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What drives sustainable climate change adaptation at the local level? Approaching three knowledge gaps

Torbjørn Selseng^{1,2} | Arild Gjertsen³

¹Western Norway Research Institute, Sogndal, Norway

²Faculty of Technology, Environmental and Social Sciences, Western Norway University of Applied Sciences, Sogndal, Norway

³Nordland Research Institute, Bodø, Norway

Correspondence

Torbjørn Selseng, Western Norway Research Institute, Sogndal, Norway.
Email: tse@vestforsk.no

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Abstract

This paper investigates three gaps in climate change adaptation research: the drivers of sustainable adaptation efforts, the role of multilevel governance, and how challenges differ by municipality size. Analyzing data from three surveys across Norwegian municipalities and counties, pooling 668 responses, the study statistically assesses drivers of adaptation efforts in 146 municipalities. Key findings show that factors such as political awareness, risk perception, stakeholder collaboration, and municipality size significantly influence adaptation efforts, with effectiveness depending on the conceptualization of adaptation. Political and stakeholder support is essential for mainstreaming, monitoring, and implementing adaptation measures, but not for promoting sustainability. This shows that local administrations are free to choose sustainable CCA, but that the quality of participatory processes should be scrutinized. The study also highlights that regional support is crucial for smaller municipalities, and that the intensity of regional engagement is more important than the support method.

KEYWORDS

adaptation, multilevel governance, municipality, sustainable adaptation, transformation

1 | INTRODUCTION

The impacts of a changing climate will not only make the Sustainable Development Goals (SDGs) hard to achieve, but also erode past human development gains (IPCC, 2022; United Nations, 2015; Wen et al., 2023). Successful adaptation can benefit economic, social, and other environmental goals (Hossain et al., 2024; Reckien, Magnan, et al., 2023), while insufficient action on climate change can undermine 16 of the 17 SDGs (Fuso Nerini et al., 2019). Currently, society is not on track. The technical dialog report of the first global stocktake of the Paris Agreement at COP28, states that “there is a rapidly closing window of opportunity to secure a liveable and sustainable future for all,” and that progress on adaptation “must undergo a step change” (UNFCCC, 2023).

At the forefront of the global effort to accelerate societal adaptation to climate change, lies local governments in different shapes and sizes (Berrang-Ford et al., 2021; Dodman et al., 2022). The local level is where many of the consequences of climate change materialize and vulnerabilities are recognized (Heidrich et al., 2016). Local governments are often also the wielders of important tools in the climate change adaptation (CCA) effort. Spatial planning and building permits are two examples of how local government can decide where and how we live and travel.

Given local governments' unique position in the CCA effort, investigations into what is being done where, by whom, how, and why (or why not), has been a growing focus of academic literature the past two decades (Castán Broto & Westman, 2020). Fundamental methodological challenges related to defining “what is CCA” and

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“what is successful CCA” have impeded progress in large-*N* comparative studies (Biesbroek et al., 2018; Ford & Berrang-Ford, 2016). For a review of the challenges of tracking adaptation, see Section A in the Appendix S1. This has led to ambiguity with only a few insights that holds true across methodologies and types of data: One, local governments around the world are not doing enough to safeguard infrastructure, people, and ecosystems (Berrang-Ford et al., 2021; Magnan et al., 2023; Olazabal & Ruiz De Gopegui, 2021). Two, the largest cities in the most wealthy countries are the most active (Magnan et al., 2023; Olazabal et al., 2019; Reckien et al., 2018).

Cross-validated evidence on drivers to adaptation is similarly limited in large-*N* studies (Fila et al., 2023; Rogers et al., 2023). Scholarship, mainly from qualitative studies, have identified political engagement and awareness (Rogers et al., 2023), network and research project participation (Fila et al., 2023; Hoppe et al., 2016; Pasquini, 2020), experience with extreme events and general risk perception (Amundsen & Dannevig, 2021; Patterson, 2021; Rogers et al., 2023), staffing, income, and expenditure (Fila et al., 2023; Rogers et al., 2023), stakeholder collaboration (Rivas et al., 2021; Singh et al., 2022), champions and change agents (Fila et al., 2023), access to data and information (Dodman et al., 2022; Rogers et al., 2023), municipality size (Amundsen et al., 2010; Fila et al., 2023; Fünfgeld et al., 2023), and support from other levels of government (Fila et al., 2023; Nalau et al., 2015; Oulahan et al., 2018) as major drivers of municipal CCA efforts.

Although several of these have been tested in comparative quantitative research designs as well, many important questions remain unanswered. Among these are three persistent knowledge gaps related to drivers of CCA at the local level. The first one is the role of multilevel governance. Although highlighted as a panacea to local CCA (Amundsen et al., 2010; Bonnett & Birchall, 2023; Castán Broto & Westman, 2020), no large-*N* studies have attempted to systematically and comprehensively assess which capacities at which higher level of government support local action. The second one is the specific challenges of small and medium-sized municipalities. Although there is wide agreement that size matters and that different-sized municipalities have vastly different preconditions, large-*N* investigations into barriers and drivers have not distinguished between municipalities at different population thresholds (Fila et al., 2023; Hoppe et al., 2016). The third one relates to the quality of the CCA process at the local level. The literature increasingly acknowledges that CCA efforts must move beyond the short-sighted, departmentalized, fragmented, and incremental approaches that have characterized efforts thus far, toward promoting a transformation toward sustainability (Dodman et al., 2022; Pelling et al., 2015; Reckien, Magnan et al., 2023). However, several authors argue that more empirical research is needed to understand the drivers associated with holistic CCA processes in line with the promise of avoiding maladaptation and promoting sustainable development (Berrang-Ford et al., 2021; Ford & Berrang-Ford, 2016; Singh et al., 2022).

In this paper, we present the first systematic and comprehensive approach that addresses these three knowledge gaps. By investigating them in tandem, the research design facilitates a robust assessment of

their relative importance. We employ data from three surveys, one to recipients in 146 Norwegian municipalities from 2021, one to 39 administrative leaders in all Norwegian counties from 2020, and one to 483 administrative employees from 2022, pooling 668 individual responses. By statistically assessing both the specific challenges that municipalities at different population thresholds face in performing holistic CCA, as well as the individual effects of the multitude of different capacities that different government levels provide, our design represents a novel contribution to the ongoing effort of systematically testing drivers of local adaptation. Among similar studies, neither the mediating effect of population size, nor the disaggregation of capacities at the regional level have been included in analyses (Dilling et al., 2017; dos Santos & Puppim de Oliveira, 2024; Patterson, 2021; Valdivieso et al., 2017).

2 | KNOWLEDGE GAPS AND CONTEXT

2.1 | The Norwegian context

The Norwegian three-tier system consists of a strong, but compartmentalized state, and a comparatively autonomous, but less powerful elected regional (county council) and local government (municipality) (Dannevig & Aall, 2015). In Norway, all cities are in a municipality's jurisdiction. The 356 municipalities have an average population of 15,240 inhabitants, and about half of them have a population below 5000. See Figure 1 for an overview of the municipalities included in the study.

Local governments are primarily responsible for CCA, a role that has evolved from voluntary to mandatory, especially in municipal activities like spatial planning and hazard mapping (Dannevig et al., 2012). They must consider future climate risks, restrict development in risk-prone areas, ensure new developments are climate-adapted, and include climate risks in assessment (Selseng et al., 2021).

The regional level includes both the elected county council (CC) and the county governor (CG), the latter being the central government's regional representative. The CG oversees CCA at the regional level, supervising municipalities and managing civil protection. Meanwhile, the CC, though having no formal CCA tasks, often actively engages in CCA efforts with municipalities, serving as a network node and coordinator.

Previous studies suggest that enhancing the CC's role could strengthen multilevel coordination in CCA, particularly benefiting smaller and medium-sized municipalities (Dannevig & Aall, 2015; Hanssen et al., 2013). This could address capacity challenges and improve the overall effectiveness of Norway's CCA initiatives.

2.2 | Gap 1: Multilevel governance

The first knowledge gap that we address is the role of higher levels of government. Higher-level governments' ability to coordinate and support local action is identified across the literature as one of the most

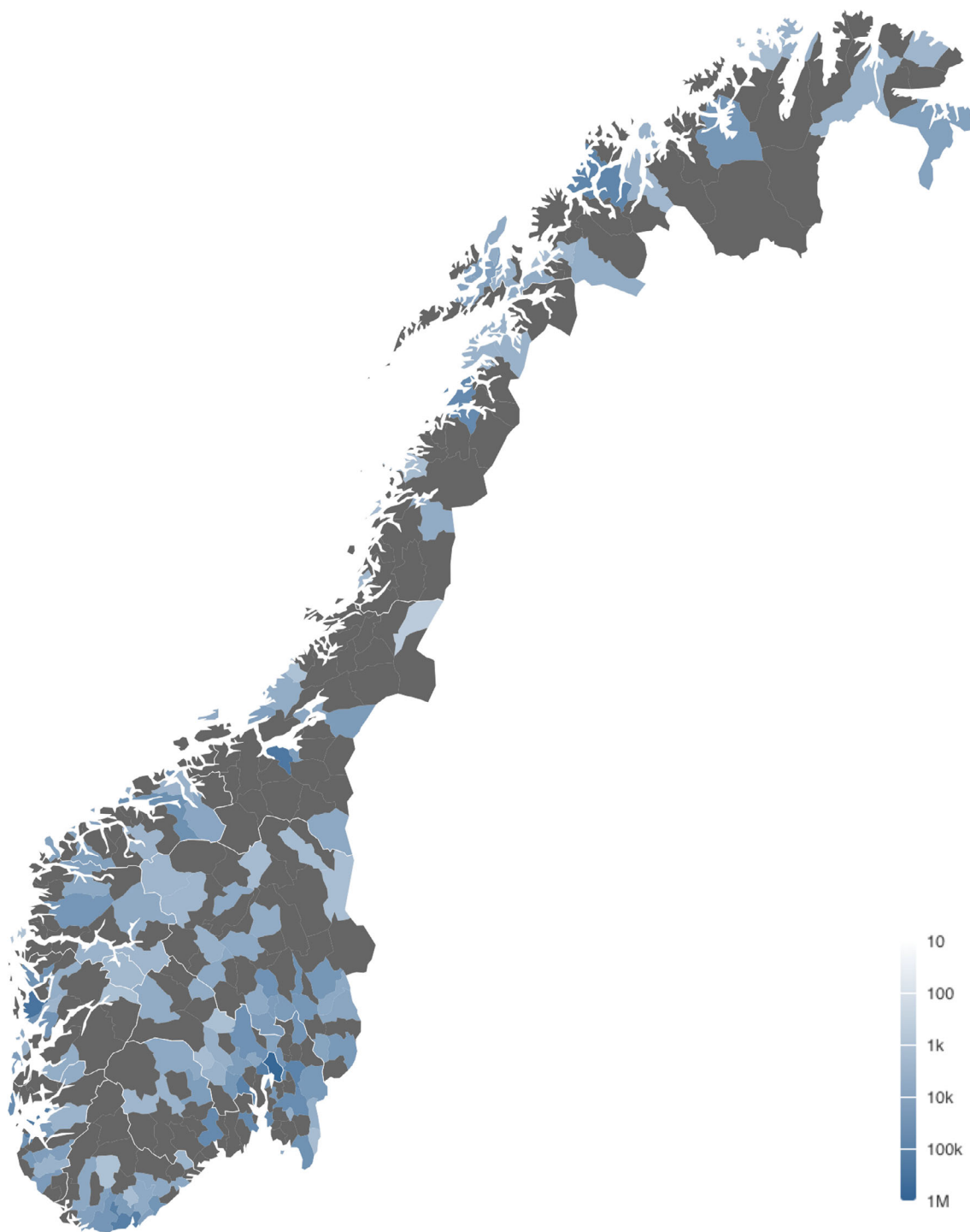


FIGURE 1 Municipalities included in the study. Darker blue shading = more inhabitants. Gray shading = municipalities not included. Thin light gray lines = municipality borders. Thick white lines = county borders.

important determinants (Castán Broto & Westman, 2020; Dodman et al., 2022; Fila et al., 2023). Higher levels of government can provide local capacity building (Hoppe et al., 2016), basic regulations and a strong mandate (Fila et al., 2023; Lesnikowski et al., 2021; Sainz de Murieta et al., 2020), technical and financial support (Dilling et al., 2017; Oulahen et al., 2018; Sainz de Murieta et al., 2020), leadership and guidance (Bonnett & Birchall, 2023; Nalau et al., 2015;

Shi, 2019), learning and knowledge (Dannevig & Aall, 2015; Orderud & Naustdalslid, 2020), and coordination of higher-level sectoral policies (Shi, 2019).

While the importance of multilevel governance is widely recognized, research often does not distinguish between the roles of various higher-level governments (Biesbroek et al., 2018; Rogers et al., 2023; Shi, 2019). And although some large-N studies recognize

the importance of the national or regional context (Araos et al., 2016; Reckien et al., 2018), very few studies quantitatively assess the impact of different capacities, policies, and jurisdictional landscapes at these levels (Biesbroek et al., 2018). Investigating national level drivers, Lesnikowski et al. (2021) looks at the relationship between national policy styles, state structure, and CCA implementation styles in local governments. Similarly, Heidrich et al. (2016), looks at the relationship between experience with CCA planning at the national level and cities' implementation of CCA plans. At the regional level, a comprehensive and systematic statistical attempt does not exist. Only some studies have treated the regional level as a heterogeneous institution: Reckien et al. (2015) looks at adaptive capacity at the regional level and the presence of a CCA plan in cities and Dilling et al. (2017) treats the state as a dichotomous variable when investigating the presence of American cities' CCA measures.

This leaves a significant knowledge gap in the literature. Local governments view, on average, their state, provincial, or regional government as more important than their national government (Patterson, 2021). Regional governments are uniquely positioned to bridge top-down national policies and bottom-up local initiatives, and provide support, guidance, and knowledge for the specific regional contexts. In this study, we address this knowledge gap by investigating seven different drivers for local CCA (see Section 3.1) provided by the regional level identified across the literature, while holding the national government level constant.

2.3 | Gap 2: Small and medium-sized municipalities

The second knowledge gap that we address concerns the efforts, drivers and barriers in small and medium-sized municipalities. The largest cities have been the focal point of the bulk of the literature and almost all large-N studies (Fila et al., 2023; Fünfgeld et al., 2023; Rogers et al., 2023). And while large cities are indeed of interest, due to increasing urbanization and big cities' corresponding influence on global policy (Brenner, 1998), the vast majority of the planet's population will continue to live in rural areas and smaller-sized towns (Hoornweg & Pope, 2017).

Small and medium-sized municipalities face distinct challenges. Although not burdened to the same degree by departmentalization as larger municipalities (Fila et al., 2023), the lack of "critical mass" exacerbate the issue of raising sufficient fiscal and staffing resources for adaptation planning (Amundsen et al., 2010; Fünfgeld et al., 2023; Hoppe et al., 2016). This matters not only for the ability to actively engage with CCA (Fila et al., 2023), but also for access to transnational or national knowledge networks (Fünfgeld et al., 2023; Orderud & Naustdalslid, 2020), access to capacity building schemes granted by national government, (Hoppe et al., 2016) access to and the ability to make use of data, tools, and knowledge (Fila et al., 2023; Fünfgeld et al., 2023), the capacity to consider long-term effects (Fila et al., 2023), to implement proactive measures (Amundsen & Dannevig, 2021; Orderud & Naustdalslid, 2020), and to initiate and sustain a holistic approach to CCA (Bausch & Koziol, 2020), as well as local governments' perception of the level of responsibility that they

should take (Amundsen et al., 2010). Interestingly, one of the most frequently identified drivers for CCA engagement in small and medium-sized municipalities is support from other government levels (Fünfgeld et al., 2023). Strong vertical policy coherence and collaboration can even out the playing field by providing knowledge and direction for smaller municipalities.

Based mostly on qualitative research, two recent reviews of this literature conclude that the smaller municipalities are lagging severely behind, and that quantitative assessments of barriers and enablers are acutely needed (Fila et al., 2023; Fünfgeld et al., 2023). Quantitative studies have confirmed that the largest cities are more likely to have adaptation plans than medium-sized ones in a sample of 200 (Reckien et al., 2015) and 885 (Reckien et al., 2018) European cities, that adaptive capacity correspond with size in 665 Brazilian municipalities (Neder et al., 2021), that large cities show higher levels of adaptation readiness than smaller ones in 104 German cities (Otto et al., 2021), and that population has significant relationship with certain types of policy implementation styles in 125 local governments in Canada, France, Germany, the Netherlands, and the United Kingdom (Lesnikowski et al., 2021). However, none of these studies investigate the specific drivers and barriers at different population levels.

2.4 | Gap 3: Holistic CCA

The third knowledge gap that we address in this study are the drivers and barriers related to what Magnan et al. (2020) identifies as the frontiers of current adaptation science: the incremental versus transformational divide and the maladaptation versus adaptation divide. These "frontiers" reflect the increasing acknowledgement that, firstly, approaches to CCA must aim at a fundamental shift in human and environmental relations and interactions to address the structural and root causes of vulnerabilities that hamper just and sustainable long-term CCA (Aall et al., 2023; Pelling et al., 2015; Shi et al., 2015). And secondly, that approaches must aim to avoid maladaptation—to preempt undesirable and unintended adaptation outcomes (Singh et al., 2022). CCA cannot be treated as a separate issue, removed from other environmental and social SDGs (United Nations, 2015), as this risks increased or shifted vulnerability to climate change, increased greenhouse gas emissions, or increased inequity, all expressions of maladaptive outcomes (Aall et al., 2023; Schipper, 2020; Singh et al., 2022). Two recent reviews of this literature find that responses to date have been fragmented and incremental (Berrang-Ford et al., 2021; Shi & Moser, 2021).

In our paper, we use the term "holistic CCA" to denote this type of process. It draws on elements from related terms in the literature, such as "avoiding maladaptation," "sustainable adaptation," and "transformation." These terms are often used interchangeably and definitions tend to be overlapping (Singh et al., 2022). However, as a point of reference, it comes closest to what Singh et al. (2022) refer to as "effective adaptation as avoided maladaptation" in their typology of normative framings of CCA.

We operationalize it based on key attributes from the literature (see Table 1): One, the presence of both physical and organizational

TABLE 1 Variable descriptions.

	Variable name	Description	Data source
Dependent variables			
	Holistic	An additive index combining Future, MRE, Sustainability, Mainstreaming and Measures	
	Holistic planning	An additive index combining Future, MRE, Sustainability and Mainstreaming	
	Measures	Existence of different types of CCA measures (soft and hard) in key sectors. Index based on 8 items: Water and sewage, roads/streets/parks, agriculture, real estate management, nature management, energy, schools, public health	Norwegian Climate Monitor (2021)
	Mainstreaming	Degree of integration of CCA into key steering documents, plans, strategies, and processes. Index based on 7 items: Building application treatment, the master plan's land-use part, the master plan's social element, subplans/area plans/thematic plans, communication, economic planning	Norwegian Climate Monitor (2021)
	Sustainability	Degree that CCA is considered in relation to other policy fields, for example, through identifying conflicts or win-win-measures. Index based on 8 items. Stormwater treatment, conservation of nature and biological diversity, climate change mitigation, energy measures, health, transport, agriculture, cultural heritage	Norwegian Climate Monitor (2021)
	MRE	Degree of integration of CCA into internal monitoring, reporting, and evaluation	Norwegian Climate Monitor (2021)
	Future	Degree that future consequences of climate change (as opposed to present) are used as a basis for CCA	Norwegian Climate Monitor (2021)
Drivers local level			
Political awareness	MUN Green Politics	Share of council members from green parties (R + SV + MDG). Percentage	Statistics Norway
	MUN Political Awareness	Degree of knowledge on CCA among elected council members	Norwegian Climate Monitor (2021)
Network and research participation	MUN Networks	Degree of participation in networks for CCA	Norwegian Climate Monitor (2021)
	MUN Years in TNN	Combined number of years as member of ICLEI, C40, and Covenant of Mayors	Their websites
	MUN Research Projects	Degree of participation in research and development projects	Norwegian Climate Monitor (2021)
Experience and risk perception	MUN Risk Perception	Degree of expected impact from consequences of climate change. Index based on 8 items: More slides and falls, more flooding, more extreme precipitation, sea level rise, storm surge, heat waves, drought, transboundary climate risk	Norwegian Climate Monitor (2021)
	MUN Experience Extreme Events	Number of different extreme weather event types experienced 2012–2022	DSB (2016, 2019, 2022)
Staffing, income and expenditure	MUN Income	The municipality's disposable income per inhabitant	Statistics Norway
	MUN Expenditure 1	Share of total wage expenditures spent on wages for planning, building applications, and environmental management. Percentage	Statistics Norway

TABLE 1 (Continued)

	Variable name	Description	Data source
	MUN Expenditure 2	Share of total expenditure spent on planning, building applications, and environmental management. Percentage	Statistics Norway
Climate plan	MUN CE plan age	Years since climate and energy has been included in master plans, implemented as a separate plan or revised	Statistics Norway
Stakeholder collaboration	MUN Stakeholder Collaboration	Degree of organized collaboration with business, inhabitants, or other actors in the municipality	Norwegian Climate Monitor (2021)
Size	MUN Size	Number of inhabitants	Statistics Norway
Drivers regional level			
Political awareness	REG Political Awareness CC	Degree of knowledge about CCA among political leadership	Norwegian Climate Monitor (2022)
	REG Green Politics CC	Share of CC members from green parties (R + SV + MDG). Percentage	Statistics Norway
Risk perception	REG Risk Perception CC/both/CG	Degree of expected impact from consequences of climate change. Index based on 9 items. More slides and falls, more flooding, more precipitation, more extreme precipitation, sea level rise, storm surge, heat waves, drought, and transboundary climate risk	Norwegian Climate Monitor (2022)
Regional collaboration	REG Role Clarification both	Degree of clear role distribution between the CC and CG in CCA work. Answers from both CC and CG combined	Norwegian Climate Monitor (2020)
	REG Collaboration both	Degree of collaboration between CC and CG in CCA work. Answers from both CC and CG combined	Norwegian Climate Monitor (2020)
Sustainability	REG Sustainability CC/CG	Degree that CCA is considered in relation to other policy fields, for example, through identifying conflicts or win-win-measures. Index based on 7 items	Norwegian Climate Monitor (2022)
Staffing and expenditure	REG Expenditure 1 CC	Share of CC's expenditure used for planning purposes. Percentage. Average 2020–2022	Statistics Norway
	REG Expenditure 2 CC	Share of CC's expenditure used for planning purposes. Percentage. Average per municipality in the county 2020–2022	Statistics Norway
	REG Expenditure 3 CC	Working hours spent on planning and treatment of plans in CC. Man-years. Average 2020–2022	Statistics Norway
	REG Expenditure 4 CC	Working hours spent on planning and treatment of plans in CC. Man-years. Average per municipality in the county 2020–2022	Statistics Norway
Leadership and support	REG Consultation CC/CG	Degree that CCA is emphasized in consultation processes	Norwegian Climate Monitor (2022)
	REG Guidance CC/CG	Degree that CCA is emphasized in guidance of municipalities	Norwegian Climate Monitor (2022)
	REG Networks CC/CG	Degree that CCA is emphasized in participation in municipal networks	Norwegian Climate Monitor (2022)
	REG Sum of Objections CG	Objections to municipal plans on the grounds of land slide risk, flood risk, or CCA. Sum of 2015–2021 as percentage of number of municipalities in the county	Statistics Norway

Note: CC, CG, and both denotes whether the variable consists of data from the county council (CC), the County Governor (CG), or an average from both (both). MUN refers to local level drivers, while REG refers to regional level drivers.

measures in different key sectors, to indicate whether there is a tangible ongoing effort across the range of relevant sectors (Rogers et al., 2023). Second, the extent of mainstreaming, understood as the process of integrating CCA into established functions, policy, and practices of local government, which determines the potential of CCA being considered across municipal processes and sectors to counteract departmentalization and fragmentation (Aylett, 2015; Olazabal & Ruiz De Gopegui, 2021). Third, the extent that trade-offs and synergies with other policy fields and SDGs are considered in CCA planning (Aall et al., 2023). Fourth, the extent of monitoring, reporting, and evaluation, which is a prerequisite for learning, adjusting, and responding to shifting vulnerabilities and uncertainties (Olazabal et al., 2017). Fifth, the extent that future consequences of climate change are considered, which is essential for long-term cross-generational planning that avoids maladaptation (Magnan et al., 2020; Singh et al., 2022).

3 | METHOD AND DATA

3.1 | Variables

CCA has different interpretations in the scientific community and local governments deal with it in different ways (Biesbroek et al., 2018; Lesnikowski et al., 2019). Handling this “dependent variable problem” requires transparent conceptualization and operationalization of dependent variables lest we continue comparing “apples and oranges” in this field (Dupuis & Biesbroek, 2013).

In this study, the concept of holistic CCA is decomposed using five different dependent variables, along with two composite indices (see Table 1). One index combines all five other dependent variables, while the other index excludes the “Measures” variable. This allows us to specifically examine the policy planning-to-implementation-gap: that many municipalities develop adaptation strategies but often stop short of actual implementation (Rogers et al., 2023). This approach also allows us to investigate the heterogeneity of drivers that is associated with different forms of and approaches to CCA, an issue that is often recognized, but not specifically dealt with (Patterson, 2021). For a description of the dependent variables, see Section 2.4 and Table 1. For a comprehensive overview of all items included in the dependent variables, see Section B in Appendix S1.

At the local level, we include variables for seven different drivers of CCA (see Table 1 for a description of each variable). First, political awareness. Lack of knowledge, commitment, and support from municipal elected leaders is the most frequently identified barrier to local CCA (Rogers et al., 2023). Some local politicians either consider CCA to be in conflict with urban development, consider it too politically risky, are attentive only to short-term goals, or do not believe in anthropogenic climate change (Rogers et al., 2023; Tenali & McManus, 2022). Shi et al. (2015) finds that greater political commitment is associated with cities engagement with CCA. Second, network and research participation. For smaller municipalities, pooling knowledge and support from surrounding municipalities can alleviate

challenges (Fila et al., 2023; Hoppe et al., 2016; Pasquini, 2020). Transnational networks, available mainly to larger cities, have shown to have a positive effect on the local CCA process and output (Heikkinen et al., 2020). Aguiar et al. (2018) also finds that participation in research projects is a key trigger for local CCA, as academia often brings more holistic perspectives to the decision making process (Colasante et al., 2024). Third, experience and risk perception. Experience with extreme weather events is assumed to be a catalyst for local CCA efforts (Dilling et al., 2017). However, others find the opposite or no effect (Nohrstedt et al., 2022; Patterson, 2021). This may be because observed or projected climate vulnerability matters little if it is not reflected in the perceptions of the municipal employees (Dilling et al., 2017; Shi et al., 2015; Stotten, 2023). Fourth, staffing, income, and expenditure. Resource constraints, either through staff time or numbers, or financial capacity, are commonly mentioned barriers to CCA (Rogers et al., 2023). In smaller municipalities, resource constraints are especially prominent (Fila et al., 2023). Shi et al. (2015) find higher general public spending to be associated with more engagement with CCA. Fifth, climate plan. According to Norwegian planning law, plans that involve climate and energy should be revised every 4 years (The Planning and Building Act, 2008, §10–1). This is where the CCA effort is grounded for most municipalities. An outdated climate and energy plan will therefore often mean a less updated adaptation effort. Sixth, stakeholder collaboration. Authors argue that stakeholder involvement is important for overcoming legal, institutional, and financial barriers (Hölscher et al., 2024; Wamsler, Wickenberg, et al., 2020), for the legitimacy and acceptance (Rivas et al., 2021), and the transformative potential (Cattino & Reckien, 2021) of the output. However, several authors find that public engagement in CCA processes to date have been largely tokenistic, lacking the depth, and scope needed to enhance sustainability (Kiss et al., 2022; Puskás et al., 2021). Wamsler, Alkan-Olsson, et al. (2020) even finds that citizen participation, in its current form in Sweden, has eroded sustainability in local CCA processes. Seventh, population. Size does matter, as we argue throughout this paper.

At the regional level, we include variables for six different drivers of local CCA (see Table 1 for a description of each). First, political awareness. Like the local level, we expect awareness among the political leadership in the counties to affect the county's level of engagement with CCA. Second, risk perception. Like the local level, we expect perceived future climate risk to correspond with higher prioritization of CCA at the regional level. We use this as an expression of the motivation for and engagement with CCA in the county that our other variables do not pick up. Third, regional collaboration. Misalignment of policies at higher levels is a significant barrier to CCA (Oulahen et al., 2018). Unclear roles and lack of collaboration hinders effective leadership and assistance vis a vis the local level. Fourth, sustainability. For the municipality to initiate holistic CCA processes in line with the promise of avoiding maladaptation, we expect the CC's focus on such processes to be impactful. Fifth, income and expenditure. The regional level can provide municipalities with guidance, leadership, capacity building, knowledge and technical, and financial assistance (Bonnett & Birchall, 2023; Fila et al., 2023; Shi, 2019). We

expect these capacities to be enhanced in counties with more available staff and financial resources. Sixth, leadership and support. Although authors have argued that leadership and support from the regional level are crucial (Fila et al., 2023; Nalau et al., 2015; Oulahen et al., 2018), little is known about the relative importance of different types of leadership and support activities. We include several measures to show that we acknowledge that CCs and CGs have different institutional cultures, interpret, and execute CCA differently. We expect overall that smaller municipalities are more dependent on regional leadership and support.

3.2 | Limitations

We include many drivers in our statistical exercise based on an extensive review of the literature. However, there are two variables that we have not been able to collect high-quality data on. One is equity and social justice, that we would have liked to include among the dependent variables (D'Adamo et al., 2024). Authors argue that ensuring equity should be regarded as a central tenet in CCA processes aimed at avoiding maladaptation (Magnan et al., 2020) and sustainable development (Singh et al., 2022). Reckien, Buzasi, et al. (2023) find that CCA plans often neglect equity and social justice. Another is the role of pioneers or “champions” in the local administration that we would have liked to have as an independent variable. Although quantitative studies does not find a significant correlation between policy champions and CCA action (Dilling et al., 2017), the presence of change agents is often mentioned as pivotal in case studies (Fila et al., 2023).

3.3 | Data

The primary data for this analysis comes from either surveys or official government sources (see Table 1). The survey data is part of the Norwegian Climate Monitor project, which examines CCA efforts across Norwegian society. This analysis combines data from a 2021-survey to 146 Norwegian municipalities with two regional surveys from 2020 to 2022 (Norwegian Climate Monitor, 2020, 2021, 2022). The municipality survey was distributed to all 356 municipalities and got 41% response rate (see Figure 1). The response rate is skewed toward the largest municipalities: Among the largest half of municipalities, 48% responded to the survey, and among the smallest half, 35% responded. The 2020-survey was done at the leadership level at different departments at the CC and CG and had 39 out of 42 responses from all counties. The 2022-survey was distributed widely to administrative employees working with CCA-relevant topics and had 483 responses spread across all counties. All survey data utilizes a 5-point Likert scale.

For analyzing this data, central tendency indices are used, combining multiple survey items. Averages are employed to calculate tendencies across different respondents, particularly in the regional surveys. Medians are used to calculate central tendency across responses from the same respondent, such as in the municipal survey.

See Section B Appendix S1 for a detailed overview of all survey items included in the variable list in Table 1.

Using self-reported survey data as proxy for engagement with CCA has faced criticism for showing higher rates of engagement with adaptation than alternative methods (Araos et al., 2016; Olazabal & Ruiz De Gopegui, 2021). However, this study argues that as long as these higher engagement rates are uniformly distributed across the sample, they do not skew the analysis results. Additionally, metrics for assessing CCA action and its drivers cannot solely rely on alternative methods, especially for small and medium-sized local governments. Alternative data sources, like formal planning documents, often provide only a partial view of CCA efforts and are less applicable in smaller municipalities where efforts are less formalized (Patterson, 2021). Public metrics often lack data fit for the research question (Biesbroek et al., 2018), or have lower quality for municipalities with insufficient resources to assess and report progress (Singh et al., 2022).

3.4 | Analysis

We adopt an explorative approach, justified by the low level of maturity of quantitative research on drivers of holistic CCA across different municipality sizes and the regional level's contribution. Our specific interest in how municipality size mediates several of the hypothesized effects, means that we also aim to investigate the interaction effect between size and the other dependent variables (Whisman & McClelland, 2005).

To do this, we apply a focused approach using a combination of the bivariate correlation between each independent variable and the dependent variables, and separate regression analysis for each independent variable and its interaction with the dependent variable for initial variable selection. We use the *p*-values for either Pearson's *r* correlation or OLS regression coefficients to decide on initial variable selection. The threshold is set at $p < .05$ for Pearson's *r* correlation and $p < .1$ for OLS regression interaction coefficient. The output from this can be seen in Section C and D in the Appendix S1. In cases where two or more highly correlated (Pearson's $r > .75$) independent variables with conceptually similar interpretation, such as “REG Risk Perception both” and “REG Risk Perception CC,” are significant, we omit the one with the highest *p*-value to mitigate excessive multicollinearity.

After initial variable selection, we apply the adaptive LASSO to the OLS models from initial variable selection (Zou, 2006). The adaptive LASSO is a type of penalty-based algorithm that applies shrinkage factors to regression coefficients based on their contribution to the modeling of the dependent variable and is particularly useful when the true underlying model is unknown. The adaptive LASSO uses the scale of the coefficients of each initial OLS model fit to calculate a weighted penalty for each coefficient, making it more consistent with variable selection than the original LASSO (Zou, 2006). We perform OLS regression analyses on each dependent variable using the non-zero coefficients from the adaptive LASSO. Each model is therefore unique, as we also would expect given the different concepts we investigate.

4 | RESULTS AND DISCUSSION

Table 2 shows the results from the multivariate regression models. The dependent variables are used as model names. We present and discuss the results from each consecutive model before addressing the cross-model results.

4.1 | Future

In the first model, Future, we find that participation in inter-municipal networks for CCA has a significant positive effect on the dependent variable: The degree that projections, as opposed to observations, are used as a basis for CCA. A 1-unit increase in the degree of participation in networks, which ranges from 0 to 4, corresponds with a 0.04 unit increase in the dependent, which ranges from 0 to 1, holding all other variables constant at their mean. Network participation has been highlighted as a key trigger for CCA process and output, and qualitative studies has hinted at a particular importance to small municipalities (Fila et al., 2023; Pasquini, 2020).

Risk perception among the administration in the municipality is similarly significant and positive (0.06), confirming findings elsewhere (Dilling et al., 2017; Shi et al., 2015).

“Log_MUN Size” is not a significant predictor on its own, but the interaction between “REG Risk Perception both” and “log_MUN Size” shows a strong positive relationship between risk perception at the regional level and the dependent variable that diminishes as municipality size increases. The relationship is illustrated in Figure 2 along with all other interactions effects. The figure shows that the level of combined risk perception from the CC and CG at the regional level is a strong driver for smaller municipalities' ability to base their CCA effort on future climate change, but the effect is close to zero for larger municipalities. As we will discuss more later, we view risk perception as an expression of capacities and efforts at the regional level that are not captured by other variables, but that quite clearly demonstrates the importance of an engaged regional level for the CCA effort in smaller municipalities.

The opposite is the case for the interaction between “REG Sustainability CG” and “log_MUN Size.” As shown in Figure 2, the CG's ability to consider CCA in relation to other policy fields is a significant

TABLE 2 OLS regression results.

	Future	MRE	Sustainability	Mainstreaming	Measures	Holistic planning	Holistic
(Intercept)	0.63***	0.40***	0.61***	0.59***	0.46***	0.56***	0.53***
MUN Political Awareness		0.09***		0.08***	0.17*	0.06**	0.12***
MUN Networks	0.04*	0.04*		0.01		0.02	
MUN Research Projects		−0.02	0.03	−0.01		0.02	
MUN Risk Perception	0.06*		0.09**			0.07***	0.06*
MUN Experience Extreme Events					0.02		
MUN CE plan age		−0.01		−0.01*			
MUN Stakeholder Collaboration		0.05*		0.07***	0.06	0.02	0.05*
Log_MUN Size	0.02	0.02	0.06***	0.00	0.04	0.01	0.01
REG Risk Perception both	0.53*					0.68***	0.23
REG Risk Perception CC			0.22	0.04			
REG Sustainability CG	0.05		−0.05				
REG Expenditure 4 CC	0.35				0.30	0.47**	
REG Networks CG						0.04	0.12
MUN Political Awareness * log_MUN Size		−0.05**					
MUN Research Projects * log_MUN Size			−0.02*				
REG Risk Perception both * log_MUN Size	−0.33*					−0.16	−0.56**
REG Risk Perception CC * log_MUN Size			−0.22*	−0.13*			
REG Sustainability CG * log_MUN Size	0.13*		−0.03				
N	117	108	108	109	54	95	63
Adjusted R ²	0.23	0.32	0.28	0.30	0.20	0.49	0.56
R ²	0.29	0.36	0.33	0.36	0.28	0.54	0.61

Note: Model names indicates the dependent variable for each model. Log = natural logarithm. All independent variables are mean-centered. All dependent variables are standardized and has a range from 0 to 1. The intercept reflects the mean of the dependent variables within their sample.

Abbreviation: CC, county council; CE, climate and energy; CG, county governor; log = natural logarithm; MRE, monitoring, reporting, and evaluation; MUN, local level variable; REG, regional level variable.

* $p < .05$. ** $p < .01$. *** $p < .001$.

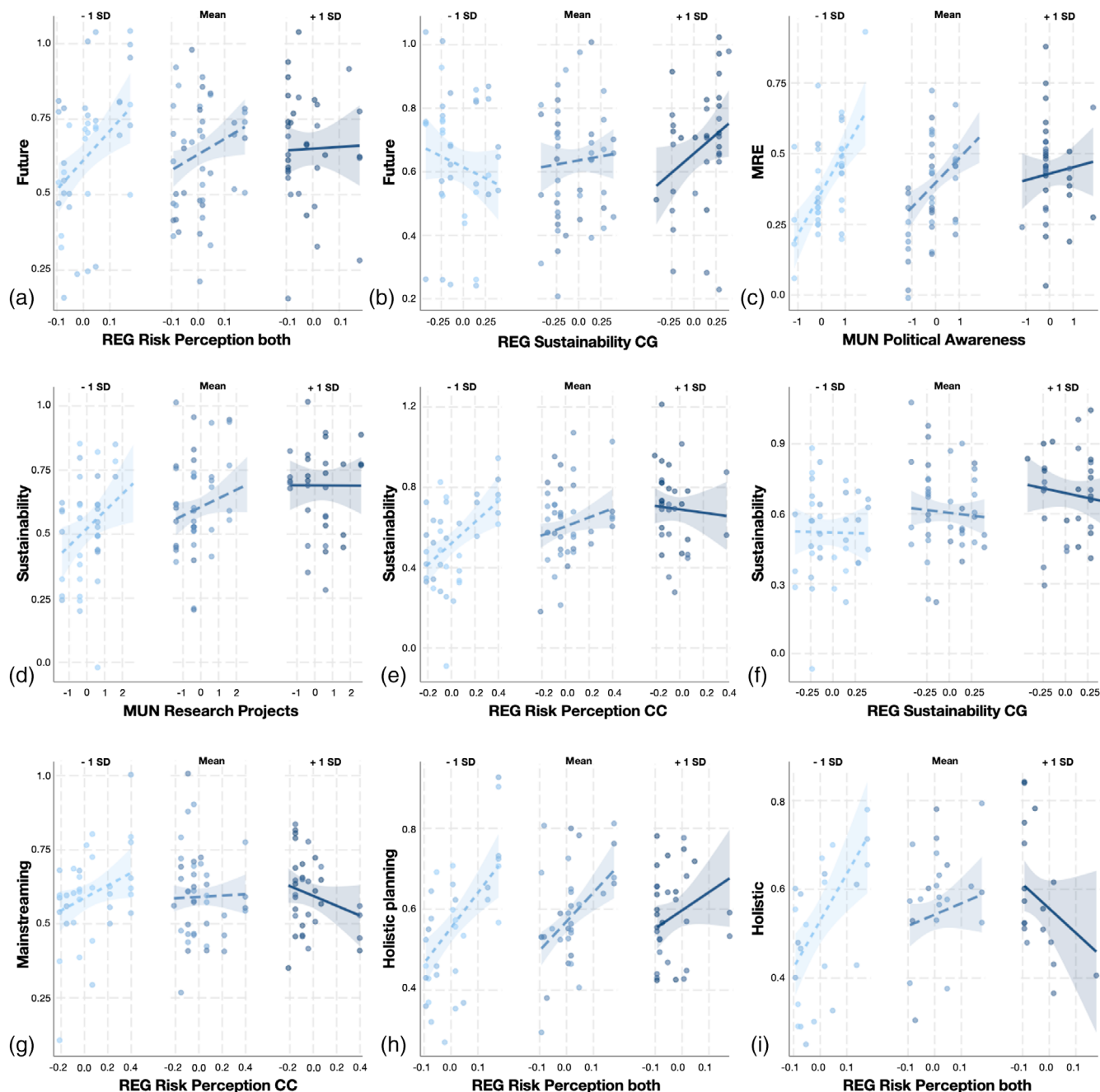


FIGURE 2 Interaction effects from all models. Dots represent the partial residuals (controlled for the effects of other predictors). Colored bands represent the 95% confidence intervals. Line represents the predicted effect. Panels show interaction effects at low (-1 SD), mean, and high ($+1$ SD) levels of log_MUN Size between Future and REG Risk Perception both (a), Future and REG Sustainability CG (b), MRE and MUN Political Awareness (c), Sustainability and MUN Research Projects (d), Sustainability and REG Risk Perception CC (e), Sustainability and REG Sustainability CG (f), Mainstreaming and REG Risk Perception CC (g), Holistic planning and REG Risk Perception both (h), and Holistic and REG Risk Perception both (i).

driver for the larger municipalities, while the effect is seemingly negative for the smaller municipalities. However, the confidence intervals are large relative to the line for the effect in the lower tercile of municipality size, and there is no strong visible trend among the partial residuals. This tells us that the negative effect is not convincing for the smallest third of municipalities.

The reason for this finding relates to how the CG is organized. The CG is characterized by a “siloe” structure that first and foremost communicates and collaborates vertically across government levels within the siloes (Orderud & Naustdalslid, 2020). In counties where these siloes are absolute and the level of horizontal cross-communication is low (low score on “REG Sustainability CG”) this

provides a strong, but narrow mandate to certain key departments in the municipalities, such as water and sewage and preparedness, where CCA effort is often guided by the current observed climate, resulting in an overall lower score on the “Future” variable. Conversely, CGs that has a high level of cross-communication across policy fields (high score on “REG Sustainability CG”) provides a wider mandate to the municipalities across departments, facilitating a CCA effort with a longer temporal perspective. We find this effect first and foremost in larger municipalities, where inter-departmental collaboration is a problem (Fila et al., 2023).

“REG Expenditure 4 CC,” representing the working hours spent on treatment of municipal plans relative to the number of municipalities in the county, has a positive relationship with the dependent but is not significant at the 5%-level.

4.2 | MRE

In the second model, MRE, we find that political awareness has a relatively strong positive relationship (0.09) with municipalities' ability to implement CCA into internal monitoring, reporting, and evaluation. Looking at the significant interaction effect between political awareness and municipality size (−0.05) in Figure 2, we see that the effect is largest for the small and medium-sized municipalities, but that the effect diminishes for the largest municipalities. This aligns with findings that identify lack of support from municipal leaders as a major barrier to local CCA (Rogers et al., 2023), especially in smaller municipalities.

Similar to the “Future” model, we find that inter-municipal network participation is positive and significantly related to the dependent.

Both participation in research projects (“MUN Research Projects”) and years since latest climate and energy plan (“MUN CE plan age”) has nonsignificant relationships with monitoring, reporting, and evaluation.

Collaboration with inhabitants and business stakeholders has a positive and significant impact on MRE. This reflects the finding from Rivas et al. (2021) that stakeholder participation is pivotal to implementation of CCA.

“Log_MUN Size” is not, on its own, a significant predictor.

4.3 | Sustainability

In the third model, Sustainability, we find that participation in research projects, on its own, do not have a significant impact on the dependent variable: the degree that CCA is considered in relation to other policy fields and development goals. However, we find that the interaction effect is significant and negative, meaning that participation in research projects is an important driver for sustainability in the small and medium-sized municipalities (see Figure 2). We believe that this illustrates that for the smallest municipalities, the level of

sustainability in local CCA are contingent on external influence and competence. The larger municipalities, who score overall much higher on this variable, are not reliant on others to pursue sustainability, as much of the competence can be found in-house.

We find that risk perception among the administration is an important driver, as we also do in the Future model.

Municipality size is highly significant and impactful. The variable is log-transformed, meaning that a 1% increase in municipality size corresponds with a 0.06 unit increase in the dependent, holding all other variables constant at their mean. The dependent variable, Sustainability, ranges from 0 to 1, meaning that the model predicts that a hypothetical doubling in municipality size would involve a 0.6 unit increase in the dependent. Since our data is Likert scale survey data, this translates to a shift from a low degree of sustainability to between a high and a very high degree of sustainability.

The main effect of risk perception in the CC administration is not significant, but the interaction between risk perception and municipality size is significant and negative. This means that the effect of an engaged CC is positively related with sustainability in small and medium-sized municipalities, while it has no effect for the largest ones (Figure 2).

The effect of sustainability at the CG as well as the interaction effect with population size are not significant. Both coefficients are negative, though the plotted interaction effects in Figure 2 gives reason to believe that the effect is probably zero.

4.4 | Mainstreaming

In the fourth model, Mainstreaming, we see that political awareness is significant and positively related to the dependent variable: the degree of integration of CCA into key documents and processes in the municipalities.

We see that both network and research project participation is nonsignificant and close to zero.

Unsurprisingly, we see that the number of years since the climate and energy plan has been implemented or revised has a negative impact on mainstreaming of CCA. In a Norwegian context, climate and energy plans are typically where the CCA effort is grounded. Yet, the effect is quite small: 1 year increase since climate and energy plan revision or implementation corresponds with a 0.01 decrease in the dependent variable.

Furthermore, we register that, like in the MRE model, stakeholder collaboration is an important driver of mainstreaming.

Municipality size is not a significant driver across the sample, but we find that the interaction effect of risk perception within the CC is significant and negative, while the main effect is not. As shown in Figure 2, this means that the effect is positive for the smallest municipalities, but negative for the largest. Looking at the partial residuals, the latter finding is less convincing, and seemingly only due to a few municipalities from one county with high risk perception and a lower-than-average score on mainstreaming.

4.5 | Measures

In the fifth model, Measures, we find political awareness to be the only significant predictor of the dependent variable: the existence of different types of CCA measures in key sectors. The coefficient (.17) is twice as large as the previous models MRE and mainstreaming, indicating that it is an even more dominant driver when it comes to CCA action.

One reason for the low number of significant predictors, and poor fit (adjusted $R^2 = .20$) is the low number of observations and corresponding low statistical power. Only 54 municipalities answered the survey sufficiently to include their score in this variable.

One interesting observation is that experience with extreme events have replace risk perception within the municipality as the included predictor in the model. We found no bivariate correlation between measures and municipal risk perception in our initial model selection approach, and no significant interaction with municipality size. Authors have argued that experience with extreme events matter little if it is not reflected in the perceptions of the municipal employees (Dilling et al., 2017; Shi et al., 2015). We do not find the opposite, but we do find an indication that adaptation action might be motivated by concrete experiences regardless of overall risk perception.

The other variables included in the model, are stakeholder collaboration, municipality size, and the working hours spent on treatment of municipal plans relative to the number of municipalities in the county. They are all positively related to Measures, but the relationships are not significant.

4.6 | Holistic planning

In the sixth model, Holistic planning, we look at what drives holistic CCA planning in municipalities up to the point of implementation of measures. It is a composite index, consisting of the previous dependent variables except Measures. We find that political awareness and risk perception in the administration is significant and positive. Network and research project participation and stakeholder collaboration are positive but not significant.

We also see that the combined risk perception at the regional level is significant, while the interaction effect is not. This means that risk perception at the regional level, and a corresponding engagement in municipal CCA efforts, is a driver across the sample.

Furthermore, we find that “REG Expenditure 4 CC,” the working hours spent by the CC on treatment of municipal plans, is a significant driver of municipal holistic CCA planning. The variable is an expression of prioritization at the CC, and shows that counties that spend more time and resources treating municipal plans, help produce better planning at the local level (Dilling et al., 2017; Fila et al., 2023; Oulahen et al., 2018; Shi, 2019).

4.7 | Holistic

In the final model, Holistic, the results from the composite index that combines Future, MRE, Sustainability, Mainstreaming, and Measures

are presented. Political awareness is positive and significant at the .001 level. We see also that risk perception within the administration as well as stakeholder collaboration is significant and positive.

Municipality size and the combined risk perception of the CC and CG do not have significant effects on their own, but the interaction between them is strong and significant. Looking at Figure 2, we see that the model predicts a positive effect of “REG Risk Perception both” for small and medium-sized municipalities, while the effect is negative for the largest municipalities. In comparison with our other models, the effect on the largest municipalities stands out. One possible reason that the effect is negative, is the lower number of observations compared to other models making it less representative of the population, leading to a type I error. Looking at Figure 2, the large area covered by the confidence intervals in the upper tercile of population size, indeed suggests that the effect might be zero. On the other hand, this is the model with best fit to the data (adjusted $R^2 = .56$). Another possible reason is that the regional level can hinder implementation of CCA measures for the largest municipalities. As we have seen, risk perception at the regional level contributes positively to Holistic planning, meaning that it is a robust driver for CCA planning across the sample and specifically pertinent to smaller municipalities, as the other models show. The fact that the introduction of Measures alters the relationship for the largest municipalities might suggest that the focus on good CCA planning encouraged by the regional level, acts as a barrier for implementation of measures by discouraging action that is not well planned. This might be the case specifically for larger urban municipalities where action is more complex and often involve larger trade-offs and a higher number of affected stakeholders.

Finally, we see that “REG Networks CG” is positive but not significant. This variable depicts the degree that CCA is emphasized in participation in municipal networks.

4.8 | Cross-model comparison

Directing the attention to the cross-model results there is a few highlights that merits further discussion. One robust finding is that the risk perception at the regional level is an important driver for small municipalities. This pertains to both the first knowledge gap that we address in this paper—the role of higher-level government, and the second—the challenges of small and medium-sized municipalities. Across all models except Measures and MRE where the variable is not included, we find that the interaction between municipality size and regional risk perception is negative, while the main effect of risk perception is positive. This tells us that the regional level is pivotal in motivating and facilitating local level CCA in small municipalities, mirroring findings elsewhere (Fünfgeld et al., 2023). We use this variable as an expression of motivation for and engagement with CCA in either the CC or both the CC and CG.

Although we have not provided an exhaustive collection, we have included several key variables to express multiple types of engagement with CCA at the regional level vis a vis the municipalities to be able to pin-point which regional approach spurs local action (Table 1). However, our model selection approach has shown clear preference

toward the risk perception variables. This shows that it is not the form or the forum of knowledge provision, technical assistance, leadership, or guidance that matter, but the degree. Instead of pondering “how” to support local governments, they should focus on “how much.”

One finding that is made interesting by its omission, is municipal resources. This finding relates specifically to the second knowledge gap that we address in the paper—the challenges of small and medium-sized municipalities. Low income and a low number of staff are commonly mentioned barriers to CCA (Rogers et al., 2023), and universally mentioned by small municipalities (Fila et al., 2023). In our analysis, we find no connection between CCA effort and resources, when controlling for other relevant predictors.

One of the most striking findings relates to the difference between the Future and Sustainability models on one side, and the rest of the models on the other. It pertains specifically to the third knowledge gap that we address in the paper—the drivers associated with holistic CCA processes. Political awareness and stakeholder collaboration are two of the most robust drivers across models. Yet, in the Future and Sustainability models they have not even met the criteria for inclusion. In their place, we find risk perception within the municipality and the degree of sustainability within the CG (although the latter effect is not very convincing). These two variables are not included in the other models except the composite indices. The variables Future and Sustainability express the municipalities' ability to pay explicit attention to trade-offs of CCA action at different spatial, temporal, and sectoral scales. In other words, they represent key requirements for sustainable CCA and achievement of environmental and social SDGs (Aall et al., 2023).

On the one hand, in the case of public deliberation, lessons from studies on local CCA processes tells us that this result might be a reflection on the quality of participatory processes. Studies have found that participation in local CCA is often symbolic and superficial (Kiss et al., 2022; Puskás et al., 2021), in some cases leading to erosion of sustainability (Wamsler, Alkan-Olsson, et al., 2020). Our measure of stakeholder support is rather ambiguous in this sense as we ask about the degree of stakeholder collaboration. This might be interpreted as either quality or quantity or both. Recent qualitative studies have indeed found that, when done right, participation leads to enhanced social and environmental output (Hölscher et al., 2024; Kiss et al., 2022). Our finding that stakeholder collaboration is not a significant predictor of sustainable CCA might point to a lack of deep and broad participation in local CCA processes in Norway. This, in turn, might arguably be considered evidence of *less* sustainable CCA instead of *more* sustainable CCA given the key intrinsic connection between participation and sustainable development (Dannevig et al., 2022). The quality of participatory processes should therefore be an avenue for future quantitative research on drivers of local CCA.

On the other hand, this tells us that municipal administrations are very much at the mercy of the elected officials and stakeholders within the municipality when it comes to monitoring, mainstreaming, and implementing CCA measures. But this is not the case when it comes to the more normative aspects of CCA. According to the literature, CCA responses to date have been largely fragmented and

incremental (Berrang-Ford et al., 2021; Shi & Moser, 2021). Our results show that this needed normative shift might be a matter of choice for municipal administrations. This does not mean that policy should aim to bypass political and stakeholder support, as this would be counterintuitive to core ideas of sustainable development. But this lack of support that is universally identified as dominant barriers to adaptation action in local governments (Rivas et al., 2021; Rogers et al., 2023), should not be used as an excuse to not pursue transformation, sustainability, and avoided maladaptation.

5 | CONCLUSION

This research paper critically examines three underexplored areas in CCA research: the influence of multilevel governance, the unique challenges faced by small and medium-sized municipalities, and the drivers of transformative and sustainable CCA efforts. Drawing on data from three surveys of Norwegian municipalities and counties, this study provides a nuanced understanding of CCA dynamics by statistically assessing the drivers and barriers of local holistic CCA.

The study reveals several key findings. First, factors such as political awareness, network participation, risk perception, stakeholder collaboration, municipality size, and updated climate and energy plans significantly enhance CCA efforts. But the results are contingent on the conceptualization of CCA. We find that classical properties of CCA, such as mainstreaming, monitoring and implementing measures require political and stakeholder support. But normative properties, such as considering spatial and temporal trade-offs, requirements for CCA to be in line with environmental and societal SDGs, are not significantly related to stakeholder support. On the one hand, this indicates that the lack of support that is universally identified as dominant barriers to adaptation action in local governments, should not be used as an excuse to not pursue sustainability. On the other hand, quantity and quality of participatory processes does not necessarily yield the same result, and quality is not well measured in our data. Future quantitative research should therefore focus on the quality of participatory processes to further untangle this relationship.

Second, the study finds no direct connection between municipal resources and CCA efforts, when controlled for other relevant factors. This challenges the conventional notion that increased resources directly translate into better adaptation outcomes.

Third, we find that regional support is crucial for the CCA efforts in smaller municipalities, while the effect on larger municipalities is minimal. We find that the effectiveness of regional support for local governments hinges more on the degree of engagement than the format or forum of the support. Instead of pondering *how* to support local governments, the regional level should focus on *how much*.

Finally, the study underscores the need for greater scrutiny of “what is CCA?” in large-N studies, as the outcomes are highly sensitive to the conceptualization of CCA. This contributes to a deeper understanding of CCA dynamics and suggests that future research puts institutional context front and center.

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ORCID

Torbjørn Selseng  <https://orcid.org/0000-0001-5593-5055>

REFERENCES

- Aall, C., Meyer-Habighorst, C., Gram-Hanssen, I., Korsbrekke, M. H., & Hovelsrud, G. (2023). "I'm fixing a hole where the rain gets in, and stops my mind from wandering": Approaching sustainable climate change adaptations. *Weather, Climate, and Society*, 15(2), 349–364. <https://doi.org/10.1175/WCAS-D-22-0113.1>
- Aguiar, F. C., Bentz, J., Silva, J. M. N., Fonseca, A. L., Swart, R., Santos, F. D., & Penha-Lopes, G. (2018). Adaptation to climate change at local level in Europe: An overview. *Environmental Science and Policy*, 86, 38–63. <https://doi.org/10.1016/j.envsci.2018.04.010>
- Amundsen, H., Berglund, F., & Westskog, H. (2010). Overcoming barriers to climate change adaptation—a question of multilevel governance? *Environment and Planning C: Government and Policy*, 28, 276–289. <https://doi.org/10.1068/c0941>
- Amundsen, H., & Dannevig, H. (2021). Looking back and looking forward—Adapting to extreme weather events in municipalities in western Norway. *Regional Environmental Change*, 21(4), 108. <https://doi.org/10.1007/s10113-021-01834-7>
- Araos, M., Berrang-Ford, L., Ford, J. D., Austin, S. E., Biesbroek, R., & Lesnikowski, A. (2016). Climate change adaptation planning in large cities: A systematic global assessment. *Environmental Science and Policy*, 66, 375–382. <https://doi.org/10.1016/j.envsci.2016.06.009>
- Aylett, A. (2015). Institutionalizing the urban governance of climate change adaptation: Results of an international survey. *Urban Climate*, 14, 4–16. <https://doi.org/10.1016/j.uclim.2015.06.005>
- Bausch, T., & Koziol, K. (2020). New policy approaches for increasing response to climate change in small rural municipalities. *Sustainability*, 12(6), 1894. <https://doi.org/10.3390/su12051894>
- Berrang-Ford, L., Siders, A. R., Lesnikowski, A., Fischer, A. P., Callaghan, M. W., Haddaway, N. R., Mach, K. J., Araos, M., Shah, M. A. R., Wannewitz, M., Doshi, D., Leiter, T., Matavel, C., Musah-Surugu, J. I., Wong-Parodi, G., Antwi-Agyei, P., Ajibade, I., Chauhan, N., Kakenmaster, W., ... Abu, T. Z. (2021). A systematic global stocktake of evidence on human adaptation to climate change. *Nature Climate Change*, 11, 989–1000. <https://doi.org/10.1038/s41558-021-01170-y>
- Biesbroek, R., Berrang-Ford, L., Ford, J. D., Tanabe, A., Austin, S. E., & Lesnikowski, A. (2018). Data, concepts and methods for large-n comparative climate change adaptation policy research: A systematic literature review. *Wiley Interdisciplinary Reviews: Climate Change*, 9, e548. <https://doi.org/10.1002/wcc.548>
- Bonnett, N. L., & Birchall, S. J. (2023). The influence of regional strategic policy on municipal climate adaptation planning. *Regional Studies*, 57(1), 141–152. <https://doi.org/10.1080/00343404.2022.2049224>
- Brenner, N. (1998). Global cities, glocal states: Global city formation and state territorial restructuring in contemporary Europe. *Review of International Political Economy*, 5(1), 1–37. <https://doi.org/10.1080/096922998347633>
- Castán Broto, V., & Westman, L. K. (2020). Ten years after Copenhagen: Reimagining climate change governance in urban areas. *Wiley Interdisciplinary Reviews: Climate Change*, 11, e643. <https://doi.org/10.1002/wcc.643>
- Cattino, M., & Reckien, D. (2021). Does public participation lead to more ambitious and transformative local climate change planning? *Current Opinion in Environmental Sustainability* 52, 100–110. Elsevier. <https://doi.org/10.1016/j.cosust.2021.08.004>
- Colasante, A., D'Adamo, I., De Massis, A., & Italiano, S. (2024). An exploratory study of stakeholder views on the sustainable development of mountain tourism. *Sustainable Development*, 32(4), 3722–3735. <https://doi.org/10.1002/sd.2878>
- D'Adamo, I., Di Carlo, C., Gastaldi, M., & Uricchio, A. F. (2024). Equitable and sustainable well-being indicators: A study of Italian regional disparities towards sustainable development. *Sustainable Development*, 32(5), 5538–5549. <https://doi.org/10.1002/sd.2985>
- Dannevig, H., & Aall, C. (2015). The regional level as boundary organization? An analysis of climate change adaptation governance in Norway. *Environmental Science and Policy*, 54, 168–175. <https://doi.org/10.1016/j.envsci.2015.07.001>
- Dannevig, H., Korsbrekke, M. H., & Hovelsrud, G. K. (2022). Advancements of sustainable development goals in co-production for climate change adaptation research. *Climate Risk Management*, 36, 100438. <https://doi.org/10.1016/j.crm.2022.100438>
- Dannevig, H., Rauken, T., & Hovelsrud, G. (2012). Implementing adaptation to climate change at the local level. *Local Environment*, 17, 597–611. <https://doi.org/10.1080/13549839.2012.678317>
- Dilling, L., Pizzi, E., Berggren, J., Ravikumar, A., & Andersson, K. (2017). Drivers of adaptation: Responses to weather- and climate-related hazards in 60 local governments in the intermountain Western U.S. *Environment and Planning A*, 49(11), 2628–2648. <https://doi.org/10.1177/0308518X16688686>
- Dodman, D., Hayward, B., Pelling, M., Broto, V. C., Chow, W., Chu, E., & Zervogel, G. (2022). Cities, settlements and key infrastructure. In H.-O. Pörtner, D. C. Roberts, M. Tignor, E. S. Poloczanska, K. Mintenbeck, A. Alegria, M. H. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, D. Belling, W. Dieck, S. Götze, T. Kershner, P. Mangele, B. Maus, A. Mühle, K. Nabiyeva, ... B. Rama (Eds.), *Climate change 2022: Impacts, adaptation and vulnerability. Contribution of working group II to the sixth assessment report of the intergovernmental panel on climate change* (pp. 907–1040). Cambridge University Press. <https://doi.org/10.1017/9781009325844.008>
- dos Santos, A. P. S., & Puppim de Oliveira, J. A. (2024). What factors drive municipal climate adaptation policy? The role of risk management capacity and transnational municipal networks. *Urban Climate*, 53, 101809. <https://doi.org/10.1016/j.uclim.2024.101809>
- DSB. (2016). *Kommuneundersøkelsen 2016 (in Norwegian)*. The Norwegian Directorate for Civil Protection (DSB), Tønsberg, Norway.
- DSB. (2019). *Kommuneundersøkelsen 2019 (in Norwegian)*. The Norwegian Directorate for Civil Protection (DSB), Tønsberg, Norway.
- DSB. (2022). *Kommuneundersøkelsen 2022 (in Norwegian)*. The Norwegian Directorate for Civil Protection (DSB), Tønsberg, Norway.
- Dupuis, J., & Biesbroek, R. (2013). Comparing apples and oranges: The dependent variable problem in comparing and evaluating climate change adaptation policies. *Global Environmental Change*, 23(6), 1476–1487. <https://doi.org/10.1016/j.gloenvcha.2013.07.022>
- Fila, D., Fünfgeld, H., & Dahmann, H. (2023). Climate change adaptation with limited resources: Adaptive capacity and action in small- and medium-sized municipalities. *Environment, Development and Sustainability*, -. Springer Science and Business Media B.V., 26, 5607–5627. <https://doi.org/10.1007/s10668-023-02999-3>
- Ford, J. D., & Berrang-Ford, L. (2016). The 4Cs of adaptation tracking: Consistency, comparability, comprehensiveness, coherency. *Mitigation and Adaptation Strategies for Global Change*, 21, 839–859. <https://doi.org/10.1007/s11027-014-9627-7>
- Fünfgeld, H., Fila, D., & Dahmann, H. (2023). Upscaling climate change adaptation in small- and medium-sized municipalities: Current barriers and future potentials. *Current Opinion in Environmental Sustainability*, 61, 101263. Elsevier. <https://doi.org/10.1016/j.cosust.2023.101263>
- Fuso Nerini, F., Sovacool, B., Hughes, N., Cozzi, L., Cosgrave, E., Howells, M., Tavoni, M., Tomei, J., Zerriffi, H., & Milligan, B. (2019). Connecting climate action with other sustainable development goals.

- In *Nature sustainability* (Vol. 2, pp. 674–680). Nature Publishing Group. <https://doi.org/10.1038/s41893-019-0334-y>
- Hanssen, G. S., Mydske, P. K., & Dahle, E. (2013). Multi-level coordination of climate change adaptation: By national hierarchical steering or by regional network governance? *Local Environment*, 18, 869–887. <https://doi.org/10.1080/13549839.2012.738657>
- Heidrich, O., Reckien, D., Olazabal, M., Foley, A., Salvia, M., de Gregorio Hurtado, S., ... Dawson, R. J. (2016). National climate policies across Europe and their impacts on cities strategies. *Journal of Environmental Management*, 168, 36–45. <https://doi.org/10.1016/j.jenvman.2015.11.043>
- Heikkinen, M., Karimo, A., Klein, J., Juhola, S., & Ylä-Anttila, T. (2020). Transnational municipal networks and climate change adaptation: A study of 377 cities. *Journal of Cleaner Production*, 257, 120474. <https://doi.org/10.1016/j.jclepro.2020.120474>
- Hölscher, K., Frantzeskaki, N., Kindlon, D., Collier, M. J., Dick, G., Dziubala, A., Lodder, M., Osipiuk, A., Quartier, M., Schepers, S., Van De Sijpe, K., & van der Have, C. (2024). Embedding co-production of nature-based solutions in urban governance: Emerging co-production capacities in three European cities. *Environmental Science and Policy*, 152, 103652. <https://doi.org/10.1016/j.envsci.2023.103652>
- Hoorweg, D., & Pope, K. (2017). Population predictions for the world's largest cities in the 21st century. *Environment and Urbanization*, 29(1), 195–216. <https://doi.org/10.1177/0956247816663557>
- Hoppe, T., van der Vegt, A., & Stegmaier, P. (2016). Presenting a framework to analyze local climate policy and action in small and medium-sized cities. *Sustainability*, 8(9), 847. <https://doi.org/10.3390/su8090847>
- Hossain, M. S., Basak, S. M., Amin, M. N., Anderson, C. C., Cremin, E., & Renaud, F. G. (2024). Social-ecological systems approach for adaptation to climate change. *Sustainable Development*, 32(3), 2766–2778. <https://doi.org/10.1002/sd.2801>
- IPCC. (2022). Climate change 2022: Impacts, adaptation, and vulnerability. Contribution of working group II to the sixth assessment report of the intergovernmental panel on climate change. In H.-O. Pörtner, D. C. Roberts, M. Tignor, E. S. Poloczanska, K. Mintenbeck, A. Alegria, ... B. Rama (Eds.), *Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (p. 3056). Cambridge University Press.
- Kiss, B., Sekulova, F., Hörschelmann, K., Salk, C. F., Takahashi, W., & Wamsler, C. (2022). Citizen participation in the governance of nature-based solutions. *Environmental Policy and Governance*, 32(3), 247–272. <https://doi.org/10.1002/eet.1987>
- Lesnikowski, A., Biesbroek, R., Ford, J. D., & Berrang-Ford, L. (2021). Policy implementation styles and local governments: The case of climate change adaptation. *Environmental Politics*, 30(5), 753–790. <https://doi.org/10.1080/09644016.2020.1814045>
- Lesnikowski, A., Ford, J. D., Biesbroek, R., & Berrang-Ford, L. (2019). A policy mixes approach to conceptualizing and measuring climate change adaptation policy. *Climatic Change*, 156(4), 447–469. <https://doi.org/10.1007/s10584-019-02533-3>
- Magnan, A. K., Bell, R., Duvat, V. K. E., Ford, J. D., Garschagen, M., Haasnoot, M., ... Winter, G. (2023). Status of global coastal adaptation. *Nature Climate Change*, 13(11), 1213–1221. <https://doi.org/10.1038/s41558-023-01834-x>
- Magnan, A. K., Schipper, E. L. F., & Duvat, V. K. E. (2020). Frontiers in climate change adaptation science: Advancing guidelines to design adaptation pathways. In *Current climate change reports* (Vol. 6, pp. 166–177). Springer Science and Business Media Deutschland GmbH. <https://doi.org/10.1007/s40641-020-00166-8>
- Nalau, J., Preston, B. L., & Maloney, M. C. (2015). Is adaptation a local responsibility? *Environmental Science and Policy*, 48, 89–98. <https://doi.org/10.1016/j.envsci.2014.12.011>
- Neder, E. A., de Araújo Moreira, F., Fontana, M. D., Torres, R. R., Lapola, D. M., da Penha Costa Vasconcellos, M., Bedran-Martins, A. M. B., Junior, A. P., Lemos, M. C., & Di Giulio, G. M. (2021). Urban adaptation index: Assessing cities readiness to deal with climate change. *Climatic Change*, 166(1–2), 1–20. <https://doi.org/10.1007/s10584-021-03113-0>
- Nohrstedt, D., Hileman, J., Mazzoleni, M., Di Baldassarre, G., & Parker, C. F. (2022). Exploring disaster impacts on adaptation actions in 549 cities worldwide. *Nature Communications*, 13(1), 1–10. <https://doi.org/10.1038/s41467-022-31059-z>
- Norwegian Climate Monitor. (2020). *The county survey [dataset]*. Retrieved from <https://klimatemonitor.no/data-offentleg-forvaltning>
- Norwegian Climate Monitor. (2021). *The municipality survey [dataset]*. Retrieved from <https://klimatemonitor.no/data-offentleg-forvaltning>
- Norwegian Climate Monitor. (2022). *The county survey [dataset]*. Retrieved from <https://klimatemonitor.no/data-offentleg-forvaltning>
- Olazabal, M., Galarraga, I., Ford, J., Lesnikowski, A., & Sainz De Murieta, E. (2017). *Towards successful adaptation: A checklist for the development of climate change adaptation plans*. Leioa. <https://doi.org/10.13140/RG.2.2.35020.62080>
- Olazabal, M., & Ruiz De Gopegui, M. (2021). Adaptation planning in large cities is unlikely to be effective. *Landscape and Urban Planning*, 206, 103974. <https://doi.org/10.1016/j.landurbplan.2020.103974>
- Olazabal, M., Ruiz de Gopegui, M., Tompkins, E., Venner, K., & Smith, R. (2019). A cross-scale worldwide analysis of coastal adaptation planning. *Environmental Research Letters*, 14(12), 124056. <https://doi.org/10.1088/1748-9326/ab5532>
- Orderud, G. I., & Naustdalslid, J. (2020). Climate change adaptation in Norway: Learning-knowledge processes and the demand for transformative adaptation. *International Journal of Sustainable Development and World Ecology*, 27(1), 15–27. <https://doi.org/10.1080/13504509.2019.1673500>
- Otto, A., Göpfert, C., & Thieken, A. H. (2021). Are cities prepared for climate change? An analysis of adaptation readiness in 104 German cities. *Mitigation and Adaptation Strategies for Global Change*, 26(8), 1–25. <https://doi.org/10.1007/s11027-021-09971-4>
- Oulahan, G., Klein, Y., Mortsch, L., O'Connell, E., & Harford, D. (2018). Barriers and drivers of planning for climate change adaptation across three levels of government in Canada. *Planning Theory & Practice*, 3, 405–421. <https://doi.org/10.1080/14649357.2018.1481993>
- Pasquini, L. (2020). The urban governance of climate change adaptation in least-developed African countries and in small cities: The engagement of local decision-makers in Dar es Salaam, Tanzania, and Karonga, Malawi. *Climate and Development*, 12(5), 408–419. <https://doi.org/10.1080/17565529.2019.1632166>
- Patterson, J. J. (2021). More than planning: Diversity and drivers of institutional adaptation under climate change in 96 major cities. *Global Environmental Change*, 68, 102279. <https://doi.org/10.1016/j.gloenvcha.2021.102279>
- Pelling, M., O'Brien, K., & Matyas, D. (2015). Adaptation and transformation. *Climatic Change*, 133, 113–127. <https://doi.org/10.1007/s10584-014-1303-0>
- Puskás, N., Abunnasr, Y., & Naalbandian, S. (2021). Assessing deeper levels of participation in nature-based solutions in urban landscapes—A literature review of real-world cases. In *Landscape and urban planning* (Vol. 210, 104065). Elsevier. <https://doi.org/10.1016/j.landurbplan.2021.104065>
- Reckien, D., Buzasi, A., Olazabal, M., Spyridaki, N.-A., Eckersley, P., Simoes, S. G., Salvia, M., Pietrapertosa, F., Fokaides, P., Goonesekera, S. M., Tardieu, L., Balzan, M. V., de Boer, C. L., Hurtado, S. D. G., Feliu, E., Flamos, A., Foley, A., Geneletti, D., Grafakos, S., ... Wejs, A. (2023). Quality of urban climate adaptation plans over time. *Npj Urban Sustainability*, 3(1), 1–14. <https://doi.org/10.1038/s42949-023-00085-1>

- Reckien, D., Flacke, J., Olazabal, M., & Heidrich, O. (2015). The influence of drivers and barriers on urban adaptation and mitigation plans—an empirical analysis of European cities. *PLoS One*, 10(8), e0135597. <https://doi.org/10.1371/journal.pone.0135597>
- Reckien, D., Magnan, A. K., Singh, C., Lukas-Sithole, M., Orlove, B., Schipper, E. L. F., & Coughlan de Perez, E. (2023). Navigating the continuum between adaptation and maladaptation. In *Nature climate change* (Vol. 13, pp. 907–918). Nature Publishing Group. <https://doi.org/10.1038/s41558-023-01774-6>
- 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., ... Dawson, R. (2018). 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*, 191, 207–219. <https://doi.org/10.1016/j.jclepro.2018.03.220>
- Rivas, S., Hernandez, Y., Urraca, R., & Barbosa, P. (2021). A comparative analysis to depict underlying attributes that might determine successful implementation of local adaptation plans. *Environmental Science and Policy*, 117, 25–33. <https://doi.org/10.1016/j.envsci.2020.12.002>
- Rogers, N. J. L., Adams, V. M., & Byrne, J. A. (2023). Factors affecting the mainstreaming of climate change adaptation in municipal policy and practice: A systematic review. *Climate Policy*, 23, 1327–1344. <https://doi.org/10.1080/14693062.2023.2208098>
- Sainz de Murieta, E., Olazabal, M., & Sanz, E. (2020). ¿Están las ciudades españolas adaptándose al cambio climático? *Papeles de Economía Española*, 163, 160–178.
- Schipper, E. L. F. (2020). Maladaptation: When adaptation to climate change goes very wrong. *One Earth*, 3, 409–414. <https://doi.org/10.1016/j.oneear.2020.09.014>
- Selseng, T., Klemetsen, M., & Rusdal, T. (2021). *Adaptation confusion? A longitudinal examination of the concept “climate change adaptation” in Norwegian municipal surveys*. Weather, Climate and Society. <https://doi.org/10.1175/WCAS-D-21-0024.1>
- Shi, L. (2019). Promise and paradox of metropolitan regional climate adaptation. *Environmental Science and Policy*, 92, 262–274. <https://doi.org/10.1016/j.envsci.2018.11.002>
- Shi, L., Chu, E., & Debats, J. (2015). Explaining Progress in climate adaptation planning across 156 U.S. municipalities. *Journal of the American Planning Association*, 81(3), 191–202. <https://doi.org/10.1080/01944363.2015.1074526>
- Shi, L., & Moser, S. (2021, June 25). Transformative climate adaptation in the United States: Trends and prospects. *Science*, 372, eabc8054. <https://doi.org/10.1126/science.abc8054>
- Singh, C., Iyer, S., New, M. G., Few, R., Kuchimanchi, B., Segnon, A. C., & Morchain, D. (2022). Interrogating ‘effectiveness’ in climate change adaptation: 11 guiding principles for adaptation research and practice. *Climate and Development*, 14, 650–664. <https://doi.org/10.1080/17565529.2021.1964937>
- Stotten, R. (2023). The natural domain and its social representation in the community resilience concept. *Sustainable Development*, 32, 1458–1470. <https://doi.org/10.1002/sd.2681>
- Tenali, S., & McManus, P. (2022). Climate change acknowledgment to promote sustainable development: A critical discourse analysis of local action plans in coastal Florida. *Sustainable Development*, 30(5), 1072–1085. <https://doi.org/10.1002/sd.2301>
- The Planning and Building Act., (2008).
- UNFCCC. (2023). *Technical dialogue of the first global stocktake*. Retrieved from <https://unfccc.int/documents/631600>
- United Nations. (2015). Transforming our world: The 2030 agenda for sustainable development. A/RES/70/1. In *United Nations General Assembly*. <https://doi.org/10.1007/s13398-014-0173-7.2>
- Valdivieso, P., Andersson, K. P., & Villena-Roldán, B. (2017). Institutional drivers of adaptation in local government decision-making: Evidence from Chile. *Climatic Change*, 143(1–2), 157–171. <https://doi.org/10.1007/s10584-017-1961-9>
- Wamsler, C., Alkan-Olsson, J., Björn, H., Falck, H., Hanson, H., Oskarsson, T., Simonsson, E., & Zelmerlow, F. (2020). Beyond participation: When citizen engagement leads to undesirable outcomes for nature-based solutions and climate change adaptation. *Climatic Change*, 158(2), 235–254. <https://doi.org/10.1007/s10584-019-02557-9>
- Wamsler, C., Wickenberg, B., Hanson, H., Alkan Olsson, J., Stålhammar, S., Björn, H., Falck, H., Gerell, D., Oskarsson, T., Simonsson, E., Torffvitt, F., & Zelmerlow, F. (2020). Environmental and climate policy integration: Targeted strategies for overcoming barriers to nature-based solutions and climate change adaptation. *Journal of Cleaner Production*, 247, 119154. <https://doi.org/10.1016/j.jclepro.2019.119154>
- Wen, J., Wan, C., Ye, Q., Yan, J., & Li, W. (2023). Disaster risk reduction, climate change adaptation and their linkages with sustainable development over the past 30 years: A review. *International Journal of Disaster Risk Science*, 14(1), 1–13. <https://doi.org/10.1007/s13753-023-00472-3>
- Whisman, M. A., & McClelland, G. H. (2005). Designing, testing, and interpreting interactions and moderator effects in family research. *Journal of Family Psychology*, 19(1), 111–120. <https://doi.org/10.1037/0893-3200.19.1.111>
- Zou, H. (2006). The adaptive lasso and its oracle properties. *Journal of the American Statistical Association*, 101(476), 1418–1429. <https://doi.org/10.1198/016214506000000735>

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