Problem Setting on Energy Risk and Climate Change Adaptation: Topics and Tools

Roberto De Lotto[1](✉), Ilaria Delponte[2], Elisabetta Venco[1], Caterina Pietra[1], and Valentina Costa[2]

[1] Department of Civil Engineering and Architecture - DICAr, University of Pavia, 27100 Pavia, Italy
uplab@unipv.it

[2] Civil Chemical and Environmental Engineering Department, University of Genoa, 16145 Genoa, Italy

Abstract. Energy risk management and climate change adaptation strategies have long been targeted as individual and independent challenges, having emerged separately along the European Union (EU) and international agenda and policy history. Nevertheless, the most recent EU initiative in this field, the Global Covenant of Mayors (GCoM), faces mitigation and adaptation strategies simultaneously within the framework of the Sustainable Energy and Climate Action Plans (SECAP) design. A similar approach may lead to a re-definition of energy-related and climate change vulnerability and consequently to developing multi-risk territorial analysis. This would require building a complex and detailed knowledge of the territorial context, thus developing a strongly data-driven local risk and vulnerability assessment (RVA). Moreover, it must be remembered that SECAPs are drawn at the municipal scale, where geometry shows to be extremely various, and large metropolitan areas, as well as fragmented hamlets, coexist. This integrated approach may prove to be particularly critical for small municipalities. The present contribution aims at providing a methodology to plan mitigation and adaptation of local actions based on land use municipal assets and consequent multi-risk territorial mapping.

Keywords: Energy Risk · Multi-risk analysis · Sustainable Energy and Climate Action Plans

1 Introduction

Increasing territorial resilience within urban contexts represents one of the main challenges that cities are currently facing [1, 2]. Regarding urban risk assessment, energy- and climate-related components have been traditionally targeted individually and independently, having emerged at different times along EU and international agenda and policy history [3, 4].

Although both mitigation and adaptation actions have been considered complementary and necessary initiatives to reduce Climate Change impact on the environment [5]

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during the last decades, they have been pursued separately and at different paces [6]. Priority has been long identified with Greenhouse Gases (GHG) emissions reduction to limit and act on the magnitude of climate change drivers before focusing on adapting as well the human environment to reduce Climate Change impacts on everyday life [7].

This time shift represents only one of the several dissimilarities between mitigation and adaptation strategies: the spatial and temporal scale of impacts of the actions, benefits, cost assessment methodologies, stakeholders, and actors involved, above all [8].

Despite deep and substantial differences, both energy- and climate- related actions need to be implemented within the same territorial framework so that interactions are no longer deniable [9–12]. Urban areas are simultaneously the main centers for GHG emissions production and the most vulnerable sites in case of extreme weather events [13].

According to the need to develop integrated initiatives targeting both mitigation and adaptation goals within limited and densely built contexts, scholars started to argue about ways to balance and combine local actions to cope with present and future challenges effectively and synergically [14, 15]. Developing synergies, indeed, requires more than the simple simultaneous design and implementation of actions [16]; a strong effort should be addressed towards a re-definition of urban vulnerability and risk concepts, towards a multi-layered and comprehensive approach.

As far as urban risk definition is concerned, energy and climate goals have been targeted as separate risks affecting the same territorial context, deriving from the action of different hazards (H), acting on different vulnerabilities (V) and exposures (E):

$$R_{energy} = H_{energy} + V_{energy} + E_{energy}$$

$$R_{climate} = H_{climate} + V_{climate} + E_{climate}$$

The traditional approach leads to a double risk assessment where consequent actions are developed independently and indifferently to potential overlaps and conflicts.

A multi-risk approach, on the other hand, could help in highlighting synergies and critical points when risk assessment layers – descending from vulnerabilities and exposures mapping – need to match with underlying urban and landscape assets [17–19].

Developing a multi-risk analysis would require building a strong, deep, and punctual knowledge of territorial context and collecting a significant amount of data, in order to implement several indicators' sets able to evaluate and monitor local response and capacity over time [20, 21].

Resilience-oriented urban planning implies relevant human and material resources to support similar data-driven processes' implementation [22, 23]. Nevertheless, according to cities' pivotal role within the global socio-economic system and the subsidiarity principle, municipal scale has been pinpointed as the most suitable for developing such planning activity. Proximity, context knowledge, accountability towards the local community, as well as the direct capacity to implement local and place-based actions led to a municipality leadership as far as mitigation and adaptation actions' planning is concerned [24–27].

Municipal scale variability in the population, territorial extension, and consequent administrative structure may undermine widespread and shared implementation of similar activities, making small municipalities unable to cope with such challenges [28].

This element proved to be significantly critical within the framework Covenant of Mayors' (CoM) initiative that started in 2008 to support municipality-led, voluntary, and bottom-up actions across the EU – and beyond with the Global Covenant of Mayors since 2015- through the design of Sustainable Energy and Climate Action Plans (SECAPs).

Among more than 11 000 signatories, beyond 65% were small municipalities with fewer than 10 000 inhabitants [29]. Despite initial enthusiastic participation, signatories faced several issues in SECAPs' design, implementation, and monitoring steps, so many have not yet submitted their local proposal [30].

Even though Joint Research Centre (JRC) in its guide for SECAP development provides a simpler methodology to be implemented by medium and small-sized centers [31], a strongly data-driven approach hampers the mitigation and adaptation capacity of the tiniest municipalities.

This paper aims to provide a multi-risk approach to be developed within the SECAP planning framework that, based on the municipal scale of the initiative, targets small municipalities with a simpler methodology based on land use of municipal assets (Sect. 2). Specifically, energy risk will be addressed in 2.1 and climate risk in 2.2. In the discussion, the authors highlight potential drivers and barriers to implementing such a multi-risk approach for adaptation and energy-related action planning at the local scale, also in light of new normative updates (Sect. 3). Finally, some considerations on the implementation of SECAPs and future challenges in multi-risk planning are reported in the conclusions (Sect. 4).

2 Methodology

The urban environment (generally the territory) is recognized as a highly multi-risk environment addressing air pollution, noise, waste, road accidents, heat island effects, climate, natural hazards, etc. Those multiple risk sources may cause damage of different degrees to the system's users at once, also generating cascading effects and mutual intensification of adverse effects. Therefore, a global vision of safety needs to be developed. The latter should be considered as a fundamental objective of urban planning, public space design, technological network planning, and mobility, as well as a design assessment criterion.

To effectively support decision-making actions, distinguishing among the possible measures and activities to manage risks is fundamental. Indeed, risk management refers to applying specific policies by exploring new opportunities to prevent new conflicts on the one hand and to reduce losses, accidents, and disasters on the other, looking to strengthen overall resilience [32–34]. It is intended to develop a systematic approach and practice that manages uncertainty to mitigate potential harm and loss. Risk management includes risk assessment, analysis, and communication.

Conducting a risk analysis establishes a risk picture, highlights different alternatives and solutions, detects the critical factors, conditions, activities, systems, components, etc., and finally shows the impact of multiple measures on risk [35].

Risk assessment establishes a methodology to evaluate risks' nature and extent through analyzing eventual hazards and testing existing vulnerability conditions "that together could potentially harm exposed people, property, services, livelihoods and the environment on which they depend" [33]. More technically, risk assessments (with related risk mapping) take into consideration: detailed features of hazards such as their location, intensity, frequency, and probability; the exposure and vulnerability study that deals with the physical, social, health, economic, and environmental components; and the estimation of the effectiveness of existing and alternative response capabilities in relation to likely risk scenarios.

Finally, risk communication is linked to a highly complex and interdisciplinary academic field that works to provide a real-time exchange of information, advice, and opinions between targeted experts, official institutions, and people who are threatened (due to a hazard) putting in danger their survival, health, economic or social wellbeing. The main objective consists in enabling people at risk to decide for their safety and mitigate hazard's effects by reaching protective and preventive measures [36, 37]. Moreover, risk communication is conceived to support a positive change in people's behavior to reduce potential threats in the long term [38].

In this regard, the SECAP tool can be detected as part of the overall risk management framework (Fig. 1). In particular, the latter represents an evaluation tool that can estimate the shift towards a low-carbon economy and climate-proof cities [39].

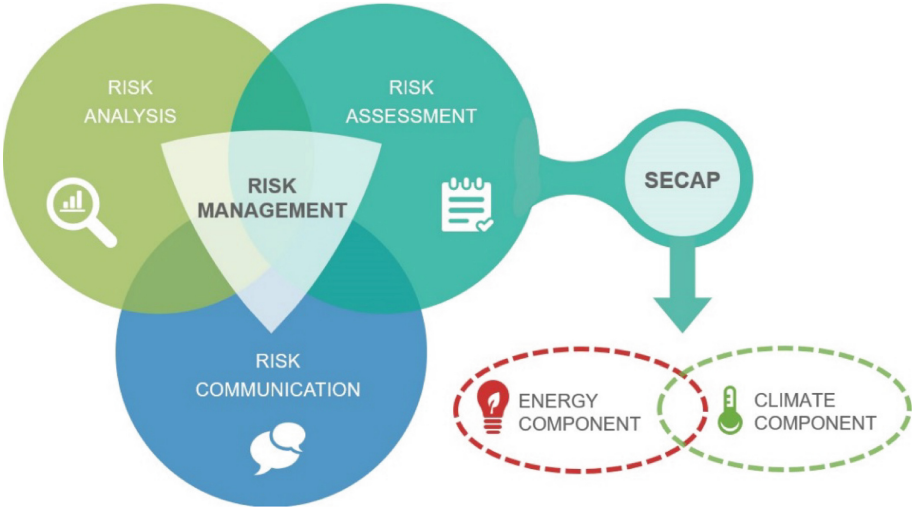

Fig. 1. SECAP within risk management framework (authors).

Given the numerous definitions in the literature, Risk represents the probability that a potentially harmful phenomenon can occur in a certain place and at a specific time, causing an expected damage value. Dealing with the concept of risk and its related evaluation process means taking into consideration several components: the triggering event, thus the hazard source, the probability of this occurring, the context in which it could take

place, the elements involved, and the damage that these elements may undergo [40–46]. Besides, many social and natural sciences fields are also involved (for example, engineering, economics, political science, sociology, psychology, and philosophy), making this topic extremely multi-inter and trans-disciplinary.

The Risk equation proposed by Dilley [47] links four main parameters (Exposure, Vulnerability, Hazard, Risk), which depend on the time (t) variable. This formulation is one of the most significant, highlighting the most evident relationships between the urban environment and urban planning:

- H (hazard) is the probability that a given calamitous event will occur within a specific period and in a particular area;
- V (vulnerability) refers to the degree of loss produced on a certain element or group of elements exposed to risk; the term represents the weakness of physical and social systems against specific dangers;
- E (exposure) represents the set of elements exposed to risk in a specific area (population, movable and immovable property, economic activities, public services, etc.). Exposure can also be seen as the overlap of the spatial and temporal distribution of human goods and dangerous phenomena;
- R (risk) is the expected total number of human losses, injuries, property damage, and business interruption due to a particular phenomenon [48].

The methodology correlates the two main components within the SECAP framework (energy and climate). It analyzes them from the point of view of risk assessment focusing on the hazard factor of risk equation, examining causes and possible interrelation (such as secondary and tertiary events, compounding, and cascading effects) among them. Thus, through a synthetic and structured representation, it is possible to define that (Fig. 2):

1. The Energetic Risk can be evaluated and analyzed considering the following factors:
   i. The issue related to energy shortage (reduction of primary sources, socio-political issues at the international level, high costs);
   ii. The level of access to energy compared on both the specific economic and the overall system spheres ("energy inequalities" due to social/cultural components, economic status, technological gap);
   iii. Energy literacy (in terms of knowledge, attitudes, and behavior that allow people to translate knowledge of what energy is, which are its production processes and sources, uses, and conservation strategies, into concrete actions), which is in turn linked to scientific and financial literacy [49, 50];
   iv. The set of infrastructure opportunities (network grids and production plants) that can be developed at different scales.

These assumptions let the SECAP tool be interpreted as the one able to reduce the mentioned Energetic Risk by enabling some given actions:

- The definition and systematization of the overall and detailed needs and vulnerabilities;
- The processing of needs, vulnerabilities, and exposures related to each urban and economic sector within the global framework;
- The population's direct involvement;

- Communication and training events.

2. The Climate Risk can be evaluated and analyzed considering the following factors:
   i. The level of greenhouse gas emissions;
   ii. The natural risk effects deriving from extreme weather events and climate change.

These assumptions let the SECAP tool be interpreted as the one able to reduce the mentioned Climate Risk by enabling some given actions:

- The targeting of dedicated responses to these risks:
  i. Emissions' reduction;
  ii. Extreme events defense;
  iii. Energy poverty alleviation.
- The population's direct involvement;
- Communication and training events.

Hence: SECAP is a multi-risk response tool (with different weights depending on context and objectives), which is also transcalar since its initiative is taken at the EU level, later implemented by municipalities, often supported and coordinated by regional agencies and/or administrations, that may represent the first step towards an integrated and multi-risk approach to energy and climate planning.

Despite climate risk having been mainstreamed into an initially energy risk-led planning program -the so-called Sustainable Energy Action Plan (SEAP) initiative- progressive evolution of SECAPs may lead to a more holistic methodology to face multi-risk assessment.

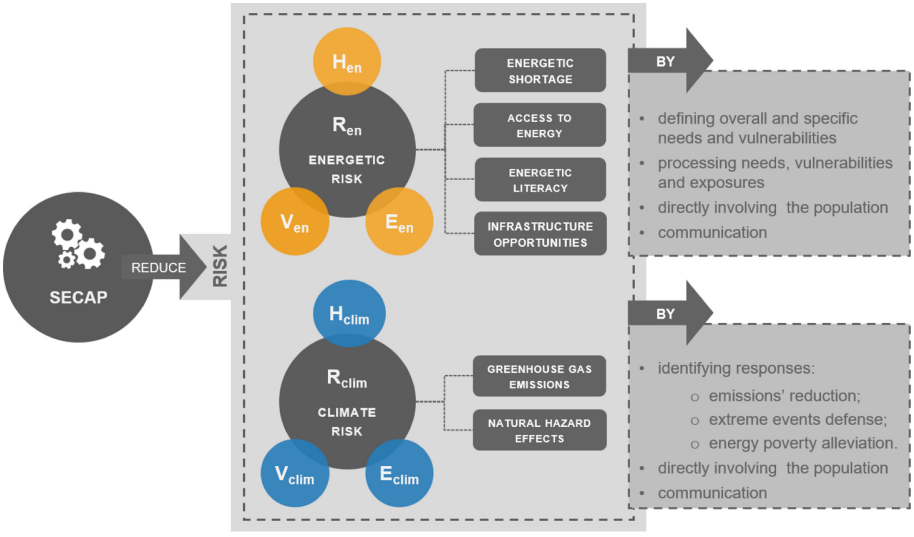

Fig. 2. Multi-risk methodology framework (authors).

The two risk components previously discussed are explained in more detail below, particularly concerning the possible hazards' sources that trigger them.

2.1 Energy Risk

Energy Risk is understood as a highly multi-disciplinary concept. Indeed, it integrates topics deriving from technology, economy, social science, environment, politics, and geopolitics, as it is displayed in Table 1, which overall denotes a sustainable-oriented approach [51]. For this reason, dealing with quantitative evaluation of energy risk means reasoning on multiple methodological approaches, particularly considering its significant set of qualitative dimensions [52, 53].

Moreover, energy production determines specific social costs and Energy Risk is considered part of them. Those social costs refer to air and water pollution, land abuse, depletion of natural resources, and other factors [54, 55].

Human health is equally affected, and the most significant threat deriving from energy systems is mainly linked either to industrial and occupational risk or pollution effects. Nevertheless, the loss' extent can be perceived differently; indeed, an industrial accident involving one individual does not have the same impact on the public as on hundreds of people [56, 57].

Table 1. Energy risk main causes (authors).

Main category	Sources
Environmental	Natural disasters Energy production (production process, type, and method of production) External factors Raw material and fuel production Materials Component fabrication Plant construction and maintenance Transportation
Economical	Market Client-related Project-related Contractor-related Performance-related Cost High price volatility Time and quality
Social	Technology Political organization Culture Energy literacy Not equal access to energy

2.2 Climate Risk

Natural hazards involve many processes that can be physical, chemical, and biological. Such processes can determine, among others, volcanic eruptions, earthquakes, landslides, and floods which consistently affect the Earth's surface. Their origin can depend on deep internal or external forces (i.e., the energy from the Sun that can generate violent storms, flooding, and coastal erosion).

Climatological hazards result from long-lived, meso to macro-scale atmospheric processes ranging from intra-seasonal to multi-decadal climate variability [58]. Overall, climate risks derive from climate-related hazards, vulnerability, and societal exposure. Temperature change, precipitation intensity, windstorms, sea-level rise, salinity, and water temperature can be listed as the main drivers of climate-related hazards. The latter are affected by natural variability and anthropogenic climate change.

In this case, vulnerability and exposure rely on socio-economic factors, including socio-economic development pathways, societal adaptation and mitigation measures, and governance.

Climate change-related hazards are associated with various events that cause many direct and indirect repercussions to people. Indeed, such hazards influence many sectors, as shown in Table 2; moreover, due to great countries' involvement in the global world economy, it becomes easy to detect several pathways for transboundary impacts [59].

Table 2. CoM Risk assessment components (LIFE Adaptate Projects).

CoM Climate Hazards	Local Vulnerabilities	Impacted sectors
Extreme heat	Socio-economic	Buildings
Extreme cold	Physical/Environmental	Transport
Heavy precipitation: rainfall, snowfall, fog, or hail		Energy
Floods: flash/surface flood, river flood, coastal flood, groundwater flood, or permanent inundation		Water
Droughts and water scarcity		Wastes
Storms: severe wind, tornado, cyclone (hurricane/typhoon), tropical or extratropical storm, storm surge, or lightning/thunderstorm		Land Planning
Mass movement: landslide, avalanche, rockfall, or subsidence		Agriculture and Forestry

(*continued*)

Table 2. (*continued*)

Wildfires: forest or land fire		Environment and Biodiversity
Chemical change: saltwater intrusion, ocean acidification, or atmospheric CO2 concentrations		Health
Biological hazards: water-borne disease, vector-borne disease, airborne disease, or insect infestation		Civil Protection and Emergency

3 Discussion

Today the link between energy consumption, global warming, climate change, environmental pollution, and biodiversity loss is evident. In this respect, the international scientific community has identified numerous initiatives and specific rules intending to establish a new balance between the environment and human activities (including energetic supplies and protection against climate change to slow and reduce them).

Some of the most relevant actions come from the energy sector, in particular from the definition of Energy Communities (ECs). From the European legislative point of view, the creation of ECs provides a responsive tool to restructure the energy systems by allowing citizens to participate actively in the ecological transition. Indeed, through the "Clean energy for all Europeans package" (2019), the Directive on common rules for the Internal Electricity Market (EU 2019/944), and the Renewable Energy Directive (2018/2001/EU, RED II) the EU sets the general framework of ECs and strengthens the role of renewable sources as the primary source of energy (for electricity and heating) production.

The Italian legislation introduced the definitions of renewable energy communities through the *Decreto Milleproroghe* ("Thousand-extension" Decree-Law, 2020) that transposes the RED II directive by encouraging the large-scale development of ECs. Additionally, the National Recovery and Resilience Plan (2021) outlines, among the others, the objectives of making Italy more resilient to the inevitable climate change and its system safer and more sustainable in the long term by ensuring its competitiveness. Moreover, it refers to energy transition, resilience, and territory, specifically with Mission 2 – Green revolution and ecological transition and its components C1, C2, C3, and C4.

At the regional level, i.e., in 2022 Lombardy Region defined a law for the Promotion and development of a system of Renewable Energy Communities (CER) at the regional scale to reach an energy independence. The Region intends to take an active role in the promotion of ECs establishing the so-called Lombardy Regional Energy Community (CERL).

At the local level, already existing since the 1990s, there are the former Municipal Energy Plans, today SECAP Sustainable Energy and Climate Action Plans. The latter materialize the objectives of the National and Community directives to have a sustainable

energy supply and to identify the potential for action existing in the municipality in terms of energy and, therefore, to use energy most rationally and efficiently possible, to encourage and increase the use of renewable energy sources to reduce emissions of CO2.

Focusing on climate risk, to support national and local implementation of the Sendai Framework, in 2017, the United Nation Office for Disaster Risk Reduction – UNDRR created guidelines on National Disaster Risk Assessment (NDRA) as a policy guide and a practical reference to introduce government, authorities, stakeholders, and scholars to policy, process, and the high-level technical requirements for a holistic national disaster risk assessment. In this framework, SECAP fits perfectly [32, 60].

It is crucial to notice that in urban areas, in case of slow natural phenomena (drought, climate change, environmental degradation, desertification), the complex urban system proves to be capable of modifying its main components (physical and functional) and adapting the urban structure and the different subjects involved [61]. It also requires the ability to accommodate very quick modifications of external (global geo-political and socio-economic situations) and internal (social and organizational scenario) conditions.

Urban planning tools are essential in planning and implementing SECAP strategies and actions at the municipal planning level, becoming the substantial and procedural focus. Through the diversified panorama of laws on territorial planning characterizing the various Italian regions, some points referring to SECAPs can be traced transversally:

- The urban fabric and urban functions are analyzed as part of the strategic component of the plan (influences on the general strategies about energy and climate change adaptation actions for the new settlements or regeneration area), and as a component of the private city with a specific normative system (influences on the local and private management);
- The technological, infrastructural system is analyzed as elements under the public management and as technical elements (energy grids, recharge stations, energy cabins, and so on);
- Mobility issues through specific (sustainable) mobility plans define the general strategies for sustainable mobility and address the practical design of soft mobility and the urban road system and cycle paths.

Furthermore, even the municipal emergency plans (or civil protection plans) include these elements to pay attention to, as a study of the context, therefore like an analysis of risk scenarios and preventive and emergency procedures.

In its substantive and procedural structuring, the proposed method allows an objective quantification of the climate risk and energy in the different portions of the territory. Therefore, the most at-risk areas are highlighted, identifying for the public administrations the possibility of prioritizing interventions on a municipal scale. It follows that this approach makes it possible to reconcile the need for political-social-economic choices that each municipality is called to make for the current and strategic management of its territory with the scientific objectivity dictated by the method itself. Furthermore, the vision on a local or municipal scale makes it possible to establish local-punctual actions, even on individual buildings or portions of infrastructure, in a general framework by defining a “system of actions” that considers the complex dynamic nature that characterizes urban contexts.

4 Conclusions

Building more resilient urban environments requires a deep change in how risk is defined and faced. The present contribution investigated the potential of a re-definition of urban risk concept through a multi-risk approach, able to mainstream both energy and climate components.

The multifaceted nature of urban risk implies targeting risk assessment, prevention, and management planning through a flexible, holistic, and multi-level approach.

Traditional allocation of competencies and sectorial planning activities and tools may prove unable to cope with climate change evolution and uncertainties. Following SECAPs' municipality-led initiative scheme, the proposed methodology suggests local urban plans as pivotal tools to foster multi-level and cross-sectoral approaches toward risk assessment.

As previously stated, being risk the result of hazards' impact on territorial assets and vulnerabilities – both in its energy and climate drivers – its modelling, analysis, as well as mitigation and adaptation strategies need to be developed at the same scale at which considered phenomena occur, as risk assessment requires taking into account its various and peculiar nature, features and causes. Similar considerations initially led the EU initiative to downscale from global energy and climate scenarios to local actions such as the Covenant of Mayors and SECAPs' implementation.

A multi-risk assessment should involve multiple governance and territorial scales, indeed. Strong network, exchange, and cooperation should interlink EU, National, Regional, and Local scales, as far as different hazards may concern different geographical and administrative entities, thus insisting on the same territory.

The unpredictable evolution of climate and socio-economic environment, as well as specific features and various risks require developing a deep background of territorial knowledge where different layers overlap, thus highlighting potential synergies and conflicts. Therefore, integrated reading and interpretation of the context are necessary to assess local vulnerabilities' components. This represents a particularly challenging task as far as multiple risks are concerned and urban assets provide an extensive range of variables and factors related to different morphology, uses, and urban fabrics, as briefly introduced in the previous section.

Consequently, similar knowledge could be deepened and collected on a quite wide scale due to the need for significant human, technological, and economic resources. Research centers, universities, and administrations should be involved in developing structured and synthetic descriptions of the territorial asset that need to improve their resilience and response to multi-risk challenges.

Nevertheless, the effectiveness of the actions requires local participation as well. Solutions should be tailored according to punctual criticalities and needs; local stakeholders and communities are essential to down-scale general goals and strategies to match top-down knowledge with bottom-up experience. Exposure enters multi-risk assessment through the closer reading of micro-dynamics.

In this direction, the present work aims to underline the crucial role urban plans may play. They may act as contact points where general goals and policies meet with local communities' needs, will, and ambitions, thus targeting solutions that aim to reach

higher objectives through tangible, place-based, and practical actions. They could represent the foundation for a multi-level and multi-disciplinary approach leading to tailored resilient solutions able to face multi-risk challenges, starting from their potential as supporting tools for SECAPs implementation, especially as far as small municipalities are concerned.

SECAP initiative represents the first step towards this mindset change, according to its EU-Local dual nature and its integration of energy and climate actions, simultaneously targeting mitigation and adaptation goals. Future challenges will therefore address:

- Further widening of territorial risks to be included within assessment procedures, thus adding new layers to local, territorial framework analysis;
- Relevant participation of small municipalities requires an intermediate governance level, where mesoscale stakeholders, such as regional agencies and research centers, act as link between local and higher scales. A similar contribution is, therefore, pivotal to fostering cooperation and collaboration and supporting smaller municipalities in the implementation phases, thus reducing the percentage of actions that remain on paper.

From a methodological and scientific point of view, a comprehensive re-definition of urban risk that needs to be translated into preventive and managing strategies and actions requires several sectorial plans and visions to be mainstreamed into a more comprehensive framework, thus targeting advanced smoothing of traditional barriers among different sectors, mitigation and adaptation planning.

Competencies and know-how should therefore converge into the wider borders of territorial multi-risk assessment and planning, thus enhancing comparing and prioritizing interventions to be implemented according to their overall impacts on the urban ecosystem.

Finally, building such a complex, integrated, multi-disciplinary, and multi-layer territorial knowledge would represent a massive challenge in terms of background standardization of methodology and tools, requiring strong efforts of coordination and cooperation to develop structured and shared layering asset able to convey a holistic, rich and synthetic reading of the local context.

A similar approach may prove highly relevant regarding resource allocation within the National Resilience and Recovery Plan framework, as far as energy risk and climate change represent key challenges and drivers.

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