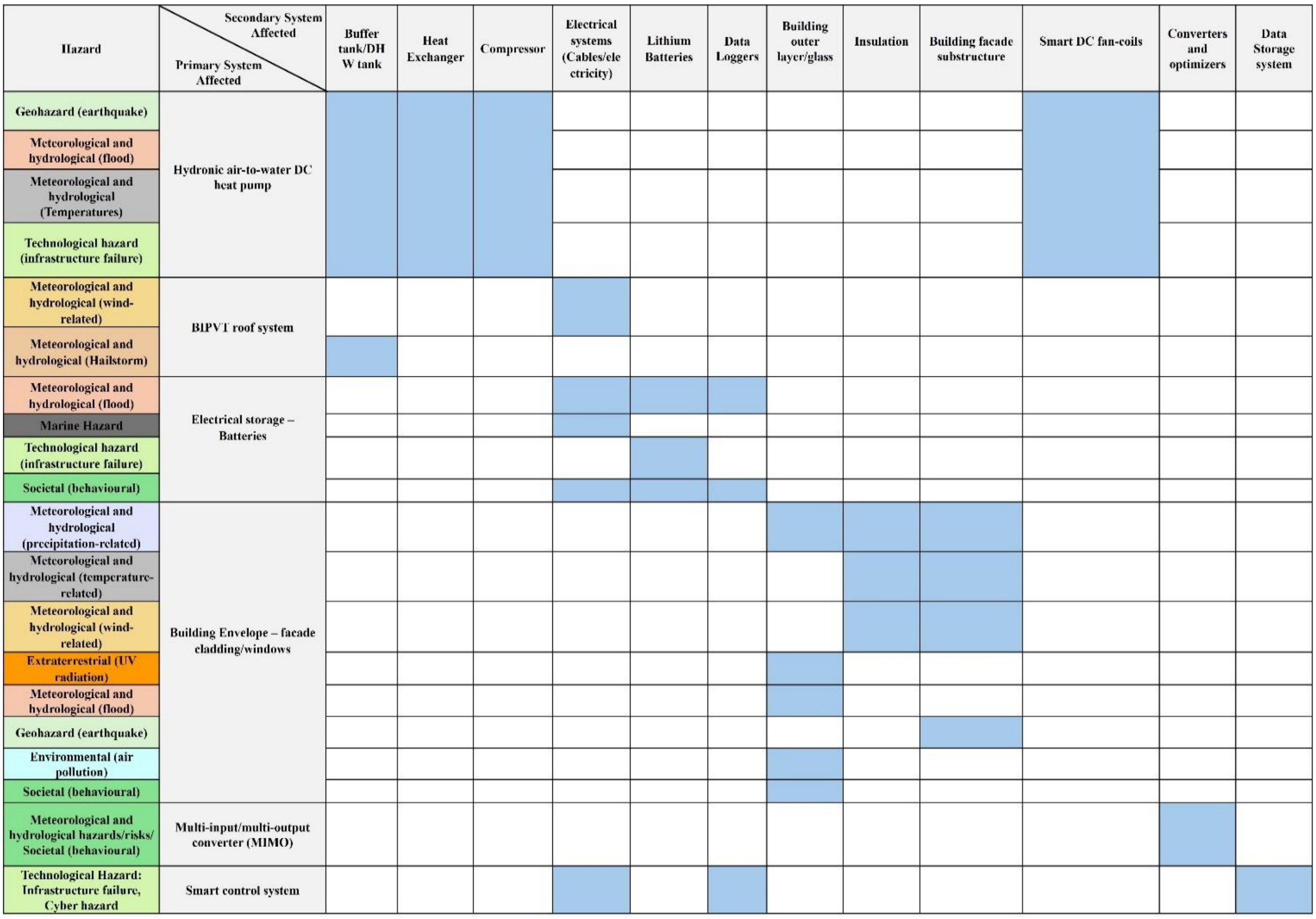

Figure 30. Primary and Secondary systems Affected Risk Assessment Matrix Map

6.4 Resilience Against Climate Change Issues

6.4.1 Building renovation and infrastructure Resilience Strategy in the EU

When discussing resilience in the context of energy infrastructure, it's important to refine the definition of disruption and tailor the response accordingly. This often aligns with the concept of "engineering resilience," where the emphasis is on the system's performance, considering the multiple components and interconnections within energy networks, some of which are classified as "critical infrastructures." While this approach provides a focused framework, it risks being too narrow and overlooking the interconnections with other ecosystems.

According to the National Infrastructure Advisory Council [167], resilience can be characterized by four key features, known as the 4Rs:

- ***Robustness**: This is the capacity to maintain essential operations and functions during a crisis. Robustness can be seen in the physical integrity and design of infrastructure (such as office buildings, power generation facilities, distribution networks, bridges, dams, and levees), and in system redundancies and alternatives (like transportation networks, power grids, and communication systems).*
- ***Resourcefulness**: This involves the ability to effectively prepare for, respond to, and manage crises or disruptions as they occur. Key aspects include identifying actionable strategies and planning for business continuity, providing training, managing supply chains, prioritizing actions to control and mitigate damage, and ensuring clear communication of decisions.*
- ***Rapid Recovery**: This is the ability to swiftly return to normal operations or reconstitute functional systems after a disruption. Rapid recovery relies on well-prepared contingency plans, competent emergency response operations, and the capability to mobilize the right personnel and resources to the necessary locations.*
- ***Redundancy**: This feature emphasizes having backup resources to support the primary systems in case of failure. Redundancy ensures that alternative resources are available and functional, providing additional layers of support to maintain operations during a crisis.*

Together, these features—Robustness, Resourcefulness, Rapid Recovery, and Redundancy—are crucial for developing resilient infrastructure.

The European Union is proactively promoting sustainable development and resilience through renovation initiatives. The "renovation wave" strategy in the European Green Deal emphasizes transforming existing buildings to meet high energy efficiency standards and address climate challenges [71],[72]. Climate-resilient infrastructure involves planning, designing, constructing, and operating buildings that anticipate and adapt to evolving climate conditions. This ongoing process aims to withstand, respond to, and recover swiftly from climate-related disruptions, aligning with broader resilience efforts against natural hazards.

While climate-resilient infrastructure can greatly reduce the risk of climate-related disruptions, it cannot eliminate them entirely. City governments play a pivotal role in ensuring that new buildings are both efficient and adapted to climate change.

Buildings are susceptible to climate change impacts. Increased risks such as structural degradation, material failure, and property value loss due to extreme weather events demand that new and existing buildings be assessed for resilience to both current and future climate threats. Besides structural impacts, climate change can affect indoor living and working conditions, necessitating effective heating and cooling systems to combat thermal discomfort from temperature extremes.

The table below, from the EU Taxonomy legislation, categorizes climate-related hazards into temperature, wind, water, and solid mass-related threats, classified as either chronic or acute. It highlights six priority hazards for buildings, denoted in blue, which significantly impact structures and their occupants across the EU.

Table 1: EU Taxonomy – Classification of Climate-Related Hazards [168]

	Temperature Related	Wind Related	Water Related	Solid Mass Related
Chronic	• Changing temperature (air, freshwater, marine water) • Heat stress • Temperature variability • Permafrost thawing	• Changing wind patterns	• Changing precipitation patterns and types (rain, hail, snow/ice). • Precipitation and or hydrological variability. • Ocean acidification. • Saline intrusion. • Sea-level rise. • Water stress.	• Costal erosion. • Soil degradation. • Soil erosion. • Solifluction.
Acute	• Heatwave • Cold wave, frost • Wildfire	• Cyclone, hurricane, typhoon • Storm (blizzards, dust, sandstorms) • Tornado	• Drought • Heavy precipitation (rain, hail, snow, ice) • Flood (coastal, fluvial, pluvial, groundwater) • Glacial lake outburst	• Avalanche • Landslide • subsidence

Key Components of Resilient Building Codes: Resilient building codes integrate measures to bolster a building's ability to endure extreme weather. Key elements include:

- **Flood-Resistant Design:** Elevating foundations, using flood-resistant materials, and incorporating proper drainage can mitigate flood damage.
- **Wind-Resistant Construction:** Codes can require impact-resistant windows, reinforced roofs, and sturdy structural systems to counteract high winds from hurricanes and tornadoes.
- **Fire-Resistant Materials:** In wildfire-prone areas, using non-combustible siding and roofing, alongside effective vegetation management, can reduce fire risks.

- **Energy-Efficient Measures:** Resilient codes often include energy-efficient design strategies to lessen dependency on central utilities during extreme weather, ensuring essential services remain operational.

Constructing low and zero-carbon developments with climate-adapted designs and sustainable material choices offers cities a significant opportunity to reduce emissions and enhance resilience.[169] It is crucial to monitor and evaluate these adaptation measures during maintenance to ensure buildings remain resilient to extreme weather events and to consider retrofitting when necessary. The following table summarizes various climate change adaptation measures and plans for integrating building efficiency strategies across different hazards [169]:

Table 105. Climate Change Adaptation Measures for Building Efficiency

Hazard	Adaptation Measure Category	Plan
Storm and Wind	Integrated Energy Efficiency	- Reduce reliance on heating, cooling, and electrical services prone to failure during extreme events. - Use passive design for comfort and resilience during power outages. - Integrate energy storage and microgrids for community resilience. - Use robust, resistant materials in standards.
	Building Design Strategies	- Develop design strategies for heating, cooling, and ventilation to mitigate damage from precipitation.
	Strategic Planning for New Development	- Include future climate projections and extreme weather events in planning guidance for new developments.
Floods	Building Location	- Use risk assessments to avoid flood-prone areas and natural drains for new developments. - Incorporate stormwater management systems (e.g., infiltration trenches, retention ponds, flood-proof materials).
	Building Design Strategies	- Implement energy efficiency to reduce demand on vulnerable services. - Create guidelines to design heating, cooling, and ventilation to minimize flood impact. - Use permeable materials, green spaces, and elevated structures. - Require raised floors and ban basements in flood zones.
	Energy Storage	- Strategically place building-scale energy storage to reduce flood damage risk.
Drought	Water Efficiency Strategy	- Develop sustainability standards for energy and water efficiency. - Use technologies like green roofs and wastewater heat recovery systems. - Install water-efficient fittings.

		- Implement stormwater/rainwater harvesting and grey water reuse systems.
Extreme Heat	Building Codes and Standards	- Use green roofs for insulation and cooling through evapotranspiration. - Increase vegetation to cool and shade external surfaces. - Apply cool or white roofs to reduce heat absorption. - Set standards for glazing ratios, performance, and shading to control solar gain. - Integrate passive design features for comfortable indoor temperatures. - Enhance thermal storage with suitable building materials.
	Urban Planning	- Apply urban design principles to reduce heat, such as considering sky view factors, using shade from buildings and trees, and designing street grids to facilitate wind ventilation.

By adopting these strategies, cities can build more resilient, sustainable, and energy-efficient structures that are better prepared to withstand the challenges posed by climate change.

6.4.2 Resilience Against Climate Change in Spain

Spain's Strategic Framework on Energy and Climate is designed to bolster the energy sector's resilience and adaptability in response to climate change through a series of comprehensive national plans. At the heart of this framework is the National Climate Change Adaptation Plan 2021-2030, which integrates considerations of climate impacts into energy planning.[170] This plan aims to protect electricity generation and infrastructure and manage changes in energy demand resulting from climate effects. Building on the previous plan from 2006-2020, which laid the foundation for addressing climate impacts across various energy sources and was closely monitored through detailed reports, the current adaptation plan focuses on enhancing resilience.

Meanwhile, the National Energy and Climate Plan (NECP) 2021-2030 introduces measures that link energy adaptation to other sectors such as water and transport and emphasizes the synergy between reducing energy demand and adapting to climate.[171] Looking further ahead, the Long-Term Strategy for 2050 envisions a climate-neutral economy by integrating climate impact projections into renewable energy planning and developing tools for risk assessment and infrastructure adaptation.

Additionally, Spain's Just Transition Strategy for the closure of thermal power plants and the Climate Change and Energy Transition Law highlight adaptation as a central objective, embedding it into national policy for the first time.

6.4.3 Resilience Against Climate Change in Bulgaria

The Bulgarian National Recovery and Resilience Plan is structured around four strategic pillars: Innovation, Climate Transition and Nature Protection, Connectivity, and Social Fairness. Each pillar is essential in steering Bulgaria towards sustainable and inclusive growth.[172]

Innovative Bulgaria focuses on boosting economic competitiveness and transforming the economy into one driven by knowledge and smart growth, with 25.3% of the plan's resources dedicated to this aim. **Green Bulgaria** allocates 41.9% of resources to sustainable management of natural resources, ensuring that current economic and societal needs are met while maintaining long-term environmental stability. **Connected Bulgaria** aims to enhance regional competitiveness and sustainable development by improving transport and digital infrastructure and fostering local development based on specific regional potentials. Lastly, **Fair Bulgaria** prioritizes inclusive growth and shared prosperity, particularly for disadvantaged groups, while promoting effective and responsible public institutions that cater to the needs of businesses and citizens, with 14.6% of resources allocated to these goals.[172]

In addition to these pillars, the plan earmarks significant funds for building renovations and energy projects. A total of BGN 2,475.4 million is planned for residential and non-residential buildings, including BGN 1,807.2 million under the Reconstruction Mechanism. Of this, BGN 1,496.4 million will finance energy efficiency and renewable energy projects in residential buildings, covering both multi-family and single-family homes. Funding includes BGN 1,189.5 million from the Recovery and Resilience Facility (RRF) and BGN 306.9 million from national co-financing, with contributions from owners' associations (BGN 70.6 million) and the state budget (BGN 236.3 million).[172]

This measure focuses on renewable energy solutions like solar panels and solar thermal systems that are not connected to heat and gas networks, as well as energy efficiency improvements such as heat pumps. It will fully cover the expenses for owners' associations that apply in the first year and provide an 80% contribution for applications from April 2023 until the end of the year. Additional funding sources will also be available to supplement these efforts.

Energy savings are a critical component, with a mandatory requirement of achieving at least 30% primary energy savings for each site after implementing the measures. This will be verified through an energy efficiency audit. The plan aims to upgrade multi-dwelling residential buildings with energy consumption classes E, F, and G to at least class B, and similarly improve single-dwelling residential buildings to meet this minimum energy consumption class.

6.4.4 Resilience Against Climate Change in Italy

Italy's revised National Recovery and Resilience Plan (NRRP) includes comprehensive reforms and investments aimed at accelerating its green and digital transitions, in line with the REPowerEU objectives.[173] The plan now features five new reforms, five enhanced investments, and twelve initiatives to reduce fossil fuel dependence. Italy will leverage EUR 2.75 billion in REPowerEU grants and reallocate EUR 8.4 billion from its current plan, bringing total REPowerEU funding to EUR 11.178 billion. Key measures under REPowerEU focus on streamlining permitting for renewable energy, reducing harmful subsidies, promoting biomethane production, and enhancing green workforce skills. These reforms are supported by investments to improve electricity grid efficiency and reliability, increase hydrogen production, address energy poverty, recycle critical raw materials, and expand zero-emission transport fleets. Additionally, the plan dedicates EUR 2,475.4 million to energy efficiency and renewable energy projects for residential buildings, further complemented by the Superbonus initiative offering tax deductions for energy and seismic renovations. On the green front, Italy will invest EUR 16.9 billion in building energy efficiency, EUR 34.5 billion in sustainable mobility, and EUR 24.7 billion in renewable energy and circular economy projects. Accompanying these are reforms to enhance water resource management, increase recycling rates, deploy EV charging points, foster market competition, improve port operations, and expedite energy and transport projects. Consequently, the updated plan dedicates 39% of its funds to climate goals, up from 37.5% previously. Meanwhile, Italy addresses its digital challenges by allocating EUR 5.3 billion to expand high-capacity networks, EUR 13.4 billion to digitalize businesses, and EUR 6.1 billion to modernize public administration. These digital investments are bolstered by reforms to streamline ICT procurement, support digital transformation across administrations, and remove obstacles to cloud adoption, boosting the plan's focus on digital transition to 25.6% of the funds, up from 25.1%. Through these integrated efforts, Italy aims to expand its renewable energy capacity, accelerate decarbonization, improve resource management, and enhance digital capabilities, driving a sustainable and inclusive recovery.

6.4.5 Resilience Against Climate Change in France

France's updated plan to reduce its reliance on fossil fuels and advance its green and digital transitions is both ambitious and multifaceted.[174] To align with the EU's REPowerEU and Fit for 55 objectives, France will implement key reforms and investments. These include accelerating the deployment of renewable energy through streamlined permitting procedures, launching an energy efficiency plan to cut consumption, and creating a General Secretariat for Ecological Planning to better coordinate ecological policies. Financially, France is seeking an additional €504 million from its Brexit Adjustment Reserve, supplementing the €2.3 billion REPowerEU grant. Major investments focus on enhancing energy efficiency in buildings, supporting hydrogen projects, and decarbonizing the industrial sector. The plan allocates a substantial €7.7 billion for building renovations and €4.4

billion for modernizing the railway network, among other green initiatives. A critical legislative piece, the Climate and Resilience Law, aims to reduce greenhouse gas emissions by 40%, touching on consumption, production, transport, and living standards. With 49.5% of the plan’s funds now dedicated to climate objectives, up from 46%, France is intensifying its commitment to ecological transition. On the digital front, France plans to address its lag in broadband connectivity and digital adoption by SMEs, with €8.7 billion devoted to digital advancements. This includes €1.8 billion for developing technologies like cybersecurity and quantum computing, €385 million to aid businesses in digital adoption, and €131 million to enhance digitalization in schools. Furthermore, €240 million will be invested in expanding high-speed broadband to achieve full fibre-to-home coverage by 2025. With 21.6% of funds now earmarked for digital objectives, an increase from 21%, France is bolstering its digital transition. This comprehensive approach underscores France's commitment to balancing immediate fossil fuel reduction with long-term sustainability and innovation, even extending to the thermal renovation of historical buildings like the Pavillon Gréard in Paris, built in 1925.

6.4.6 Resilience Plan in RE-SKIN Project

The authors outline a structured six-stage resilience strategy to adapt building infrastructure to climate change risks and that can be used in RE-SKIN project case studies (Figure 31). This approach begins with assessing climate impacts and defining adaptation objectives, followed by evaluating current vulnerabilities and resilience levels. It then identifies and prioritizes adaptive actions, considering local capacities and decision-making contexts. The plan includes developing KPIs to measure the success of resilience efforts. Implementation involves integrating these adaptive measures into building design, planning, and operations. Finally, the strategy emphasizes continuous monitoring and evaluation to ensure effective adaptation and improvement over time. By following this comprehensive framework, the strategy aims to enhance the robustness and adaptability of buildings against climate-related disruptions.

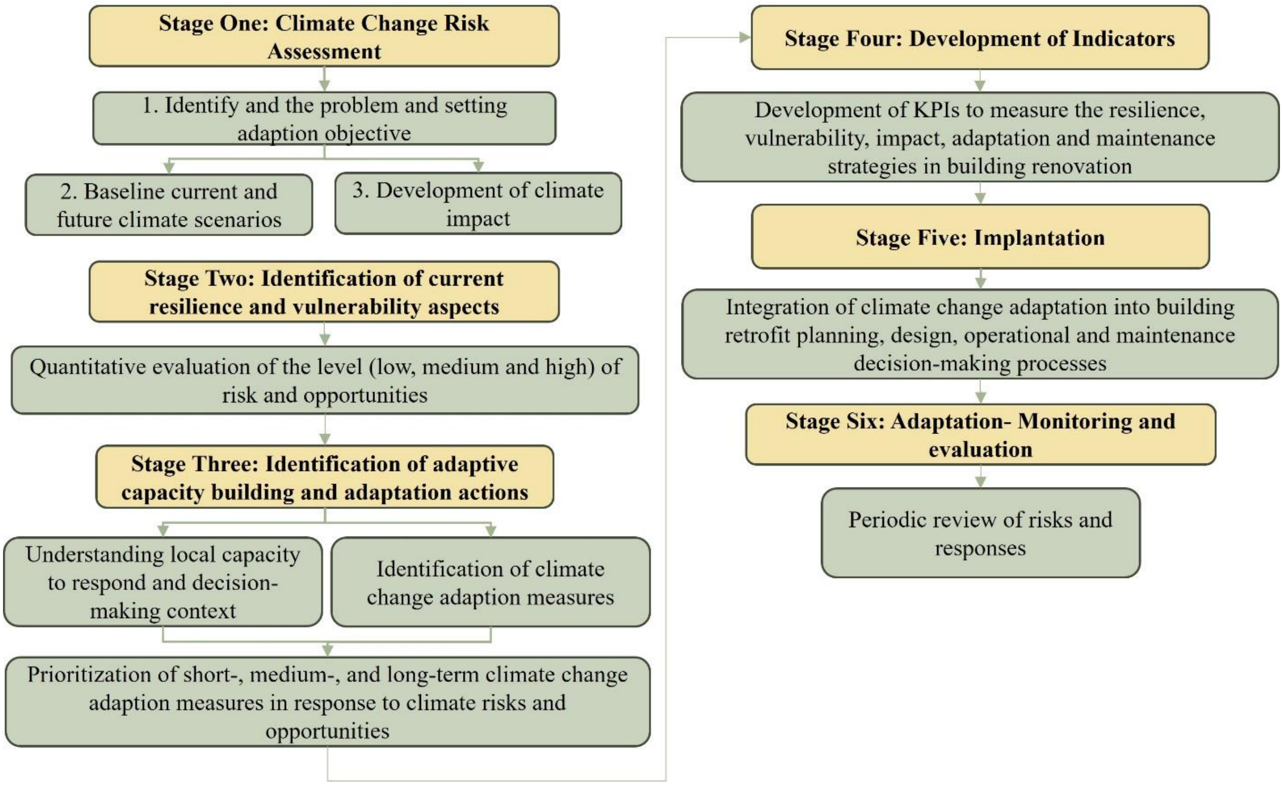

Figure 31. Resilience Strategy in Renovated Buildings

References

(1) *Compte satellite du logement (CSL) - data.gouv.fr*. https://www.data.gouv.fr/fr/datasets/compte-satellite-du-logement/ (accessed 2024-07-09).
(2) Eurostat. Share of Fuels in Final Energy Consumption, 2022. https://doi.org/10.2908/NRG_IND_FECF.
(3) *EU Building Stock Observatory - Database*. https://building-stock-observatory.energy.ec.europa.eu/database/ (accessed 2024-07-04).
(4) *Estimation annuelle du parc de logements - Nombre total de logements - France métropolitaine | Insee*. https://www.insee.fr/en/statistiques/serie/001687211#Tableau (accessed 2024-07-04).
(5) Eurostat. Distribution of Population by Degree of Urbanisation, Dwelling Type and Income Group, 2023. https://doi.org/10.2908/ILC_LVHO01.
(6) *Average household size | Eurostat*. https://ec.europa.eu/eurostat/databrowser/view/ilc_lvph01/default/table?lang=en (accessed 2024-07-04).
(7) *Banque centrale européenne*. https://sdw.ecb.europa.eu/myracloud-blocked/?r=MmJmYjVmNmNjZDdlY2RhMmZiNjI2MzdlZDcxNDdlMGIzNWQ1ZTFjMjViMjA1YWM4&t=ZDk5NjUwYTAwNjU0ZWIwZDE3L0p1bC8yMDI0OjE2OjI4OjAxICswMjAw&w=NzVkNWQxYmMyZjViNGFmYWU3NTQ2NGQ4ZGM2NzQ1NzA4ZDBmYzlhMzc2MTc1MjMw (accessed 2024-07-17).
(8) *France - Population urbaine (% de la population totale) | Statistiques*. https://perspective.usherbrooke.ca/bilan/servlet/BMTendanceStatPays?codeTheme=1&codeStat=SP.URB.TOTL.IN.ZS&codePays=FRA&optionsPeriodes=Aucune&codeTheme2=1&codeStat2=SP.URB.TOTL.IN.ZS&codePays2=BGR&optionsDetPeriodes=avecNomP (accessed 2024-07-04).
(9) *Statistics | Eurostat*. https://ec.europa.eu/eurostat/databrowser/view/nrg_d_hhq/default/table?lang=en (accessed 2024-07-04).
(10) Eurostat. Inability to Keep Home Adequately Warm, 2022. https://doi.org/10.2908/ILC_MDES01.
(11) *Final energy consumption by sector | Eurostat*. https://ec.europa.eu/eurostat/databrowser/view/ten00124__custom_11628422/default/table?lang=en (accessed 2024-07-04).
(12) *Disaggregated final energy consumption in households - quantities | Eurostat*. https://ec.europa.eu/eurostat/databrowser/view/nrg_d_hhq/default/table?lang=en (accessed 2024-07-04).
(13) *Efficacité énergétique en France et politiques d'évolution | Profil de la France | ODYSSEE-MURE*. https://www.odyssee-mure.eu/publications/efficiency-trends-policies-profiles/france.html#overview (accessed 2024-07-04).
(14) *Statistiques | Eurostat*. https://ec.europa.eu/eurostat/databrowser/view/nrg_chdd_a/default/table?lang=en&category=nrg.nrg_chdd (accessed 2024-07-04).

(15) *Greenhouse gas emissions from energy use in buildings in Europe*. https://www.eea.europa.eu/en/analysis/indicators/greenhouse-gas-emissions-from-energy (accessed 2024-07-04).

(16) *Energy consumption in France*. Worlddata.info. https://www.worlddata.info/europe/france/energy-consumption.php (accessed 2024-07-04).

(17) *La librairie ADEME*. https://librairie.ademe.fr/ (accessed 2024-07-04).

(18) 2.Annex_to_final_report_0.Pdf. https://energy.ec.europa.eu/system/files/2019-12/2.annex_to_final_report_0.pdf (accessed 2024-07-04).

(19) *Energy efficiency*. https://ec.europa.eu/eurostat/databrowser/view/nrg_ind_eff__custom_11632880/default/table (accessed 2024-07-04).

(20) *Le parc de logements par classe de performance énergétique au 1er janvier 2022*. Données et études statistiques pour le changement climatique, l'énergie, l'environnement, le logement, et les transports. https://www.statistiques.developpement-durable.gouv.fr/le-parc-de-logements-par-classe-de-performance-energetique-au-1er-janvier-2022-0 (accessed 2024-07-04).

(21) *Spain Dwelling Stocks | Moody's Analytics*. https://www.economy.com/spain/dwelling-stocks (accessed 2024-07-04).

(22) *Spain energy efficiency & Trends policies | Spain profile | ODYSSEE-MURE*. https://www.odyssee-mure.eu/publications/efficiency-trends-policies-profiles/spain.html#overview (accessed 2024-07-04).

(23) *Energy consumption in Spain*. Worlddata.info. https://www.worlddata.info/europe/spain/energy-consumption.php (accessed 2024-07-04).

(24) *Permanent census of population and housing*. https://esploradati.censimentopopolazione.istat.it/databrowser/#/en (accessed 2024-07-18).

(25) *SHI.A.IT.DWEL.A | ECB Data Portal*.
https://data.ecb.europa.eu/data/datasets/SHI/SHI.A.IT.DWEL.A?chart_props=W3sibm9kZUl
kIjoiMjA0NDYyMCIsInByb3BlcnRpZXMiOlt7ImNvbG9ySGV4IjoiIiwiY29sb3JUeXBlIjoiIiwiY2hhc
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(26) *Italy energy efficiency & Trends policies | Italy profile | ODYSSEE-MURE*. https://www.odyssee-mure.eu/publications/efficiency-trends-policies-profiles/italy.html#overview (accessed 2024-07-04).
(27) *Climatic zones*. Celsius Panel. https://www.celsiuspanel.it/en/climatic-zones/ (accessed 2024-07-04).
(28) *Преброяване 2021 Начало - НСИ Преброяване 2021*. https://census2021.bg/ (accessed 2024-07-18).
(29) *Bulgaria Dwelling Stocks | Moody's Analytics*. https://www.economy.com/bulgaria/dwelling-stocks (accessed 2024-07-04).
(30) *Newly built dwellings completed | National statistical institute*. https://www.nsi.bg/en/content/3137/newly-built-dwellings-completed (accessed 2024-07-18).
(31) *Bulgaria energy efficiency & Trends policies | Bulgaria profile | ODYSSEE-MURE*. https://www.odyssee-mure.eu/publications/efficiency-trends-policies-profiles/bulgaria.html#overview (accessed 2024-07-04).
(32) Bg_ltrs_2020_en_version_0.Pdf. https://energy.ec.europa.eu/system/files/2021-08/bg_ltrs_2020_en_version_0.pdf (accessed 2024-07-18).
(33) Directive (EU) 2024/1275 of the European Parliament and of the Council of 24 April 2024 on the Energy Performance of Buildings (Recast) (Text with EEA Relevance).
(34) *Renovation of near 20% of existing building stock to zero-carbon-ready by 2030 is ambitious but necessary – Analysis*. IEA. https://www.iea.org/reports/renovation-of-near-20-of-existing-building-stock-to-zero-carbon-ready-by-2030-is-ambitious-but-necessary (accessed 2024-06-10).
(35) Jelle, B. P.; Kalnæs, S. E. Chapter 3 - Phase Change Materials for Application in Energy-Efficient Buildings. In *Cost-Effective Energy Efficient Building Retrofitting*; Pacheco-Torgal, F., Granqvist, C.-G., Jelle, B. P., Vanoli, G. P., Bianco, N., Kurnitski, J., Eds.; Woodhead Publishing, 2017; pp 57–118. https://doi.org/10.1016/B978-0-08-101128-7.00003-4.
(36) Shaikh, P. H.; Shaikh, F.; Sahito, A. A.; Uqaili, M. A.; Umrani, Z. Chapter 9 - An Overview of the Challenges for Cost-Effective and Energy-Efficient Retrofits of the Existing Building Stock. In *Cost-Effective Energy Efficient Building Retrofitting*; Pacheco-Torgal, F., Granqvist, C.-G., Jelle, B. P., Vanoli, G. P., Bianco, N., Kurnitski, J., Eds.; Woodhead Publishing, 2017; pp 257–278. https://doi.org/10.1016/B978-0-08-101128-7.00009-5.
(37) *REZBUILD Educational and training materials – nZEB Ready Platform*. https://platform.nzebready.eu/initiative-output/rezbuild-educational-and-training-materials/ (accessed 2024-07-30).
(38) *REZBUILD project: an innovative refurbishment ecosystem for Near Zero Energy Building in Europe*. https://cordis.europa.eu/article/id/122868-rezbuild-project-an-innovative-refurbishment-ecosystem-for-near-zero-energy-building-in-europ (accessed 2024-07-30).
(39) *Holistic Energy and Architectural Retrofit Toolkit | HEART | Project | Fact sheet | H2020 | CORDIS | European Commission*. https://cordis.europa.eu/project/id/768921/fr (accessed 2024-07-30).

(40) *Triple SEC (Ireland) - European Commission*. https://citizen-led-renovation.ec.europa.eu/pilots/triple-sec-ireland_en (accessed 2024-07-30).
(41) *Schools Energy Retrofit Pathfinder Programme – Policies*. IEA. https://www.iea.org/policies/13487-schools-energy-retrofit-pathfinder-programme (accessed 2024-07-30).
(42) *Energy efficiency - targets, directive and rules*. https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficiency-targets-directive-and-rules_en (accessed 2024-06-19).
(43) *Fit for 55 - The EU's plan for a green transition*. https://www.consilium.europa.eu/en/policies/green-deal/fit-for-55/ (accessed 2024-06-19).
(44) *Energy Efficiency Directive*. https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficiency-targets-directive-and-rules/energy-efficiency-directive_en (accessed 2024-06-19).
(45) *Renewable Energy Directive*. https://energy.ec.europa.eu/topics/renewable-energy/renewable-energy-directive-targets-and-rules/renewable-energy-directive_en (accessed 2024-06-19).
(46) *Ecodesign for Sustainable Products Regulation - European Commission*. https://commission.europa.eu/energy-climate-change-environment/standards-tools-and-labels/products-labelling-rules-and-requirements/sustainable-products/ecodesign-sustainable-products-regulation_en (accessed 2024-06-19).
(47) *EU-Rules - Fluorinated Greenhouse Gases – Climate Action*. https://climate.ec.europa.eu/eu-action/fluorinated-greenhouse-gases/eu-rules_en (accessed 2024-06-19).
(48) *Construction Products Regulation approval in April*. Eurovent. https://www.eurovent.eu/policyupdates/construction-products-regulation-approval-in-april/ (accessed 2024-06-20).
(49) Lissoni, D. *Parliament votes to strengthen air quality laws*. https://eeb.org/parliament-votes-strengthen-air-quality-laws/ (accessed 2024-06-20).
(50) Lissoni, D. *Council's COREPER Approves Future Ambient Air Quality Law*. https://eeb.org/councils-coreper-approves-future-ambient-air-quality-law/ (accessed 2024-06-20).
(51) *Revision of the Ambient Air Quality Directives - European Commission*. https://environment.ec.europa.eu/topics/air/air-quality/revision-ambient-air-quality-directives_en (accessed 2024-06-20).
(52) *Strategia Energetica Nazionale 2017 | Ministero dell'Ambiente e della Sicurezza Energetica*. https://www.mase.gov.it/comunicati/strategia-energetica-nazionale-2017 (accessed 2024-06-20).
(53) *(PDF) Italian local codes for energy efficiency of buildings: Theoretical definition and experimental application to a residential case study*. https://www.researchgate.net/publication/270565566_Italian_local_codes_for_energy_efficiency_of_buildings_Theoretical_definition_and_experimental_application_to_a_residential_case_study (accessed 2024-06-20).
(54) *Regolamento Edilizio del Comune di Milano*. Comune di Milano. https://www.comune.milano.it/aree-tematiche/edilizia/sportello-unico-edilizia/regolamento-edilizio (accessed 2024-06-20).
(55) *Réglementation thermique RT2012 | Ministère de la Transition écologique et de la Cohésion des territoires*. https://www.ecologie.gouv.fr/politiques-publiques/reglementation-thermique-rt2012 (accessed 2024-06-20).

(56) *Réglementation environnementale RE2020 | Ministère de la Transition écologique et de la Cohésion des territoires*. https://www.ecologie.gouv.fr/politiques-publiques/reglementation-environnementale-re2020 (accessed 2024-06-20).

(57) Energy Transition for Green Growth Act in Action - Regions, Citizens, Business (32 Pages - Juillet 2016 - Versions Anglaise).Pdf. https://www.ecologie.gouv.fr/sites/default/files/documents/Energy%20Transition%20for%20Green%20Growth%20Act%20in%20action%20-%20Regions,%20citizens,%20business%20(%2032%20pages%20-%20juillet%202016%20-%20Versions%20anglaise).pdf (accessed 2024-06-20).

(58) *Understanding Energy Performance Certificates in France | BUILD UP*. https://build-up.ec.europa.eu/en/news-and-events/news/understanding-energy-performance-certificates-france (accessed 2024-06-20).

(59) *Building Renovation Passports: consumer's journey to a better home | BUILD UP*. https://build-up.ec.europa.eu/en/resources-and-tools/publications/building-renovation-passports-consumers-journey-better-home (accessed 2024-06-20).

(60) *RGE : Reconnu Garant de l'Environnement*. https://www.ecologie.gouv.fr/politiques-publiques/label-reconnu-garant-lenvironnement-rge (accessed 2024-06-20).

(61) *Le plan climat-air-énergie territorial (PCAET)*. https://outil2amenagement.cerema.fr/outils/plan-climat-air-energie-territorial-pcaet (accessed 2024-06-20).

(62) *Zones à faibles émissions (ZFE)*. https://www.ecologie.gouv.fr/politiques-publiques/zones-faibles-emissions-zfe (accessed 2024-06-20).

(63) *Technical Building Code – Policies - IEA*. https://www.iea.org/policies/1986-technical-building-code (accessed 2024-06-21).

(64) *Spanish & EU energy building renovation | Policy brief | ODYSSEE-MURE*. https://www.odyssee-mure.eu/publications/policy-brief/spanish-building-retrofitting-energy-efficiency.html (accessed 2024-06-21).

(65) *EU Tracker – Local heating and cooling plans in Spain*. Energy Cities. https://energy-cities.eu/countries/spain/ (accessed 2024-06-21).

(66) *Municipalities tackle Energy Poverty - mPOWER*. https://municipalpower.org/best-practice-guides/guide4/ (accessed 2024-06-21).

(67) Long-Term National Strategy to Support the Renovation of the National Building Stock of Residential and Non-Residential Buildings by 2050. https://energy.ec.europa.eu/system/files/2021-08/bg_ltrs_2020_en_version_0.pdf (accessed 2024-06-21).

(68) *Energy Efficiency Act*. https://www.me.government.bg/en/library/energy-efficiency-act-537-c25-m258-2.html (accessed 2024-06-21).

(69) *Bulgaria - Energy*. https://www.trade.gov/country-commercial-guides/bulgaria-energy (accessed 2024-06-21).

(70) *Bulgaria's recovery and resilience plan - European Commission*. https://commission.europa.eu/business-economy-euro/economic-recovery/recovery-and-resilience-facility/country-pages/bulgarias-recovery-and-resilience-plan_en (accessed 2024-06-21).

(71) *Delivering the European Green Deal - European Commission*. https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/delivering-european-green-deal_en (accessed 2024-06-22).
(72) *EU Funding & Tenders Portal*. https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/home (accessed 2024-06-22).
(73) *Incentives for Green Retrofit | Italy | Global Sustainable Buildings Guide | Baker McKenzie Resource Hub*. https://resourcehub.bakermckenzie.com/en/resources/global-sustainable-buildings/europe-middle-east-and-africa/italy/topics/incentives-for-green-retrofit (accessed 2024-06-22).
(74) Adigrat. *Insights: Italy's home bonuses 2024: everything you need to know*. Adigrat Real Estate. https://www.adigrat.it/en/italys-home-bonuses-2024-everything-you-need-to-know/ (accessed 2024-06-22).
(75) *Bonus colonnine per imprese e professionisti | Ministero dell'Ambiente e della Sicurezza Energetica*. https://www.mase.gov.it/node/17179 (accessed 2024-06-27).
(76) *Cittadini - Ristrutturazioni edilizie - Agenzia delle Entrate*. https://www.agenziaentrate.gov.it/portale/web/guest/schede/agevolazioni/detrristredil36-cittadini (accessed 2024-06-22).
(77) *MaPrimeRénov' : la prime pour la rénovation énergétique*. https://www.economie.gouv.fr/particuliers/prime-renovation-energetique (accessed 2024-06-22).
(78) *Éco-prêt à taux zéro (éco-PTZ)*. https://www.service-public.fr/particuliers/vosdroits/F19905 (accessed 2024-06-22).
(79) *Certificats d'économie d'énergie (CEE) "Standard."* https://www.service-public.fr/particuliers/vosdroits/F35584 (accessed 2024-06-22).
(80) *Bonus "sortie de passoire" : aide indispensable à la rénovation*. https://www.effy.fr/travaux-energetique/bonus-de-sortie-de-passoire-thermique (accessed 2024-06-22).
(81) *Le crédit d'impôt pour la transition énergétique (CITE) est-il encore accordé ?* https://www.service-public.fr/particuliers/vosdroits/F1224 (accessed 2024-06-22).
(82) *L'aide du Fonds Air Bois*. Agir pour la transition écologique | ADEME. https://agirpourlatransition.ademe.fr/particuliers/finances/aides-a-renovation/aide-fonds-air-bois (accessed 2024-06-22).
(83) *Chèque énergie (gaz, chaleur, électricité)*. https://www.service-public.fr/particuliers/vosdroits/F33667 (accessed 2024-06-22).
(84) *Prime "Coup de pouce chauffage."* https://www.service-public.fr/particuliers/vosdroits/F34421 (accessed 2024-06-22).
(85) Cohn, V. V. IDAE'S GRANT PROGRAMMES Best Practices & Lessons Learned.
(86) *PREE 5000 Program. Energy rehabilitation of buildings in municipalities facing demographic challenges | Idae*. https://www.idae.es/en/support-and-funding/renovation-buildings/programa-pree-5000-rehabilitacion-energetica-de-edificios (accessed 2024-06-26).
(87) *Incentives for Green Retrofit | Spain | Global Sustainable Buildings Guide | Baker McKenzie Resource Hub*. https://resourcehub.bakermckenzie.com/en/resources/global-sustainable-buildings/europe-middle-east-and-africa/spain/topics/incentives-for-green-retrofit (accessed 2024-06-26).

(88) *National Energy Efficiency Fund | Idae*. https://www.idae.es/en/support-and-funding/national-energy-efficiency-fund (accessed 2024-06-26).
(89) *Programa GIT | Idae*. https://www.idae.es/ayudas-y-financiacion/para-instalaciones-de-energias-renovables/programa-git (accessed 2024-06-26).
(90) *BOE-A-2011-7441 Resolución de 7 de abril de 2011, de la Secretaría de Estado de Energía, por la que se publica la Resolución del Instituto para la Diversificación y Ahorro de la Energía, por la que se establece la convocatoria y bases correspondientes para la habilitación de empresas colaboradoras en el Programa GIT con empresas del sector de las energías renovables para la ejecución de Grandes Instalaciones Térmicas en la edificación.* https://www.boe.es/diario_boe/txt.php?id=BOE-A-2011-7441 (accessed 2024-06-26).
(91) *Third Party Financing (FPT) | Idae*. https://www.idae.es/ayudas-y-financiacion/financiacion-del-idae/financiacion-por-terceros-fpt (accessed 2024-06-26).
(92) *Tax Agency: Summary table: Deductions for energy efficiency improvement works in homes*. https://sede.agenciatributaria.gob.es/Sede/en_gb/ayuda/manuales-videos-folletos/manuales-practicos/irpf-2023/c16-deducciones-generales-cuota/deducciones-obras-mejora-eficiencia-energetica-viviendas/cuadro-resumen-deducciones-obras-eficiencia-viviendas.html (accessed 2024-06-26).
(93) *Where in Europe offers the biggest grants for heat pumps?*. euronews. https://www.euronews.com/green/2024/01/21/heat-pumps-government-subsidies-in-europe-are-making-green-tech-more-affordable (accessed 2024-06-26).
(94) *Residential heat pump subsidies across Europe*. pv magazine International. https://www.pv-magazine.com/2023/03/22/residential-heat-pump-subsidies-across-europe/ (accessed 2024-06-26).
(95) *Aid program for actions to improve energy efficiency in homes | Ministry of Transport and Sustainable Mobility*. https://www.transportes.gob.es/ministerio/proyectos-singulares/prtr/vivienda-y-agenda-urbana/programa-de-ayuda-las-actuaciones-de-mejora-de-la-eficiencia-energetica-en-viviendas (accessed 2024-06-26).
(96) *EUMIS 2020*. https://eumis2020.government.bg/en/s/Procedure/Info/f4d6a4ca-0a30-4c90-bd51-991551164a73 (accessed 2024-06-27).
(97) *Inforegio - Operational programme “Regions in Growth.”* https://ec.europa.eu/regional_policy/in-your-country/programmes/2014-2020/bg/2014bg16rfop001_en (accessed 2024-06-26).
(98) Rdp-Factsheet-Bulgaria_en.Pdf. https://agriculture.ec.europa.eu/system/files/2023-02/rdp-factsheet-bulgaria_en.pdf (accessed 2024-06-27).
(99) *Bulgaria: EU Funds to Boost Energy Efficiency and Solar Thermal Energy | Solarthermalworld*. https://solarthermalworld.org/news/bulgaria-eu-funds-boost-energy-efficiency-and-solar-thermal-energy/ (accessed 2024-06-27).
(100) *За нас*. Фонд “Енергийна ефективност и възобновяеми източници.” https://www.bgeef.com/bg/about-us/ (accessed 2024-06-27).
(101) *CEF Energy | Innovation and Networks Executive Agency*. https://wayback.archive-it.org/12090/20221222153316/https://ec.europa.eu/inea/en/connecting-europe-facility/cef-energy (accessed 2024-06-27).
(102) *Home | Bridge*. https://bridge-smart-grid-storage-systems-digital-projects.ec.europa.eu/ (accessed 2024-06-27).

(103) *EU action plan on digitalising the energy system*. European Commission - European Commission. https://ec.europa.eu/commission/presscorner/detail/en/qanda_22_6229 (accessed 2024-06-27).

(104) *Trans-European Networks for Energy*. https://energy.ec.europa.eu/topics/infrastructure/trans-european-networks-energy_en (accessed 2024-06-27).

(105) *TEN-E (Trans-European Networks for Energy): CCUS – Policies*. IEA. https://www.iea.org/policies/12670-ten-e-trans-european-networks-for-energy-ccus (accessed 2024-06-27).

(106) *Register of Commission expert groups and other similar entities*. https://ec.europa.eu/transparency/expert-groups-register/screen/expert-groups/consult?lang=en&do=groupDetail.groupDetail&groupID=2892 (accessed 2024-06-27).

(107) *Projects of Common Interest and Projects of Mutual Interest*. https://energy.ec.europa.eu/topics/infrastructure/projects-common-interest-and-projects-mutual-interest_en (accessed 2024-06-27).

(108) *Clean Energy Technology Observatory (CETO) - European Commission*. https://setis.ec.europa.eu/publications/clean-energy-technology-observatory-ceto_en (accessed 2024-06-27).

(109) *The ETIP SNET R&I Implementation Plan 2025+ is now published! | ETIP SNET*. https://smart-networks-energy-transition.ec.europa.eu/news-and-articles/news/etip-snet-ri-implementation-plan-2025-now-published (accessed 2024-06-27).

(110) *About*. https://www.enel.com (accessed 2024-06-27).

(111) *Terna: 2024-2028 Industrial Plan approved - Terna spa*. https://www.terna.it/en/media/press-releases/detail/2024-2028-industrial-plan-results-31-december-2023 (accessed 2024-06-27).

(112) Pniec_finale_17012020.Pdf. https://www.mase.gov.it/sites/default/files/archivio/pniec_finale_17012020.pdf (accessed 2024-06-27).

(113) Coppo, M.; Pelacchi, P.; Pilo, F.; Pisano, G.; Soma, G. G.; Turri, R. The Italian Smart Grid Pilot Projects: Selection and Assessment of the Test Beds for the Regulation of Smart Electricity Distribution. *Electr. Power Syst. Res.* **2015**, *120*, 136–149. https://doi.org/10.1016/j.epsr.2014.06.018.

(114) International, S. E. *A guide to France's Linky smart meter*. Smart Energy International. https://www.smart-energy.com/features-analysis/smart-meters-101-frances-linky-electricity-meters/ (accessed 2024-06-27).

(115) *FLEXGRID – A novel smart grid architecture ... | Open Research Europe*. https://open-research-europe.ec.europa.eu/articles/1-128 (accessed 2024-06-27).

(116) *Nice Grid*. Smart Grids - Le site édité par la CRE. https://www.smartgrids-cre.fr/projets/nice-grid (accessed 2024-06-27).

(117) *Millener*. Smart Grids - Le site édité par la CRE. https://www.smartgrids-cre.fr/projets/millener (accessed 2024-06-27).

(118) *ODRI*. Smart Grids - Le site édité par la CRE. https://www.smartgrids-cre.fr/projets/odri (accessed 2024-06-27).

(119) *4 new projects winners of the ADEME's "smart electrical systems" call for projects*. Think Smartgrids. https://www.thinksmartgrids.fr/en/actualites/4-new-projects-winners-of-the-ademes-smart-electrical-systems-call-for-projects (accessed 2024-06-27).
(120) *Interflex - Home*. https://interflex-h2020.com/ (accessed 2024-06-27).
(121) *Greenlys*. Smart Grids - Le site édité par la CRE. https://www.smartgrids-cre.fr/projets/greenlys (accessed 2024-06-27).
(122) *SMILE project (Smart Ideas to Link Energies) | Interreg Europe - Sharing solutions for better policy*. https://www.interregeurope.eu/good-practices/smile-project-smart-ideas-to-link-energies (accessed 2024-06-27).
(123) *L'essentiel sur SMILE | Smile*. https://smile-smartgrids.fr/fr/qui-sommes-nous/lessentiel-sur-smile.html (accessed 2024-06-27).
(124) *Spain: EIB and Iberdrola agree a €700 million green loan for power grid expansion*. https://www.eib.org/en/press/all/2024-112-eib-and-iberdrola-agree-a-eur700-million-green-loan-for-power-grid-expansion-in-spain (accessed 2024-06-27).
(125) *Home | Red Eléctrica*. https://www.ree.es/en (accessed 2024-06-27).
(126) *Spain 2021 – Analysis*. IEA. https://www.iea.org/reports/spain-2021 (accessed 2024-06-27).
(127) Eléctrica, R. *The Electricity Transmission Grid Planning with a 2026 horizon has been approved to drive a greener future for Spain*. Red Eléctrica. https://www.ree.es/en/press-office/news/press-release/2022/04/the-electricity-transmission-grid-planning-2026-horizon-has-been-approved-to-drive-a-greener-future-for-spain (accessed 2024-06-27).
(128) CORPORATE, I. *Iberdrola Strategic Plan 2024-2026*. Iberdrola. https://www.iberdrola.com/about-us/iberdrola-strategic-plan (accessed 2024-06-27).
(129) Ferrer, J.-R. Barcelona's Smart City Vision: An Opportunity for Transformation. *Field Actions Sci. Rep. J. Field Actions* **2017**, No. Special Issue 16, 70–75.
(130) *Smart Grid Incentive Programme within the Andalusian Sustainable Energy A+ Programme | Interreg Europe - Sharing solutions for better policy*. https://www.interregeurope.eu/good-practices/smart-grid-incentive-programme-within-the-andalusian-sustainable-energy-a-programme (accessed 2024-06-27).
(131) *Endesa secures further €250m for smart grid in Spain - Industrial News*. https://industrialnews.co.uk/endesa-secures-further-e250m-for-smart-grid-in-spain/ (accessed 2024-06-27).
(132) *Grids for Europe's energy transition*. Ember. https://ember-climate.org/insights/research/putting-the-mission-in-transmission-grids-for-europes-energy-transition/ (accessed 2024-06-27).
(133) *Bulgaria: Pioneering grassroots energy project bears fruit – DW – 01/29/2024*. dw.com. https://www.dw.com/en/bulgarias-first-ever-democratic-citizen-energy-community-is-learning-by-doing/a-68067637 (accessed 2024-06-27).
(134) *Izgrei (Bulgaria) - European Commission*. https://citizen-led-renovation.ec.europa.eu/pilots/izgrei-bulgaria_en (accessed 2024-06-27).
(135) *About us*. ADD Bulgaria. https://add-bg.com/en/about-us/ (accessed 2024-06-27).
(136) *Stride – Improve Energy Security and Energy Efficiency*. https://energy-stride.com/ (accessed 2024-06-27).
(137) Li, H.; Johra, H.; de Andrade Pereira, F.; Hong, T.; Le Dréau, J.; Maturo, A.; Wei, M.; Liu, Y.; Saberi-Derakhtenjani, A.; Nagy, Z.; Marszal-Pomianowska, A.; Finn, D.; Miyata, S.; Kaspar, K.; Nweye, K.; O'Neill, Z.; Pallonetto, F.; Dong, B. Data-Driven Key Performance Indicators and

Datasets for Building Energy Flexibility: A Review and Perspectives. *Appl. Energy* **2023**, *343*, 121217. https://doi.org/10.1016/j.apenergy.2023.121217.
(138) Zenhäusern, D. *Key Performance Indicators for PVT Systems*; IEA SHC Task 60, 2020. https://doi.org/10.18777/ieashc-task60-2020-0007.
(139) *Documents download module*. https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5c0ff8a20&appId=PPGMS (accessed 2024-07-05).
(140) Emeric, B. Key Performance Indicators for the Monitoring of Large-Scale Battery Storage Systems.
(141) *Documents download module*. https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5c0ff8a20&appId=PPGMS (accessed 2024-07-05).
(142) TechBrief_HSP_Oct2021.Pdf. https://www.energycodes.gov/sites/default/files/2021-10/TechBrief_HSP_Oct2021.pdf (accessed 2024-07-05).
(143) Al Dakheel, J.; Del Pero, C.; Aste, N.; Leonforte, F. Smart Buildings Features and Key Performance Indicators: A Review. *Sustain. Cities Soc.* **2020**, *61*, 102328. https://doi.org/10.1016/j.scs.2020.102328.
(144) Li, H.; Hong, T.; Lee, S. H.; Sofos, M. System-Level Key Performance Indicators for Building Performance Evaluation. *Energy Build.* **2020**, *209*, 109703. https://doi.org/10.1016/j.enbuild.2019.109703.
(145) Hachem-Vermette, C.; Singh Grewal, K.; Desthieux, G.; Hasan, J.; Yadav, S.; Hachem-Vermette, C.; Singh Grewal, K.; Wall, M. *Strategies for the Design of New and Existing High Energy Performance Solar Neighborhoods*; IEA SHC Task 63, 2024. https://doi.org/10.18777/ieashc-task63-2024-0003.
(146) Gazzola, V.; Menoni, S.; Ghignatti, P.; Marini, A.; Mauri, R.; Oldani, G. Analysis of Territorial Risks and Protection Factors for the Business Continuity of Data Centers. *Sustainability* **2023**, *15* (7), 6005. https://doi.org/10.3390/su15076005.
(147) Engineers (AIChE), A. I. of C. *Dow's Fire and Explosion Index Hazard Classification Guide*; John Wiley & Sons, 2010.
(148) *Inventaire national des installations de risque d'accidents*. https://www.mase.gov.it/pagina/inventario-nazionale-degli-stabilimenti-rischio-di-incidente-rilevante-0 (accessed 2024-07-09).
(149) Legislative Decree of 17 August 1999, n. 334 "Implementation of Directive 96/82/EC on the Control of Major-Accident Hazards Involving Certain Dangerous Substances". https://www.agid.gov.it/sites/default/files/repository_files/approfondimentocircolare18062019_0.pdf (accessed 2024-07-09).
(150) *Territorial Office of the Government of Milan - External Emergency Plan of major accident sites.* Prefettura - Ufficio Territoriale del Governo di Milano. https://www.prefettura.it/milano/multidip/index.htm (accessed 2024-07-09).
(151) *Province of Milan - Program of Prevision and Prevention of Risk, 2013*. Programma di Prevenzione e Previsione. https://www.cittametropolitana.mi.it/protezione_civile/ORGANIZZAZIONE/Programma_di_Prevenzione_e_Previsione.html (accessed 2024-07-09).

(152) *Piano gestione rischio alluvioni EN – AUTORITÀ DI BACINO DISTRETTUALE DELL'APPENNINO SETTENTRIONALE*. https://www.appenninosettentrionale.it/itc/?page_id=8772 (accessed 2024-07-09).
(153) *ARPA Lombardia | Home Page*. https://www.arpalombardia.it (accessed 2024-07-09).
(154) *Italian National Legislation (UNI 10349:1994)*.
(155) *Integrated Regional Risk Mitigation Program of Lombardia Region (PRIM)*. https://www.protezionecivile.servizirl.it/ (accessed 2024-07-09).
(156) *GéoRisques portal*. Géorisques. https://www.georisques.gouv.fr/accueil-particulier (accessed 2024-07-09).
(157) *Décret N° 2010-1255 Du 22 Octobre 2010 Portant Délimitation Des Zones de Sismicité Du Territoire Français*; 2010.
(158) *Plateforme ouverte des données publiques françaises*. https://www.data.gouv.fr/fr/ (accessed 2024-07-09).
(159) *Programme d'Actions de Prévention des Inondations, PAPI*. Les services de l'État dans le Rhône. https://www.rhone.gouv.fr/Actions-de-l-Etat/Securite-et-protection-de-la-population/La-securite-civile/Les-risques-majeurs/Les-risques-majeurs-dans-le-Rhone/Les-Programmes-d-actions-de-prevention-des-inondations-PAPI/Presentation-du-dispositif (accessed 2024-07-09).
(160) *Géoportail*. https://www.geoportail.gouv.fr/ (accessed 2024-07-09).
(161) Burgas Municipality. *1-Burgas Risk Assesment*. https://www.iag.bg/ (accessed 2024-07-09).
(162) Burgas Municipality. *2-Burgas Risk Assesment*. https://mvr.bg/ (accessed 2024-07-09).
(163) Burgas Municipality. *3-Burgas Risk Assesment*. Община Бургас. https://www.burgas.bg// (accessed 2024-07-09).
(164) *Sistema de Información Territorial e Infraestructura de Datos Espaciales de Asturias (SITPA-IDEAS).* https://ideas.asturias.es/inicio (accessed 2024-07-09).
(165) *IGN : produire et diffuser les données géographiques et forestières en France - Portail IGN - IGN*. https://www.ign.fr/ (accessed 2024-07-09).
(166) *Plan Especial de Proteción Civil de Emergencias por Incendios Forestales del Principado de Asturias (2017).* https://www.112asturias.es/v_portal/apartados/apartado.asp?te=65 (accessed 2024-07-09).
(167) Washington : NIAC. NIAC. Critical Infrastructure Resilience Final Report and Recommendations., 2009.
(168) *EU taxonomy for sustainable activities - European Commission*. https://finance.ec.europa.eu/sustainable-finance/tools-and-standards/eu-taxonomy-sustainable-activities_en (accessed 2024-07-09).
(169) London : C40 Cities Climate Leadership Group. Knowledge, C40. Reducing Climate Change Impacts on New Buildings., 2019.
(170) *Spain's recovery and resilience plan - European Commission*. https://commission.europa.eu/business-economy-euro/economic-recovery/recovery-and-resilience-facility/country-pages/spains-recovery-and-resilience-plan_en (accessed 2024-07-10).
(171) *National energy and climate plans*. https://commission.europa.eu/energy-climate-change-environment/implementation-eu-countries/energy-and-climate-governance-and-reporting/national-energy-and-climate-plans_en (accessed 2024-07-10).
(172) Europe, Housing. Recovery and Resilience Plan. Bulgaria : Housing Europe., 2023.

(173) *Italy’s recovery and resilience plan - European Commission*. https://commission.europa.eu/business-economy-euro/economic-recovery/recovery-and-resilience-facility/country-pages/italys-recovery-and-resilience-plan_en (accessed 2024-07-10).
(174) *France’s recovery and resilience plan - European Commission*. https://commission.europa.eu/business-economy-euro/economic-recovery/recovery-and-resilience-facility/country-pages/frances-recovery-and-resilience-plan_en (accessed 2024-07-10).