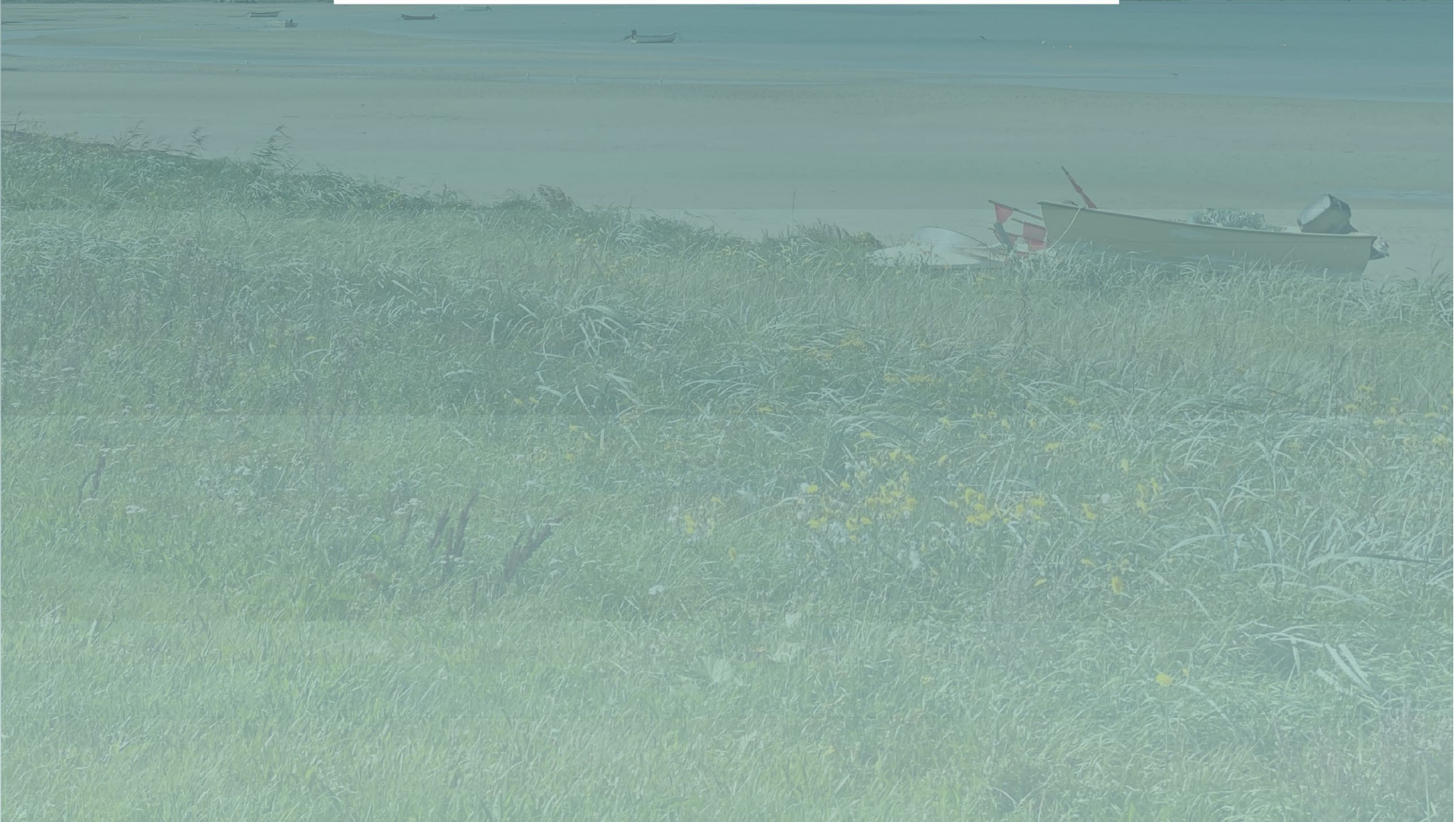
EMPOWERING LOCAL CLIMATE ACTION

AGRICULTURE, FORESTRY, AND OTHER LAND USE CHALLENGES IN THE REGION OF SOUTHERN DENMARK



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Suggested citation: N. Tollin, M. Lehmann, C. Attombri, A. Deeg, T. Skou Grindsted. *Empowering Local Climate Action: Agriculture, Forestry, and Land Use Challenges in the Region of Southern Denmark.* Region of Southern Denmark: Vejle (2025).

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ACRONYMS AND ABBREVIATIONS

AFOLU	Agriculture, Forestry, and Other Land Use
AAU	Aalborg University
BBR	Bygnings-og Boligregistret (Building and Housing Register)
C40	C40 Cities Climate Leadership Group
CAPF	Climate Action Planning Framework
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
IPCC	Intergovernmental Panel for Climate Change
KKR	KommuneKontaktRådet
KL	Kommunernes Landsforening
KPIs	Key Performance Indicators
MoI	Means of Implementation
MRV	Monitoring, reporting, and validation
$MtCO_2e$	Million tons of carbon dioxide equivalents
PtX	Power-to-X
RCP	Representative Concentration Pathway
RE	Renewable Energy
SDGs	Sustainable Development Goals
SDU.Resilience	UNESCO Chair on Urban Resilience

EXECUTIVE SUMMARY

This report is the result of the collaboration between the Region of Southern Denmark in spring 2023 by involving the UNESCO Chair on Urban Resilience at the University of Southern Denmark, Aalborg University, and Roskilde University. The first output of this collaboration resulted in the publication of a first report analyzing the climate action plans of the 22 municipalities in the Region of Southern Denmark, the known barriers to plan development and implementation, and a first set of recommendations. What became evident in this research is that extensive work in reducing emissions in Agriculture, Forestry, and Other Land Use (AFOLU) will be crucial for the Region to achieve its climate targets, hence the focus of this report.

The research was developed by extracting data from the local climate plans completed between 2019 and 2023, surveys to municipal employees and external stakeholders, and interviews with climate coordinators performed in 2024, and it was integrated with insights from scientific and grey literature.

The **key highlights** of this report are:

1. The AFOLU sector persistently constitutes the biggest emitter, representing **41%** of total regional emissions in 2019 and is predicted to contribute to **64%** of emissions in 2050.

2. The current **planned climate actions** related to AFOLU include a) extraction of low-lying soils, b) change in cultivation, c) afforestation and reforestation, d) establishment of eelgrass meadows and wetlands, e) Power-to-X, f) nitrification inhibitors, change in cattle feed composition, g) establishment of a plant protein factory, h) biogas production and plants, and i) pyrolysis.

3. **Some land-based actions** (actions from a. to d.) planned to tackle emission reduction also generate **co-benefits** for adaptation.

4. AFOLU-related actions that will contribute most to regional emission reductions are the **extraction of low-lying soils** and **afforestation**.

5. The sectors of **agriculture and food** and **ecosystems** are indicated among those most impacted by climate hazards, particularly by cloudbursts, storm surges, high groundwater levels, higher temperatures, droughts, and wildfires.

6. Almost all municipalities estimated **loss and damages**, but mostly with only reference to flooding, which is the climate hazard, with more data available at the local scale.

7. Most municipalities estimated **land demand or availability** for some or all their actions, while a minor part didn't estimate it at all but, in many cases, mentioned the need to do so.

8. **Cross-municipal collaboration** is ubiquitous in climate planning, focusing primarily on sharing expertise, aligning goals, and jointly pursuing large-scale energy solutions for mitigation or pooling resources and knowledge to address common climate adaptation risks.

9. **Stakeholder engagement** is considered key to climate mitigation; in climate adaptation, the level of engagement initiated by municipalities is higher with non-municipal actors than with other municipalities.

10. Among the main **barriers** to climate action, finance is considered the most significant hindrance, followed by the lack of capacities and skills within the municipal workforce, as well as challenges given by the institutional structure, and the lack of supporting legislation for emission reduction.

11. Other barriers include a lack of incentives and ingrained habits that lead to limited public **participation**, the scarcity of available, accurate **data**, and the lagging implementation of appropriate **technology**.

12. Denmark's **land use** is heavily dominated by AFOLU, posing significant challenges to biodiversity, climate adaptation, and

sustainable development. Reforms are needed to balance competing demands for food production, energy generation, urban development, and nature conservation, emphasizing area efficiency and multifunctional land use.

13. A cohesive, adaptive **national land-use strategy** is essential to address Denmark's climate and biodiversity crises. This requires innovative farming practices, land-efficient energy solutions, compact urban planning, and dedicated nature zones supported by public dialogue, clear policies, and incentives for landowners to prioritize sustainability.

14. **Regenerative agriculture** in Denmark is emerging as a promising approach to balance food production with ecological restoration, addressing the nation's biodiversity crisis through practices like minimal soil disturbance, year-round land cover, and integrated crop-livestock systems.

15. While regenerative agriculture offers potential benefits for soil health, biodiversity, and emissions reduction, debates about its mitigation potential, scalability, and monitoring systems highlight the need for **further research**, **empirical evidence**, and robust **certification frameworks** tailored to the Danish context.

The last chapter of this document summarizes the results of the research into conclusions that lead to the formulation of general and sector-specific **recommendations** for improved climate planning and implementation in the Region of Southern Denmark and beyond.

The recommendations were written before the Danish Health reform (*Aftale om Sundheds-Reform 2024*) and the Green Tripartite Agreement *(Den Grønne Trepart*) were released in their final versions, whose implications radically change the governance landscape concerning climate planning and policy. At the moment it is not possible to reformulate the recommendations accordingly, as adjustments for this shift are still being defined. Nevertheless, these recommendations can be of support in strengthening the revision of the municipal climate action plans that are currently being updated.

1. INTRODUCTION

The project DK2020 – Climate plans for all Denmark (*DK2020 - Klimaplaner for hele Danmark*) unified local climate action in Denmark through a partnership between Realdania, KL – Local Government Denmark (*Kommunernes Landsforening*), and the five regional administrations. The partnership originates from the DK2020 project, which was initiated in 2019 by Realdania with 20 pilot municipalities; the initiative to scale it up with the involvement of the DGOs revealed great interest throughout the nation. The first round of the nationwide project involved more municipalities, and a report on the combined mitigation efforts of those equipped with a finalized climate plan was published briefly after, indicating them as representing almost half of Denmark's CO_2e emissions (Ea Energianalyse, 2023). The project ultimately comprised the voluntary participation of 96 municipalities across the nation, which summed to those already part of the C40 network, totaled all Danish municipalities engaged in climate action. In collaboration with C40 and Concito, the project guided local governments in the development of their climate plans, providing a version of C40's Climate Action Planning Framework (C40 Cities, 2020) adapted to the Danish context.

DK2020 – Climate plans for all Denmark ended in 2023, with an evaluation of the whole project published the following year (IRIS Group, 2024), but the continuation of the partnership was ensured by the new 5-year agreement of the Climate Alliance (*Klimaalliencen*, not to be confused with the European Climate Alliance). Beyond the objectives of the DK2020 project to meet Denmark's targets of the Paris Agreement (meeting or exceeding the national reduction targets at that time) and adapting to the consequences of climate change, the Climate Alliance also intends to support the achievement of the climate targets at the local level (Klimaalliencen, 2023). A follow-up on the nationwide mitigation efforts of the 96 municipalities was published briefly after the end of DK2020 (Ea Energianalyse, 2024), revealing that they plan a combined reduction of 76% in 2030 compared to 1990 – 6 percentage points more than the national target of 70% set by the government. In the same period, an in-depth analysis of their adaptation efforts was also published (NIRAS, 2024).

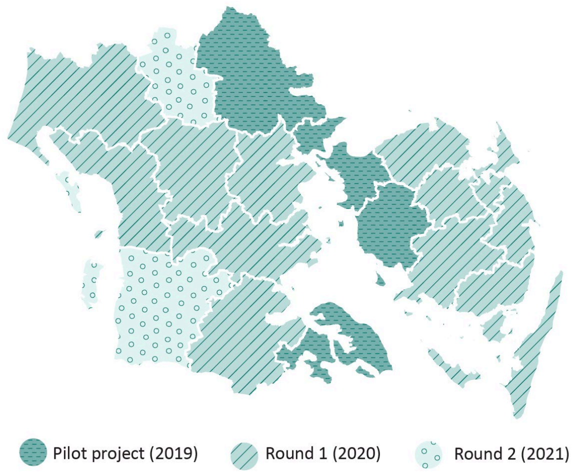


Figure 1. Rounds of involvement of municipalities of the Region of Southern Denmark to the DK2020 project.

By June 2023, all municipalities in the Region of Southern Denmark (*Figure 1*) had developed their climate action plan. Preliminary work on the analysis of their planned climate efforts began as a collaboration among the regional administration, the UNESCO Chair on Urban Resilience and the Climate Cluster at the University of Southern Denmark, and Aalborg University. The results were gathered in a report (Tollin et al., 2023) that provided an overview of the current local climate action efforts, considering both climate adaptation and mitigation and identifying key challenges in the development of the plans and in their implementation.

From the results of the preliminary report it became evident that efforts in the sectors of Agriculture, Forestry, and Other Land Use (AFOLU) will be crucial for the Region to achieve its climate targets. While the other major emission sectors of energy and transport see a drastic reduction of their emissions according to future projections, the agricultural sector currently is and is predicted to be the most emitting, with technological advancements coupled with drastic changes needed to significantly impact its carbon footprint. On the other hand, current knowledge of forestry and land use change (e.g., conversion of cultivated low-lying soils) indicates that there is a good potential to counter emissions by the preservation and the establishment of natural areas that, beyond absorbing and storing carbon, provide a wide array of co-benefits.

This new report aims to integrate the preliminary analysis and focus on a deep dive into AFOLU, which includes an overview of the state of the art and the indications of the current gaps to support more action in that direction. This is delivered by expanding the number of documents analyzed related to climate action planning and increasing the reach of surveys and interviews to relevant municipal figures. While the survey and interviews were performed to gain some updated insights on the current state of climate action planning, the information gathered from the documents in this report only represents the state of the art at the end of the project DK2020 – Climate plans for all Denmark in early 2023.

2. METHODOLOGY

A limited number of climate plans and related technical documents were analysed for the preliminary report (Tollin et al., 2023), coupled with a few surveys and interviews with municipal climate coordinators. Such methodology was refined for this new report, and the analysis was integrated with additional technical documents - especially to integrate planned efforts on climate adaptation-, an extensive round of surveys, and interviews with internal and external stakeholders. As the results of the preliminary work indicated that action in the AFOLU sectors would be most significant for the Region of Southern Denmark to reach its climate targets, in-depth data was collected for this report through the documents, the surveys, and the interviews, with various stakeholders were organised to obtain insights in this regard.

2.1. Analysis of climate plans

To perform the analysis, data from every municipality's DK2020 climate plan was extracted, together with information found in additional technical documents annexed to the plans, and in the climate adaptation plans.

A taxonomy was developed as following, where each element represents an indicator group (*Figure 2*):

1. **Documents**: list of all documents considered for each municipality (summarized in *Figure 3).*

2. **Mitigation challenges**: baseline values of the most recent emission estimate by sector.

3. **Mitigation goals**: *residual emissions* for 2030 and 2050 and emission gaps by sector. Residual emissions were required by the CAPF and defined as those emissions remaining after all technically and economically feasible opportunities to reduce emissions, in all covered scopes and sectors, have been implemented (C40 Cities, 2020). They can also be mentioned as *target years*. The 2030 *emissions gap* has also been calculated for each municipality, as the gap between the 70% reduction target by 2030 and the residual emissions, since all municipalities expressed their intention to align with the national target: the value of the 2050 emission gap equals to 2050 residual emissions.

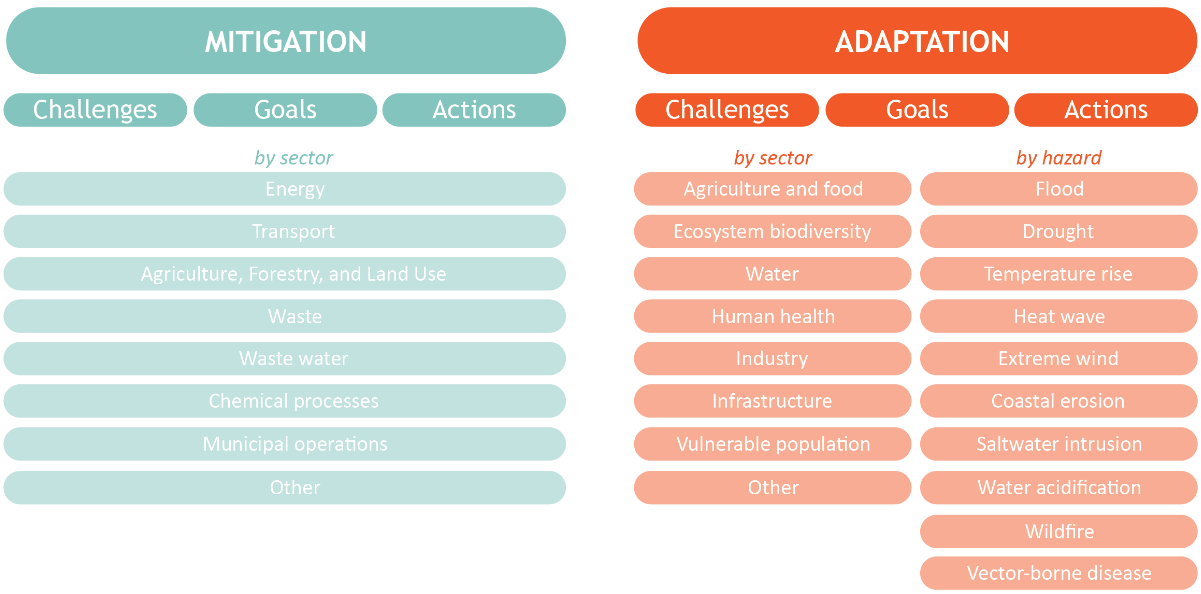


Figure 2. Taxonomy for data collection.

4. **Mitigation actions**: collection of planned actions to reduce and prevent emissions.

5. **Adaptation challenges**: risk assessments by hazard and by sector, including loss and damages estimations

6. **Adaptation goals**: goals by hazard and by sector.

7. **Adaptation actions**: collection of planned actions to reduce and prevent climate risks.

8. **Implementation**: annotations on whether implementation elements such as responsible parties, timeline, and budget were expressed for each mitigation and adaptation action; this indicator group was not taken into consideration for this report due to the early stage of the climate plans.

9. **Barriers**: collection of all mentioned barriers, grouped according to legislation, governance, capacity, finance, participation, and stakeholder engagement, technology, and data.

The emission sectors of energy, transport, and AFOLU were compulsory for the municipalities to include in the emission projections of the plans, while those of waste, wastewater, and chemical processes were optional. The taxonomy included also a final category to include other sectors, such as tourism and municipal operations.

The adaptation sectors and hazards were inspired by a methodology previously developed for extracting data from Nationally Determined Contributions (UNDP, 2024).

The focus on AFOLU made use of all collected municipal actions involving such sectors. Based on the taxonomy, this means that the indicator of AFOLU actions was considered for mitigation, while the indicators of actions concerning agriculture and food, and ecosystems and biodiversity were taken into account for adaptation.

To quantify the impact of the AFOLU mitigation actions, the estimated emission reductions of the individual actions were extracted when available, according to the most common target years of 2030 and 2050.

On the other hand, the impact of AFOLU adaptation actions was measured by the estimation of financial loss and damages in the scenario of lack of action for preventing a specific hazard.

	Climate Plan	Climate Action Planning Framework	Climate Adaptation Plan	Other documents
Assens	0	1	1	1
Billund	0	1	0	1
Esbjerg	0	1	1	3
Fanø	0	1	1	2
Fredericia	1	1	2	2
Faaborg-Midtfyn	0	1	0	0
Haderslev	0	1	0	1
Kerteminde	0	1	1	1
Kolding	0	1	0	7
Langeland	0	1	0	1
Middelfart	1	1	1	1
Nordfyns	0	1	0	4
Nyborg	0	1	1	2
Odense	1	1	1	1
Svendborg	0	1	0	1
Sønderborg	0	1	1	0
Tønder	0	1	0	2
Varde	0	1	0	4
Vejen	0	1	1	3
Vejle	1	1	1	1
Ærø	1	1	0	1
Aabenraa	1	1	1	2

Figure 3. Types of consulted documents for each municipality.

Some mitigation actions involve some kind of land use change (e.g., change of kind of cultivation). When this change is planned for the establishment of natural areas, this creates an overlap with adaptation actions. Integration between mitigation and adaptation efforts is encouraged, although to prevent repetition in the report, such actions have been listed in the mitigation section of the report only, with a reminder in the adaptation section. A supplementary metric was used to gather data on the land demanded by each individual land use-related AFOLU action.

2.2. Survey

A tripartite survey was developed in order to obtain quantitative data concerning the state, impacts, and outcomes of municipalities' ongoing climate action work. The survey was initially derived and expanded upon the preliminary report's survey (Tollin et al., 2023). The survey was also meant to serve as the starting point for the subsequent interviews so that the surveys might build a broad outline of the opportunities, challenges, and characteristics of climate action work whereas the interview might allow for more detailed investigation. This foundational survey was divided into three separate surveys to reflect three relevant DK2020 stakeholder groups in the Region of Southern Denmark, namely: (1) the climate coordinators for each municipality in the Region; (2) municipal employees in each municipality; and (3) non-municipal organizations and companies working within and across the Region. This partition was made in an attempt to understand the climate action work from three separate but interlinked stakeholder perspectives.

Although three different surveys were developed, they all endeavored to ascertain the state of climate action planning throughout the Region of Southern Denmark's municipalities. All three surveys began with 3 meta questions concerning the respondents' workplace, job title, and years of experience to allow for anonymous referencing. All surveys allowed participating respondents to rate to what degree certain climate action themes concerning DK2020 were relevant and/or successful. All respondents were instructed to answer according to their own individual experiences and perceptions rather than represent the corresponding municipality or organization as a whole. This preface was added in an attempt to enable respondents to answer more freely on their own experience and knowledge, as well as to acknowledge the certain perspective that each individual has within a larger organization. Survey data were all collected in SurveyXact, and all survey invitations were sent to the appropriate respondents via email.

The first survey of the Region's climate coordinators was structured to be the most comprehensive given the extensive involvement, knowledge, and responsibility of the role. In total, this survey contained 21 questions, 15 of which utilized a 5-point Likert scale with an additional "do not know/is not relevant" option. 4 following questions asked the respondent to rank the relevance or impact of sectors, climate hazards, and barriers discussed within the municipal CAPs. The remaining 2 questions were comment based. These respondents were intended to cover both climate mitigation and climate adaptation in their answers.

The second survey, geared towards internal municipal employees, intended to verify the climate coordinators' answers. Respondents were chosen because of their position within the department most related to the biggest emission sector in that particular municipality. These respondents were therefore not explicitly sought out due to a position in the climate adaptation or climate mitigation team within the municipality, but their role might natural lean towards climate mitigation (if, for example, working with climate ang energy) or climate adaptation (if, for example, working with nature and environment). This survey did not assume the same degree of climate expertise as the climate coordinators and was thus shorter with 13 total questions. 9 used the aforementioned 5-point Likert scale whereas the final 4 questions were comment based.

The third survey centered on stakeholders outside of the municipality such as utility companies, agricultural associations, and energy businesses to provide an external perspective on a municipality's climate work and the accompanying influence on the respondent's organization. Respondents were chosen due either to their mention in the climate action plans of one or more municipalities or due to their specific influence on the AFOLU sector within one or more municipalities. Out of the 14 total questions, 8 followed the same 5-point Likert scale as the other surveys, 2 asked each respondent to rank the degree of involvement with both the municipality and other actors in terms of climate adaptation and climate mitigation, and the last four questions were comment based.

The corresponding surveys were sent directly to 183 respondents: 26 of the first survey to climate coordinators, 44 of the second to internal municipal employees, and 113 of the third to external organization or company employees. Of those 183 respondents, 81 (44.3%) completed the survey with 15 (57.7%) respondents for the first survey, 21 (47.7%) for the second, and 45 (39.8%) for the third.

The analysis in chapter 3 incorporates complete and partially complete responses to the surveys. The survey and concomitant data analysis were designed to identify overarching comparisons and overlapping themes across municipalities, which the interviewed would then investigate in more qualitative detail. No statistical analysis was conducted as the limited sample size would not yield statistically significant results. The evaluation of the surveys therefore relied solely on the summary report generated by SurveyXact, which supplied an overview of the data through comparative diagrams.

2.3. Interviews

As an expansion on the survey elucidated above, 24 interviews were conducted by the report authors and a DK2020 student lab (detailed in the following paragraph). 18 of these 24 interviews were deemed relevant (the exclusion of some student lab interviews was due to either redundancy or irrelevance to this report) and utilized as part of this report's analysis (see *Table 1* for a complete list). These qualitative interviews intended to augment the quantitative figures of the survey by elaborating on themes discussed in the survey and posing more sector and hazard-specific questions.

The **DK2020 student lab** was developed at AAU to support 12 students (2 Bachelor's projects and four Master's' projects) with their respective theses centered on various aspects of the DK2020 climate action work. The student lab entailed shared resources and data, regular meetings, workshops, and divided synergistic tasks where applicable. In terms of interviewee choice, students were given the index of stakeholders invited to participate in the survey and self-determined the criteria for an ultimate decision to contact certain actors for an interview. This is why some of the lab's interviewees also entail external stakeholders rather than municipalities in the Region of Southern Denmark, which was the stakeholder focus for interviews conducted by the report authors. While the students utilized the interview guide of the report (see next paragraphs) as a point of departure, they may have had additional questions or a specific project or thematic focus in their interviews. Any such differences are articulated in *Table 1*. Nonetheless, these student-led interviews were included because they maintained the same thematic scope as the prescribed interview guide and the expanded reach of the interviewees; the two additional municipalities were predominantly used for cross-municipal comparison, while the two city councils, three external stakeholders, and one utility were used to supplement insights from the municipalities.

If not anonymized in the students' elaborations, this report has anonymized all amassed interviews. Most of these interviews were conducted in Danish, while 1 took place in English. 15 of the 24 interviews are a product of this student lab. 9 interviews were conducted by the authors of this report. All interviews, which lasted between 50-80 minutes, were recorded and transcribed in Danish or English, depending on the language used during the interview.

Table 1. Interview list. While students were provided with the same interview guide as those used by the report authors, any changes made to said guide are articulated below.

No	Interviewee	Type	Interview guide changes
01	Municipality 01	Authors	None
02	City Council 01	Lab	Focus on barriers and involvement
03	Municipality 02	Authors	None
04	Municipality 03	Authors	None
05	Municipality 04	Authors	None
06	Municipality 05	Authors	None
07	Municipality 06	Authors	None
08	Municipality 07	Authors	None
09	Municipality 08	Authors	None
10	Municipality 09	Authors	None
11	City Council 09	Lab	Focus on climate adaptation
12	Municipality 10	Lab	Focus on future climate action work and climate adaptation
13	City Council 10	Lab	
14	Municipality 11	Lab	Focus on citizen engagement and climate adaptation
15	External Company 01	Lab	Focus on climate adaptation and organization
16	External Company 02	Lab	Focus on climate adaptation and organization
17	External Company 03	Lab	Focus on climate adaptation
18	Utility 01	Lab	Focus on climate adaptation

7 of the 9 interviews were conducted by two interviewers, while the remaining 2 only by one, with the primary interviewer posing questions and the second maintaining the interview structure and taking notes in line with the report's taxonomy. The resulting interview material and interviewee information is only shared among the research partners, and personal information is kept securely on encrypted servers.

While the interviews have been anonymized, the interviewees were sourced directly from the survey. Only survey respondents who indicated an interest in being contacted for further dialogue were invited to participate in an interview.

The **interview guide** served as the structural guideline for each dialogue. The guide directed each respondent to answer personally, rather than represent their organization. Similar to the surveys, this preface was included to encourage respondents to provide more open and reflective answers based on their own experiences and knowledge while also recognizing the unique perspectives each individual holds within a larger organizational context. Each interview and resulting interviewee responses were thereby positioned as contextual statements influenced by the dynamic interaction between interviewer and interviewee (Gubrium & Holstein, 2012). Using the survey and the interview guide from the previous report as a foundation, the new interview guide dived into specifics concerning the status of municipalities' climate action work in terms of resources, collaboration, and synergies as a result of the DK2020 process and the CAPF. The questions also prompted respondents to discuss mitigation and adaptation measures more explicitly, with supplementary follow-up questions focused on specific sectoral themes, particularly AFOLU.

Following the interviews, the transcriptions of the 9 interviews conducted by the authors and 9 interviews conducted through the student lab were thematically coded based on this report's established taxonomy (see Section 2.1) to cover 11 of the 22 municipalities in southern Denmark. These themes were subsequently cross-referenced between interviews to ascertain similarities and discrepancies across the analyzed municipalities.

Further work would include comparing and contrasting these qualitative interviews against ten related DK2020 interviews conducted at the end of that project (NIRAS, 2024). A precursory analysis highlights thematic overlaps and differences; the four overarching themes of the NIRAS and Concito report (internal process and organization, external process and involvement, goals for climate adaptation, DK2020, and CAPF) largely relate to themes discussed in the interviews presented in this report, with one major difference lying in their explicit thematic focus on climate adaptation. The interviews in this report attempted to equally understand the state of climate adaptation and climate mitigation in the interviewed municipalities. From a methodological perspective, the logic behind the case selection of interviewed municipalities noticeably differs. The interviewed municipalities in this report were delimited to the Region of Southern Denmark and to those who expressed interest in such an interview following the survey, whereas the NIRAS and Concito study selected case municipalities from across Denmark in attempt to reflect an appropriate variety of regions and cities, sizes, participation in DK2020 and networks, and experience with climate.

The questions from the Danish interview guide are reiterated in full below:

1. Please describe the process of developing and integrating the Climate Action Planning Framework (CAPF) into your municipality from your personal involvement.

2. How is the CAPF applied and/or implemented in your daily work of your municipality? *answer for both adaptation and mitigation*

3. How is the CAPF applied and/or implemented in other planning processes in your municipality? *answer for both adaptation and mitigation*

4. Do you think you could benefit from planning mitigation and adaptation actions together?

5. How is adaptation/mitigation planning and the CAPF communicated and managed from employee to employee?

6. What is your assessment of why municipal employees in non-climate related positions ARE/ARE NOT aware of the municipality's mitigation and adaptation planning??

7. What is your assessment of why the climate measures indicated in your municipality's climate action plan ARE/ARE NOT financed and part of the budgeting of funding in planning?

8. What is your assessment of why the financial costs of inaction ARE/ARE NOT accounted for in your municipality's planning?

9. What is your assessment of whether the necessary resources (money/person-years) are/will be allocated in the short, medium, and long term to implement the initiatives?

10. Please describe the methods used to engage and involve various actors (such as citizens, local

organizations, companies, etc.) in your municipality's climate adaptation/mitigation planning process.

11. Please describe the collaboration process with other municipalities in terms of climate adaptation/mitigation.

12. How have other municipal climate plans influenced your municipal climate plans regarding climate adaptation and mitigation? Which plans?

13. Why did you specify sector X as the most relevant for the municipality's climate planning? *specific sector from survey question*

14. Why are the three chosen hazards (X (1), Y (2), Z (3)) prioritized? *specific hazards from survey question*

15. In your assessment, what could be done to overcome the barriers you have identified in terms of implementing climate adaptation and mitigation?

2.4. Thematic research

The original intention of this research was to follow the survey and subsequent interviews with one or more focus groups to investigate further discussions, barriers, and successes unearthed through said survey and interviews. However, this final method was changed as limited stakeholder availability rendered a focus group impossible. Consequently, directed desk research into land use and regenerative agriculture was substituted for the focus groups to dive deeper into themes derived from the survey and interviews. This research did not constitute a full literature review or state of the art, but rather a focused investigation into the contemporary debates, scholarly literature, potential solutions, and future research opportunities shaping Denmark's land use, and regenerative agriculture. The literature search for this research encompassed both scholarly literature and gray literature in the form of reputable media organizations, think tanks, and relevant companies. To ensure up-to-date information, only sources written within the last five years were included.

2.5. Limitations

Due to the different stages of involvement in the DK2020, the climate plans were developed in different years. Hence, there are obstacles in providing a homogeneous overview of the regional mitigation efforts in absolute terms; relative terms were used instead.

For the same reason, some of the analyzed documents may be considered partially obsolete, as some actions might have already been carried out or modified along the way, and gaps filled since the implementation of the plans. In this regard, it is essential to highlight that this report does not include a distinction between planned efforts and implemented ones.

All plans and their integrating documents were certified to comply with the formal requirements of the DK2020 project. This report has not reviewed the entirety of the documents and has assessed the materials according to its own requirements.

Given the survey's subjective self-selection and small sample size, the meaning of the different results should only be seen to show the variability in perceptions of climate action work. As the respondents are assumed to be climate-motivated individuals (for example, over half of the internal municipal employees are in roles related to the environment and/or climate and therefore do not presumably represent an accurate breakdown of all municipal employees), the above analysis could potentially portray an overly positive state of climate action work awareness, integration, and opportunities in these municipalities. This possibility underscores the necessity for further integration of climate action work within and beyond municipalities.

Half of the municipalities in the Region of Southern Denmark were not interviewed within the confines of this report, meaning that those personal perspectives from climate-related municipal employees are lacking. As certain experiences, insights, and conclusions derived from the interviewed municipalities are only assumed as representative – to a certain extent – for the remaining municipalities, interviews with these municipalities would be necessary to comprehensively validate generalizable conclusions for the whole region.

While the interviews completed under the purview of the student lab did use some of the same questions and all followed the same theme of investigating the climate action work derived from the DK2020 project, they did not *exactly* follow all of the questions from the interview guide developed for this research agenda. This discrepancy could mean that the discussion from these student-led interviews might be somewhat incongruent with that of the author-led interviews. However, any discrepancy is estimated to be inconsequential because any and all findings used in this report from these student lab interviews were taken from questions and dialogues directly related to this report's interview guide.

The thematic research of this report was not conducted as a systematic literature review. The results of this research are therefore not as comprehensive as results obtained from a full literature review and could potentially, although not intentionally, omit certain perspectives from the articulated debates contained within this section. With that in mind, the intent of this thematic research is to objectively depict the current state of Danish land use and regenerative agriculture, but it is possible that the literature used presents a certain bias in the analysis.

3. RESULTS

3.1. General results

The climate plans were produced at different stages compared to when the survey was filled out and the interviews took place, hence they are distinguished into two different chapters. In subchapter 3.1.1 on the overview of the climate plans, the first section focuses on climate mitigation and elaborates on the same data set of the first report; the subsequent section on climate adaptation presents significant new additions, such as how various socio-economic elements are estimated to be affected by climate risks, how loss and damages were considered, and how climate risks were tackled by climate actions.

Subchapter 3.2.1 on the stakeholder insight is comprised of results chronologically extracted from the survey and followed by interviews, with each consecutive method implying a greater degree of specificity. These sections determine the updated state of the climate action work, equally in terms of mitigation and adaptation, based off of the earlier climate plans. They are derived from the personal perspectives of various municipal employees (including but not limited to the climate coordinators) and external stakeholders involved in the climate action plans.

3.1.1. Overview of the climate plans

3.1.1.1. Climate mitigation

The regional emissions equal **13.16 MtCO₂e**. Each municipality utilized different years to estimate their current emissions (*Figure 4*); for this reason, the above-mentioned value to present the most current estimations at a regional level uses 2019 data (Viegand Maagøe, 2019). This value differs by slightly more than 1 $MtCO_2$ compared to the 2019 emission data offered by the current national platform (SparEnergie, 2024), which estimates them to equal 11.79 MtCO2e for the region and 27% out of the total nationwide.

Figure 4. Baseline years.

If we used the heterogenous values provided by each municipality in their climate plan, the cumulative emissions would amount to 13.4 Mt CO_2e. The difference with the value estimated at a regional level is attributed not only to the different reference years, but also to the different methodologies for the calculations used before 2019.

The regional emissions in 1990 amounted to **22.26 Mt CO_2e** (Viegand Maagøe, 2019). The year 1990 was indicated at a national level as the baseline year from which to calculate national and local residual emissions. The methodologies used to estimate emissions by sector vary among municipalities but are obtained from the same data by Viegand Maagøe (2019). In the case of **AFOLU**, all but four municipalities only considered the agriculture sector. *Figure 5* shows that it is the biggest emitter in the present and the future, representing 41% of total emissions in 2019 and 64% in 2050. The smallest emitters are represented by waste, wastewater, and chemical processes.

Figure 6 shows an overview of the municipalities' estimation of current emissions (challenges) and residual emissions (goals) by 2030 and 2050. Several residual emissions for 2030 had to be independently calculated for this report, as some municipalities communicated their emission gap instead or calculated it for different target years. The latest global emission gap report (United Nations Environment Programme, 2024) suggests 2035 as an additional, closer target year for planning actions and quantifying their emission reduction effect, as it will be a requirement for the next Nationally Determined Contributions.

The regional **residual emissions by 2030** are estimated to be **6.56 Mt CO_2e**, equivalent to a 71% reduction compared to 1990: this means that the region is on a path to reduce 1% more than the national reduction target of 70%. In particular, 9 municipalities are set to perform better than the requirement of the 2030

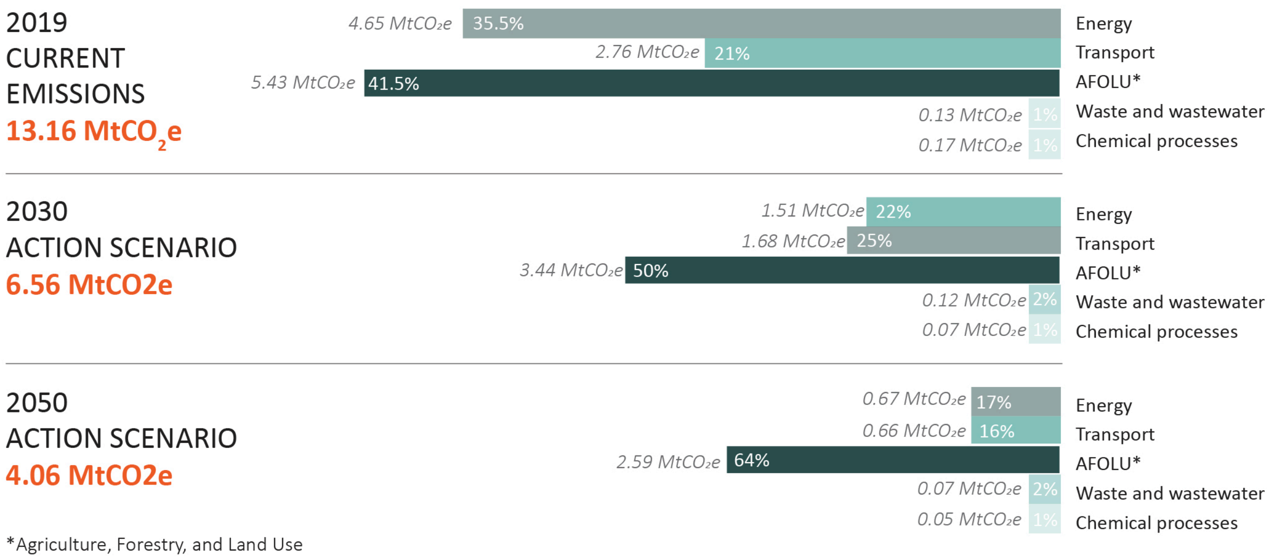


Figure 5. Regional current emissions and mitigation scenarios.

target: Fanø, Fredericia, Kerteminde, Nordfyns, Nyborg, Odense, Svendborg, Sønderborg, and Vejen. For example, Odense aims at achieving climate neutrality by 2030 with the current actions, while also estimating some residual emissions at this current stage with the planned actions.

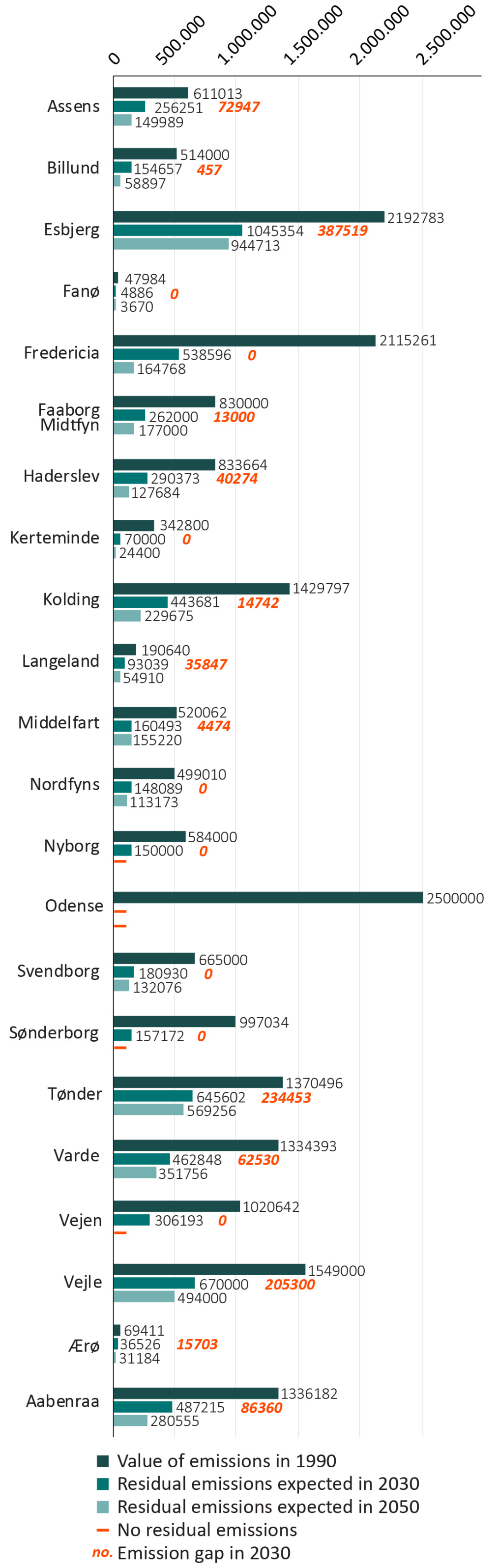
With reference to **residual emissions by 2050**, it is estimated to be **4.06 Mt CO_2e** in 2050, which equals 82% progress towards the target. According to their planned actions, Nyborg, Sønderborg, Odense, and Vejen will achieve climate neutrality by 2050.

The consistency of consideration of the emission sectors in municipal plans is illustrated in *Figure 8*. The majority of challenges, goals, and actions involve the three major emission sectors in the Region, namely those of **energy**, **transport**, and **AFOLU**: all municipalities accounted for their current emissions within these sectors, and almost all set up one or more targets and actions for emission reductions by mid-century. This becomes even more apparent in *Figure 7*, which presents a focus on which sectors are considered by each municipality in their actions. The only exception is the municipality of Fredericia, which didn't plan actions within AFOLU, as it accounts for only a negligible share of its local emissions.

Only some municipalities present actions for **waste**, **wastewater**, and **industrial processes** due to the fact that such sectors constitute a very small proportion of their total emissions.

The estimation of the emissions produced on **municipal operations** (e.g., from the heating of their buildings, the exhaust of their vehicles, etc.) was not a requirement of the CAPF, but over half of the municipalities in the Region planned actions to reduce them (e.g., electrification of their car fleet, plant-based canteens, etc.). This is a significant initiative that can lead other institutions by example.

Most municipalities indicate that their **current actions are insufficient** to reach 100% emission reduction by 2050. This realistic statement informs us that more efforts must be made in the coming years – at the local level, as much as the global level. While progress in energy and transport seems to ensure a steady path toward decarbonization, further efforts will be significant for the Region to focus on AFOLU. This also emerges in the following subchapter on adaptation and is deepened in the subsequent chapter on the deep dive into AFOLU. A summary of the specific mitigation actions planned for the other emission sectors can otherwise be found in the preliminary report**.**



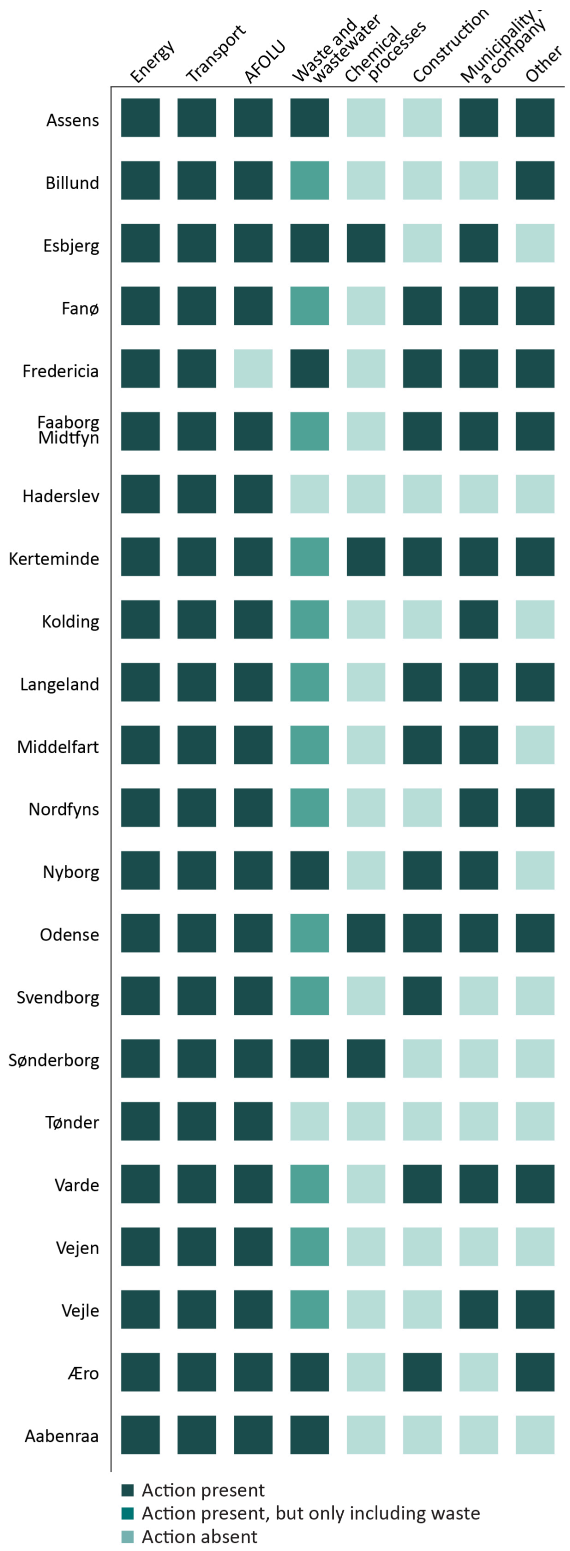


Figure 6. Municipal emission accounting of 1990, residual emissions in 2030 and 2050, and emission gap in 2030 (tons CO2e).

Figure 7. Mitigation actions by municipality.

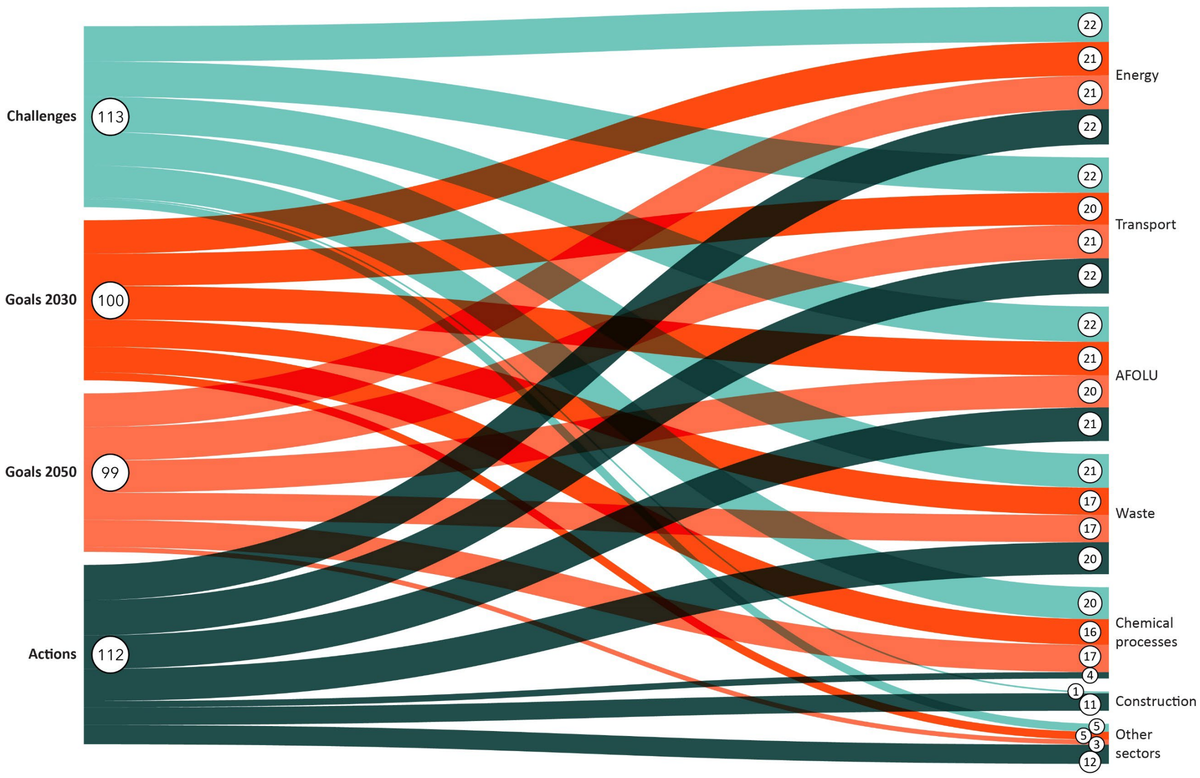


Figure 8. Mitigation challenges, goals, and actions by sector.

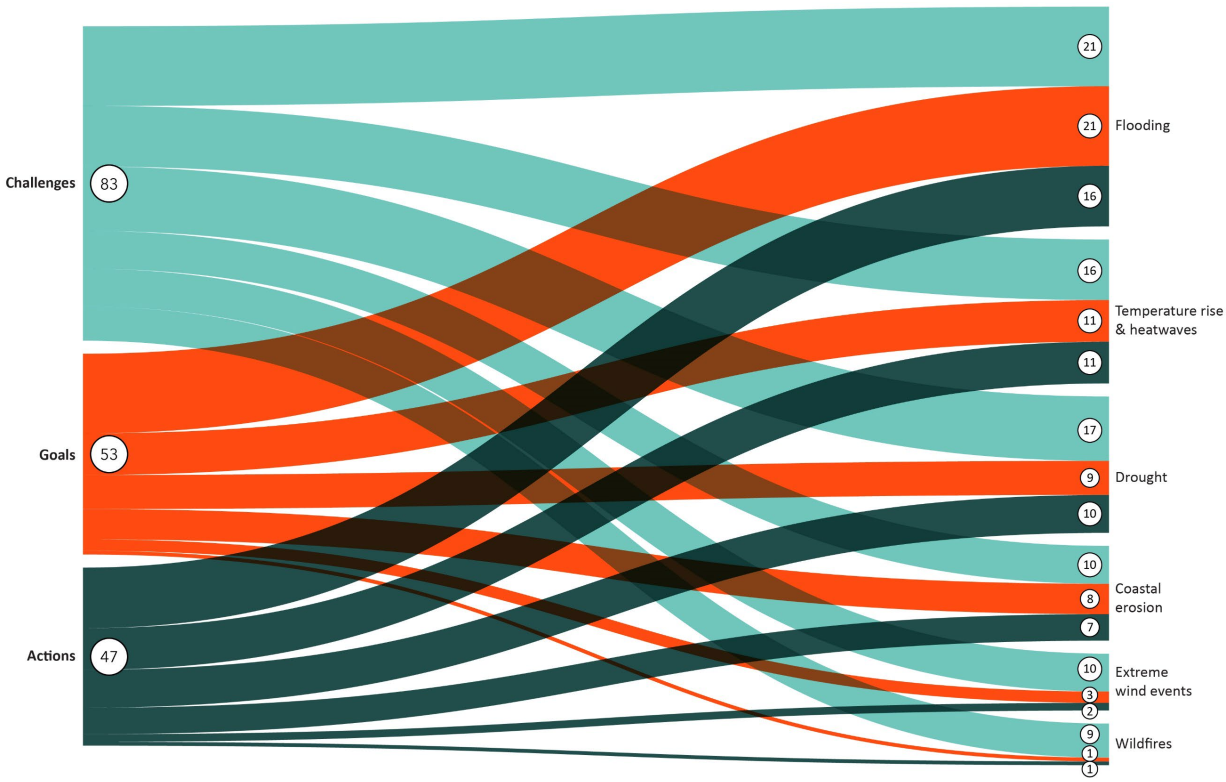


Figure 9. Adaptation challenges, goals, and actions by hazard.

3.1.1.2. Climate adaptation

The **adaptation challenges** in the municipalities are represented by their climate risk assessments, which were produced with a mix of data sourced from the Danish Meteorological Institute (DMI)'s Climate Atlas (DMI, 2024), from the Region, and from studies made by the individual municipalities. The DMI provides data on precipitation and its return values, water level and storm surge, temperature, wind, solar radiation, evaporation, wildfire, and drought. They are all proposed into the different scenarios of RCP of 8.5 (steady increase in emissions), 4.5 (intermediate), and 2.5 (increase up to 2°C), and in the timeframes up until 2040, until 2070, and until the end of the century. The Region provided the municipalities with a flooding and coastal erosion map with more precision than the materials of the national agency, while the studies were generally performed with the help of external consultants.

The **adaptation goals** of almost all municipalities are linked to a timeline (*Figure 10*), where 2030 and 2050 are the most mentioned target years by 14 and 17 municipalities, respectively.

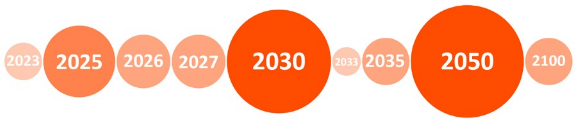


Figure 10. Target years to achieve adaptation goals, weighted according to number of occurrences.

Some **adaptation actions** respond to multiple hazards contemporarily, such as floods originating from different causes, temperature rising with heat waves or storm surges with coastal erosion.

The **flooding** hazard stands out in *Figure 9* as the one most municipalities assessed and generated goals and actions for. This is supposedly due to the widespread know-how and tools available to map such risk compared to the others. This translates into well-informed scenarios on which to base preventive and reduction actions. Some municipalities tend to generalize the risk of flooding when assessing it, though different phenomena can cause it. When flooding is constituted by surface runoff caused by heavy rain, it is called a **flash flood**. The risk of **flood from rivers** occurs when the water overflows out of its riverbed, which is typically due to heavy rainfall; however, it can also originate from snowmelt and the collapse of dikes or other protective infrastructures. The risk of **flood from groundwater** happens when the underground drainage system doesn't absorb rainfall quickly enough, resulting in the water table rising above the ground surface. Ultimately, the risk of **flood from the sea** derives from water flooding into the coastal land due to high tides, storm surges, subsidence, etc.

The risks of **temperature rise** and **heatwaves** follow next as the second-most assessed after flooding.

Most municipalities also assessed the risk of **drought**, 2 of which identifying it as low risk in the short term. At the same time, 5 chose not to assess it due to irrelevance in the short/medium period. The same irrelevance was pointed out by 3 municipalities about **coastal erosion**.

Events of **extreme wind** (or storm events) and storm surges are two different phenomena, though they are strictly related. While storm surges (englobed as 'floods from the sea' in this report) are often considered, the risk of extreme wind is only included by less than half of the municipalities, 5 of which identify it as not a priority to be assessed.

Various socio-economic elements are affected by climate risks and need special attention when planning actions. *Figure 11* shows the considerations of these elements among adaptation challenges, goals, and actions. The distance between the circles represents an interval of two, up to a maximum of 12 municipalities considering each sector. The socio-economic elements most commonly mentioned as being affected by future risks concern infrastructure, ecosystems, water, and other sectors. **Infrastructure** includes buildings, public services such as the power grid, and infrastructural elements such as roads. **Ecosystems** include any natural assets and their biodiversity and are deepened in section 3.3.2 of this report. **Water** includes its local water management (as well as its scarcity) and the sewage system. Other elements can include **tourism**, **cultural heritage**, and **emergency systems**.

Figure 13 outlines all adaptation actions by hazard planned by each municipality. Here, the distinction of floods into the four causes shows that actions tackling flash floods are the most planned, followed by those caused by the sea, with the only exceptions being the municipalities of Billund and Vejen, as they do not present any coastal area, therefore any action in this regard would be irrelevant.

Figure 11. Consideration of challenges, goals, and actions by sector.

The figure also shows that some municipalities mentioned the risks of **saltwater intrusion** and **water acidification**. The former characterizes the seepage of seawater into surface freshwater and groundwater (e.g., coastal aquifers) due to its higher density (Sharan et al., 2021); the latter refers to the process of acidification of seawater due to the excess of CO_2 it absorbs from the atmosphere, which is a phenomenon caused mainly by global factors (i.e., global warming), but with local consequences, such as aggravating the living conditions of marine species (NOAA, 2024).

In the analysis of this report, **exposure** and **vulnerability** are considered both for adaptation challenges and actions, but not for goals. In most cases, when exposure is considered in the plans, it is also only referred to flooding events, with the exceptions of Kolding that considered erosion events, and Varde that also considered drought events. Vulnerability is also usually expressed in relation to flooding events only in the plans, but in a few examples also temperature rise and heatwaves events are considered, by identifying vulnerable population groups (i.e., children and elders) and other forms of life.

The estimation of **loss and damages** can give a solid perspective on the consequences in the event of lack of adaptation, in economic terms but also with value systems that highlight possibly affected intangible assets in need of protection. 19 municipalities estimated them, most commonly by examining flooding events only. Common methods utilized for the estimations include the Damage Economics model (*modellen SkadesØkonomi*), developed in collaboration between the Funen municipalities, GeoFyn, DTU, KL and several suppliers; NIRAS' point value system, and EnviDan's damage calculation tool.

Figure 12 illustrates how many municipalities considered various hazards when estimating loss and damages in case of climate inaction. Most municipalities estimated them for action related to flooding events due to **precipitation** (38%), followed by flooding due to **storm surge** (36%), **river overflow** (20%), and **high groundwater level** (4%); only one municipality estimated them for **coastal erosion**.

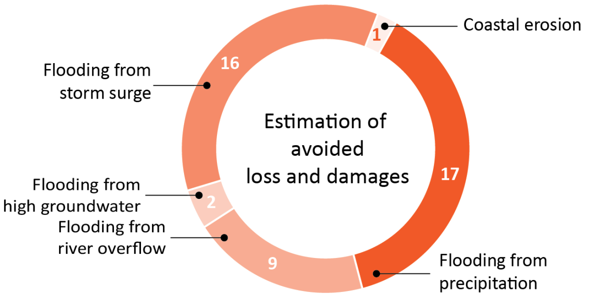


Figure 12. Number of municipalities estimating avoided loss and damages for adaptation actions.

Many plans clearly state that the calculation of loss and damages show that the loss in value can be far higher than the cost of climate adaptation actions, and a few municipalities disclosed the financial value of the loss and damages. The available information can help provide a sense of the size of the impact of adaptation actions: storm surges have the highest impact on the region (881,03 million DKK/y), followed by cloudbursts (497,70 million DKK/y), river overflow (48 million DKK/y), and coastal erosion (0, 80 million DKK/y).

Figure 13. Adaptation actions by municipality.

3.1.2. Stakeholder insight

Climate planning in general is ostensibly integrated into many other municipal planning processes (73% to some extent and 20% to a great extent), and opportunities to apply the climate action plan in the future are seen as fairly substantial (80% to a great or very great extent). The **climate coordinators** hypothesized that two-thirds (67%) of municipal employees in non-climate-related positions are aware of the municipality's climate action planning to some or a great extent.

Although 87% of **internal municipal employees** are familiar with their municipality’s climate action plan at least to some extent (and 2/3 to a very great extent), opportunities to incorporate that climate action into their daily work going forward are not as apparent (57% to a great or very great extent) as they are to the climate coordinators. Nearly two-thirds (63%) of these municipal employees indicate that their municipality prioritizes learning more about and infusing climate action work within and across the municipality to at least some extent or greater.

83% of the **external stakeholders** surveyed are familiar at least to some extent with their municipality’s climate action work (and their potential role in it), 63% have collaborated with their municipality to develop its climate action plan to some extent or greater.

According to the surveyed **climate coordinators**, **climate adaptation planning** is included at least to some extent in 94% of new urban development policies, strategies, and projects, whereas **climate mitigation planning** is included at least to some extent in 73% of the aforementioned new development policies, strategies, and projects. This high percentage of climate adaptation and climate mitigation integration has not yet been verified, so this finding must be viewed with a certain degree of skepticism.

However, this distinction between adaptation and mitigation is erased in the eyes of the **internal municipal employees**; climate adaptation planning and climate mitigation planning are both incorporated in two-thirds (67%) of the municipality's new urban development policies, strategies and projects.

In interviews, respondents underscored the **symbiotic similarities** between climate adaptation and climate mitigation. The reality of reduced emissions in turn reducing the need for adaptation makes for a motivating symbiosism, though this can only happen if reduction is effective globally. Indeed, a number of the interviewed municipalities articulated the ambition to develop projects that address both adaptation and mitigation aspects *where possible*, with a particular spotlight on integrating land-use and afforestation strategies which might synchronously capture carbon and manage surface water and erosion (Interviewee 01, 04, 05, 06, 08, 12). Capitalizing on and planning for these synergies where it makes contextual sense exemplifies the municipalities’ aim to adapt holistic thinking in their climate work as much as possible. A couple of municipalities suggest that these synergies should be unearthed and molded as project development progresses rather than pre-planned (Interviewee 01, 12). At the same time, one municipality expressed an uncertainty about how mitigation and adaptation fit together, except for some lowland water issues (Interviewee 07). This discrepancy might indicate a gap between theoretical ambitions for holistic planning and the reality of more siloed practice.

Despite the aspiration for this integrated approach, creating a seamless synergy between mitigation and adaptation remains a work in progress in many municipalities. Some municipalities are in a nascent stage of integrating adaptation into a historic focus on mitigation, while others have elucidated a specific strategy to think synergistically about nutrient management, water retention, and afforestation to simultaneously reduce greenhouse gas emissions, protect urban infrastructure from flooding, and enhance local ecosystems. In one municipality where future AFOLU projects are intended to focus on restructuring agricultural land use, synergies are intended to expand past just mitigative emission reductions and adaptive resilience, building to biodiversity increase.

The pursuit of **financial synergies**, where multiple funding sources co-finance projects that achieve both mitigation and adaptation goals, holds promising potential for many municipalities as they look to achieve more comprehensive and cost-effective solutions. For example, one municipality detailed a tripartite financing model where the municipality jointly co-funded a new forest together with the water utility and the Forest and Nature Agency; despite the goal of this initiative being linked to groundwater protection, it comes with added CO_2e reduction benefits.

While many municipalities recognize the potential for synergies between climate adaptation and mitigation, they also articulate that realizing this symbiosis is an ongoing and complex process. Many note that the geographical constraints of specific projects also limit the ability to merge these strategies, making synergies more context-specific. The physical reality of geography crossing borders might necessitate cross-municipal collaboration to manage large waterbodies and land adaptation actions such as those related to coastal protection. In contrast, mitigation efforts remain generally more localized and independent in comparison (Interviewee 01, 05, 06, 10). Additionally, the increasing visibility of damaging weather events has spurred a growing interest in climate adaptation, whereas the concrete changes involved in reducing emissions are seen as more of a detractor.

For some municipalities, adaptation, and mitigation are managed as two distinct departments, each with its objectives, strategies, and culture. This separation has made it challenging to integrate the two approaches in practice, with not all municipal employees seeing the potential for synergies in the projects being developed. Singular technical solutions for each and limiting geographic conditions are seen as further barriers to generating synergy between mitigation and adaptation.

Cross-municipal collaboration in mitigation planning is ubiquitous: the **climate coordinator** respondents indicated that they collaborate with other municipalities to at least some extent (33% to some extent, 40% to a great extent, 27% to a very great extent). Furthermore, comparative municipal climate mitigation work is often used as a starting point for climate mitigation planning (80% to some extent or greater).

The pervasiveness of cross-municipal collaboration on climate mitigation is reiterated in the interviewes, where collaboration primarily revolves around sharing expertise, aligning goals, and jointly pursuing large-scale energy solutions. The municipalities on Fyn have formalized their “very strong tradition of collaboration” into a close-knit network where cities collaborate regularly (Interviewee 08). This network has allowed them to co-develop cohesive climate mitigation projects, especially in the energy sector, where initiatives like transitioning district heating systems to renewable sources and implementing carbon capture technologies benefit from this collaboration (Interviewee 04, 06, 07, 08). Similarly, the coordinator network throughout southern Jutland predominantly centers around knowledge-sharing rather than extending into project collaboration, which depends on a case-by-case basis (Interviewee 12).

Despite the success of these cross-municipal networks, stakeholders report a lack of a **national coordination** group to share advice, guidance, and ideas. One municipality highlights the lack of a similar network for sharing experiences and cases on a national scale: “I actually sometimes miss a national mail group or LinkedIn group or whatever group with all climate coordinators from all over the country, where you can ask questions like: ‘do you have any good examples of how you succeed in creating climate partnerships with agriculture?’” (Interviewee 03). This support is especially missing for dialogues concerning transportation (for example, when the municipality obtains offers to replace the vehicle fleet) and agricultural sectors (Interviewee 03).

In one municipality, partnerships with other municipalities were deemed as key to successful mitigation projects (Interviewee 05). For instance, a joint biogas plant project leverages its technical expertise in planning and execution, demonstrating how pooling resources can enhance regional sustainability efforts (Interviewee 05). Meanwhile, the technical planning of large-scale PtX projects, which encompasses a scale with corresponding water and wind turbine issues that extend across borders, points to the necessity of cross-municipal collaboration for energy transitions (Interviewee 01).

Most municipalities (10) underline their use of other municipalities’ climate work for inspiration (Interviewee 01, 03, 04, 05, 06, 07, 08, 09, 10, 14), while one points to partnerships such as the Triangle Energy Alliance (a private and public sector collaboration on joint strategic energy plans, including large scale demonstration energy projects) as evidence that climate-related cross-pollination even predates the climate action plan (Interviewee 05). This influence varies from looking at various municipal communication and setups (Interviewee 06) to looking for specific examples from some instances (Interviewee 03). One municipality details that drawing inspiration from other municipalities was more of an experience in developing the CAPF (Interviewee 09), while another articulates their intention to continue looking to other municipalities for inspiration in the future (Interviewee 01).

Collaboration on climate mitigation also extends past cross-municipal cooperation to engagement across various sectors, from businesses to civil society. In that regard, the climate coordinators indicate a high degree of **external stakeholder engagement with the municipality** (87% to some extent or greater) regarding climate mitigation planning. While some (3) municipalities have already found success engaging with local businesses and utilities (Interviewee 01, 04, 12), others are in the process of solidifying partnerships (Interviewee 03). Many are still working on how best to involve citizens in climate efforts (Interviewee 03, 04, 06), while one has outsourced this engagement to project developers (Interviewee 05).

One municipality has found success working with industries, mainly through large energy projects like PtX, but citizen engagement has proven more challenging to sustain without ongoing support (Interviewee 01). Another municipality has taken a community-based approach, launching initiatives like a climate village project, where citizens are actively involved in reforestation, switching to district heating, and promoting sustainable practices (Interviewee 12). This project has measurably improved the village's climate impact, demonstrating how deep citizen engagement can drive successful mitigation and adaptation (Interviewee 12). A different municipality has similarly experimented with localized solutions, such as collectively owned solar parks and thermal heating systems in villages that are too remote for district heating, further emphasizing the importance of citizen collaboration in mitigation efforts (Interviewee 08).

The **external stakeholders** surveyed alternatively designated a slightly lower level of **cooperation with municipalities** (70% to some extent or greater) for climate mitigation planning. However, the level of **collaboration with other non-municipal actors** was higher (89% to some extent or greater).

In looking to the future, the majority (61%) of external stakeholders indicated their plan to maintain their current mitigation cooperation with the municipality. In comparison, the remaining stakeholders (39%) indicated their interest in increasing the level of collaboration with their respective municipalities. A slight minority of these stakeholders (45%) indicated their plan to maintain their current mitigation cooperation with other non-municipal actors, while a slight majority (55%) indicated their intention to increase collaboration with other non-municipal interests. No stakeholder indicated any interest in decreasing the level of engagement in climate mitigation with either the municipality or other stakeholders.

While many of the **barriers** to climate mitigation are multifaceted and intersectional, one barrier was consistently cited as the restrictive constraint. **Financing** (ranked as number 1) is the most significant hindrance, as climate-friendly solutions are often rejected if they exceed traditional budgets or there is a lack of clarity about who will bear the costs. In one municipality, the gap between ambitious climate action plans and the available resources has slowed progress significantly, as the sustainability committee has a limited budget and must rely on external collaborations or other political committees to find funds (Interviewee 04). In another municipality, energy transition efforts have stalled due to the high costs of implementing district heating systems, leaving citizens reluctant to participate (Interviewee 07).

This funding barrier is often exacerbated by a complex interplay of institutional and political factors, with a lack of political support and will (rank 6) to make tough decisions potentially stalling climate progress (Interviewee 04, 05, 06, 07, 08, 09, 12). In some municipalities, while the financial needs are clear, the more significant challenge lies in the political prioritization of climate initiatives: "A high degree of political awareness and political prioritization is clearly crucial to moving forward" (Interviewee 04). There is an ongoing debate with politicians concerning trade-offs and resource prioritization, with climate measures often competing with more immediate social needs, like healthcare or education (Interviewee 04, 05, 08). Another municipality laments the perceived priority of politicians "to be elected again for a long time, so they do not dare say something about [climate] or choose some unpopular [climate actions], and then [climate planning] just goes round in circles with some slow processes and a lot of discussions, and then nothing happens" (Interviewee 07).

Following these financial constraints, the **institutional structure** (rank 2) of various municipalities and external organizations presents the second most significant challenge in comprehensively embedding climate goals into operations, defining clear targets and definitions, and communicating and measuring emissions and reduction progress. Limitations in scope and direct impact further complicate institutional roles and impede the ability to influence. For example, one municipality lacks the capacity to act as more than a facilitator for businesses responsible for the bulk of emissions (Interviewee 01).

Legislation (rank 3) was the next most significant barrier, often due to the absence of specific sub-targets and regulations that mandate emission reductions at various levels, such as emission maximums for new construction. The local governments' lack of legal authority can also hinder the implementation of climate action (Interviewee 04, 06, 07, 08, 12). For example, one municipality specifies the limitations of district heating legislation, which obstructs the implementation of more sustainable yet less conventional heating technologies like geothermal energy (Interviewee 08).

A **shortage of capacity and skills** (rank 4), including a lack of climatic understanding, knowledge, and human resources, also limits climate mitigation work: "There has also been a relatively clear challenge in terms of having sufficient competencies" (Interviewee 16). This limitation in capacity and skilled personnel can have a cyclical negative impact, as evidenced by onerobust municipality where ongoing frustration with inaction has led to high employee turnover (Interviewee 07).

A lack of incentives and ingrained habits is reflected in **limited participation** (rank 5), the scarcity of available, accurate **data** (rank 7), and the slow implementation of appropriate **technology** (rank 8) (Interviewee 05, 09). To that end, one municipality references resistance from citizens when it comes to projects like wind turbines, due to NIMBY (Not In My Backyard) attitudes (Interviewee 12). Despite the availability of certain sustainability indicators like a national platform for CO_2 emissions, another municipality calls for more robust data systems to better track sustainability footprint parameters (the interviewee generally referred to climate or health dimensions) as a foundational part of the sustainable transformation (Interviewee 05). This data issue might also be a capacity issue; in other words, the lack of experienced climate planners available to perform calculations or understand and apply climate data limits the use of said data (Interviewee 16).

Sector-specific issues were frequently articulated as particular challenges for climate mitigation. In particular, agriculture (as part of AFOLU) was commonly cited as a major impediment to emissions reductions (Interviewee 04, 07, 08, 10, 12, 14). Certain aspects in the energy sector, such as local resistance to renewable energy plants and district heating legislation regarding geothermal energy, were also considered critical obstacles (Interviewee 07, 08).

The same barriers that present stifling challenges also offer (visible or latent) potential for their own solution; many of the articulated **opportunities in climate mitigation** (for example, a strong political mandate supported with corresponding funding) are the antithesis of the articulated barriers. Successful climate mitigation requires a comprehensive and collaborative approach that involves multiple stakeholders, with a distinct focus on actors from the agricultural sector (Interviewee 05, 06, 07, 08, 09, 12). Key elements include a strong **political mandate** to render clear guidelines and enact impactful policies, such as higher taxes on fossil fuels, direct legal requirements for industries, and incentives for renewable energy adoption (Interviewee 06, 07, 09). This naturally requires adequate **funding** (from the national and EU level) and human and time **resources** to ensure and co-create coordinated mitigation efforts across municipalities and stakeholders. In that vein, one interviewed municipality underscores the necessity of pressure from EU legislation to drive businesses towards sustainable practices (Interviewee 06).

To counteract barriers, effective climate mitigation depends on building **knowledge** and **awareness** among stakeholders about the climate crisis and the concomitant environmental consequences of inaction (Interviewee 03, 05, 07, 09, 10, 11, 12, 14). This involves investing in education, technological innovation, and data accessibility, as well as developing coherent targets and frameworks to generate collaborative solutions, particularly in heavy-emitting sectors like energy and agriculture (Interviewee 05, 11, 12).

Municipalities are finding success in initiating **small-scale actions** to address climate mitigation, which can later expand into larger, impactful projects. For instance, one municipality's approach is to subtly integrate climate work into various departments by encouraging small green actions, such as using electric bikes instead of cars or reducing paper consumption, which are then scaled up over time (Interviewee 03). Other municipalities also focus on smaller projects like afforestation and wetland creation, recognizing that while large sectors such as agriculture and renewable energy pose challenges, smaller initiatives can build momentum and gradually inspire more ambitious projects (Interviewee 07). One municipality has found financing smaller projects easier, with citizen-driven initiatives playing a crucial role in community engagement and developing joint climate projects (Interviewee 09).

Opportunities also arise as municipalities transition from considering climate action as a "nice to do" task to an essential part of governance. In one municipality, this **shift** involves ensuring that climate considerations are included from the beginning of all projects, transforming climate work from a separate task into a natural part of the municipality's operations (Interviewee 03). Similarly, another municipality is working to make climate work a seamless part of their municipal culture, recognizing that different departments can contribute to climate efforts in unique ways based on their expertise (Interviewee 04). In one municipality, the strategy for making climate action necessary involves creating financial **disincentives** for non-sustainable practices, making it cheaper to "do the right thing" (Interviewee 06). On the other hand, a different municipality emphasizes that embedding climate action in everyday operations—rather than just seeking additional funding—will be key to making it part of their "core business" (Interviewee 08).

Cross-municipal collaboration in adaptation is less pervasive (80% to at least some extent) than in climate mitigation planning, although it is still seen as essential where geographically mandated by shared environmental risks. The inspiration derived from the climate adaptation work of other municipalities is likewise lesser: only 53% of adaptation planning is influenced by other municipalities to some or to a great extent.

Indeed, three municipalities have developed robust cross-municipal cooperation with neighboring areas that face similar physical risks, such as storm surges and rising sea levels (Interviewee 03, 06, 07). This has led to shared solutions for climate risks, with municipalities pooling their resources and knowledge to address common problems. For two others, cross-municipal collaboration primarily manifests in developing sparring partners to discuss common climate adaptation challenges and goals (Interviewee 01, 05). While cross-municipal collaboration has been quite geographically based, one municipality suggested that future collaboration might broaden to focus on issue-based projects so that, for example, agriculturally dominant municipalities across Denmark might collaborate on like issues (Interviewee 10).

As detailed in the mitigation section, the climate coordinator networks on Fyn and southern Jutland also cover adaptation; these groups allow for exchanging knowledge and strategies for tackling adaptation, particularly through nature-based solutions (Interviewee 06, 07). This cooperation extends to project-specific work, such as collaborative planning for afforestation and flood management efforts, which benefit from the shared expertise and resources available through these regional frameworks. There is no distinction between climate mitigation and adaptation regarding the level of inspiration drawn from other municipalities.

The level of **cooperation between the municipality and external actors** is also lesser than that of climate mitigation. However, this extrinsic engagement for climate adaptation planning is nonetheless high (73% to some extent or greater). Similarly to the municipalities' external engagement concerning mitigation, three municipalities highlight their engagement with local organizations and communities on adaptation efforts (Interviewee 01, 04, 10). For example, one municipality has fostered both formal and informal partnerships in adaptation measures for the port and city center, which proactively engage citizens in strengthening preparedness against climate risks (Interviewee 01). Three other municipalities articulate their near-term intention to engage and inform citizens and companies regarding future adaptation work, including vulnerable populations who are often the hardest to reach but the most impacted by climate change and young citizens who provide different perspectives and fresh ideas (Interviewee 03, 10, 14).

The **external stakeholders** surveyed followed the same pattern as for climate mitigation: a slightly lower level of climate adaptation **cooperation with municipalities** (69% to some extent or greater) was coupled with a higher degree of **collaboration with other non-municipal actors** (82% to some extent or greater).

In regard to future climate adaptation work, half of the external stakeholders indicated their plan to maintain their current cooperation with the municipality, while the other half indicated their interest in increasing the level of collaboration with their respective municipality. A slight minority of these stakeholders (47%) indicated their plan to maintain their current cooperation with other non-municipal actors, while a slight majority (53%) indicated their intention to increase the level of collaboration with other non-municipal interests. No stakeholder indicated any interest in decreasing the level of engagement in terms of climate adaptation with either the municipality or other stakeholders.

The multifaceted **barriers to climate adaptation** often stem from the same financial and institutional challenges that hamper mitigation efforts. Just as for climate mitigation, **financing** (ranked as number 1) is seen as the most significant barrier to implementing climate adaptation planning, including the ignorance of funding opportunities on a larger EU scale. Financing is a significant hurdle as adaptation projects rely on varying responsibilities and unpredictable funding streams combined with tight budget legislation and regulations (Interviewee 02). The prohibitive nature of economics also extends to reactions to weather events where municipalities and utilities are restricted in their ability to act and aid citizens by what is socio-economically profitable (Interviewee 10, 18).

One municipality points out that long-term adaptation projects often require large up-front investments, which can be politically difficult to justify when the project benefits are only visible in the future (Interviewee 08). This highlights a critical weakness in democratic processes when it comes to prioritizing long-term climate goals. Indeed, financing, political prioritization (rank 8), and decision-making are often interlocked and fragmented, which slows down the implementation of necessary adaptation measures and makes it difficult to keep the political focus on long-term climate risks (Interviewee 09, 12). Fostering political will and funding is also difficult when financing adaptation projects is seen as a trade-off between funding for other municipal administrations and tasks (Interviewee 01, 11, 13).

The **lack of capacity and appropriate skills** (rank 2) also represents a substantial barrier, further hindered by a lack of responsibility and ownership, which results in inaction (Interviewee 01, 07, 12). One municipality details that the lack of resources – in this case, the necessary employees to carry though climate action work – can stall a project where funds are not an issue (Interviewee 07). Another municipality details this lack of capacity in terms of still developing the expertise of employees in more novel climate strategies (Interviewee 01).

Legislation (rank 3) can represent another significant hindrance, in partic outdated laws that have not kept pace with municipalities' evolving climate challenges can obstruct the implementation of climate work (Interviewee 04, 06, 09). For example, one municipality broadly denotes that the current system does not support afforestation efforts (no elaboration on the failings of the current system was made) to address rainfall as a hazard and thus, meaningful progress requires legislative changes and new framework conditions (Interviewee 09). **Institutional structures** (rank 4) likewise pose challenges: one municipality emphasizes the challenge of effectively implementing climate initiatives across various departments as the administration struggles with bottlenecks that limit momentum (Interviewee 04). This bottleneck is further complicated by the difficulty of managing complex phenomena like water and flooding, especially when the responsibility is divided across sectors (Interviewee 12).

Additional barriers manifest in limited **data** (rank 5), **participation** (rank 6), and **technology** (rank 7). At least two municipalities struggle with the lack of readily available data and knowledge, which can leave municipalities stuck in a holding pattern, waiting for crucial information before projects like climate-proofing urban infrastructure can proceed (Interviewee 01, 14, 16). In addition, calculating the cost of inaction, something only two municipalities have partially done (Interviewee 04, 12), is hindered by the lack of data and methods for this calculation to help assess the full scope of climate risks (Interviewee 01, 03, 05, 06, 07, 08, 09, 14). While two municipalities have been able to assess risks for specific hazards (Interviewee 12, 14), other areas remain difficult to evaluate without adequate technological support.

The challenge of **communication** and participation also persists, particularly when adaptation measures involve private landowners. One municipality articulates the difficulty in executing adaptation projects that affect private properties, especially when the financial burden falls on individual landowners (Interviewee 03). Another specifically details a similar issue in low-lying cottage areas, where convincing landowners of the importance of adaptation measures and the financial responsibilities that come with them remains a struggle (Interviewee 06).

Hazard-specific challenges (notably flooding, increased participation, cloudbursts, and storm surge, sea level rise, and rising groundwater) were frequently cited as obstacles to effective water management (Interviewees 01, 03, 04, 05, 06, 07, 08, 09, 12). The overwhelming focus on water was also detailed as a barrier if municipalities and utilities do not define climate adaptation as more than just water and plan for other hazards such as droughts and heatwaves: "Right now, [other climate hazards] are being down-prioritized. It is also part of the efforts in our climate adaptation plan that, of course, we have to deal with drought and heat. It is just not as urgent" (Interviewee 12).

Opportunities in climate adaptation mirror the barriers to adaptation and reiterate many of the same opportunities articulated for climate mitigation. It involves substantial **investments** (of funding, skilled professionals, and engaged citizens) in long-term, holistic projects that combine urban regeneration and utility infrastructure with climate adaptation. Leaning into (financial, co-benefits, and other) **synergies** to tie climate adaptation actions to other initiatives might be critical to maintaining viability. **Political prioritization** is crucial and entails effective communication about climate trade-offs alongside legislation supporting the holistic integration and centralization of adaptation planning from a project's inception.

Strong **national and regional cooperation** is essential, particularly in managing coastlines and developing water management systems. This collaboration must extend across multiple levels—municipal, regional, state, and international—but, as suggested by one stakeholder, with clear state leadership: there is a need for some form of regionalized planning led by the state due to disagreements at the local level that hinder advancements in some themes (Interviewee 16). This collaborative emphasis would ensure shared knowledge, consistent legislation, and coordinated strategies decentralize certain elements (for example, local knowledge) while centralizing work on shared issues (such as borderless water bodies).

In one municipality, the gradual integration of climate-conscious decisions, starting with departments most open to change, allows for the steady infusion of green practices across the entire organization, creating momentum for more significant adaptive measures (Interviewee 03). One municipality clarifies that smaller adaptation projects, such as afforestation and wetland creation, are easier to implement, allowing the municipality to focus on achievable successes while continuing to explore more complex, larger-scale challenges in agriculture (Interviewee 07). Another municipality has seen the benefits of starting small with citizen-led projects, which create engagement and act as a stepping stone for larger community-based climate adaptation initiatives (Interviewee 09).

The shift from seeing adaptation as optional to making it a core responsibility is becoming increasingly vital. One municipality is working towards incorporating climate considerations into every stage of project planning, intending to make adaptation a central aspect of governance rather than a secondary task (Interviewee 03). In a different municipality, the goal is to ensure that climate adaptation becomes ingrained in municipal employees' mindsets and everyday work, focusing on encouraging departments to naturally adopt climate-conscious practices (Interviewee 04). Another municipality's strategy is centered on making non-sustainable practices costly, thus incentivizing the adoption of climate-friendly measures from the start (Interviewee 06). Meanwhile, a different municipality is pushing for integrating climate evaluation tools in decision-making processes, ensuring that each decision is assessed for its potential climate impact, thereby embedding adaptation considerations into the core of governance (Interviewee 08).

3.2. A deep dive into AFOLU

The AFOLU sector persistently constitutes the biggest emitter in the municipalities of the Region of Southern Denmark. While the current efforts for forestry and other natural areas push the needle towards a decrease in emissions, the agricultural sector is of concern regarding mitigation. The sector had already been highlighted as accounting for around ¼ of the emission in the region of Funen. The Funen partnership agreement (Fyn2030, 2024) was created as a response to that and signed by 10 municipalities in the Region. It is significantly mentioned in both mitigation and adaptation efforts in the municipalities, as it focuses on the themes of biomass (e.g., biogas and PtX), land (e.g., afforestation and multifunctional land use projects), and farms (e.g., cultivation methods, feed technologies).

The following subchapters first offer an overview of how the actions in the climate plans have tackled AFOLU (subchapter 3.2.1), report some considerations from surveys and interviews (subchapter 3.2.2), and then integrate the deep dive with some additional themes relevant to climate action in agricultural and land use practices (subchapter 3.2.3.3).

3.2.1. How AFOLU is addressed in the climate plans

This subchapter delves into analyzing the actions related to AFOLU. The first subchapter focuses on climate migration, scanning the extent to which municipalities estimated the emission reduction potential and the land demand or availability for each relevant action. The second subchapter presents how the agriculture sector and natural areas are indicated to be affected by various climate hazards. Finally, the last subchapter presents a complete list of planned actions related to AFOLU, which also collects perspectives and implications mentioned in the climate plans.

3.2.1.1. Mitigation potential of the actions

8 out of 22 municipalities estimated the **emission reduction** for *each* of their AFOLU actions (see the actions listed in the next subchapters); 9 only of some action, and 5 did not provide any. Some estimations are missing because areas for implementing the actions have not been mapped yet (e.g., Odense's afforestation and Svendborg's establishment of eelgrass meadows). Some estimations are englobed in other actions therefore they are sometimes accounted for one action and not both (e.g., the low-lying agricultural lands converted into forests, eelgrass meadows, or wetlands).

By summing only the estimations that are currently available, the actions related to AFOLU that contribute most to regional emission reductions are the conversion of carbon-rich agricultural soil (20% by 2030 and 29.4% by 2050) and afforestation (17% by 2030 and 25.8% by 2050). Various additional activities (e.g., cooperation between the single municipalities and the agricultural businesses in their territory) are also quite impactful (15.4% by 2030 and 16.8% by 2050), as well as biogas production (12.1% by 2030 and 10.7% by 2050) and change in feed composition for cattle (10.7% by 2030 and 16.8% by 2050).

An overview of all mitigation actions is shown in *Figure 14*, while the single actions are enumerated in detail in the following subchapters, with a general description of what the action entails based on the content of the plans, a brief contextualization, and the possible barriers mentioned by the municipalities. The estimation of the **land demand and availability** for actions in need of land and land use change is fundamental to gauge whether the actions are enough to contribute to reaching the reduction targets and whether there is enough land for implementation. According to the documents analyzed in this report, only 4 of the 22 municipalities estimated the land demand or availability for each action, while 11 did it only for some actions, while 8 didn't estimate it at all, but in many cases, mention the need to do so. Supposedly, such land-based actions with an accompanying estimation of emissions reduction must have considered the hectares of land needed to calculate tCO_2e/ha but not reported in the plans or other accompanying documents.

Figure 14. AFOLU mitigation actions.

3.2.1.2. Hazards impacting the sectors

Adaptation **challenges** are reported in this subchapter as mentioned in the climate plans, starting from those affecting the agricultural sector, to then focus on forests and other land uses. Adaptation **goals** could not be analyzed through the lens of the hazards, as their formulation can vary among municipalities and is not always specific. For example, a goal might mention the prevention of flooding without specifying its cause. Other goals may refer to heat and drought together, as opposed to referring to them as separate phenomena. Adaptation **actions** within AFOLU include some that are mainly enumerated as mitigation efforts and can be found among the sheets in subchapter 3.2.1.3 of this report: the planning of agricultural land ("change in cultivation"), the conversion of farmland to wetlands ("conversion of carbon-rich agricultural land" and "wetland (or mini wetland) restoration"). Other AFOLU adaptation actions include:

- Dialogue with farmers related to flood, heat, and drought;
- Info and knowledge creation on drought in relation to agriculture;
- Management of water resources Compensation for farmers;
- Support for sustainable food production;
- Construction of dikes in current agricultural land or other land use.

The Region of Southern Denmark's land is vastly agricultural (e.g., according to the climate plans, approximately 31,000 hectares in Billund, 68% of Esbjerg's territory, 69% in Vejen), and the forecast climate risk depicts a scenario that will particularly challenge the **agricultural sector**.

Varde indicated the risk of an increase in crop destruction by **cloudburst**, but also by **sandstorms**. Svendborg and Tønder pointed out that large agricultural areas, especially the low-lying ones, can be inundated by **flooding from watercourses** for long periods, which can also have negative consequences for the cultivation of crops. Similarly, Kolding, Nordfyns, and Varde suggested that areas that will be waterlogged because of **high groundwater levels** will increase the demand for drainage and may have to be abandoned as arable land.

A significant number of municipalities (Faaborg-Midtfyn, Kolding, Langeland, Nordfyns, Svendborg, Sønderborg, Varde, Vejen, Ærø) highlighted that the growing season will be extended in Denmark due to **higher temperatures**. This may mean that farmers will consider switching their productions for increased opportunities for crop variety and a higher yield per area unit. But it can also have a negative synergy effect because of the additional use of commercial fertilizers and pesticides, leading to an increase in greenhouse gas emissions and discharge into the aquatic environment, if a technological or practical solution is not developed at the same time. Furthermore, Middelfart acknowledged that higher temperatures can negatively affect species adapted to the Danish climate, including animals, plants, fungi, etc. This includes animals such as horses, cows, sheep, and pigs, which are a vulnerable group within the sector that need extra water on warmer days.

Water scarcity can lead to **droughts**, which a number of municipalities (Billund, Fanø, Nordfyns, Nyborg, Kerteminde, Langeland, Svendborg, Sønderborg, Vejle, Ærø) indicated in their plan that it would have a major impact on the harvest yield, due to a significant demand for more water to irrigate, resulting in the risk of loss of food production. Nyborg and Svendborg also add that consequences can include the need to change operating methods and crops, lost investments in production equipment and costs for new ones, and challenges with financing existing and new loans. Esbjerg described having a well-developed network of boreholes for field irrigation, assessing that the drought risk won't have noticeable changes up to 2050, while Billund points out that the current data doesn't allow for a definitive drought scenario. Some municipalities (Ærø, Kerteminde) recognized the need to collect rainwater in preparation for periods of water scarcity. Kerteminde elaborates on the potential of involving farmers in this.

Varde noted that its river valley is increasingly affected by **saltwater intrusion**, and the surrounding agricultural practices will be challenged regarding the production of grass for livestock and grazing; Fanø mentioned a similar issue.

Billund recognized that **wildfires** may cause future financial loss for plantations. At the same time, they are also considered a recognized maintenance measure for the succession of natural areas and burning of, for example, the heath.

Tønder suggested there is a need to gather further knowledge and data on the consequences of increased water saturation in autumn, winter, and spring, high groundwater levels, scarce precipitation, high temperatures, and a decrease in solar radiation, as well as an extended growing season. Aabenraa notified that they tried to do just that: it disclosed that the municipality's groundwater team reported an increasing number of applications for requests for field irrigation in the western part of the municipality, which confirms that the plants in the area are under pressure today. Its response is that adaptation of agriculture to the future climate will, in the short term, involve attempts to save water for later consumption through control, restore natural hydrology in low-lying areas, and search opportunities for irrigation. In the longer term, it could involve breeding plants, where crop species are made more resistant to drought and changed irrigation patterns, as well as change in crop types that will be more adapted and robust than the current varieties and species (e.g., soy or quinoa).

Beyond the agricultural sector, AFOLU also consists of other land uses, and the Region presents a variety of land dedicated to **forests and other natural areas**.

Some municipalities (Nyborg, Kolding, Svendborg, Tønder) highlight that biodiversity and nature are at risk of **storm surge** – for example, salt meadows and their distinctive coastal flora, the streams in the estuaries at Holckenhavn Fjord and Storebælt –, though some of these areas are designated as low-lying, and are either already established wetlands or potential wetlands.

Nyborg and Tønder add that natural areas can also be affected by **cloudburst** due to increased water volumes, adding that wastewater piled up in the sewage systems because of flooding can bring environmental consequences of the discharge of contaminated wastewater. Many biotopes are sensitive to nutrient inputs, but it is the specific conditions of the biotope that determine whether any consequences are harmful or beneficial: for example, it is good for the raised bog areas to become wetter as a result of more annual precipitation and rising groundwater, but negative if they are flooded by river water or water from other soil types, where nutrients and calcium are added to the floodwater.

Tønder notes that prolonged periods of precipitation will often be experienced in winter, which will lead to water-saturated soil reservoirs and **shallow groundwater**. Kolding indicates this as a potential change in the nature type: the areas can, for example, change from a dry meadow to a wetter meadow or marsh, but it is required that the habitat requirements of the natural types are met, as otherwise it is nutrient-loving species that will dominate. The increased groundwater level can also make the care and operation of the areas more difficult, which in exposed locations can mean that operations must cease with overgrowth as a result. For primarily hot and dry grasslands, unwanted species can gain an increased competitive advantage through climate change, and one must expect increased growth in warmer climates.

Sea level rise means that coastal areas will be flooded with salt water in the future. It is mainly salt meadows at risk (Kolding, Svendborg), as increases in the water level will push them further into the hinterland. Here, the salt meadows can develop again over time, but there is often too little space, and the areas lying behind may be affected by previous cultivation with drainage and fertilisation, which can prevent their growth. Sønderborg generally indicates that the quality of nature along its coast will decline and will result in a loss of biodiversity, though the total area is not expected to decrease. It expands by saying that the new nature will have a lower quality than the existing one due to future climate conditions. Ærø specifies that, if the sea water manages to flood the Natura2000 areas, it can have consequences for the freshwater animals and plants that live there.

Four municipalities (Billund, Nordfyns, Tønder, Aabenraa) stress that **rising temperatures** can affect the distribution of certain species towards more heat-tolerant ones. For example, Billund mentions reducing frost days can affect the early germination of certain plant species that depend on frost; Aabenraa exemplifies with the consequences of the hot summer of 2008, saying that small trees and bushes on sandy soil will wither early or die, many herbs will not flower with the consequence of a lack of food for insects, grass will wither early, and many berries and mushrooms will not develop fruiting bodies. There will be warmer water in streams and lakes (Tønder, Vejen), which will affect fish and other small animals due to lower oxygen solubility. In addition, the water temperature plays a decisive role in a number of physiological processes for fish: very high water temperatures (above 08 °C) negatively affect salmonids (present, for example, in Vejen's Nature 2000 sites) in particular and lead to higher mortality. Often, the rare habitats and species that depend on the right interaction between the species and the climatic and hydrological conditions are at risk of decline due to climate change. In contrast, resilient and adaptable habitats and species can thrive. When conditions are unstable or changing, a particular challenge is that some species are highly adaptable, easy to spread, and highly dominant. These species can easily take over habitats at the expense of other species. If these species are not native, they become invasive. Nordfyns highlights how the possibility of two growing seasons can be opened up, which, from an economic point of view, is an advantage, but from a climate perspective, can lead to increased consumption of fertilizers and pesticides and an increased discharge into the aquatic environment. Middelfart sustains that longer and more frequent heat periods are estimated to have a positive effect on biodiversity in a nutrient-rich and low-lying country like Denmark.

Prolonged **drought** is mentioned to have a major impact on biodiversity (Kolding, Esbjerg, Fanø, Varde). Some (Nordfyns, Tønder, Varde, Ærø, Aabenraa) mention that watercourses and natural areas such as wetlands will dry up, with consequences on species that depend on them. Tønder specifies that it may be difficult to fulfill the objectives of the river basin management plans for good ecological status in many watercourses. A deterioration in the status of watercourses will lead to stricter requirements for how much other actors (e.g., farms and utility companies) are allowed to impact the watercourses, restricting their room for maneuvering and options for action. Esbjerg dictated that the use of boreholes for irrigation must use caution in such periods so as not to have negative effects on streams and vulnerable natural areas. In these periods of droughts, Fanø highlighted that open landscapes such as beaches and dunes offer extreme enough conditions to challenge particularly robust species such as the heather. The two municipalities collaborate for creating good conditions for vipers and other endangered meadow birds, whose breeding season is affected by dried up puddles of water as early as May, and whose younglings are dependent on finding food in the shallow waters. On heaths, there are also depressions whose species require a relatively high groundwater level, including peat moss, cranberries, orchids, dragonflies, and birds such as reeds. To restore a higher summer water level in the depressions, Fanø closed some ditches. Kolding recognizes that some species will not be able to thrive due to the recurrence of droughts and will, therefore, risk extinction (e.g., tree frogs and other amphibians), while other species will migrate from the south. Varde hints at the issue between long periods of drought and heavy downpours and cloudbursts, which in agricultural context will lead to increased leaching of nutrients to streams and the coast: wet nature types are assumed to do better the more it rains, but only if the nutrient balance is not affected.

Billund indicates that **wildfires** are not considered a threat to natural areas or biodiversity today, nor are they expected to be so in the future. Other municipalities state the opposite (Varde, Aabenraa). For example, Aabenraa assesses that a combination of increased wind and drought could create the possibility of more forest and natural fires, and work in underway in this regard: according to the government's plan, the majority of the forest areas in the municipality are to be managed without commercial forestry, while others areas, which are predominantly coniferous plantations, are part of a Life project, where work is being done to make them robust to the future climate by planting more hardwood species.

3.2.1.3. Planned climate actions in AFOLU

This section collects all climate actions involving AFOLU extracted from the climate plans, a list of which can also be seen in *Figure 14*. Forestry has the **highest reduction potential** by 2030 and 2035 across all sectors—not only in AFOLU. The action that provides the highest mitigation density per unity area among all AFOLU measures concerns the reduction of deforestation coupled with wetland conversion, particularly of old growth or primary ecosystems. Actions in agriculture have lower mitigation density, though multiple agricultural measures can often be applied on the same parcel of land.

Only in a few climate plans were the actions accompanied by indicators to monitor their progress, as they were not compulsory to include. The latest report on the global emission gap (United Nations Environment Programme, 2024) provides benchmarks to track **sectorial transformations** in the world up to 2030. Such indicators, of which a selection is reported in *Table 2*, can orient mitigation future climate action planning from the local to the national level in line with the global objectives of the Paris Agreement.

The **action sheets** in the following pages give a quick overview of every single action mentioned in the climate plans, enumerating how many municipalities planned it and, if relevant, how many municipalities estimated its potential emission reduction and land demand or availability to implement it. Insights from experts consulted for this report accompany the sheets.

Table 2. Relevant indicators for tracking mitigation progress in AFOLU.

Sector	Indicator
Agriculture and food in general	CO_2e emission intensity (gCO_2e/1000 kcal)
	CO_2e emissions on agrifood systems (tCO_2e/yr)
	Share of food production lost (%)
	Food waste (kg/capita)
	Reduction ion food loss and waste (%)
	Share of population that adopts a healthy plant-based diet (%)
Animal agriculture	Livestock methane emissions (tCO_2e/yr)
	Ruminant meat productivity (kg/ha)
	Ruminant meat consumption (kcal/capita/day)
Crop farming	Crop yields (t/ha)
Forestry	Deforestation (ha/yr)
	Afforestation/Reforestation (total ha)
	Adoption of climate-smart forestry across timber-producing natural forests or improved forestry management (total ha)
Other land use	Avoided loss of forests and wetlands (total ha)
	Protected terrestrial, freshwater, and marine ecosystems (%)
	Peatland degradation (ha/yr)
	Peatland restoration (total ha)

EXTRACTION OF LOW-LYING SOILS

21 municipalities planned this action

16 calculated the potential emission reductions

10 municipalities estimated the land demand or availability

DESCRIPTION

When draining and cultivating carbon-rich agricultural land - also called low-lying soils - a breakdown of the organic matter in the soil takes place, which results in the emission of greenhouse gases. This process is slowed if natural hydrology is established in the areas, as they can convert from a carbon source to a carbon sink. Such areas can also contribute to the restoration of natural areas which, among other things, can add values such as biodiversity and recreation.

CONSIDERATIONS FROM THE CLIMATE PLANS

National policies are considered the biggest barrier for low-lying projects (Billund, Langeland, Varde, Vejen). For starters, in accordance with the Nature Protection Act (Miljøministeriet, 2022), in case the land is converted into protected natural area, there is no one-off compensation for landowners (Tønder). Also, when the projects are carried out, it is a requirement to limit the discharge of phosphorus into the aquatic environment. Furthermore, the legislation sets a minimum limitation of 10ha to select projects, which is a challenge because many potential areas are under 10 ha (Langeland). Finally, areas set aside for them could be otherwise used as fallow areas (ploughed and harrowed but left for a period without being sown in order to restore its fertility or to avoid surplus production). Concerning voluntariness in low-lying and wetland projects, history shows that the proportion of voluntary participation increases with the degree of public subsidy. It is therefore very important that the subsidy rates at least correspond to market prices for agricultural land. It should be considered whether expropriation can be an option to implement projects (Vejle).

All municipalities in the Region but Fredericia - whose land use only minorly including agriculture - planned this action. This is likely due to the possibility for municipal administrations to apply for up to 100% funding for feasibility studies and the establishment of low-lying projects via the Danish rural district programme. In the period 2020-2022, the Ministry of the Environment and Food ran a pilot project regarding multifunctional land distribution where municipalities and the Danish Nature Agency could apply to the state for free land distribution. In 2020, the Ministry of the Environment and Food also launched a new national subsidy scheme: DKK 255.5 million was set aside for it in 2020-2022. Municipalities, landowners, and foundations could access subsidies for feasibility studies, construction, and landowner compensation, but not for land distribution. The scheme's purpose was to provide "a fast track", where land could be set aside immediately and without land distribution. For the biennium of 2024 and 2025, the initiative was renewed. The land eligible for this action is strictly geographically determined by the land use mapping performed by Aarhus University, which includes a categorization of low-lying soils (Levin, 2024).

When such a financing scheme is accessed, the area must be converted into nature afterward, though an area does not strictly need to be natural to have a climate effect. Converting agricultural land into natural areas is especially preferred for the added values they come with, one of which is the overall increase of protected nature towards the achievement of the Nature Restoration Law (European Parliament and the Council, 2024). The Climate Council, the European Commission, and the IPCC also advocate that nature is a prerequisite for achieving climate goals.

CHANGE IN CULTIVATION

14 municipalities planned this action

8 calculated the potential emission reductions

5 municipalities estimated the land demand or availability

DESCRIPTION

In Denmark there is a total of 2,700,000 ha of agricultural land. Part of the emission of greenhouse gases from agriculture consists of nitrous oxide (N2O) and CO_2 emissions from ploughing and cultivating the land. That discharge can be influenced by changed cultivation methods.

CONSIDERATIONS FROM THE CLIMATE PLANS

The kinds of change in cultivation mentioned in the plans include:

1. Plow-free cultivation or no-till farming: 285,000 ha - or 10.6% - are cultivated without plowing in Denmark, of which 32,000 ha are cultivated with direct sowing. AU estimates that the potential for plow-free cultivation is over 400,000 ha. or 14.8%.

2. Precision fertilisation (e.g. sensor technology for more precise and need-based allocation of nitrogen fertiliser)

3. Increased use of follow-on crops, etc.

4. Increased amounts of catch crops and grass in crop rotation

5. Organic farming

Change in land use is also mentioned, such as for solar parks and afforestation (e.g., Aabenraa). CO_2e emissions from cultivated land, including those resulting from the use of nitrogen fertilizers, are difficult to limit. The climate partnership between Esbjerg Municipality, DIN Forsyning, Port of Esbjerg, and Aalborg University has establishing the Esbjerg Transition Lab, where technologies are tested on a 1-1 scale.

One of the major causes of decline for coastal ecosystems is excess **nutrient pollution** (nitrogen and phosphorus) from riverine systems to the coasts, leading to eutrophication (i.e., increase in productivity, changes in primary producers, increased oxygen depletion events). High nutrient loads come from intensive land-use activities, such as agriculture and urbanization. In Denmark, 60% of the land use is agricultural, making it the second country in the world with the largest share of intensively cultivated land. While the sources of nutrients can vary across different river basins, national nutrient balances in Denmark estimate that 90% of coastal nitrogen is delivered from diffuse sources, mainly comprised of runoff from agriculture (Thodsen et al., 2019). There is a significant opportunity to improve Danish coastal conditions by addressing nitrogen runoff from agricultural land use.

Nutrient runoff from river basins, and in Denmark primarily nitrogen, fuels the proliferation of opportunistic algae. These algae can block sunlight and cause anoxia, placing undue stress on bottom-dwelling native species like eelgrass and degrading the health of coastal ecosystems. However, it is possible to see coastal ecosystem recovery following significant nutrient reductions from riverine systems to the coast. Since 1990, Denmark has achieved reductions of nitrogen from diffuse sources (~37%, Thodsen et al. (2019)) through legislation like the Danish Aquatic National Plans and thereafter the EU Water Framework Directive, allowing for a partial recovery of seagrass in Danish coastal waters as indicated by expansion in eelgrass coverage depths (Miljøministeriet, 2023; Riemann et al., 2015)Still, this was not sufficient for substantial coastal recovery, as only 5 out of 109 coastal waters in Denmark currently achieve 'good' ecological status. Finally, the mechanisms of coastal degradation become exacerbated under climate change. Increasing extreme precipitation may enhance nutrient delivery, and subsequent eutrophication may be intensified by warming coastal waters and stratification. Taken together, this underscores the need for timely intervention.

Improved Danish land management and conservation are working to counteract nutrient loss through specific, local management, targeting small catchments (<15 km2) with high losses of nutrients. One effective conservation strategy is the targeted removal of low-lying, carbon-rich soil areas from agricultural production. The removal of this land is

NITRIFICATION INHIBITORS

1 municipality planned this action

1 calculated the potential emission reductions

The estimation of land demand or availability is not relevant for this action.

DESCRIPTION

Nitrification inhibitors can contribute to better nitrogen utilisation and thus reduce the consumption of ammonium in commercial fertilisers.

CONSIDERATIONS FROM THE CLIMATE PLANS

Langeland planned this action and calculated the potential emission reductions on the basis of the amount of commercial fertilisers consumed in its territory.

intended as a climate mitigation method to prevent carbon emissions; however, it also reduces nutrient loss by removing agricultural land from production and ceasing fertilizer application. Still, there are also many other practices to improve the sustainability of agricultural lands still in production. These include, but are not limited to, restoration of wetlands, nitrogen and phosphorus quotas, restrictions in soil tillage, and catch crops (e.g., winter rye). The aim of all these practices is to retain agricultural runoff for longer times within the landscape, which can allow for the removal of nutrients in runoff through natural processes and reduce nutrient loading to aquatic systems. However, extensive action is needed with any of these practices to achieve nutrient reduction goals. For example, in the Odense Fjord River Basin, an estimated 6,700 ha of new wetlands within the river basin area are needed to achieve the necessary nitrogen reductions to improve fjord ecological conditions (Odense Fjord Samarbejdet, 2025).

CHANGE IN CATTLE FEED COMPOSITION

13 municipalities planned this action

9 calculated the potential emission reductions

The estimation of land demand or availability is not relevant for this action.

DESCRIPTION

Cattle (i.e., dairy cattle, heifers, suckler cows) are known to produce a considerable amount of methane emissions. Changes in their feed composition (also referred to as promotion of stable and fodder technology, or as livestock digestion) involve using food additives or enzymes in fodder as an established technology for reducing methane emissions.

CONSIDERATIONS FROM THE CLIMATE PLANS

Major CO_2e emission reductions, derived by livestock digestion, will be highly dependent from the development of new technologies (Haderslev, Faaborg-Midtfyn), such as the change in livestock feed composition, preventing high-emissions from digestion (Aabenraa).

Changing cattle feed composition responds to the issue of carbon emissions in livestock production, but it does not tackle it at the source. In fact, production in the sector is expected to increase in the coming years.

There are several nutritional strategies to mitigate enteric methane emissions from ruminants, some generally with greater anti-methanogenic effects than others, and some with more or fewer concerns regarding animal health. The meta-analysis of Almeida et al. (2021) is a comprehensive review that shows that the most effective feed additives are (i) seaweed, (ii) 3-NOP, and (iii) nitrate, ensuring a promising methane mitigation strategy within the short term.

i. Seaweed refers to various kinds of marine macroalgae, which vary in their effects due to their different chemical compositions. Asparagopsis is the most effective macroalgae for methane mitigation, but its consequences on digestibility, animal performance, and health have not been extensively addressed using in vivo trials yet.

ii. 3-Nitrooxypropanol (3-NOP) is a commercially developed compound that has not been shown to represent a significant food security threat or risk to animal health. It offers a reliable solution for beef, sheep, and dairy cattle.

iii. Nitrate (NO3) has shown a risk of NO2 poisoning, impairing the capacity of blood to transport oxygen to an animal's tissues, though its supplementation combined with oil seems to reduce the likelihood of poisoning.

The first two solutions are quite novel and not well-established in the market yet. Nitrate, on the other hand, is more well-known in the sector. In the example of the Australia Emission Reduction Fund, its use has been widely spread through the allocation of carbon credits, which could prove a viable option to promote the less-marketed feed additives.

Further research is currently being performed through a partnership among a private company, three Danish universities, and Innovation Fund Denmark to develop bacteria that can digest methane already in the animal's digestive system, preventing it from being emitted.

The recent introduction of the Green Tripartite agreement (Landbrug & Fødevarer et al., 2024) which, among other things, imposes taxes on carbon emissions in agriculture, could be an instrument to indirectly curb emissions in the sector, but it will have to compete with the existing price for slaughter subsidy (*slagtepræmie*) (Landbrugsstyrelsen, 2024b), which awards farmers who raise cattle (heifers, bulls, and steers) for meat production in Denmark. Another way forward for the sector can be a turn towards another form of production. For example, towards plant-based production, as suggested in Track C of the "Roadmap for the sustainable transformation of the Danish agri-food system" (Olesen et al., 2021b). The government's plan to strengthen Danish production and processing efforts towards a plant-based future provides financial aid for various activities, including seaweed production (Ministeriet for Fødevarer, 2023).

ESTABLISHMENT OF A PLANT PROTEIN FACTORY

2 municipalities planned this action

1 calculated the potential emission reductions

The estimation of land demand or availability is not relevant for this action.

DESCRIPTION

This action involves the establishment of a factory for the production of grass protein to reduce the import of soy protein.

CONSIDERATIONS FROM THE CLIMATE PLANS

Langeland comments that Danish agriculture imports large quantities of soy protein to be used in pig feed, primarily from South America, where the intensive production can have a major negative effect on the rainforests. An alternative is to produce feed protein locally (e.g. horse beans). Despite estimating the emission prevention of the action, it adds that such action has no influence on its CO_2 accounts, as such value falls into scope 3 emissions. Vejen mentions the establishment of a grass protein factory.

PYROLYSIS

4 municipalities planned this action

3 calculated the potential emission reductions

The estimation of land demand or availability is not relevant for this action.

DESCRIPTION

Pyrolysis or biochar plants burn biomass without the presence of oxygen. Half of the carbon in the biomass becomes so-called biochar, which can be spread in fields to increase the carbon content on the soil. Pyrolysis is a novel technology, potentially effective in the short term, whereas long-term reductions are more uncertain. Pyrolysis plants can contribute to greenhouse gas reduction by absorbing CO_2 and producing carbon-neutral fuel.

CONSIDERATIONS FROM THE CLIMATE PLANS

Ærø set to investigate by 2025 whether it is profitable to establish a pyrolysis plant: by taking residual products from a number of sectors, a pyrolysis plant can produce biochar, fuel and heat that can potentially be used in district heating. Esbjerg aims at sending all residual livestock manure to pyrolysis by 2030. Aabenraa notes that it can be particularly advantageous to combine a pyrolysis plant in collaboration with a large local biogas plant: in addition to manure, there are some residual products from the agricultural sector as well as sewage sludge that can be used in pyrolysis plants. Svendborg highlights that there is a need for research on the short- and long-term consequences of applying biochar to agricultural land in a Danish context.

BIOGAS PRODUCTION

18 municipalities planned this action

12 calculated the potential emission reductions

The estimation of land demand or availability is not relevant for this action.

DESCRIPTION

Biogas is generated through anaerobic digestion of biomass, a natural process in which microbes digest organic material in sealed containers. The biomass can commonly include livestock manure, which would otherwise be kept in storages or spread on fields, emitting greenhouse gases. Biogas can be used for cooking, heating, cooling, electricity production, and even upgraded and used for vehicle fuel or gas-grid injection.

CONSIDERATIONS FROM THE CLIMATE PLANS

Biogasification is mentioned mostly in connection with livestock manure, but also in conjunction with straw and other kinds of biomass such as food waste (Vejen). When listing this action, municipalities mainly mention some of the existing biogas plants, such as that of the Nature Energy's facility in Ringe, and that of Kerteminde Biogas. Within these municipalities, Langeland is included for mentioning its action on better slurry management, rather than explicifctly mentioning the use of slurry for biogasification.

BIOGAS PLANTS

4 municipalities planned this action

2 calculated the potential emission reductions

The estimation of land demand or availability is not relevant for this action.

DESCRIPTION

The action is intended to expand capacity at existing biogas plants or establish a new one.

CONSIDERATIONS FROM THE CLIMATE PLANS

Langeland, Nordfyns, Sønderborg, and Vejen plan the expansion of their biogas plants; Vejen, in particular, also plans the establishment of a new one. Other municipalities elaborate on the supply they can offer to biogas plants. Assens assumes that it can supply 50% of the total amount of its cattle and pig manure in 2030, and up to 100% in 2050. Haderslev and Sønderborg stress that climate challenges and changing food habits, as well as agriculture's own transition challenges, may increase the risk of lower demand and thus lower agricultural production. If this happens, the expected biogas plants will be threatened by the necessary supplies from agriculture and food. In the long term, efforts may need to be made to find alternatives to the forms of biomass used today. Straw that is crushed cannot be used for energy purposes, and thus cannot contribute to meeting the existing demand (Kerteminde). Moreover, plant location must also be close to slurry, and not too far from the national grid, to allow its cost-effective use. In order to achieve good economy in the individual projects and minimise inconvenience during transport, the slurry should not be transported more than 20-25 kilometres from farm to plant (Billund).

POWER-TO-X

6 municipalities planned this action
No municipality calculated the potential emission reductions
The estimation of land demand or availability is not relevant for this action.

DESCRIPTION
Power-to-X (PtX) is a collective term for plants where a source such as electricity from the sun and wind (power) is converted via electrolysis into hydrogen, which can be refined into a range of transportation fuels (X). It is relevant from a land use perspective because, even though its production doesn't require a lot of space, the renewable capacity that runs it does, namely the direct air capture technologies and biogenic CO_2 sources (e.g., from the combustion of biogas). Also, high purity water intake affect AFOLU.

CONSIDERATIONS FROM THE CLIMATE PLANS
Beyond the five municiaplities that listed this action, 9 mention it as a necessary option to reach the 2050 targets (Billund, Esbjerg, Fanø, Kerteminde, Kolding, Langeland, Søndergborg, Tønder, Varde). For example, Esbjerg mentioned the announcement of a new PtX plant that will be fundamental for heavy transport fuels.

As the global population is projected to reach 10 billion by 2050 and 11.2 billion by 2100, the demand for land and biomass will rise significantly due to increased food and bioenergy needs. This surge, coupled with dietary shifts towards higher meat consumption, will intensify land use for animal feed production, challenging the sustainability of existing agricultural practices. Given the global sustainable biomass potential of around 10-30 GJ per person per year by 2050 (Lund et al., 2022), relying solely on biomass to replace fossil fuels is not feasible. Therefore, additional technologies like Power-to-X (PtX) and carbon capture are essential to avoid land and biomass constraints, enabling a more sustainable and diversified renewable energy system.

Electrification and PtX integration play a critical role in creating a fully renewable energy system that respects global biomass limitations and, consequently, land use. A high degree of system electrification and hydrogen integration (at least 15 GJ of hydrogen per person per year (Mortensen et al., 2020)) is necessary to remain within sustainable biomass limits. Each 6 MW offshore wind turbine can save approximately 5 km² of natural or agricultural land, equivalent to producing 2,500 tons of food crop kernels per year, which is sufficient to meet the caloric needs of 10,000 people (Weizel, 2010).

In summary, integrating PtX and land-use-based actions can create synergies that address both climate mitigation and adaptation challenges. By reducing the dependence on biomass through advanced PtX processes and hydrogen utilization, it is possible to preserve land for food production, protect natural ecosystems, and enable a more sustainable and resilient energy system. This integrated approach not only supports the transition to a renewable energy future but also helps to manage global land resources more effectively.

The projected PtX capacity for Denmark is 4-6 GW by 2030, utilizing its abundant wind resources to produce green hydrogen and e-fuels. In the Southern Denmark region, several key projects are emerging, such as the Green Hydrogen Hub in Esbjerg and the upcoming electrolysis plant in Fredericia. North Sea nations have signed the Esbjerg Declaration, agreeing to develop 65 GW of offshore wind capacity and 20 GW of electrolyzer capacity on- and offshore in the region by 2030. Other planned electrolysis capacities in the Southern Denmark region are as follows: Sønderborg: 153 MW, Aabenraa: 222 MW, Fredericia: 1000 MW, Vejen: 1000 MW, Esbjerg: 2015 MW.

Energinet has also initiated a feasibility study for the Danish Hydrogen Backbone in Jutland, aiming to connect large-scale hydrogen production with the future German hydrogen market and hydrogen storage in Ll. Torup, Northern Jutland (Energinet, 2024). This integration of PtX technology can reduce pressure on land resources while contributing to Denmark's climate goals. Nonetheless, aligning PtX infrastructure with existing land-use priorities remains a challenge that requires careful planning and coordination.

AFORESTATION

21 municipalities planned this action

16 calculated the potential emission reductions

12 municipalities estimated the land demand or availability

DESCRIPTION

Through afforestation or reforestation, trees can contribute to the reduction of emissions by absorbing and storing CO_2 from the air, as well as contribute to a number of related ecosystem services (benefits that human activities can get from a functioning ecosystem). Planting trees has received a lot of attention from involved citizens, as many citizens want more trees in urban areas and more forest areas for recreational use. It also comes with further functions in relation to groundwater protection, surface water protection, biodiversity, natural quality/cohesive nature, dispersal corridors for animals, outdoor life, etc. However, afforestation can cause shadows to be cast to the nuisance of neighbors and the experience of a deteriorated view.

CONSIDERATIONS FROM THE CLIMATE PLANS

Legislation can motivate privates against afforestation or reforestation, since if subsidies are granted, the forest must be established as a protected one and therefore cannot be returned (Aabenraa), for example to be used as a turnover area (Kerteminde, Tønder). For several landowners the financial compensation is not considered adequate, because protected land is poorly valued (Varde). Also, according to current regulations, afforestation is not allowed in areas that are classified as lowland areas, even though a lowland project is not always the most suitable means of taking land, either due to local conditions or the landowner's conviction (Billund, Varde).

Planting a forest is cash intensive (Tønder). There are already many climate accounts from several different players. Creating a municipal climate and nature fund can be in competition with commercial companies such as SEGES and others (Kolding).

Planting a forest is cash intensive (Tønder). There are already many climate accounts from several different players. Creating a municipal climate and nature fund can be in competition with commercial companies such as SEGES and others (Kolding).

Actions are dependent on the voluntary participation of the landowners (Nyborg, Svendborg, Aabenraa): afforestation and reforestation, where the owner would have to be willing to cede the land (Svendborg), as well as establishing wetlands (Fredericia); reductions at farm in general and extraction of low-lying soils, where it is on farmers to provide for the land; pyrolysis, where CO_2 capture and storage can be done by private companies (Nyborg, Aabenraa). Land can only be used for one purpose and there is a battle for farmland - and since the removal of carbon-rich farmland is based on voluntary agreements, the positivity of landowners will be crucial (Kolding). This contributes to maintaining a high price on agricultural land, for example for it to be set aside for solar cells or conversion or use for afforestation and wetlands (Varde). Subsidies for afforestation compete with other schemes for land set-aside, e.g. lowlands (Billund).

Reduced deforestation and ecosystem conversion are among the most cost-effective mitigation measures (United Nations Environment Programme, 2024). Afforestation, together with the establishment of eelgrass meadows and wetlands, can respond to the targets of the Nature Restoration Law (European Parliament and the Council, 2024) entered into force on August 2024, which aims to restore 20% of degraded ecosystems by 2030 and 100% by 2050.

Funding for measures to restore ecosystems and to compensate possible losses of income can come from a wide range of sources, including expenditure under the Union budget and Union financing programmes, such as the LIFE Programme; the European Maritime Fisheries and Aquaculture Fund (EMFAF); the it funds objectives of the first pillar of the EU's Common Agricultural Policy; the European Agricultural Fund for Rural Development (EAFRD): in existence since 2007, it funds objectives of the second pillar of the EU's Common Agricultural Policy, which includes support to projects for the

WETLAND RESTORATION

3 municipalities planned this action

1 calculated the potential emission reductions

No municipality estimated the land demand or availability

DESCRIPTION

Wetland or mini wetland restoration and extensification reduce CO_2e emissions by slowing or stopping the decomposition of organic matter. Stopping fertilization also reduces nitrous oxide emissions. Salt marshes (coastal wetlands) can be effective carbon sinks on low-carbon soils, so converting coastal lowland soils to salt marshes can help reduce CO_2e emissions. New salt marshes also help make the landscape and nature more resilient to climate change. They could eventually replace flooded salt marshes and act as natural coastal defenses.

CONSIDERATIONS FROM THE CLIMATE PLANS

Langeland estimated the land demand for this action. Kolding stresses that "there is a battle for agricultural land - and since the establishment of mini-wetland areas requires the removal of agricultural land, the positivity of the plot owners will be of decisive importance."

countryside, such as sustainable land management, water quality preservation, erosion and flooding prevention through afforestation, and more; the European Regional Development Fund (ERDF); the Cohesion Fund, the Just Transition Fund; Horizon Europe – the Framework Programme for Research and Innovation, which contributes to biodiversity objectives with the ambition to dedicate 7,5 % in 2024, and 10 % in 2026 and in 2027 of annual spending under the multiannual financial framework for the years 2021 to biodiversity objectives. The Recovery and Resilience Facility is a further source of funding for protecting and restoring biodiversity and ecosystems.

Aquatic ecosystems in Denmark have important roles in delivering ecosystem services. The integration of aquatic ecosystem protection and restoration for climate adaptation and mitigation can also be called aquatic nature-based solutions, or ‘AquaNbS’. The focus of integration of these ecosystems into climate action is because of their value for providing regulating ecosystem services on, for example, increased carbon storage and water quality, and for their cultural and societal value, such as well-being and economic prosperity associated with a higher biodiversity. While these ecosystems can provide many benefits, the quantification of carbon mitigation and water quality improvement can vary broadly depending on local conditions. Freshwater wetlands can be both a carbon source and a sink, while most salt marshes influenced by seawater are a carbon sink. Similarly, eelgrass systems have been investigated as a ‘blue carbon’ solution, as it was expected that they may have extensive ability to sequester carbon. However, recent studies in Danish fjords suggest that eelgrass beds are often net neutral in terms of carbon storage (Kristensen et al., 2024). This finding is consistent with global scientific reviews, which find the burial time of carbon is too short in seagrass systems to serve as a ‘permanent’ carbon store and enhance climate mitigation capacity (Johannessen, 2022). Improved research on the restoration in a Danish context is needed to provide accurate information on the carbon mitigation potential of AquaNbS ecosystems.

Still, AquaNbS remain valuable as a climate adaptation solution because of the multiple co-benefits they provide. In addition to improving water quality and sequestering carbon, eelgrass beds, upland and coastal wetlands provide important habitat that is critical for biodiversity support.

ESTABLISHMENT OF EELGRASS MEADOWS

7 municipalities planned this action

1 calculated the potential emission reductions

No municipality estimated the land demand or availability

DESCRIPTION

The establishment of eelgrass meadows has been listed by municipalities among the actions to reduce their greenhouse gas emissions. Coastal or marine ecosystems such as eelgrass meadows wouldn't technically be defined as a subject of land use due to their geographical location. However, land use practices affect these ecosystems (e.g., nutrient leakage from farmland into the ocean), and their protection would, in turn, affect land-based activities. Additionally, according to the requirements of the EU's Marine Spatial Planning directive (European Parliament and the Council, 2014), the sea space is to be considered part of the space of a territory and planned among other land uses.

CONSIDERATIONS FROM THE CLIMATE PLANS

7 municipalities planned this action, particularly those involved in the Odense Fjord collaboration (Odense, Kerteminde) and Nyborg Fjord. **One** of these municipalities estimated its emission reductions (Kolding, only by 2050), and another one estimated its land demand (Nybord), by adding that "It is estimated that eelgrass can grow on approx. 800 ha in Nyborg Fjord, depending on the quality of the seabed." Odense also mentioned some preliminary calculations: "For eelgrass, it is estimated that there is a potential of approx. 6,000 – 10,000 tonnes of CO_2 per year, growing towards 2030. The concrete potential for expansion, including growth conditions, must be mapped together with professional experts and other relevant municipalities".

However, solving conflicting land-use challenges is the main key to the restoration and protection of AquaNbS ecosystems. For one, eutrophication from land-use activities threatens the health and ecosystem services of all aquatic habitats, especially in the case of eelgrasses in Denmark. Extensive land-use activities in Denmark have drained historic coastal and freshwater wetlands, and there can be difficulties in re-allocating land use for wetland creation and restoration. In a similar vein, coastal 'squeeze' threatens Denmark's coastal wetlands. Sea level rise causes wetland migration inland, which is then prevented by existing land-use that uses coastal dikes and extensive drainage systems to prevent wetland flooding. Hence, one of the most important facets of AquaNbS is the engagement of stakeholders to consider the land-use needs of various sectors and resolve conflicts of interest.

OTHER

11 municipalities planned other actions

1 calculated the potential emission reductions

No municipality estimated the land demand or availability

DESCRIPTION

The establishment of eelgrass meadows has been listed by municipalities among the actions to reduce their greenhouse gas emissions. Coastal or marine ecosystems such as eelgrass meadows wouldn't technically be defined as a subject of land use due to their geographical location. However, land use practices affect these ecosystems (e.g., nutrient leakage from farmland into the ocean), and their protection would, in turn, affect land-based activities. Additionally, according to the requirements of the EU's Marine Spatial Planning directive (European Parliament and the Council, 2014), the sea space is to be considered part of the space of a territory and planned among other land uses.

CONSIDERATIONS FROM THE CLIMATE PLANS

Municipalities mention other measures within their cooperation agreement with the agricultural sector, referring to ways the municipality can help farmers transition to greener practices (e.g., climate accounting), but also other actions such as mapping potentials for multifunctional land distribution (Vejle). **3** mention that they will help farmers with the introduction ESGreen tool (Billund): the agricultural development organization SEGES and Økologisk Landsforening (ØL) have developed this tool which supports, among other things climate accounting for the individual farm, so that the farmer gets an overview of their carbon footprint and how it can be reduced through various measures.

3.2.2. AFOLU from the surveys and interviews

Despite its substantial contribution to regional emissions, AFOLU is not the top priority in climate action planning uniformly. Indeed, the surveyed climate coordinators equally positioned AFOLU and energy as the most relevant sectors for their municipality's climate work. The main focus on AFOLU stems from its significant contribution to emissions, its insufficient development in terms of adaptability, and the large size of the industry and corresponding political influence in certain municipalities. Alternatively, the top focus on the **energy sector** is due to a number of factors: the high percentage of municipal CO_2e emissions; political prioritization; historic experience and knowledge; visibility of problems and possibilities; and ability for municipal action in the here and now.

Even where energy is not (necessarily) perceived as the most important sector, it is the domain with the most climate work success to date (Interviewee 08). This outcome is in part due to the capability of the municipality to exert some measure of control over actions within the energy sector, leading at least one municipality to redirect efforts to this field rather than develop AFOLU strategies which are constrained by the municipality's **limited authority** over agricultural practices (Interviewee 08).

Despite recognizing agriculture as a major issue, municipal efforts in the AFOLU sector are largely influenced by **private agricultural organizations** and **individuals** and tend to lean on national legislation rather than rely on their own power as a municipal authority (Interviewee 04, 07, 08, 10, 11, 12, 14). In acknowledging this limitation, one municipality explicitly states that while the municipality can cooperate with farmers, it cannot mandate specific actions (Interviewee 04). In another municipality, agricultural initiatives have not yet been prioritized because the municipality has so few tools to influence agricultural practices (Interviewee 08). A different municipality echoes this sentiment, emphasizing the difficulty in managing agricultural land use without formal authority (Interviewee 12). While this municipality has established partnerships between itself and agricultural stakeholders, these efforts rely on **voluntary agreements** rather than regulatory enforcement.

Multiple municipalities (3) cite that actions to convert land for environmental purposes, such as protecting vulnerable drinking water or implementing afforestation projects, are complicated or prohibited by the inability to compel farmers to act and/or the exorbitant **cost of land** (Interviewee 06, 09, 12). Reducing emissions related to farmland with livestock is perhaps even more difficult given the longer timeframe of converting heavily populated farms, the necessity of a different approach given market demands for livestock products like dairy, and a lack of political interest (Interviewee 10). Thus, strategies and actions within the purview of the AFOLU sector may be compelled to depend on voluntary agreements with the agricultural sector, as municipalities lack the legal power or financial resources to influence land use directly.

3.2.3. Relevant themes for the future of AFOLU

This report concludes with a directed investigation into three themes: land use and regenerative agriculture in the Danish context, and the interconnectedness of floods and droughts for their assessment. The first two themes aim to provide a focused analysis of recent debates and elements in applicable scholarly literature shaping the Danish landscape. The last one highlights the need to understand the connection between the most assessed climate risk – flooding – with one that is underestimated mostly due to its complex and delayed effects – drought. This discourse is ultimately directed toward potential solutions and further research opportunities for climate-resilient development.

3.2.3.1. Land use

Land use in Denmark is currently dominated by agriculture (59%) and production forests (12%) which collectively cover almost three-fourths of the country's landscape (CONCITO, 2024b). Despite this pervasiveness, there are mounting appeals from organizations such as Concito for reforming land use to address the climate crisis, with climate change predicted to impact approximately 30% of land in the future (CONCITO, 2024c). Carving out space for climate-robust areas of nature conservation and green energy production thus requires a reconfiguration of the AFOLU landscape, particularly as some think tanks such as Concito contend that sustainable land use calls for agriculture to operate on a smaller scale with reduced emissions and nutrient runoff without externalising impacts (CONCITO, 2024b; Duer & Norn, 2022). The reality of climate-impacted land use and subsequent land use reform necessitates a balancing act between protecting certain areas with broader land priorities, thereby raising a discussion of which values should be prioritized in the future.

To that end, there is a growing petition from scholars and organizations, including Concito, that land use must prioritize nature in balance with social and economic demands (CONCITO, 2023). Public debate in Denmark posits the land-use proliferation and prioritization of agricultural practices – such as larger fields devoid of small biotopes and instead overloaded with nutrients, pesticides, and increased tillage – as a major ecological issue that critically limits space for nature (Liefferink et al., 2023). Indeed, intensive land use driven by AFOLU has been documented as a leading factor in biodiversity loss, groundwater pollution, and the substantial paucity of healthy, natural ecosystems (Foster & Bjerre, 2023; Liefferink et al., 2023; Nielsen et al., 2021). Despite the designation of Natura 2000 conservation areas – nearly half of which are on land dominated by AFOLU and thus inadequently 'conserve' nature, resulting in a meager 2.3% of protected area according to the EU's definition – Denmark is failing to meet its biodiversity commitments (Biodiversitetsrådet, 2022; CONCITO, 2023; Liefferink et al., 2023). Although securing land exclusively for nature is essential for future biodiversity as well as meeting the EU's biodiversity strategy for 30% of the EU's land and sea area to be protected - policies driving AFOLU land use change are currently focused on emissions reduction related to climate and nutrient imbalances rather than preserving nature for its inherent value (Liefferink et al., 2023).

On the other hand, the inflating energy demand – and consideration of energy security in the face of global conflicts – would suggest a high priority be placed on dedicating land to energy production. Indeed, with global land allocated to energy production projected to increase sixfold and Danish energy demand expected to double by 2050, Concito contends that designating and optimizing space for renewable energy parks, as well as carbon capture systems and PtX projects, will be critical to attain carbon neutrality (CONCITO, 2024a).

Alternatively, Concito additionally posits that the vulnerability of the Danish **built environment**, where extreme weather events currently endangers roughly 720.000 structures, suggests a need to prioritize settled areas both in terms of operationalizing climate adaptation efforts and reframing construction in line with planetary boundaries (CONCITO, 2024c). Growing square meter footprints and detached housing correspondingly increase CO_2 emissions and resource use in urban areas while also limiting land for natural spaces, making it essential to reverse this trend to mitigate its climate impact (Viegand Maagøe, 2023). Yet, to focus on singular structures rather than overall built areas would be a mistake; although recent LCA regulations in building codes set CO_2 limits per square meter, they do not address the total built area, which remains the primary factor in overall emissions from urban spaces (Viegand Maagøe, 2023).

In line with this approach, one municipality interviewed in this report's analysis expressed the desire to move away from the single-minded construction of resource-intensive structures: "We don't want any more new construction with large villas that use a lot of resources in materials, and we need these areas for other things than densification, we shouldn't [build] so big and so on and so forth" (Interviewee 06). This quote implies a shift towards land use planning for a multitude of diverse applications where size-conscious, smaller-scale projects co-exist with multifunctional areas.

While this ongoing dialogue on land use prioritization remains as yet undetermined – and indeed, Concito suggests the need for national debate – it is readily apparent that current land use planning must be revised to a long-term, cross-cutting and climate-resilient land use planning (CONCITO, 2024c). Indeed, in the face of Denmark's climate and biodiversity challenges, a cohesive national land-use strategy is essential to harmonize the competing needs of food production, energy generation, urban development, and ecosystem restoration. Developing a shared, hopeful vision for the future is critical for building collective engagement and ensuring long-term commitment, even as some measures may present short-term inconveniences. The scale of the challenge is immense, requiring a democratic process where all voices contribute to a unified vision. Concito further states that this vision, however, cannot simply emerge from government offices but should evolve through public dialogue, reflecting shared values and diverse regional priorities (Duer, 2024).

The "**Future Land Use**" project by Concito offers a compelling framework for this vision, proposing three distinct scenarios: one prioritizes traditional food production, another centers on human engagement with nature, and a third shifts focus to nature's needs (Duer, 2024). Each vision offer different socio-economic and environmental benefits, with sustainable land use potentially enhancing societal welfare by DKK 12–56 billion per year. The development of new business models that incentivize landowners to protect nature, conserve groundwater, and support climate adaptation are called for.

Denmark's national land use strategy could embrace long-term, adaptable, and climate-resilient planning to address changing environmental conditions (CONCITO, 2024c). This strategy should prioritize flexibility, allowing land uses to shift gradually as knowledge of climate impacts and technological advancements evolve. A dynamic, cross-cutting approach that integrates various land uses and sectors will foster multifunctional solutions, rather than isolated measures, enhancing both resilience and sustainability. Essential to this adaptive framework is a structured process for testing and refining strategies as new data emerges. Additionally, clear and balanced roles are necessary, with national prioritization guiding regional and local implementation to ensure coherent, multifunctional land management that balances climate adaptation with sustainability needs.

There is a clear consensus that the path towards a robust future land use hinges on optimizing area efficiency. For food production (and food security in the future), this would entail the application of innovative farming practices, technologies, and frameworks alongside new, area-efficient crops and foods; a shift towards land-efficient plant-based food production, which could free up to 30% of land while simultaneously producing more food than today; and a balanced approach to land use in Denmark's forests – where competing goals of wood production and biodiversity conservation must coexist – demands a market-based valuation of biodiversity to incentivize private landowners (CONCITO, 2024b). In terms of energy production, this might mandate efficient energy solutions such as hybrid parks that combine wind and solar, which are significantly more area-efficient than biomass (CONCITO, 2024a). For the built environment, municipalities can significantly reduce urban emissions by optimizing land use through efficient area regulation, sustainable material choices, compact development, and enhanced public transport and cycling infrastructure (Viegand Maagøe, 2023).

The gap between Denmark's policy intentions and actual land use practices has highlighted the need for a comprehensive reform, including the establishment of dedicated 'nature zones' solely for biodiversity conservation (Liefferink et al., 2023). Scientists argue that reserving areas exclusively for biodiversity, rather than relying on conservation within agricultural zones, may be essential to counter ecological decline. A national land-use strategy rooted in regenerative practices—including smart zoning, diversified crops, and nature-based solutions—could provide essential space for nature while advancing Denmark's sustainability goals. The Nature Restoration Act demonstrates the potential to unify restoration efforts across sectors, connecting climate mitigation, EU agricultural compliance, renewable energy, and local community benefits (Vallgårda, 2024). However, to balance these needs effectively, Denmark requires binding biodiversity targets and a political framework to ensure the prioritization of biodiversity alongside production and social needs (CONCITO, 2023).

3.2.3.2. Regenerative agriculture

With discussions around conventional land use increasingly exploring alternative actions, a discussion on regenerative pathways is a necessary complement for defining municipalities' sustainable practices, both within the agricultural sector and beyond. Moreover, the gap between intended emissions reductions and current reductions (Liefferink et al., 2023) further underscores the urgent need for regenerative pathways – and given the focus of this report, regenerative agriculture – that can progressively reduce emissions and restore ecosystems. Regenerative agriculture – which lacks a universal definition or global certification and is often used interchangeably with the term '**regenerative farming**' (Sass, 2024; Wilson et al., 2024) – generally encompasses methods aimed at improving water management, increasing biodiversity, and reducing emissions while simultaneously revitalizing soil and ecosystem health through practices such as cover cropping, crop rotation for plant and species diversity, minimal chemical use, and reduced tillage (Jameson et al., 2024).

The multifaceted potential of regenerative agriculture is increasingly discussed both in the scholarly literature (Khangura et al., 2023; Newton et al., 2020; Rehberger et al., 2023) and in Danish media (Jensen, 2024; Sass, 2024; Svensgaard, 2020). One report envisages the implementation process of regenerative agriculture in Denmark while also underscoring the **financial benefit** to the entire agri-food sector (including farmers, food manufacturers, and consumers) over the medium to long term (Jameson et al., 2024). Within the framing of Denmark as a nature-poor agricultural country, regenerative agriculture offers a different path forward – one that seeks not only to balance food production with ecological health but to actively restore the land to address Denmark's **biodiversity crisis** (Liefferink et al., 2023). As a result, 'organic' regenerative agriculture in a Danish context – specifically defined by strategies of minimal soil disturbance, year-round land cover, livestock-integrated crop production, maximized biodiversity and resource recycling – is posited as a potentially pivotal part of a **robust** and **resilient** Danish agricultural system (Jørgensen Rav et al., 2024).

Given the ambitious allure of regenerative agriculture, it is little surprise that this alternative to conventional farming has taken root in Denmark; a number of farms from Northern Jutland to Copenhagen - Egedal, Hjørring, Syddjurs - advertise their regenerative agricultural practices (Den Gode Gård, 2020; SoilValues, 2025; Søagergård, 2025). Regenerative agriculture activities and farmers in Denmark are coalesced in the Regenerative Agriculture Association (Foreningen Regenerativt Jordbrug, 2025); Regenerative Agriculture Laboratory (FabLab RUC, 2020) combines this association with university researchers to further investigate sustainable agricultural practices. Similarly, the AFOLU-centered research of the Department of Agroecology at Aarhus University includes a variety of interdisciplinary projects on sustainable food (Pathways for Sustainable Food, 2025), plant-based techniques (Leguminose, 2025), developing healthy soils (PrepSoil, 2024), and others in line with climate-resilient farming practices (MIXED, 2025).

One of the municipalities interviewed in this report's analysis explicitly expressed their growing recognition and interest in regenerative cultivation methods (amongst other synergistic actions) which can dually function as a carbon sink (through soil carbon sequestration) and ameliorate surface water issues and erosion risks (Interviewee 04). This expanding interest emphasizes an apt avenue for further research to explore the integration of this organic regenerative agriculture research with the climate action planning of Danish municipalities.

Despite the growing momentum behind regenerative agriculture, current debates reveal **uncertainty** around its inconclusive effects, loose definition, and lack of monitoring systems (Ranganathan et al., 2020). While some regenerative practices such as reduced tillage and year-round plant cover have demonstrated positive contributions to soil health (Jordon, Willis, et al., 2022) and the nutritional value of crops and livestock (Montgomery et al., 2022), the potential for climate mitigation remains contested. One report countered optimistic projections for regenerative agriculture's **mitigation potential** with skepticism given the uncertain benefits of no-till practices, insufficient carbon accounting which omits off-farm effects, the need for nitrogen which often escapes and becomes pollution, and the challenge of scaling up small practices (Ranganathan et al., 2020). This assertion was directly rebutted by a group of scientists (Paustian et al., 2020), while recent studies continue to document soil carbon sequestration in varying contexts together with conclusions that more research and empirical data is necessary (Byrne et al., 2022; Jordon, Smith, et al., 2022; Tan & Kuebbing, 2023).

This debate is equally ongoing in the Danish context; one report suggests that the implementation of regenerative agriculture could possibly reduce emissions by roughly 4 megatons of CO_2e per year from 2035 to 2040, or 30% of Denmark's 2022 agricultural emissions (Jameson et al., 2024). Conversely, a separate report underlines the uncertainty of regenerative agriculture's mitigation potential as the novelty and contextual caveats of existing research render substantiating climate mitigation claims difficult (Jørgensen Rav et al., 2024). A different analyst cautions against overstating the potential of soil carbon sequestration; while existing research may tentatively indicate positive climate mitigation possibility, the process of integrating regenerative agriculture and seeing concomitant results is slow and complex (Svensgaard, 2020).

At the same time, regenerative cultivation methods like reduced tillage can only constitute limited mitigation potential when the majority of Danish agricultural emissions are related to **livestock production** (Nielsen et al., 2023). While integrated crop-livestock systems fall within the umbrella of regenerative agriculture, their impact on soil health and emissions reduction is as yet understudied (Rehberger et al., 2023). Given Denmark's proposed **agricultural carbon tax** on emissions from livestock as well as fertilizer, forestry, and the disturbance of carbon-rich agricultural soils, regenerative agriculture might be the answer to substantially decrease emissions and curtail costs from this levy. The animal products sector receives roughly 1.200 times more public support than the plant-based industry (Vallone & Lambin), underscoring the need for subsidies and policies championing regenerative agriculture focused on plant-based production. Further research and debate might therefore consider if the proposed agricultural tax could be extended and/or refined to incentivize regenerative agriculture practices in a broader regenerative pathway landscape. Inversely, the use of a national **payment for environmental services** (PES) scheme might incentivize regenerative agriculture (Olesen et al., 2021a).

Following this amplifying discourse, a number of international businesses, as well as a few Danish companies, have articulated ambitious objectives and initiated **pilot projects** for regenerative agricultural practices (Arla, 2021; Carsberg, 2025; Nestlé, 2024) – but concerns about **greenwashing** characterize these actions (Bregendahl, 2023; Wilson et al., 2024). Food producers in particular are criticized for their indeterminate branding of products as regenerative despite the use of pesticides, herbicides, and more (Sass, 2024). Presented as a win-win for farmers, consumers, and society alike, this buzzword marketing of regenerative agriculture by major corporations is seen by some as a mask for corporate political and economic motives (Wilson et al., 2024). While specifying the ambiguity currently surrounding regenerative agriculture might address the misappropriation of the practice, others advocate for flexibility to allow for innovation and experimentation to further the approach (Sass, 2024; Wilson et al., 2024).

A **national certification system** could thwart off the aforementioned greenwashing and establish what 'regenerative' means in a Danish context. Drawing inspiration from the ecology-based Regenerative Organic Certified (ROA, 2025) program in the United States, Denmark could implement a certification – potentially in alignment with the existing state-controlled Danish organic label system – that sets specific criteria for practices like reduced tillage and integrated crop-livestock systems alongside stringent labels for genuinely regenerative products (Bregendahl, 2023). This certification could engender consistent, high standards for Danish farmers and ensure that regenerative claims align with actual ecological improvements.

To foster **experimentation** within clear guidelines, this certification scheme might be supplemented by a transparent documentation process that enables farmers and researchers to regularly record and report their practices, impacts, and outcomes. This verification might also allow for flexibility in innovative techniques and methods based on real data. Given the uncertainty surrounding certain benefits of regenerative agriculture, Danish policymakers and researchers should continue to develop rigorous, **context-specific studies** to document the effects and potentials of regenerative methods, especially in the areas of soil carbon sequestration. **Co-creating** these actions with farmers (explicitly in terms of research design, decision-making, and evaluation) is essential to ensure the relevance, inclusivity, and success of the transition to regenerative agriculture (Luján Soto et al., 2021). This co-creation might specifically focus on certain significant farm structural variables such as land type, farm type and practice compatibility – to tailor and incentivize adoption approaches (Thompson et al., 2023).

While research into regenerative agriculture in Denmark is advancing (see Frej (2025), for instance), there is a need to extend **regenerative thinking** – regeneration being, fundamentally, a notion of living in reciprocity and balance with nature and planetary boundaries into other domains to build a genuinely sustainable future for the country. To that end, regenerative thinking has started to emerge in sectors like tourism (Aquino et al., 2024) and the built environment (Lund, 2022). While the climate action plans of Denmark's municipalities are a similar step in the right direction, the incorporation of more ambitious regenerative thinking might close emissions and circularity gaps.

In that vein, one municipality interviewed in this analysis contended that the solution to the climate crisis is not to do more but to do things differently (Interviewee 12). This call for **transformation** over expansion aligns with the concept of regenerative pathways in which sustainability is characterized as an intersectional, cross-sectoral standard that foregrounds economies of care, well-being, and regeneration over consumption and production. In other words, regenerative agriculture should be positioned within a paradigm of public and private action predicated on ecological viability and social flourishing as a measure of success. This sustainable and holistically resilient regenerative pathway – one that goes beyond minimizing environmental harm into actively restoring ecosystems and societal well-being – requires further research into explicit implementation and evaluation.

3.2.3.3. Interconnectedness between floods and droughts

Climate change is amplifying the frequency and intensity of both floods and droughts, two interconnected extreme weather events that are part of the same hydrological cycle (Ward et al., 2020). While these hazards have traditionally been studied separately, their interactions pose a significant threat to communities worldwide and also in Denmark. Understanding these interactions is crucial for effective disaster risk reduction.

The rising threat is multifaceted. Climate change is altering precipitation patterns, leading to more frequent and intense floods and droughts. Regions historically prone to floods may now experience severe droughts, while arid areas could face increased flooding risks (IPCC, 2023). Moreover, floods and droughts often occur together, exacerbating their impacts. Floods following droughts can be particularly devastating, with 24% of global floods occurring during or after drought conditions (Matanó et al., 2024).

Human activities are also contributing to the vulnerability of these extreme events. Rapid urbanization and land use changes, characterized by increasing impermeable surfaces and population density, can amplify flood and drought risks (Guerreiro et al., 2018).

Despite the growing threat, research on the interconnectedness of floods and droughts remains limited, hindering effective planning for disaster risk reduction. The IPCC and Sendai Framework emphasize the importance of a multi-hazard approach to disaster risk reduction, recognizing the interconnectedness of different hazards (IPCC, 2023; UN, 2015). Understanding the interactions between hazards, exposure, and vulnerability is crucial for assessing and managing risks. Existing research has primarily focused on either flood or drought risk, often neglecting their combined impact. For instance, Yao et al. (2024) analyzed flood-drought interactions but only considered flood risk in non-urban areas. Conversely, studies by Panigrahi and Arabinda (2024) and Wang et al. (2024) examined urban flood risk without incorporating drought factors. While Vieira Passos et al. (2024) investigated both flood and drought risks, their analysis was not conducted at the urban scale.

According to Pizzorni et al. (2024), the urban planning for disaster risk reduction of floods and droughts in the context of climate change requires a new framework. This framework should incorporate risk factors, contextual information, drivers, impacts, responses, and historical event data. By adopting a holistic approach, it becomes possible to comprehend the interconnected risks of floods and droughts, as well as their combined causes and effects. The proposed framework promotes a shift in paradigm in urban planning, towards a multi-hazard, multi-sectoral, resilient, and adaptable approach.

Therefore, in order to effectively address the increasing threat of floods and droughts, it is crucial to further examine their interactions, comprehend the underlying causes, evaluate the potential consequences, and explore practical solutions, especially in urban areas. This approach will enable us to create more comprehensive and efficient strategies for reducing disaster risks and constructing resilient cities and communities.

4. CONCLUSIONS & RECOMMENDATIONS

The aim of this report was to portray the current status of climate acion planning in the Region of Southern Denmark, to formulate a set of recommendations for the regional admistration to support the local governments in the next steps for climate action. The municipalities in the Region of Southern Denmark have identified key climate challenges and developed comprehensive plans for climate mitigation and adaptation which represent a very valuable starting point for the implementation of local climate actions. Although, several barriers and opportunities emerge for the future improvement of the current municipal climate planning and their implementation.

This report was preceded by a preliminary analysis (Tollin et al., 2023) that delineated some first elements in terms of general climate action planning, of climate mitigation, and climate adaptation. This new report proposes a subchapter (4.1) on updated recommendations for climate action in general, valid for both mitigation and adaptation planning, and an additional subchapter (4.2) on recommendations specific for the advancement of AFOLU.

Recommendations to strengthen the climate action planning in the Region of Southern Denmark are numbered in the following two subchapters. The results that generated them are distinguished with the following symbols:

- ■ From document analysis (sections 3.1.1 and 3.2.1 of the report)
- ▲ From survey (sections 3.2.1 and 3.2.2 of the report)
- ▼ From interviews (sections 3.2.1 and 3.2.2 of the report)
- ● From additional relevant literature (section 3.2.3 of the report)

Each recommendation is introduced by a box with concluding remarks based on the results of this report, and followed by additional paragraphs containing an actionable explanation of the recommendations.

4.1. Next steps for climate action planning

1. Unify methodologies for estimating CO_2e emission projections under a common standard (■).

The climate plans were developed in different years, utilizing emission data from various baseline years - 2017, 2018, 2019, and 2020. They also used different methodologies for their estimations. Since then, the methodology for generating CO_2e baseline accounts has been reduced to mainly two among municipalities, which are fairly similar, comparable, and possible to strengthen in retrospect. A national platform currently also offers publicly available data that harmonizes the values.

The same cannot be said for the estimation of future emissions, which is only now beginning to work towards a common standard. This prevents the comparison of the data among municipalities and the cumulative estimation of the regional current estimations; ultimately, it hinders the process of monitoring reporting and validation of the mitigation reduction actions.

Climate plans shall present the current emissions and their projections based on the same baseline year (e.g., data from 2023 for all municipalities) and target years (e.g., all reduction targets estimated by 2030) and harmonise the methodology for the estimation of future emissions.

Work is currently ongoing on beta version of a tool that is directly linked to data for the estimations. Acknowledging such initiative, it is recommended to:

- Clearly separate the estimation of the emission gap (the gap between the 70% reduction target by 2030) and the residual emissions (the emissions produced in a given target year).
- Include 2035 as a target year for the estimation of residual emissions and emission gap, as it will be a requirement for the next Nationally Determined Contributions;
- Consider scope 3 emissions beyond those from waste, wastewater, and industrial processes.
- Consider emissions from municipal operations.

2. Strengthen integrated climate risk assessment by generating data on climate risks other than that of flooding at the regional level and/or at the local level (■▼).

Many climate plans are assessing in-depth water-related hazards, which predominate the adaptation landscape due to their visibility, the availability of data at the regional-municipal level (e.g., the regional flooding map), and tools simulating risk scenarios. Most municipalities recognize the threat of other climate risks (e.g., heatwaves and droughts most commonly mentioned after floods), although the assessment for these hazards is usually of scares quality and the definition of actions to respond to the corresponding risks is also low. This is also due to limited data availability, mostly provided at the national level (e.g., Klimaatlas), which has a degree of precision that doesn't qualify the assessment at the regional and local level. For example, when consulting the platform for a municipality's temperature difference in RCP 8.5, it is possible to obtain only the general average for the whole territory, while observing the difference at the scale of a neighbourhood would allow for a better-informed assessment to generate ad-hoc interventions.

In addition to that, the methods for assessing climate risks are numerous, which renders the various assessments difficult to compare (e.g., a 'high risk' in one municipality might be defined as a 'medium risk' in another one, depending on the methodology used).

The frequency and level of detail of the assessments for the risk of floods directly correlate to the formulation of actions to tackle the issue. This example shall be of inspiration to make data on other climate variables as available, for example by collaborating with universities for generating mapping assessments at the regional level for temperature rise and heatwaves, drought, extreme wind, wildfires, saltwater intrusion, and water acidification.

As data for the assessments is improved, the Region can collaborate with professionals conducting the assessments in municipalities and external consultancies to nudge the creation of a minimum standard to make the assessments comparable. For example, the fundamental definition of risk shall always include not only the hazard taken into consideration (e.g., increase of heatwave days per year from 4 to 7 by 2030) but also the exposure (i.e., the spatialization) and the vulnerability of relevant assets (e.g., concentration of population groups vulnerable to higher temperatures).

3. Determine the financial loss and damages in case of inaction (■▼▲).

Various models are utilised to determine the lost value of different assets (e.g., buildings, people, public services, etc.) in case of damages linked to the occurrence of a given climate scenario. Most scenarios also only consider the risk of flooding for the estimations, overlooking the identification of non-water-related hazards or compounded climate risks. Beyond the current state of risk mapping, the cost of inaction is not a central issue in the municipalities, either because of a lack of expertise, time, or know-how to carry out this calculation. Municipalities are, therefore, not used to thinking this way unless a specific weather event (like damaging storm surges) prompts consideration of the potential expenses of doing nothing.

Instead of this reactive reflection, municipalities should be invited to proactively calculate how the cost of inaction measures against the cost of implementing climate measures. Indeed, some municipalities already affirmed the potential applicability of this assessment. The existence of various common methodologies for estimating the loss and damages in case of flooding indicates that it would be realistic to require all municipalities to produce them, *at least* for the potential financial losses related to flooding events. A requirement for the next climate plans should cover the cost of inaction for multiple climate risks. This might require regional and/or national support in providing data and allocating resources to create hands-on tools and guidelines.

4. Uphold and enhance cross-municipal collaboration (▼▲).

Collaboration among municipalities has already proven essential for successful climate action, as sharing experiences helps verify processes and determine effective solutions. Moreover, municipalities across Denmark share many of the same obstacles, fostering a sense of unity as they navigate common issues. Regional collaboration allows municipalities to address common challenges that cross administrative boundaries, such as cross-municipal water management and district heating initiatives, and, in collectively doing so, scale their efforts and share resources to develop resilient and renewable projects more effectively. The power of these collaborations extends to other actors; therefore, municipalities should continue and increasingly link climate action to local businesses, organizations, citizens and developments to enable local synergies.

The Climate Alliance is in the works to create a system for fostering cross-municipal collaborations. The idea is to use the results of next year's municipal monitoring reports to identify topics that are relevant to exchange knowledge in, unite municipalities for cofounding opportunities, and hire a facilitator to exchange knowledge across municipalities. This is easier when the possible collaborating municipalities border with each other; when this is not the case, a national platform is needed, and a software is being built to achieve this.

The Region can play a pivotal role as a facilitator in this system, as seen in its past successes. Expanding its influence in areas like procurement policy and Scope 3 emissions could drive impactful change on a regional or even national level, offering a structured approach to address climate challenges. To be even more effective, the Region should continue supporting funding efforts, especially for project structures and investments, while enhancing its role in bureaucratic and institutional matters. Additionally, the Region can lead the effort to craft a compelling narrative that harmonizes environmental sustainability with a high quality of life, fostering a cultural shift towards greener living and minimizing the need for fragmented information campaigns. By reinforcing these roles, the Region can serve as a strong bridge between local, regional, and national climate initiatives.

5. Embed climate into core municipal operations (▼▲).

Climate initiatives must be transitioned from optional 'nice-to-do' projects to essential 'need-to-do' elements embedded in all municipal activities. A lack of political prioritization and organizational support makes this foundational climate integration challenging or impossible and has been seen to even result in some climate employees leaving out of frustration with inaction. Without strong, cross-administrative coordination and ownership, climate action plans may be politically approved but left inactive for extended periods due to insufficient internal structure. This lack of organizational backup, coupled with the finding that collaboration between municipalities often operates more smoothly than within their own organization, highlights the necessity of the local council cementing climate as a permanent item on the agenda.

To that end, climate should always inform political decision-making processes. All cases for political consideration by the city council should have a climate label. All recommendations to the municipal council, and especially within spatial planning, must have a fixed point that has a guideline in terms of monitoring an environmental impact assessment and carbon budget.

The infusion of climate in the local political process should extend to reorganizing the municipal's inner set-up to similarly integrate climate across the municipality's administrations. For example, one municipality emphasizes embedding climate responsibility in leadership roles, transitioning from steering committees to direct accountability in each department. Similarly, another municipality has created a climate network with a contact person from each administration, ensuring a core of climate-aware employees who share knowledge and coordinate efforts, making climate considerations an integral part of daily operations. This example points to the potential for success in integrating sustainability throughout municipalities if climate coordinators ask how other administrations can play a role in climate action work, rather than the other way around.

6. Restructure municipal financing with the climate in mind (▼▲).

Several coordinators indicate that it would be an advantageous solution to be able to combine operating and capital budgets. This might also erase or alleviate the issue of initially unfunded climate plans where a budget for running the organization is in place but not one for implementation, which is part of the annual budget negotiations. One municipality highlights the idiosyncrasy that funding is seldom for the actual structures and investments of a project, and that the Region of Southern Denmark might continue their work in helping municipalities find funding and help address this financing nuance.

Futhermore, based on municipalities' experience, it can be easier to financially support the implementation of small initiatives now that can later be scaled up into more impactful projects. For example, even though the agricultural sector should be given priority, small initiatives for afforestation and wetland creation developed in parallel can build momentum and gradually inspire more ambitious projects. In addition, supporting citizen-driven initiatives can foster community engagement and the development of joint climate projects over time.

Support municipalities in combining operating and capital budgets and nudge towards supporting modest projects that show potential to be scaled up.

4.2. Prospects for climate action in AFOLU

1. Map the land demand and land availability at the regional level for climate actions (■).

Several AFOLU actions require the estimation of both the land demand (i.e., hectares required for implementation) and land offer (i.e., hectares available for implementation) to obtain an overview of the actual possibilities for implementation. The current plans foresee many actions implying a land demand, including the conversion of carbon-rich agricultural land or extraction of low-lying soils, change in cultivation, Power to X, afforestation or reforestation, and the establishment of eelgrass meadows, wetlands, and mini-wetlands. The action with the highest rate of land availability estimation concerns low-lying projects, presumably due to it being a requirement to access the national subsidies for implementing it. Land is a limited resource with a competitive demand; the availability of land is fundamental to the implementation of climate actions and climate plans as a whole. The georeferentiation of the land demand is also a fundamental factor for assessing the feasibility of the plans and the implementation of the actions.

Climate plans shall include full estimation of land use for all relevant mitigation and adaptation actions and assess and geolocalize land availability. This is currently not a requirement in the new C40's Climate Transition Framework, which will be used for updating the climate plans. Therefore, the Regional administration can make the definition of the following a requirement for the plans:

- Estimation of the land demand for mitigation and adaptation actions (hectares)
- Estimation and mapping of the available land (hectares)

Another role of the Region can be of support to harmonize the methodology for the mapping, which shall include the geolocalization of the available land. In the current climate plans, the municipalities disclosed either the land demand or the land offer of their AFOLU actions according to different assumptions; for example, one municipality expressed that there is currently available land for implementation by 2030, while another one only by 2050; another municipality expressed a goal of given hectares for implementation, but omitted whether the land is or will be available to achieve it.

One more role of the Region can be to promote cross-municipal collaborations for municipalities to jointly respond to their land demands: mix-matches between demand and offer can be covered by land available in other municipalities, potentially also those located outside of the Region.

2. Address the cost of land acquisition through temporary and permanent strategies (▼).

Multiple municipalities underscore the cost of land acquisition as a major barrier to mitigation and adaptation actions, with a specific sectoral impact on AFOLU measures. Many climate actions in the plans require land use change, such as afforestation or the protection of drinking water sources. Implementing these actions requires the municipalities to acquire land and change land use. Land availability is limited: it is either rarely for sale and often prohibitively expensive. Where the municipalities lack the legal power or financial means to influence land use directly, successful implementation may depend upon voluntary agreements and partnerships with private landowners and farmers. One municipality has found success with agreements concerning temporary land use for climate adaptation measures by changing their operational legislation so that the municipality can 'borrow' land to flood and compensate the landowner for this temporary use.

The plans shall include a clear assessment of land acquisition costs for implementing climate actions.

Alternative market and non-market measures to facilitate land acquisition at accessible cost shall be investigated, considering short and long-term solutions. These measures may include voluntary agreements with landowners, as well as establishing a public fund.

Legislative and administrative measures to support the implementation of the market and non-market mechanism for land acquisition shall also be explored.

3. Track the progress in the sector with common relevant indicators (●).

Benchmarks are for tracking the global progress in various sectors by the years 2030 and 2035. Such benchmarks generate a list of relevant indicators that can be relevant also at the local, regional, and national level.

Guide the formulation of future local actions by responding to the required sectorial transformations in AFOLU at the global level, which are enumerated according to the sectors of general agriculture and food (e.g., reduction in food loss and waste), animal agriculture (e.g., ruminant meat consumption), crop farming (e.g., crop yields), forestry (e.g., improved forestry management), and other land used (e.g., peatland restoration).

4. Reduce agricultural runoff to support nature restoration for emission reduction and adaptation to climate risks (■).

Coastal ecosystems such as wetlands and eelgrass meadows come with several benefits that also cover mitigation and adaptation objectives by being natural carbon stocks and buffer zones that protect coastlines from erosion and storm surges. Such ecosystems need a sound environmental quality to be preserved and created, but eutrophication, caused by excess nutrient pollution (nitrogen and phosphorous) hinders their functionality and effectiveness. In Denmark, this excess comes predominantly from runoff of agriculture.

Nutrient reductions can be achieved, for instance, a) by changing cultivation methods, and b) by changing the land use.

a) Some alternative cultivation methods that emit less emissions include restrictions in soil tillage, catch crops, and organic farming more than the previous ones. Specifically concerning organic farming, two national funding sources are currently in place: 3,6 billion DKK are invested to double the organically-farmed area by 2030 in Denmark, while half of the yearly budget of the fund for national plant-based production is destined for organic production (Ministeriet for Fødevarer, 2024).

b) Measures that concern changing the land use include the removal of low-lying soils from agricultural, as the land is not subjected to agricultural practices once it is converted. Other actions that retain the agricultural runoff for longer times within the landscape, reducing the loading to aquatic systems, include restoration of wetlands, nitrogen and phosphorus quotes. These practices are supported by the national scheme supporting water and climate projects: subsidies are awarded to the Danish Nature Agency and municipalities for *preliminary studies and establishment* of wetlands for nitrogen removal, and of low-lying projects for greenhouse gas emissions reduction, nitrogen removal, and nature improvement; and for *feasibility studies and the establishment* of wetlands projects for the removal of phosphorous, and river valley restoration projects for the improvement of the physical conditions of streams, nitrogen and phosphorous removal, and reduction of greenhouse gas emissions (Ministeriet for Fødevarer, 2024). To date, the scheme is ongoing, and landowners can still apply for financial aid for different rounds until October 2025 (Landbrugsstyrelsen, 2024a). However, more ambitious action is necessary, as, for example, in the Odense Fjord River Basin alone, it is estimated that 6,700 ha of new wetlands are vital to achieve the necessary nitrogen reductions to improve its ecological conditions. Such ambitions might be met by the new regulatory measures introduced with the agreement on the green transition of the agricultural sector, which are set to be reviewed by 2024 to align with the EU's Water Framework Directive (Ministeriet for Fødevarer, 2024)The success of the above-mentioned scheme can inspire the generation of more financial aid for actions that can also contribute to reducing pollution from agricultural practices. The region's role can be to support landowners in making information about these financing tools accessible.

5. Guide agricultural businesses towards a more carbon-neutral production (■).

It is agricultural businesses that contribute the most to the regional and national emissions. Among these practices, livestock production is the biggest emitter and therefore deserves great attention to bring the needed change for a more carbon-friendly future.

Reducing livestock production doesn't need to translate into an economic downfall. This transition to a more carbon-neutral production can be achieved, for example, by the following approaches: a) by improving the current production processes to make them net-zero, or close to net-zero; b) and/or it by generating revenue through other kinds of productions that have little to no carbon footprint.

a) The first is supported by the will of municipalities to aid farmers with the utilization of tools specifically developed for carbon accounting in agriculture, which can aid farmers in understanding what and how their processes generate emissions and how to reduce them: ESGreen tool has been mentioned by some municipalities, while in parallel 249 million DKK are allocated at the national level for the development of an emissions model for accounting and regulation of the emissions from the individual farm, connected to the ongoing work on a green tax reform. Among the measures to reduce emissions, one is particularly common among the municipalities in the Region, and it involves modifying the composition of animal feed: currently, the only fodder additive allowed in Denmark is 3-NOP, known by the commercial name of Bovaer (Fødevarestyrelsen, 2022); another viable solution is to increase fat in the feed. However, there is a general lack of knowledge on whether these mitigation solutions would impact animal welfare (AAU, 2024), though from 2021 funding has been allocated for more research in this area (Ministeriet for Fødevarer, 2024).

b) The transition towards other kinds of productions can align with the ambitions of the Denmark's plan for plant-based food, which includes financial aids for developing various productions (Ministeriet for Fødevarer, 2023): a yearly budget of 85 million DKK is allocated until 2030, of which 580 million DKK is allocated to support the production of plant-based foods, and 260 million until 2026 for biorefining of grass in order to develop the production of new sources of plant-based protein for both animal feed and human consumption (Ministeriet for Fødevarer, 2023).

The Region can encourage or require all farms to utilize one common tool for carbon accounting in agriculture. It can also collect positive experiences of production change within and outside the region to learn from best practices and provide guidance for businesses that could explore other ways of production.

6. Create a national certification for regenerative agriculture (●).

Regenerative agriculture is gaining traction in Denmark as a potential solution to reduce emissions, restore ecosystems, and improve biodiversity, though debates persist regarding its climate impact, scalability, and lack of clear certification. While some studies highlight its benefits, others caution against overstating its mitigation potential, particularly given Denmark's significant livestock-related emissions. The country is exploring policies such as agricultural carbon taxes and incentives for plant-based production, alongside growing corporate and municipal interest in regenerative practices. However, concerns about greenwashing emphasize the need for standardized certification and continued research to ensure meaningful environmental and economic outcomes.

A Danish certification system for regenerative agriculture would set clear standards for sustainable practices like reduced tillage and integrated crop-livestock systems. This approach would establish "regenerative" as a meaningful, high-standard label, supporting transparency and accountability in ecological claims.

7. Incorporate transparent documentation and farmer co-creation (●).

Given uncertainties about the benefits of regenerative agriculture, rigorous, context-specific studies—especially on soil carbon sequestration—are needed. Expanding regenerative thinking beyond agriculture into sectors like tourism, the built environment, and municipal climate planning could help Denmark achieve true sustainability. A shift from mere sustainability to active regeneration, prioritizing ecological and social well-being over production and consumption, is essential for meaningful transformation, requiring further research on implementation and evaluation.

To support the certification scheme and encourage innovation within guidelines, a transparent reporting system could be implemented which allows farmers and associated researchers to document their regenerative practices and results. Co-designing this system with farmers would ensure relevance, adaptability, and ongoing improvement based on real-world insights and data.

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