

Enhancing Local Climate Resilience: Insights on Climate Action from the Piedmont Region, Italy

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Abstract – While the impacts of climate change are increasingly apparent and expected to worsen in the near future, effective mitigation and adaptation strategies, plan and actions are becoming compelling. Despite the need for an integrated approach among governance levels, local authorities lie at the forefront of climate action, due to their proximity to the affected communities. However, the potential of this local climate governance is under discussion, as its efficacy is still unclear. This study focuses on the municipalities in the Piedmont region (Italy) and investigates how these municipalities tackle climate change within the consolidated framework of the Covenant of Mayors. The assessment is based on a qualitative-quantitative analysis, owing to official documents and expert surveys. The results show that mitigation is rather consolidated, but it often relies on the willingness of private actors to act, hence pushing the achievement of climate targets beyond the direct control of the municipal authority. Furthermore, the study reveals a significant underdevelopment in terms of adaptation; though a certain attention for ecosystem services and wellbeing emerges, the ability to effectively act appears limited. Overall, the results hint at the inherent complexity of local climate governance, especially for municipalities, that suffer from limited funds and resources, as well as internal political instability. Despite the difficulties structured in the socio-political context, we argue that local partnerships connecting different levels of governance and incorporating private actors and communities in the planning and implementation system can strengthen local resilience against global challenges and foster the sustainability of local communities.

Keywords – Adaptation; climate action; Covenant of Mayors; local governance; mitigation; Piedmont.

1. INTRODUCTION

Climate change is exerting increasingly heavy tolls on local communities worldwide, requiring prompt and effective action in terms of both mitigation and adaptation [1]–[3]. It is commonly maintained that climate action shall be a shared, comprehensive, integrated, multi-level, and multi-actor effort [4]–[9]. Nevertheless, municipalities are often expected to enact to climate action, owing to their privileged position near the communities, where climate impacts occur and thus countermeasures shall be tailored and implemented [4], [10]. Despite this premise, advancements on both climate change mitigation and adaptation objectives are varied if not limited [11]–[14], and climate governance is proving a significant challenge [5], especially for medium and small municipalities [15].

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Indeed, local governments [16] and above all smaller municipalities [7], [17] have been often reported to face significant difficulties in dealing with climate planning and action, especially due to their limited technical resources, available funds, but also limited support from higher governance levels [7], [18]. In this context, the European Commission introduced the Covenant of Mayors initiative [19]. Launched in 2008, the initiative underwent several revisions; one of the major changes occurred in 2015, when adaptation became a formal requirement for local climate planning. Nowadays, signatory municipalities are expected to reach a GHG (Greenhouse Gas) emission reduction of 55 % within 2030 (compared to a selected base year), strengthen local resilience and alleviate energy poverty [19]. In particular, municipalities are required to prepare, publish, and enact an action plan, that is either a SEAP (Sustainable Energy Action Plan) or a SECAP (Sustainable Energy and Climate Action Plan), depending on the inclusion (SECAP) or not (SEAP) of adaptation.

The increasing relevance of the Covenant of Mayors initiative in support of local authorities is proved by the rise from the European to the global stage as well as the growing number of signatories, and the consistent attention paid by the international literature [16], [17], [20]–[26]. In this context, we deemed the case of Italy particularly interesting. First, Italy is a hotspot of climate change [27], [28], thus needing timely and efficient countermeasures against climate risks. Second, local authorities are joining the efforts to tackle climate impacts, for instance participating in the Covenant of Mayors initiative; indeed, Italian municipalities represent a high portion of the overall signatories in the European context [29], [30]. As such, studies have started to investigate how municipalities are dealing with the challenges of climate change in this area [31]–[35]. However, to the best of our knowledge, this is one of the first in-depth assessments of the development of the Covenant of Mayors initiative in the Northern regions of Italy. Although it will be later explained, it is worth mentioning that here we explore the case of the Piedmont region.

Against this background, the objective of this study is to investigate the development of climate mitigation and adaptation planning at the municipal level, identifying favouring as well as limiting factors that can affect the enhancement of local climate resilience and sustainability. Although focused on a case study, we argue that the experience gained in this context can be significant also in other situations, within the Covenant of Mayors initiative and beyond, in any case local authorities are placed at the forefront of climate action.

2. MATERIALS AND METHODS

The advancement of local climate action was investigated by means of an integrated, qualitative-quantitative methodology, that availed of both an in-depth analysis of a structured database and interviews with local experts of involved municipalities. We applied this methodology to the case study of the Piedmont region, in the North-East of Italy.

2.1. Case Study

This study explored the case of the Piedmont region. From the administrative point of view, in Italy municipalities correspond to the European Local Administrative Unit (LAU) level, while regions to the NUTS 2 level, following the European Nomenclature of Territorial Units for Statistics (NUTS). Notably, there is an additional, intermediate level, the NUTS 3, represented by the provinces, that connect regions and municipalities [36]. The configuration of the Piedmont region entails 8 provinces and 1180 municipalities (Fig. 1).

We argue that this study can contribute to the international discourse on climate action and inform other case studies in Europe and beyond, owing to the characteristics of the Piedmont

region in the context of the Covenant of Mayors initiative. Indeed, Piedmont hosts about 1/7 of Italian municipalities [37] and a consistent portion of Italian signatories to the Covenant of Mayors initiative [33], while Italy has some of the highest number of signatories to the initiative [29], [30]. Accordingly, the municipalities of the Piedmont region represent a sample relevant also in the context of the global initiative, especially to further the understanding on the enabling and limiting factors that influence the participation and engagement in local climate efforts.

In addition, it is relevant to note that the Piedmont municipalities are rather diverse in terms of resident population; however, most of them counts less than 5000 inhabitants, hence can be considered “small” municipalities. Accordingly, this study can provide relevant insights also on the ongoing discussion on the relevance of the dimension of the municipalities on their potential to drive and implement effective climate action. Indeed, smaller municipalities have been found to have lesser resources, be more susceptible to change in political priorities and mandates, and benefit more from higher-level support [17], [18], [38], [39]. Consequently, the case of the Piedmont region can contribute to identify and thus remove the restraints to an effective climate action, that needs to occur starting from the local level.

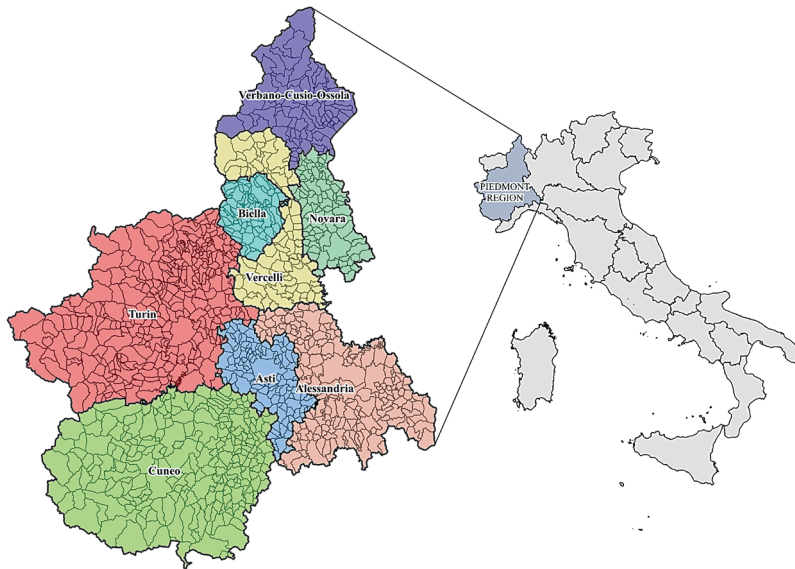


Fig. 1. The Piedmont region: provinces and municipalities in the broader context of Italy.

2.2. Methodology

As mentioned, this study was based on a two-fold methodology, comprising a quantitative analysis, intended to provide the overall picture on the advancement of local climate action, and a qualitative analysis, aimed at integrating this knowledge with the thoughts, perceptions and experiences of those directly involved in the development of such climate action (Fig. 2). Before the in-depth analysis, a preliminary step was developed to prepare the database; in particular, it was necessary to identify the signatory municipalities to the Covenant of Mayors. To this end, the official website of the initiative was explored in order to retrieve a first list of signatories and the basic, associated information, such as year of adhesion, type of

commitment and (if any) joint effort to develop the SEAP/SECAP [40]. In brief, the signatory municipalities of the Piedmont region were identified and, thus, the database was set.

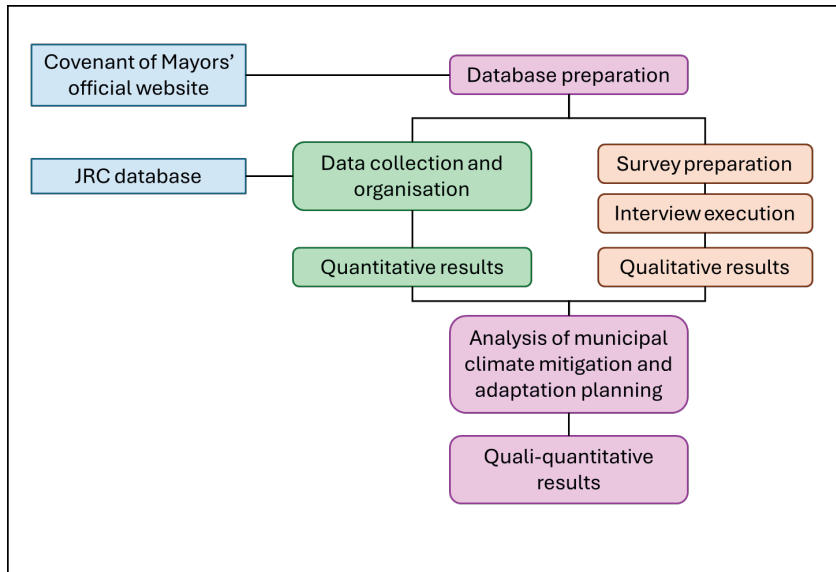


Fig. 2. Workflow diagram of the implemented methodology.

At this point, the actual analysis could start. In particular, the quantitative analysis was based on the data made available by the European Joint Research Centre (JRC) [41]. Notably, the last update was published in January 2024, hence this study is necessarily limited in the timeframe. The database extensively reports information on the signatories of the Covenant of Mayors initiative and, whenever possible, the related SEAPs and/or SECAPs. Information ranges broadly from date and typology of adhesion to date of submission of the action plan, targets and reduction objectives, mitigation and adaptation sectors and actions. Several datasets are available, providing further information in some thematic areas, e.g., mitigation actions. Notably, each signatory municipality is provided with an organization ID, and each SEAP/SECAP is given an action plan ID. Consequently, it was necessary to first associate each municipality of the Piedmont region with the appropriate organization ID: this was made merging the preliminary database with the JRC database using the name of the municipality as a key; then, per each organization ID the related action plan ID was integrated. At this point, further merging operations involved the specific databases provided by the JRC on the mitigation and adaptation contents of the SEAPs/SECAPs. We acknowledge here that this process represents a limitation for this study, as sometimes the association was not possible due to technical issues, that nonetheless can cause a loss of information. Indeed, that is probably the main reason behind the progressively narrower number of available SEAPs/SECAPs with the increasing detail of requested information, e.g., adaptation policies and measures.

The qualitative analysis started shortly after the other and was intended to integrate and complement the outcomes of the quantitative analysis. To this end, a sample of municipalities was purposively selected. A series of indicators was applied (e.g., level of urbanisation, altimetric position, dimension of the municipality) to ensure that it was representative of the

overall social, ecological and environmental conditions of the Piedmont region. As a result, the selected sample involved 112 municipalities and 4 inter-municipal bodies. We designed and delivered tailored semi-structured interviews, conceived to gather the respondents' position on some central themes, namely: role in the participation to the Covenant of Mayors initiative; perception and consideration of the initiative and the related action plans, in the current and future scenarios; enabling and limiting factors in this kind of climate planning. The answers were collected and structured in an appropriate database, in order to facilitate the emergence of common trends and characteristics.

3. RESULTS AND DISCUSSION

3.1. Overview

The first result of the quantitative analysis relates to the diffusion and typology of participation to the Covenant of Mayors initiative among the Piedmont municipalities (Table 1). In particular, the region confirms a high interest in the initiative, as about 30 % the municipalities are official signatories. Nonetheless, it is relevant to observe the difference between the number of municipalities that are signatories and those that actually develop an action plan. Indeed, 85 out of the 363 signatory municipalities never developed an action plan, representing about a quarter of the overall signatories. Although some of them still have time to issue the action plan due to the recent participation to the initiative, it is relevant to mention that part of the municipal engagement in climate action is lost well before becoming working element of the local political agenda. In addition, it is particularly important to evidence that the portion of municipalities that include adaptation in their action plans is significantly limited, being about 5 % of the overall signatories. This aspect is crucial, as adaptation efforts are urgent and compelling, especially at the local level, due to the increasingly severe tolls that climate change is exerting on local communities. Consequently, we argue that the issue of adaptation must represent a priority, for research as well as local climate governance.

TABLE 1. NUMBER OF MUNICIPALITIES THAT ARE SIGNATORIES TO THE COVENANT OF MAYORS INITIATIVE, EQUIPPED WITH PLANS CONCERNED WITH MITIGATION AND ADAPTATION

Signatories of the CoM	363
Signatories (also) of the CoM, second version	87
Signatories only of the CoM, second version	172
Equipped for mitigation	261
Equipped for mitigation and adaptation	17
Not equipped for mitigation and adaptation, but still time	40

The target year of the issued action plans represents an additional element of interest. Although probably depending on the year of adhesion and thus on the requirements valid at that moment, it is relevant to observe that the wide majority of the municipalities set 2020 as the target year to achieve their commitments and objectives (Fig. 3). As we are already beyond that date, the current engagement of municipalities in climate action shall be questioned. It would be especially relevant to investigate the reasons behind the missed update of the action plan to advanced objectives, as well as the other factors that curbed the ambition of the plans.

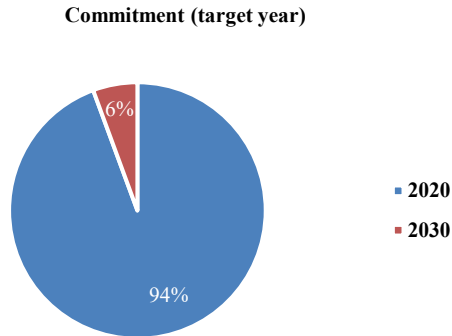


Fig. 3. Share of action plans per commitment year, intended as target year of the action plan.

Although it will be later considered more in depth, it is worth mentioning that the interviewees provided a rather clear picture on these matters. In particular, the lack of resources and support appeared crucial to limiting the potential and reach of the action plans, thus hinting at the inherent difficulties that local authorities face to effectively engage in these global issues, confirming the evidence emerging from the literature [7], [33], [39], [42], [43].

3.2. Mitigation

Despite the introduction of adaptation and energy poverty as additional pillars of local climate governance, mitigation planning and action remains a primary focus of the action plans, owing to the consolidated activity and support that the Covenant of Mayors developed since its launch in 2008. As such, it is relevant to explore how municipalities tackle this side of climate governance, that should be well established.

A first observation reveals that the most common base years adopted in the action plans are either 2000 or between 2005 and 2008, although others are distributed until 2011 (Fig. 4). Notably, the Covenant of Mayors guidebook advises to use 1991 as a reference or, as an alternative, the furthest year in which data is consistently available [44], [45]. Hence, the choices of Piedmont municipalities hint at an inherent difficulty of retrieving reliable and comparable data in the past, further suggesting a limited availability of structured, consolidated information. This shortcoming can undermine the possibility of municipalities to obtain a clear overview on the conditions of their area and the changes – possibly improvements – that occurred. In addition, choosing a relatively close base year translates in a shorter timeframe to achieve the expected emission reduction targets. Though one could expect a robust effort to meet this requirement, it may be more realistic to anticipate a failure or at least a significant difficulty in complying with these goals, considering the often limited resources and capacities that affect municipalities. We believe that this shortcoming may cast doubt – if not undermine – the very significance of these climate action plans; thus, we strongly recommend that the overall process of designing and devising SEAPs/SECAPs is aided by appropriate technical and scientific support, to provide a credible and reliable base for local climate action.

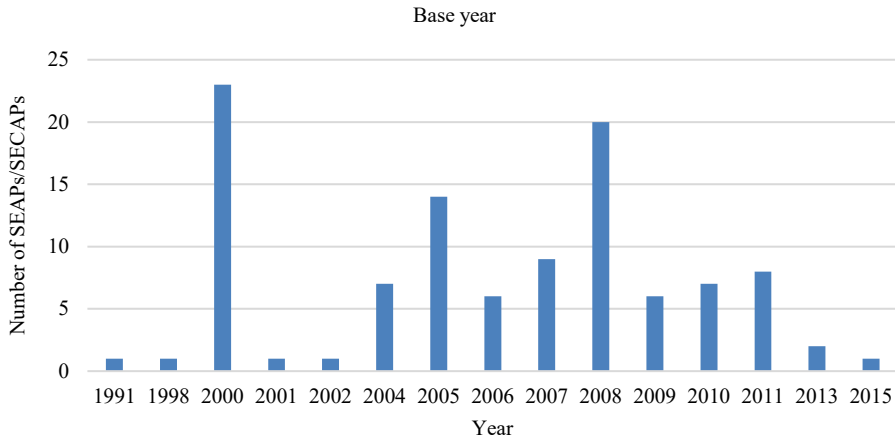


Fig. 4. Number of action plans per adopted base year.

In line with these considerations, the emission reduction targets reported in the action plans suggest a cautious approach of the Piedmont municipalities (Fig. 5). The Covenant of Mayors initiative first set the minimum target at 20 % reduction compared to the base year, while the following updates heightened the minimum requirements up to 30 % reduction and, currently, 55 % reduction within 2030 [19]. In the case of Piedmont, the majority (66 %) of the set reduction targets are close to the proposed minimum (0.20–0.24), though it should be noted that within this class, targets of 20 % and 21 % reduction are predominant, both within the class (73 %) and among all the action plans (49 %).

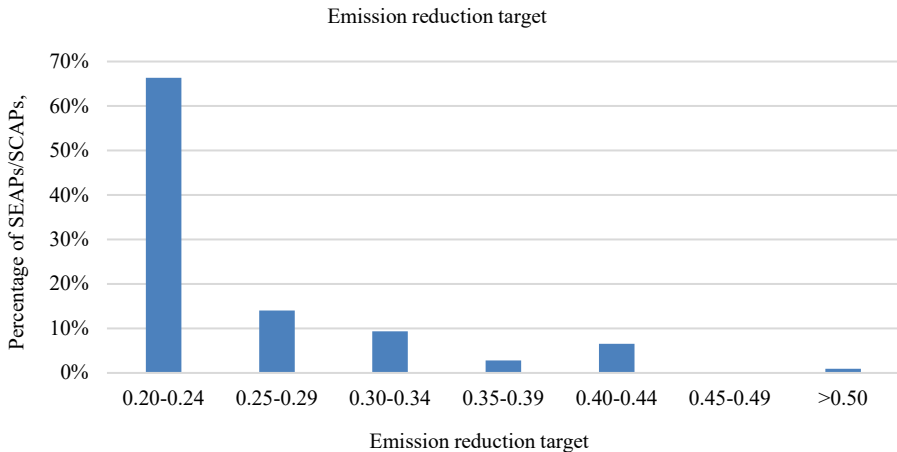


Fig. 5. Share of action plans per defined emission reduction target.

We evidence that this result may hint at two different issues, namely, municipalities may not retain either enough resources or enough motivation to aim at higher targets, similarly to the insights provided by other case studies [33], [43], [46]. Indeed, interviewees reported both

points; the lack of resources is a frequently mentioned limiting factor for any policy and measure at the local level, while some respondent pointed out that the participation in the Covenant of Mayors initiative aimed more at gaining an advantage in (dedicated) funding rather than being a specific interest in climate governance. In both cases, we stress that this condition can undermine the actual contribution of municipalities to national and international emission reduction targets. As the GHG emissions are constantly on the rise, there is an urgent need to curb and reverse this trend [47]; while all actors are called to action, municipalities are recognised as potentially pivotal to tackle this global challenge [30], hence it is paramount to support their efforts in order not to fall short of a fundamental player.

Lastly, it is relevant to investigate on which sectors municipalities intend to act to achieve the set reduction targets (Fig. 6). In Piedmont, municipalities tend to include almost all sectors that can be envisioned in the action plans, although a significant preference emerges for the electricity, residential, transport and municipal sectors [46], [48]. Nevertheless, these sectors broadly correspond to those that are mandatory for emission reduction [44], [45], hence the possibly more interesting result is the consistent inclusion of the electric power generation, suggesting a solid awareness on the contribution of this sector to the overall emission scenario [13].

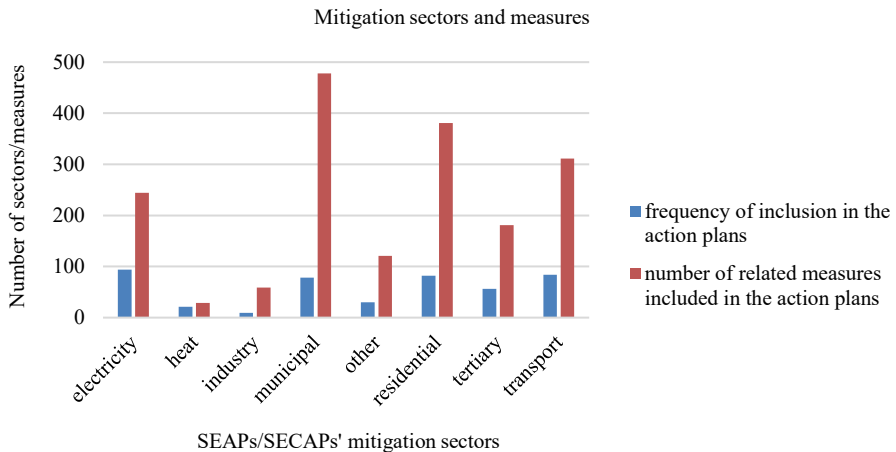


Fig. 6. Mitigation sectors per frequency of inclusion in the action plans (blue) and number of related measures (red).

However, a fundamental aspect is the number of measures associated with each sector, that can indicate the overarching approach of the municipalities. In this case, it is evident that most of the attention is directed towards the municipal sector, that is the domain under the direct responsibility of the local authority. This should be expected, as it is easier to act on properties and assets already owned by the municipal authority, renovating and upgrading them for a higher climate resilience. In addition, by doing so, municipal authorities can assume the role of model for the local communities, championing climate resilience and sustainability by means of measures clearly visible to all, thus possibly prompting the engagement of the population. Nevertheless, this may also represent an inherent weakness of the action plans for two main reasons: first, the emissions from the municipal sector are usually a minority compared to the overall emissions of the municipality, hence the effects of mitigation measures on this domain may be limited; second, focusing on this sector may diverge attention and resources from the efforts to collaborate and act on the major sources

of emissions, thus further curbing the potential of action plans to foster the climate resilience of the community in the broader sense. Although similar trends have already been registered [38], we argue that this critical issue can represent a significant weakness in the action plans, but also Covenant of Mayors initiative at large; hence we reaffirm the need of local authorities for a stronger support in order to be able to act more consistently on the community, in all its components.

3.3. Adaptation

As mentioned, the engagement of Piedmont municipalities in adaptation efforts resulted rather limited compared to the mitigation side [5], [43]; in addition, the part devoted to adaptation is usually minor in action plans. In light of these considerations, the information gathered through the interviews appeared particularly relevant to gain a more consistent understanding of the local trends.

Similarly to the case of mitigation, it is possible to identify selected areas of intervention and the extent of investment in each of them (Fig. 7). It emerged that some sectors (i.e., civil, buildings, environment, land, health, water) are common and consistently included in the action plans of the Piedmont municipalities, denoting a shared and consolidated awareness on the relevance of fostering adaptation in these sectors. Conversely, the distribution of adaptation measures is uneven, with an apparent predominance of the environment, land and health sectors. We highlight the importance of recognising the role of natural ecosystems and habitats to enhance the climate resilience of local communities, not to mention the role in reducing local risks possibly exacerbated by climate change [49]. As such, we argue that the efforts of Piedmont municipalities to positively affect the local environment are particularly noticeable and encouraging. Furthermore, it is appreciable the attention paid for the wellbeing and health of local communities, whose most fragile components significantly suffer from the increasingly extreme conditions caused by climate change. Lastly, it should be also noticed that the education sector was mentioned, although very rarely. We stress the importance of including campaigns to raise awareness on climate impacts and resilience, as well as provide adaptation options and solutions, in order to promote a thorough involvement of the overall community in adaptation efforts.

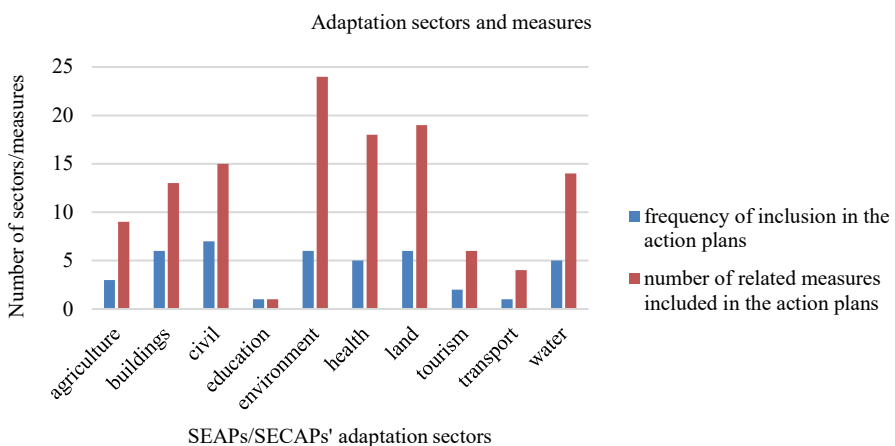


Fig. 7. Adaptation sectors per frequency of inclusion in the action plans (blue) and number of related measures (red).

Despite these promising perspectives on local adaptation, we posit that the first reported outcome remains a critical issue that needs to be addressed. Indeed, the limited engagement of Piedmont municipalities in the governance of adaptation can compromise the future conditions of wellbeing, livelihoods – and, eventually, survivability – of local communities. When questioned on this missed change to foster local adaptation, the respondents highlighted some crucial points: first, adaptation is far less known and understood than mitigation, hence municipal authorities have difficulty in committing to something that is not well understood; second, adaptation planning and action require resources and knowledge that municipalities, especially smaller ones, do not have [5], [43]. In fact, this aspect is limiting to the point that municipalities rather not participate in the Covenant of Mayors initiative, than needing to deal with adaptation. In light of these concerns, we highlight that it is of paramount importance to build a network of appropriate support can aid municipalities throughout the process of designing, preparing, implementing, and monitoring a sound and comprehensive climate action plan, that entails effective and tailored mitigation and adaptation measures, intended to be maintained in the long-term.

4. CONCLUSIONS

The impacts of climate change are increasingly severe, especially on local communities. Consequently, local authorities are urgently called to take action in terms of both mitigation and adaptation. Accordingly, it is becoming fundamental to gain a thorough understanding of the breadth, comprehensiveness and effectiveness of local climate planning and action. In light of this premise, we explored the case of the Piedmont municipalities in the context of the Covenant of Mayors initiative.

We acknowledge here that the study presents some inherent limitations. For instance, the questionnaire sample was limited to make it more manageable while ensuring the due representativeness; nevertheless, it would be interesting to extend the survey to all the municipalities of the Piedmont region to strengthen its reliability. In addition, future research shall implement this approach to other regions, in Italy and abroad, to identify emerging trends as well as collect common or innovative solutions to the detected issues. Despite these shortcomings, we believe that this study can nonetheless contribute to the ongoing discourse on local climate governance.

Indeed, quantitative evidence show that local authorities are increasingly engaged in climate action, devising plans and identifying measures to increase local climate resilience and sustainability. However, municipal authorities report a sense of powerlessness, due to a lack of knowledge, resources and funds within the administration. We observed that this condition hinders – if not halts – local climate efforts, with a manifold of consequences, that can be recognised in the documents: for instance, the ambition of climate action plans is limited in terms of timeframe as well as reduction targets; adaptation is rarely included or provided little space compared to mitigation; measures are mostly dedicated to sectors of direct responsibility of the authority, thus easier to manage but limited in impact. We also found that this situation is especially challenging for smaller municipalities, that already suffer from inherent limitations, as further witnessed by the local experts.

Given these observations, we argue that, in brief, a problem of climate governance emerges. To tackle it, further efforts are needed to strengthen the potential of local authorities to actually and effectively foster local climate resilience and sustainability. In particular, it is paramount to address the lack of local capacities, providing appropriate resources, information and support. In this sense, the establishment of an operative, multi-actor, multi-level governance would be pivotal [50], to foster dialogue, coordination and empowerment,

and a common vision, connecting all the administrative levels. Notably, a particularly significant solution would be a broader, integrated network of public and private actors in a common, shared effort to tackle climate change. This network, that we may consider a “local alliance” [51], [52], shall remove the main limiting factors that curb climate action at the municipal level, namely the lack of appropriate knowledge and resources. The strength of its mandate would also champion a broader engagement of the local community, especially the major industries and other entities that can significantly contribute to reducing local GHG emissions –and possibly also participate in adaptation efforts.

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REFERENCES

- [1] IPCC. Climate Change 2022: Impacts, Adaptation and Vulnerability. In: *Working Group II contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Pörtner H.-O., Roberts D. C., Tignor M., Poloczanska E. S., Mintenbeck K., Alegria A., Craig M., Langsdorf S., Löschke S., Möller V., Okem A., Rama B., Eds. Cambridge, UK and New York, USA: Cambridge University Press, 2022. <https://doi.org/10.1017/9781009325844>
- [2] IPCC. Climate Change 2022: Mitigation of Climate Change. In: *Working Group III contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Shukla P. R., Skea J., Slade R., Al Khourdajie A., Diemen V. R., McCollum D., Pathak M., Some S., Vyas P., Fradera R., Belkacemi M., Hasija A., Lisboa G., Luz S., Malley J., Eds. Cambridge, UK and New York, USA: Cambridge University Press, 2022:1–30. <https://doi.org/10.1017/9781009157926.001>
- [3] IPCC. Summary for Policymakers. In: *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change*. Masson-Delmotte V., Zhai P., Pörtner H.-O., Roberts D., Skea J., Shukla P. R., Pirani A., Moufouma-Okia W., Péan C., Pidcock R., Connors S., Matthews J. B. R., Chen Y., Zhou X., Gomis M. I., Lonnoy E., Maycock T., Tignor M., Waterfield T., Eds. 2018:24.
- [4] Amundsen H., Hovelsrud G. K., Aall C., Karlsson M., Westskog H. Local governments as drivers for societal transformation: towards the 1.5 °C ambition. *Current Opinion in Environmental Sustainability* 2018:31:23–29. <https://doi.org/10.1016/j.cosust.2017.12.004>
- [5] Kythreotis A. P., Jonas A. E. G., Mercer T. G., Marsden T. K. Rethinking urban adaptation as a scalar geopolitics of climate governance: climate policy in the devolved territories of the UK. *Territory, Politics, Governance* 2023: 11(1):39–59. <https://doi.org/10.1080/21622671.2020.1837220>
- [6] Soto-montes-de-oca G., Cruz-bello G. M., Quiroz-rosas L. E., Flores-Gutiérrez S. The challenge of integrating subnational governments in multilevel climate governance: the case of Mexico. *Territory, Politics, Governance* 2022:12(8):1114–1133. <https://doi.org/10.1080/21622671.2022.2106298>
- [7] Melica G., Bertoldi P., Kona A., Iancu A., Rivas S., Zancanella P. Multilevel governance of sustainable energy policies: The role of regions and provinces to support the participation of small local authorities in the Covenant of Mayors. *Sustainable Cities and Society* 2018:39:729–739. <https://doi.org/10.1016/j.scs.2018.01.013>
- [8] Sabūnas A. Climate Diplomacy of the Baltic States : The Role of Estonia , Latvia and Lithuania in the Annual Climate Change Summits. *Environmental and Climate Technologies* 2025:29(1):822–839. <https://doi.org/10.2478/rtuct-2025-0055>
- [9] Aboltins R., Jaunzems D. Identifying Key Challenges of the National Energy and Climate Plan through Climate Policy Integration Approach. *Environmental and Climate Technologies* 2021:25(1):1043–1060. <https://doi.org/10.2478/rtuct-2021-0079>
- [10] Measham T. G., Preston B. L., Smith T. F., Brooke C., Gorddard R., Withycombe G., Morrison C. Adapting to climate change through local municipal planning : barriers and challenges. *Mitigation and Adaptation Strategies for Global Change* 2011:16:889–909. <https://doi.org/10.1007/s11027-011-9301-2>
- [11] Crippa M., Guizzardi D., Pagani F., Banja M. GHG Emissions of All World Countries. Publications Office of the European Union, 2023.
- [12] Berrang-Ford L., Ford J. D., Paterson J. Are we adapting to climate change? *Global Environmental Change* 2011:21(1):25–33. <https://doi.org/10.1016/j.gloenvcha.2010.09.012>

- [13] Singh P., Mulay P., Patil Y. Mapping Climate Change Mitigation Strategies Adopted by Industries: An Overview from First Commitment of Kyoto Protocol (2009–2023). *Environmental and Climate Technologies* 2023;27(1):775–796. <https://doi.org/10.2478/rtuect-2023-0057>
- [14] Pakere I., Prodanuks T., Kamenders A., Veidenbergs I., Holler S., Villere A., Blumberga D. Ranking EU Climate and Energy Policies. *Environmental and Climate Technologies* 2021;25(1):367–381. <https://doi.org/10.2478/rtuect-2021-0027>
- [15] Fünfgeld H., Fila D., Dahlmann H. Upscaling climate change adaptation in small- and medium-sized municipalities: current barriers and future potentials. *Current Opinion in Environmental Sustainability* 2023;61:101263. <https://doi.org/10.1016/j.cosust.2023.101263>
- [16] Reckien D., Salvia M., Heidrich O., Church J. M., Pietrapertosa F., De Gregorio-Hurtado S., D'Alonzo V., Foley A., Simoes S. G., Lorencová E. K., Orru H., Orru K., Wejs A., Flacke J., Olazabal M., Geneletti D., Feliu E., Vasilie S., Nador C., Krook-Riekkola A., Dawson R. How are cities planning to respond to climate change? Assessment of local climate plans from 885 cities in the EU-28. *Journal of Cleaner Production* 2018;191:207–219. <https://doi.org/10.1016/j.jclepro.2018.03.220>
- [17] Rivas S., Urraca R., Bertoldi P. Covenant of Mayors 2020 Achievements: A Two-Speed Climate Action Process. *Sustainability* 2022;14(22):15081. <https://doi.org/10.3390/su142215081>
- [18] Bonnett N. L., Birchall S. J. The influence of regional strategic policy on municipal climate adaptation planning adaptation planning. *Regional Studies* 2023;57(1):141–152. <https://doi.org/10.1080/00343404.2022.2049224>
- [19] European Commission. Objectives and key pillars [Online]. [Accessed 03.04.2025]. Available: <https://eu-mayors.ec.europa.eu/en/about/objectives-and-key-pillars>
- [20] Melica G., Bertoldi P., Kona A., Iancu A., Rivas S., Zancanella P. Multilevel governance of sustainable energy policies : The role of regions and provinces to support the participation of small local authorities in the Covenant of Mayors. *Sustainable Cities and Society* 2018;39:729–739. <https://doi.org/10.1016/j.scs.2018.01.013>
- [21] Kona A., Bertoldi P., Monforti-Ferrario F., Rivas S., Dallemand J. F. Covenant of mayors signatories leading the way towards 1.5 degree global warming pathway. *Sustainable Cities and Society* 2018;41:568–575. <https://doi.org/10.1016/j.scs.2018.05.017>
- [22] Joint Research Centre: Institute for Energy and Transport, The covenant of mayors – In-depth analysis of sustainable energy action plans report. Publications Office of the EU, 2015. <https://data.europa.eu/doi/10.2790/043140>
- [23] Basso M., Tonin S. The implementation of the Covenant of Mayors initiative in European cities: A policy perspective. *Sustainable Cities and Society* 2022;78:103596. <https://doi.org/10.1016/j.scs.2021.103596>
- [24] Doukas H., Papadopoulou A., Savvakis N., Tsoutsos T., Psarras J. Assessing energy sustainability of rural communities using Principal Component Analysis. *Renewable and Sustainable Energy Reviews* 2012;16(4):1949–1957. <https://doi.org/10.1016/j.rser.2012.01.018>
- [25] Coelho S., Russo M., Oliveira R., Monteiro A., Lopes M., Borrego C. Sustainable energy action plans at city level: A Portuguese experience and perception. *Journal of Cleaner Production* 2018;176:1223–1230. <https://doi.org/10.1016/j.jclepro.2017.11.247>
- [26] Christoforidis G. C., Chatzisavvas K. C., Lazarou S., Parisses C. Covenant of Mayors initiative-Public perception issues and barriers in Greece. *Energy Policy* 2013;60:643–655. <https://doi.org/10.1016/j.enpol.2013.05.079>
- [27] European Environment Agency. European climate risk assessment – Executive summary. Publications Office of the European Union, 2024. <https://data.europa.eu/doi/10.2800/204249>
- [28] Spano D., Mereu V., Bacciu V., Marras S., Trabucco A., Adinolfi M., Barbato G., Bosello F., Breil M., Chiriaco M. V., Coppini G., Essenfelder A., Galluccio G., Lovato T., Marzi S., Masina S., Mercogliano P., Mysiak J., Noce S., Pal J., Reder A., Rianna G., Rizzo A., Santini M., Sini E., Staccione A., Villani V., Zavatarelli M. Analisi del rischio. I cambiamenti climatici in Italia (Risk Analysis: Climate Change in Italy). 2020. https://doi.org/10.25424/CMCC/ANALISI_DEL_RISCHIO (In Italian).
- [29] Kona A., Monforti-Ferrario F., Bertoldi P., Baldi M. G., Kakoulaki G., Vetter N., Thiel C., Melica G., Vullo E. L., Sgobbi A., Ahlgren C., Posnic B. Global Covenant of Mayors, a dataset of greenhouse gas emissions for 6200 cities in Europe and the Southern Mediterranean countries. *Earth System Science Data* 2021;13(7):3551–3564. <https://doi.org/10.5194/essd-13-3551-2021>
- [30] Kona A., Bertoldi P., Monforti-Ferrario F., Rivas S., Dallemand J. F. Covenant of mayors signatories leading the way towards 1.5 degree global warming pathway. *Sustainable Cities and Society* 2018;41:568–575. <https://doi.org/10.1016/j.scs.2018.05.017>
- [31] Pietrapertosa F., Salvia M., Hurtado S. D. G., D'Alonzo V., Church J. M., Geneletti D., Musco F., Reckien D. Urban climate change mitigation and adaptation planning: Are Italian cities ready? *Cities* 2019;91:93–105. <https://doi.org/10.1016/j.cities.2018.11.009>
- [32] Di Battista D., Barchiesi C., Paolo L. D., Abbate S., Sorvillo S., Cinocca A., Carapellucci R., Ciamponi D., Cardone D., Corroppo S. The reporting of sustainable energy action plans of municipalities: Methodology and results of case studies from the abruzzo region. *Energies* 2021;14(18):1–17. <https://doi.org/10.3390/en14185932>
- [33] Santopietro L., Scorza F. The Italian experience of the covenant of mayors: A territorial evaluation. *Sustainability* 2021;13(3):1–23. <https://doi.org/10.3390/su13031289>

- [34] Famoso F., Lanzafame R., Monforte P., Scandura P. F. Analysis of the Covenant of Mayors Initiative in Sicily. *Energy Procedia* 2015:81:482–492. <https://doi.org/10.1016/j.egypro.2015.12.122>
- [35] Pietrapertosa F., Salvia M., De Gregorio S., Geneletti D., Alonzo V. D., Reckien D. Multi-level climate change planning: An analysis of the Italian case. *Journal of Environmental Management* 2021:289:112469. <https://doi.org/10.1016/j.jenvman.2021.112469>
- [36] Eurostat. NUTS – Nomenclature of territorial units for statistics. Overview [Online]. [Accessed 02.04.2025]. Available: <https://ec.europa.eu/eurostat/web/nuts>
- [37] Istat. Resident population on 1st January [Online]. [Accessed 02.04.2025]. Available: https://esploradati.istat.it/databrowser/#/it/dw/categories/IT1.POP.1.0/POP_POPULATION/DCIS_POPRES1
- [38] Lucchitta B., Palermo V., Melica G., Molteni T., Burro A., Bertoldi P., Croci E. Are European cities achieving emission reduction commitments? A comparative analysis under the Covenant of Mayors initiative. *Heliyon* 2024:10(1):e23423. <https://doi.org/10.1016/j.heliyon.2023.e23423>
- [39] Rivas S., Urraca R., Palermo V., Bertoldi P. Covenant of Mayors 2020 : Drivers and barriers for monitoring climate action plans. *Journal of Cleaner Production* 2021:332:130029. <https://doi.org/10.1016/j.jclepro.2021.130029>
- [40] Global Covenant of Mayors for Climate and Energy. Our cities [Online]. [Accessed 01.04.2025]. Available: <https://www.globalcovenantofmayors.org/our-cities/>
- [41] Baldi M., Franco de Los Rios C., Melica G., Treville A., Bertoldi P. GCoM - MyCovenant, 5th Release - January 2024. European Commission Joint Research Centre [Dataset], 2023 [Online]. Available: pid: <http://data.europa.eu/89h/9575255b-5807-4494-9f53-3c382c89df10>
- [42] Reckien D., Salvia M., Pietrapertosa F., Simoes S. G., Olazabal M., Hurtado S. D. G., Geneletti D., Lorencova E. K., D'Alonzo V., Krook-Riekkola A., Fokaides P. A., Ioannou B. I., Foley A., Orru H., Orru K., Wejs A., Flacke J., Church J. M., Feliu E., Vasilie S., Heidrich O. Dedicated versus mainstreaming approaches in local climate plans in Europe. *Renewable and Sustainable Energy Reviews* 2019:112:948–959. <https://doi.org/10.1016/j.rser.2019.05.014>
- [43] Tuğaç Ç. Climate change adaptation: The missing component in the local climate change action plans of Turkish metropolitan municipalities. *Urban Climate* 2025:61:102396. <https://doi.org/10.1016/j.uclim.2025.102396>
- [44] Bertoldi P. How to develop a Sustainable Energy and Climate Action Plan (SECAP)" PART 2: Baseline Emission Inventory (BEI) and Risk and Vulnerability Assessment (RVA), EUR 29412. Guidebook. Luxembourg: Publications Office of the European Union, 2018.
- [45] Bertoldi P. How to develop a Sustainable Energy and Climate Action Plan (SECAP). Guidebook. 2018.
- [46] Neij L., Heiskanen E. Municipal climate mitigation policy and policy learning – A review. *Journal of Cleaner Production* 2021:317:128348. <https://doi.org/10.1016/j.jclepro.2021.128348>
- [47] Crippa M., et al. GHG Emissions of All World Countries. Publications Office of the European Union, Luxembourg, 2023.
- [48] Croci E., Lucchitta B., Molteni T. Low carbon urban strategies: An investigation of 124 European cities. *Urban Climate* 2021:40:101022. <https://doi.org/10.1016/j.uclim.2021.101022>
- [49] Vicarelli M., Sudmeier-Rieux K., Alsadadi A., Shrestha A., Schütze S., Kang M. M., Leue M., Wasielewski D., Mysiak J. On the cost-effectiveness of Nature-based Solutions for reducing disaster risk. *Science of The Total Environment* 2024:947:174524. <https://doi.org/10.1016/j.scitotenv.2024.174524>
- [50] Picavet M. E. B., de Macedo L. S. V., Bellezoni R. A., Puppim de Oliveira J. A. How can Transnational Municipal Networks foster local collaborative governance regimes for environmental management? *Environmental Management* 2023:71(3):505–522. <https://doi.org/10.1007/s00267-022-01685-w>
- [51] Colocci A., Borello S., Pietta A. Local alliances against climate change: exploring urban experiments within the Covenant of Mayors initiative in Piedmont. *Territory, Politics, Governance* 2025:2671:1–20. <https://doi.org/10.1080/21622671.2025.2563627>
- [52] Bulkeley H., Castán Broto V. Government by experiment? Global cities and the governing of climate change. *Transactions of the Institute of British Geographers* 2013:38(3):361–375. <https://doi.org/10.1111/j.1475-5661.2012.00535.x>
- [53] Davidson K., Coenen L., Gleeson B. A Decade of C40: Research Insights and Agendas for City Networks. *Global Policy* 2019:10(4):697–708. <https://doi.org/10.1111/1758-5899.12740>