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Storm surge protection for the development of Nakskov – Funding Strategy

Baseline Report - FINAL



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Prepared by	Marianne Skov, Maria Facchin A., Brian Gardner, Evelina Gunnarsson
Checked by	Alvaro Fonseca
Approved by	Christian Nyerup Nielsen

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Resumé

Denne baselinerapport etablerer det analytiske, juridiske, institutionelle og interessentmæssige fundament for udviklingen af en finansieringsstrategi for stormflodsbeskyttelse i Nakskov. Rapporten konkluderer følgende:

1. Oversvømmelsesfare og -risiko

- Nakskov er udpeget som et "risikoområde" i henhold til EU's Oversvømmelsesdirektiv.
- Den eksisterende stormflodsbeskyttelse er fragmenteret og utilstrækkelig til at opfylde det fremsatte beskyttelsesniveau på 2,50 m DVR90.
- Oversvømmelser fra forhøjede havvandsstande og stormfloder udgør alvorlige risici for infrastruktur, forsyninger, boligområder og havneaktiviteter i Nakskov.

2. Eksisterende stormflodsbeskyttelse og beredskab

- Digelag spiller en central rolle i stormflodsbeskyttelsen af Nakskov. Dog har områdets digelag varierende niveauer af beredskab.
- Beredskabsprotokoller er på plads, men de afhænger af nøjagtige vandstandsprognoser og en koordineret indsats.

3. Tekniske løsningsforslag

- Tre løsninger for stormflodsbeskyttelse er tidligere blevet foreslået. Løsningerne har forskellige omkostninger, navigationspåvirkninger og beskyttelsesgrad:
 - Løsning 1: 60 m portåbning, dyreste løsningsforslag, fuld beskyttelse af havnen.
 - Løsning 2: 40 m portåbning, hverken dyreste eller billigste løsningsforslag, fuld beskyttelse af havnen med mulighed for fremtidige tilpasninger.
 - Løsning 3: 10 m portåbning, billigste løsningsforslag, begrænset beskyttelse af havnen.
- Alle løsninger er designet til et sikringsniveau på 2,50 m DVR90 og med mulighed for en dynamisk adaptiv planlægningstilgang.

4. Juridisk og politisk ramme

- Danmarks Kystbeskyttelseslov etablerer det juridiske grundlag for bidragsfordeling mellem dem, der opnår fordel af kystbeskyttelsen.
- Planlægnings- og klimatilpasningsstrategier på kommunalt og nationalt niveau understøtter integreringen af oversvømmelsesbeskyttelse som en del af byudviklingen.

5. Interessenter

- En række af interessenter identificeres i rapporten; inklusiv offentlige myndigheder, borgere, virksomheder, og forsyningsselskaber.
- Interessentinddragelse er essentielt for at skabe medejerskab hos interessenterne og en langsigtet succes.
- En plan for interessentinddragelse er blevet udviklet i Baseline for at styre og promovere deltagelse i alle projektfaser.

6. Metodegrundlag

- En risikoanalyse vil blive udarbejdet baseret på eksisterende oversvømmelsesmodellering men med et opdateret værdikort, der trækker på flere danske værktøjer og kilder for oversvømmelsesrisikomodellering.
- Projektets cost-benefit analyse vil følge nationale retningslinjer og inkludere skadesreduktion såvel som andre gevinster som ejendomsværdiændring.
- Udvikling af finansieringsstrategien vil udforske flere finansielle modeller og principper for bidragsfordeling.

Executive Summary

This Baseline Report establishes the analytical, legal, institutional, and stakeholder foundation for the development of a funding strategy for storm surge protection in Nakskov. The key findings in this report are:

1. Flood Exposure and Risk

- Nakskov is designated as an Area of Potential Significant Flood Risk under the EU Floods Directive.
- Existing flood protection is fragmented and insufficient to meet the projected 2.50 m DVR90 protection level.
- Coastal flooding poses severe risks to infrastructure, utilities, residential areas, and port operations.

2. Existing Flood Protection and Emergency Protocols

- Dike associations play a central role in flood protection with varying levels of preparedness.
- Emergency response protocols are in place but rely on accurate water level forecasting and coordinated activation.

3. Technical Proposals

- Three storm surge protection solutions have been proposed, each with different costs, navigational impacts, and protection coverage:
 - **Solution 1:** 60 m gate, highest cost, full port protection.
 - **Solution 2:** 40 m gate, moderate cost, full port protection, potential for future adaptation.
 - **Solution 3:** 10 m gate, lowest cost, limited port protection.
- All solutions target a protection level of 2.50 m DVR90 and are designed with adaptive capacity in mind.

4. Legal and Policy Framework

- The Danish Coastal Protection Act provides the legal basis for cost-sharing among beneficiaries.
- Planning and climate adaptation strategies at municipal and national levels support the integration of flood protection with urban development.

5. Stakeholder Landscape

- A wide range of stakeholders have been identified, including public authorities, citizens, businesses, and utilities.
- Stakeholder engagement is essential for legitimacy, co-ownership, and long-term success.
- A structured engagement framework has been developed to guide participation across all project phases.

6. Methodological Foundations

- Risk assessment will build on existing flood modelling and be enhanced with local data and sensitivity analyses.
- Cost-benefit analysis will follow national guidelines and include both direct damage reduction and co-benefits (e.g., property value retention).
- Funding strategy development will explore multiple financial models and cost distribution principles.

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1. Introduction

1.1 Background on Assignment

Nakskov, a town on the Danish island of Lolland, is a relatively flat low-lying area, that has been identified as an Area of Potential Significant Flood Risk under the EU Floods Directive, based on the risk of storm surges. This includes both the town centre and port areas.

The existing coastal flood protection structure was implemented because of the 1872 storm surge, that had dramatically changed the conditions and development of Lolland. The current structure ends at Nakskov Fjord, leaving the central part of the town of Nakskov (with a population of ca. 12,500) unprotected. There is a need to establish a coherent coastal flood protection for Nakskov, where whatever type of solution that is in the end implemented, is both taking stock of the latest data on expected storm surges and sea levels and also aligned with the visioning and plans for the future of Nakskov.

EIB, the financing institution of the European Union (EU), offers a large range of advisory services that embrace all stages of the project cycle and beyond, to make investment projects happen inside and outside the European Union. Lolland Municipality and European Investment Bank (EIB) are therefore investigating the opportunities for establishing common infrastructure to address flood risk and, through coastal protection infrastructure, benefit the city of Nakskov in its further development. The Assignment is funded under InvestEU mandate and will be managed by the Advisory – Public & Infrastructure Finance Division of the EIB.

As this project is developed under Danish legislation and planning frameworks, several terms used throughout the report originate from Danish regulatory practice and does not necessarily have a direct English equivalent. To ensure clarity and consistency, all such terms have been translated and defined in a dedicated glossary provided at the end of this report. Readers are encouraged to consult the glossary.

1.2 Objectives and purpose

The overall objective of the assignment is to develop a funding strategy for establishing storm surge protection for the town of Nakskov, demonstrating and quantifying the benefits as well as the direct and indirect risks of action and inaction. This assignment will be delivered through a structured, phased methodology aligned with the five tasks defined in the Terms of Reference (ToR).

The objective of this Baseline Report (Task 1) is to establish a shared analytical, legal, and institutional foundation for the assignment by confirming the development context for Nakskov, identifying and categorising key stakeholders, aligning with planned activities in the town of Nakskov and the Municipality as a whole, reviewing policy, financial, economic, and technical materials relevant to funding coastal protection, and refining the methodological approach.

2. Project description

In this chapter, the project is outlined and presented in relation to the coastal flood risk and the visions of the area and region. The chapter likewise introduces the ideas and reasons behind the proposed technical solutions for storm surge protection.

2.1 Nakskov

The city's location has been intact for almost a thousand years, but the city has also a history of dramatic changes. Throughout the centuries, the harbour was the mainstay of the town, and with the harbour, shipbuilding also became a main source of activity in the town. Nakskov is one of Denmark's old medieval market towns, and this is clearly seen in the town centre, where the land registers and street courses still have a medieval character [1]. Nakskov is also one of Denmark's best-preserved market towns with many beautiful merchants' houses and homes, several of which date back to the 1600s and some even further back. The quality and quantity of preservation-worthy properties make Nakskov completely unique and provide good opportunities for the development of the urban environment [2].

When the modern city broke out, people began to talk about the city as a shipyard, about the buildings as ocean liners. Like a shipyard, the city was on the move, vital, full of movement, full of noise. In Nakskov, the town and the shipyard were two sides of the same coin, with water as the lifeblood of the town. The water brought sounds into the middle of the city, and the sounds meant life. First and foremost, the sounds from the shipyard when iron plates were riveted, but also all the other sounds from the harbour, shrill freight cars in the railway tracks, the noise of loading and unloading, honking ferries, tourists and the screams from seagulls [1]. Map of the harbour and port area development is depicted in Figure 1.

The shipyard has closed, and the coal crane is gone, but the harbour remains vibrant and holds great potential for even more activity. With a livelier harbour, new opportunities arise to bring renewed energy and life to the city. Nakskov is Lolland's largest town and is crucial for the development of the entire island.

With its waterfront, its silos, its alleys, its classic square, and its enormous potentials for outdoor life along the coast, on the fjord and inner fjord, it has potentials as a tourist town and experience city. The development of Nakskov in the future requires a joint and comprehensive effort, a vision jointly shared by the municipality, businesses, local investors and citizens.

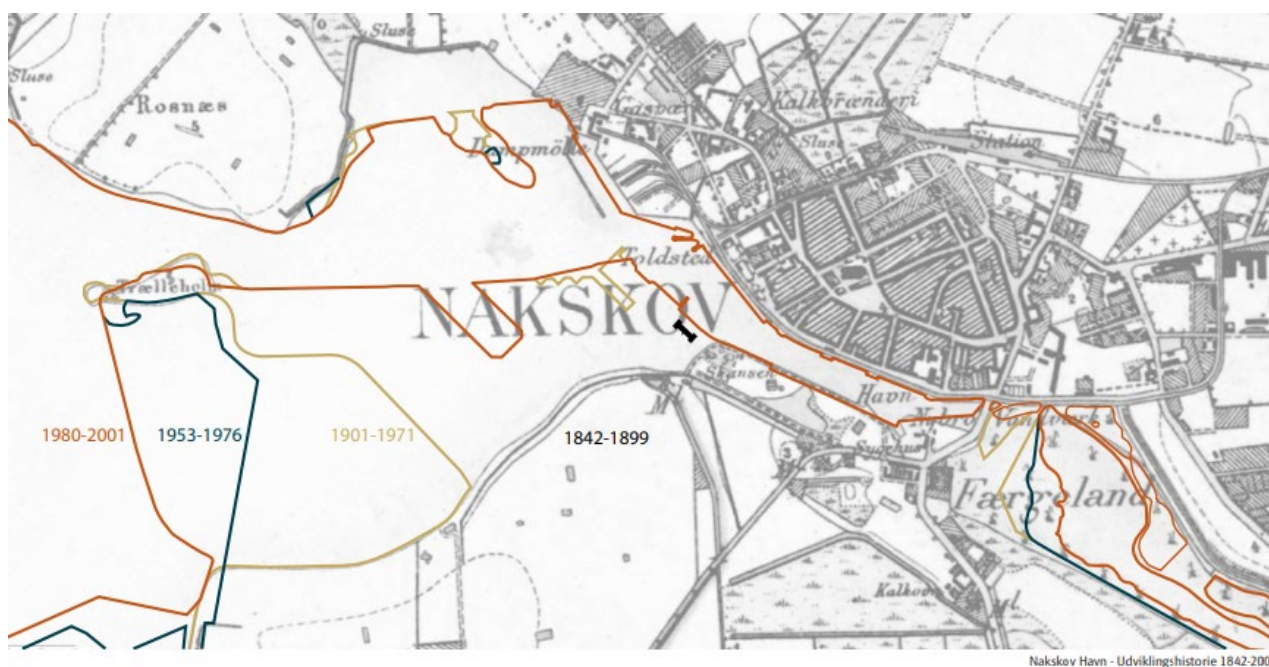


Figure 1: Nakskov harbour and port area development, [1]

2.1.1 Nakskov 2030 vision

Nakskov is currently in a prosperous development phase. Jobs in the industries are coming back, and population growth is stable. But there is still a need to work purposefully to develop the town if it is to continue to be an attractive town on Lolland. Nakskov 2030 sets the direction for how tourism can be a lever for this development. This is done on the basis of the development and investment strategy. Additionally, an architectural competition was issued, showcasing history and identifying great potentials [1].

A set of development principles have been developed with a focus on tourism development being seen as a lever for the entire town's development. Thus, tourism development should be seen as a connection between developing the town for the citizens, and developing the town for the tourists - both citizens and tourists must benefit from the new urban spaces, shared experiences, offers and activities, and neither party can create the future of Nakskov alone [3].

Considering tourism as business development, tourism development shall be created based on Nakskov's special character and history. The well-preserved market town centre, the harbour activities, and the fjord landscape. Municipal, commercial and non-profit investments must go hand in hand. The municipality must take the lead with investments that show the will and prioritisation of the effort, and that make it attractive for private and non-profit investors to participate. This creates the basis for a sustainable business and strengthens the experience of a vibrant and active city.

Recreational initiative – from the harbour to the beach shorelines

Project 'Harbour to Beach' is a strategic development initiative under Nakskov 2030, the purpose of which is to establish a new recreational harbour environment in and around the ferry berths that invites activity, stay and offers commercial offers at the Port of Nakskov. The project is a business development project where the investments will create a framework for growth in the tourism industry, maritime industry, experience economy and local service companies. At the same time, the project will contribute to creating a more coherent and attractive access to and use of nature, the fjord and the town in the form of a new coherent experience corridor between Nakskov Harbour and Hestehoved.

The project may be considered as both as a physical construction project and a strategic investment in Nakskov's future business and experience economy. The project is supported by the Danish Business Promotion Board, the EU Regional Development Fund, Realdania and the Municipality of Lolland [4].

2.1.2 Nakskov Port Strategy

The Port of Nakskov is situated on Nakskov fjord and is one of the largest ports in the Southern part of Denmark. The port is connected to an international shipping route, with a navigational depth of 8.5 meters. The fjord itself is largely of shallow depth, offering natural sheltering and limiting wave height.

The Port is since 2014 owned by the Municipality of Lolland and is managed for transport and commerce [5]. The Port of Nakskov offers versatile cargo handling in a regionally important commercial port. Nakskov Port has 14 quays slightly different from each other, with a total of more than 2,000 meters of quays and able to withstand loads of up to 20 tons per square meter [6]. The water depth varies from 6.3 m to 8.5 m [7]. Large commercial areas are adjacent to the port area, with several Greentech companies establishing themselves in recent years.

The largest enterprise using the Port is Vestas, a Danish wind turbine manufacturer. A range of ship sizes use the port, the largest being for the transport of wind turbine blades. Other economically important shipping relates to food, given the agricultural importance of the island of Lolland.

- Vestas, wind turbine blade manufacturer
- DLG, agricultural producer and distributor
- Nordic Sugar A/S (Nordzucker), agricultural producer and distributor

There have been significant investments in relation to the Port over the years, and recently a major deepening and widening of the navigation channel through Nakskov Fjord has been approved [8]. The strategy and master plan 2050 propose to support the ongoing development and at the same time set the direction for the port development on Lolland in the coming years. With this strategy, Lolland Municipality and the Climate, Technology, and Environment Committee outline clear long-term development drivers in Nakskov [7].

The strategy is based on existing positions of strength and core businesses in bulk products, among other things, project cargo and larger constructions, which are supplemented by the potentials derived from the green transition. The strategy is also based on the development wishes for the Port of Nakskov as a commercial port, as well as the development of the industrial areas around Stensø [7].

The overall strategy goals for the Port of Nakskov are to [5]:

- Ensure an efficient and flexible infrastructure.
- Consolidate existing freight areas and exploit the opportunities in the green transition and attract new types of goods.
- Support business development in the region.
- Ensure that business and industry are prioritised in harmony with a natural town and tourism development where possible.

In Nakskov, Lolland Ports expects a stable development in the core business within wind, cereals and animal feed, fertilisers, raw materials and building materials. In addition, the Port of Nakskov has a strength in relation to handling larger structures, which contains growth potentials in areas such as wind turbines, the environment and recycling, as well as bulky general cargo. A significant area is being allocated to industry, and there are good opportunities for expansion of the port facilities.

With the island of Lolland being part of the Fehmarn Belt Region, where greater growth is expected because of the tunnel, Lolland Municipality wants to be a key player in the region's tourism and business development [7]. As part of the long term growth potentials, the masterplan for Nakskov Port contains proposals of a new deep-sea quay outside and to the West of the current port activities in the inner fjord, with the aim of increasing overall capacity and to accommodate even larger vessels in the future, see Figure 2.

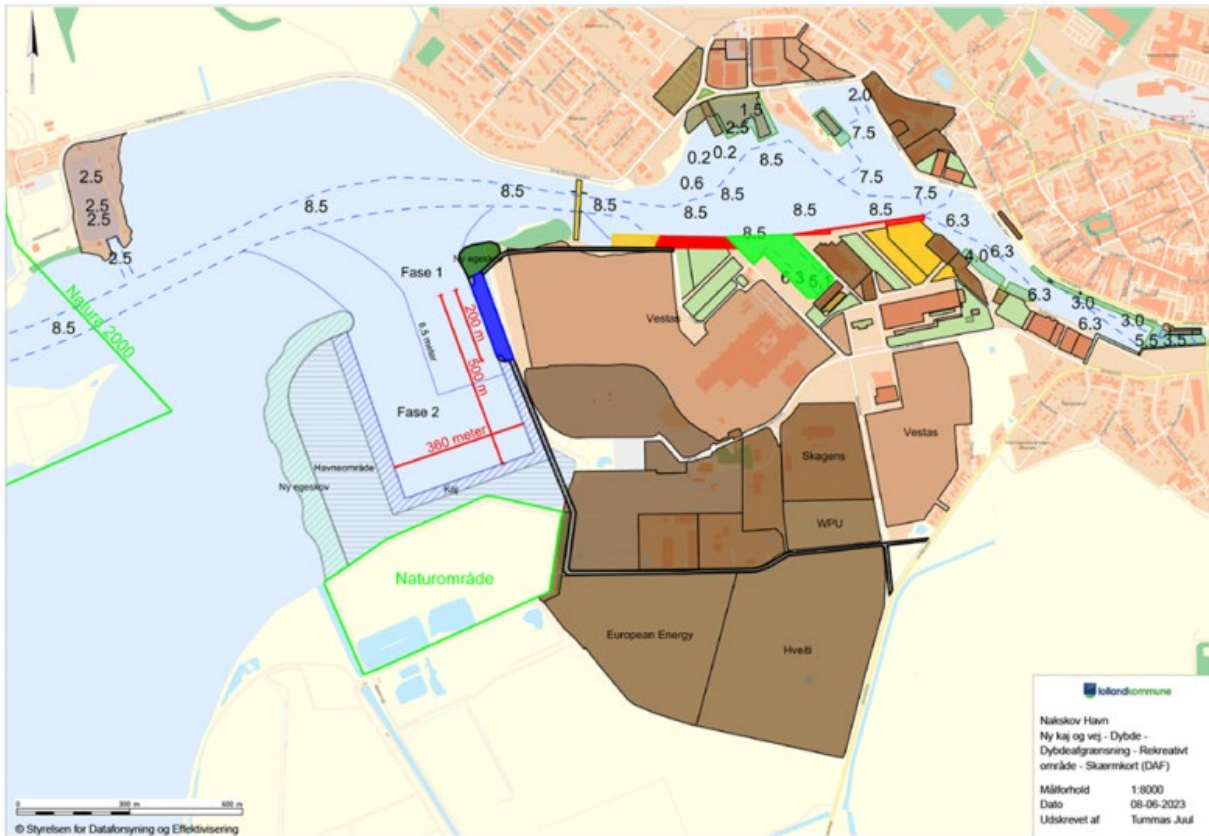


Figure 2: Development masterplan for Nakskov Port. Source: Ports of Lolland [7].

2.2 Flood risk

Nakskov is exposed to flooding from the sea, which has hit the town and port several times. With climate change and rising sea levels, the threat will increase, and flooding will worsen. The flood exposure is depicted in Figure 3. Port quay sides are primarily overflowed when sea water levels exceed +2.0 m DVR90.

The area exposed may be viewed from a perspective of Nakskov Fjord, Nakskov Harbour and Inner Fjord, and is split in a northern and southern part which is connected by the road bridge Nybro on top of a lock structure dividing the sea (Nakskov Harbour and Nakskov Fjord) and freshwater water bodies inland (Nakskov Indrefjord) [9]. Inner Fjord has an inflow from the pumping stations for Halsted Å and Ryde Å. Coastal flooding can occur both from the harbour and the innermost part of the fjord at the shorelines between Hestehoved and Trælholm, and just north of Hestehoved and south of Trælholm.

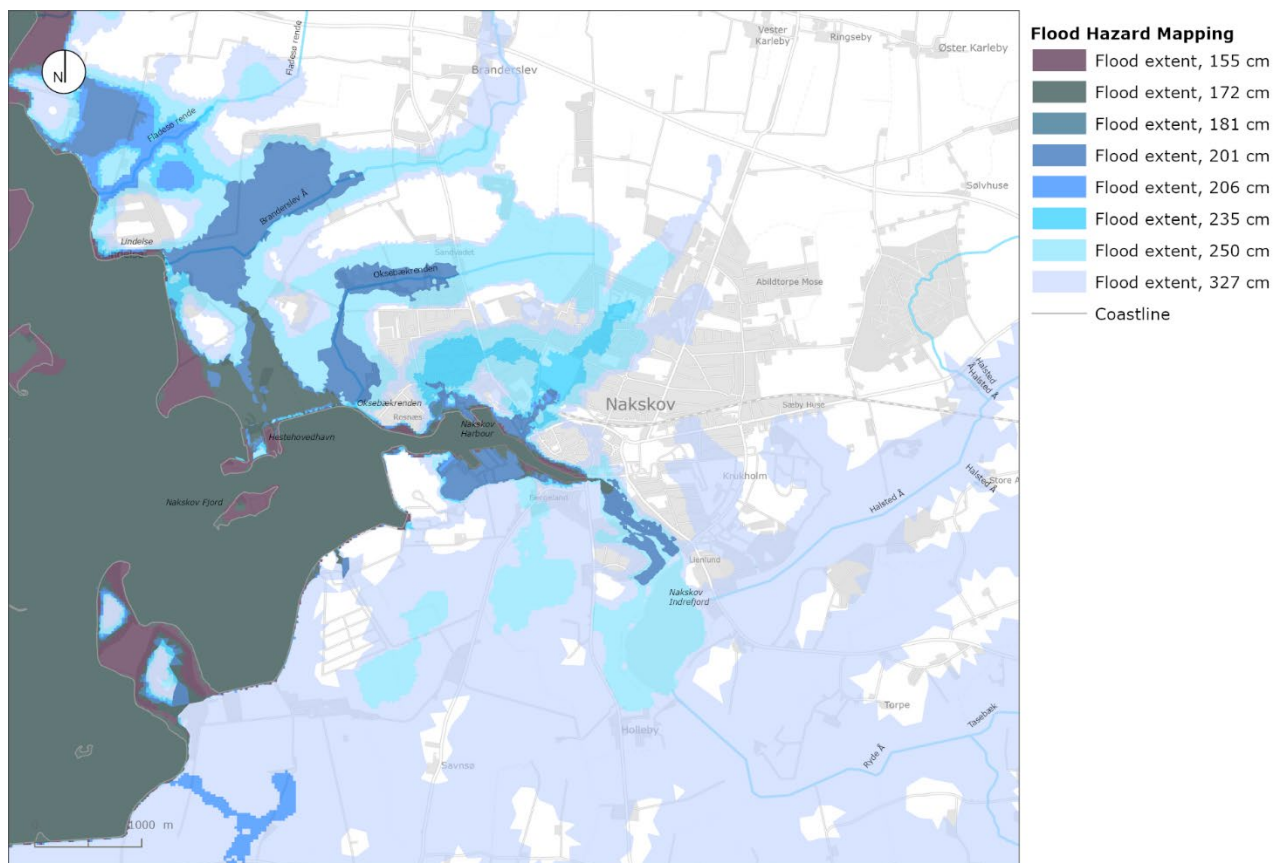


Figure 3: Nakskov flood exposure based on flood maps from Danish Coastal Authority.

Coastal flooding of Nakskov can have severe consequences: the electricity supply will be cut off in large parts of the city, and the flooding will be a threat to the drinking water supply and the telephone network. Access will be blocked and highly dangerous when floodwaters cover roads and manhole covers are missing or hidden. Leaking untreated wastewater or other pollutants will cause both health and environmental risks. Many other functions will not work unless significant emergency response is deployed. Once a large flood event has retracted, major tasks will await to get city conditions back to normal (recovery). It can take several days before the worst is over, and much longer before everything can work as normal. And there will be damages that, in addition to direct losses, can have far-reaching consequences both for society and for individual citizens [10] and [9].

2.3 Flood Risk Management

Storm surge protection is traditionally a cross-disciplinary discipline at the island of Lolland Municipality. Citizens have all grown up with the stories – and the legacy – of the storm surge in 1872. Therefore, there is great awareness both politically and among citizens of the risk posed by the sea – especially with climate change in sight. There is also generally a long-standing tradition of working together on the challenges, incl. associations of dike maintenance and pumping operations, land reclamation teams, volunteers, emergency services, etc. [10].

2.3.1 Development of flood risk management plan

Lolland Municipality has prepared a risk management plan for Nakskov to mitigate the risk of sea flooding. The plan includes descriptions of risks which form the basis for a municipal planning of protective measures in Nakskov, especially in relation to urban development. This ensures that there will be no new buildings at risk; and it limits land-use activities that could hinder the implementation of flood protection measures. The plan also identifies areas that are not expected to be protected from storm surges if the project is carried out [9].

The flood risk management plan has been prepared by Lolland Municipality, the Technical and Environmental Authority in collaboration with the Lolland-Falster Fire Brigade and other stakeholders.

[9]. The decision-making responsibility for objectives and initiatives for risk reduction lies with the municipality, so that the preparation of the risk management plan can include local knowledge and ensure coordination. Lolland Municipality has decided to work with a protection level of 2.50 m DVR90 for the Nakskov town and port area [9]. The risk management plan does not contain any agreements on the execution of measures because the plan does not provide for the financing of measures or joint solutions.

2.3.2 Existing flood protection

There are some flood protection schemes near Nakskov, see Figure 4. In the southern part, the area south of Skansen and Skibsværftsvej up to Nybro is primarily protected by a dike and mobile measures against flooding. This part managed by the Dike Association of Lolland is referred to as 'Fjorddiget – Nybro-Langø' [11]. In the northern part, the coast north of Hestehoved is partly protected by a dike of the Branderslev/Sandby Dike Association. Apart from a sea wall along Fiolstræde in Havnegade, no coastal flood protection has been built to protect Nakskov town and port against coastal flooding above +1.6-1.7 m DVR90 [10], [12].

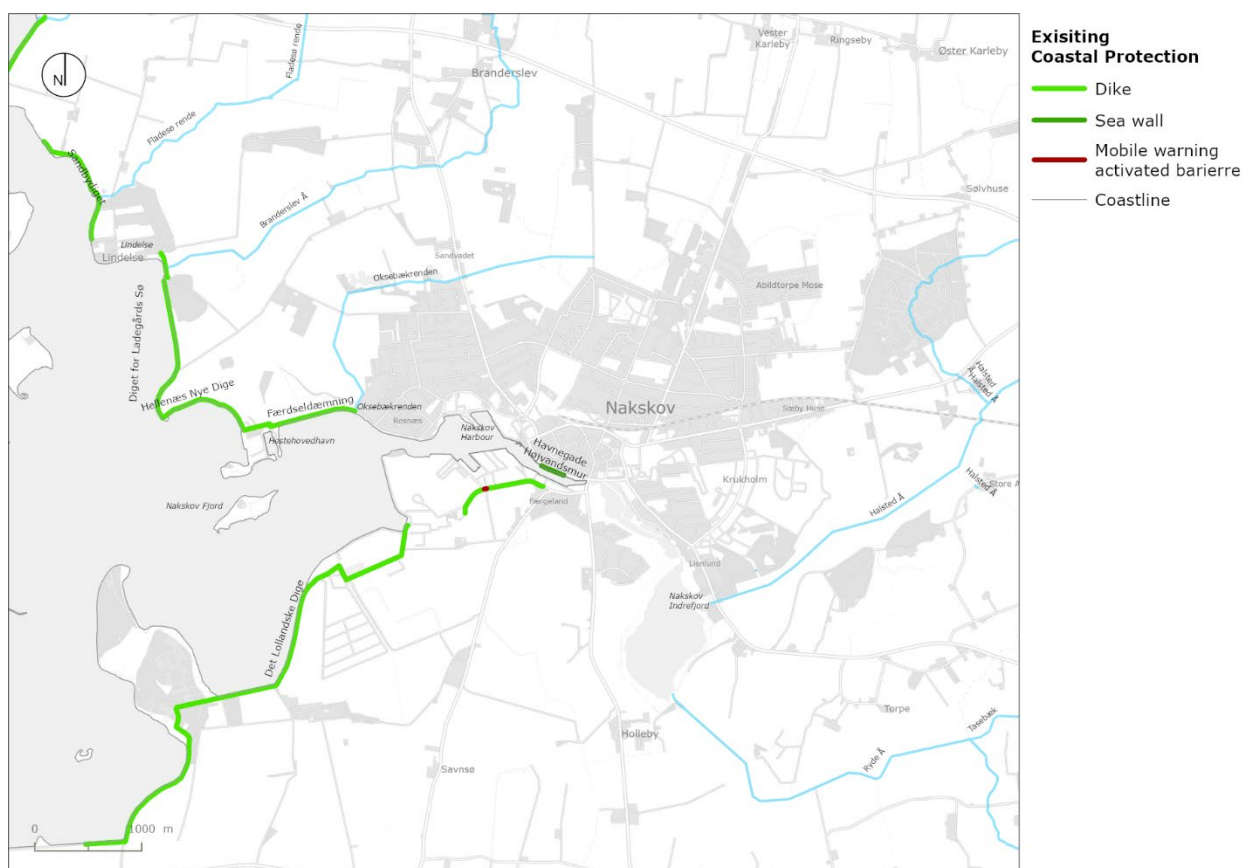


Figure 4: Existing flood defences. Data source: Danish Coastal Authority [13] and Lolland Municipality [10]

Lolland Municipality is actively engaged in coastal protection, primarily through collaboration with dike maintenance and pumping associations. These efforts include ongoing dialogue with the municipality and cover the protection of Nakskov's town and port areas, as well as a few smaller sections.

S-SW of Nakskov town and port area

The dike by the Dike Association of Lolland, which runs along Lolland's southern coast and further along the south side of Nakskov Fjord to Nybro, was built in the mid/late 1870s [14]. At that time, the area between Trælleholm and Stensø was not reclaimed. The flood protection structure was therefore established with a withdrawn alignment between Nybro and Stensø - the location of the coastline at the time. No additional dike structures were built on Stensø, as the terrain here was above the agreed

protection height at the time. On the west side of Stensø (where the wastewater treatment plant is now located), the dike continues towards the west. Here the dike was designed with a construction height corresponding to 2.75 m and is thus higher than the 2.50 m DVR90 that the risk management plan has as target design protection level [10]. The statutory protection level is a minimum of +2.5 m DVR90 for the sections relevant to Nakskov.

High sea water level warning protocols are in place in relation to the deployment of temporary measures as well as monitoring the surge development and inspection of the structural state of flood protection measures. The Dike Association of Lolland is structured and organised around three levels of emergency response [15]. For details on implementing individual measures under a designated preparedness level, please refer to the specific locations outlined in the Emergency Response Protocol [15]. The emergency plan is built using the national emergency plan as a reference framework and applies the preparedness levels from the national operational staff (NOST). It should be noted that, without activating temporary measures, the structure protects against high sea water levels above approx. +2.29 m DVR90, [11].

Table 1: Emergency Response Organisation and Protocols for the Dike Association of Lolland [15].

Level 1	General preparedness state -> Activation of basic organisation. Criteria: - Sea water level of +1.00 m above mean sea level DVR90, at Rødbyhavn and wind speeds of 13.9 – 17.1 m/s, or sea water level of +1.20 m DVR90 and wind speeds of 10.8 – 13.8 m/s and further rising probable according to prognoses. Task: - When the state of 'general emergency preparedness' is introduced, the police, municipalities, ports, Scanlines, as well as emergency preparedness and guild patrol personnel are notified, each of which gives further warning in its own organisations. - At a sea water level of +1.20 m DVR90 dike patrolling is initiated by appointed Guild personnel.
Level 2	Elevated preparedness state -> Activation of emergency staff. Criteria: - Estimations of sea water level +1.50 m and further rising probable according to prognoses. Dike patrolling is taken over by property with patrolling responsibilities. Task: - All involved partners are contacted, and personnel are called in in the various organisations.
Level 3	Emergency preparedness state. Criteria: - Water level +2.00 m DVR90, and further rising probable according to prognoses or - In case of dike breach and failure or water overflow is observed.

N-NW of Nakskov town and port area

Branderslev-Sandby Dike is from 1876, and their dikes were established on the low stretches of the coastline along Nakskov Fjord, from Oksebæksrenden to Krageskov north of Lindelse. At Hellenæs, the property owners later established a dike along the coast. Along the coast north of Krageskov there are private dikes, but north of this at Middelgrundvej there is no storm surge protection, and the lowest terrain ridges from here and inland to Nakskov are approx. 2.00 m DVR90. Thus, it may be possible that large storm surges entering here reach Nakskov, depending on the duration and peak of the event, [10].

2.3.3 Effectiveness of existing flood protection measures

To achieve an overall protection level of 2.50 m DVR90, the design basis will depend on criteria for effectiveness. The design water level is likely to be between approximately 2.00-2.5 m DVR90, depending on the inherent adjustments for wave activity and potential wave impacts.

The dike along the south-western part of Nakskov Fjord was levelled in 2013 by the Dike Association of Lolland, with only a few sections below an elevation of 2.50 m DVR90 [10] [11]. Some locations, e.g., Nybro and Skibsværftsvej by Taxi Lolland, have warning activated measures, such as placement of sandbags, whereas other locations such as the Skibsværftsvej by the intersection of Stensø/Vingevej utilise 'at-location-ready' clay wing measures when water level prognoses exceeds 2.00 m DVR90 cf.

Appendix 22, section: 'Instruks for lukning af hul på Vingevej i Nakskov' [11]. Smaller sections close to the Sewerage Treatment Plant which had experienced structural degradation, have recently been restored, and are only awaiting confirmation of levels [11].

At the north-western part of Nakskov Fjord, the dikes administrated under Branderslev-Sandby association have a statutory elevation of 2.50 m DNN, which corresponds to 2.42 m DVR90, [9]. Based on a chosen storm surge protection level of 2.50 m DVR90, considerations must be discussed in relation to the Risk Management Plan.

It may be considered that Nakskov can be protected from the northwest by either raising the dikes in Branderslev-Sandby to 2.50 m DVR90 with a supporting wing dike until higher ground is reached, and by establishing a smaller dike inland north of Krageskov on terrain that is lower than 2.50 m DVR90. Or raising the existing dike to 2.50 m DVR90, both the Branderslev-Sandby dike and the private dike stretches along the coast, all the way to Middelgrundsvej, where higher elevations may be met, [9]. Additionally, it may be considered if the inland flood protection structures shall be implemented, dividing the hinterland into zones with different protection levels, and improving adaptive buffer capacity. There will also be an opportunity to allow a varying flood protection level depending on a differentiation between land uses and functions. This could mean that there will be some agricultural areas that will not receive the same protection level as the built town environment. Not necessarily because of lower importance, but because agricultural land can better withstand a flood without loss of great value and its resilience.

It could also be planned to lower the protection level and changing the design conditions and criteria, resulting in no additional raising of existing flood protection structures. Further project advancement and studies may result in modification or adaptation of current technical proposals for coastal flood protection.

Within the current project scope and set design criteria, it is assumed that no additional measures or upgrades are urgent. Dialogues with surrounding and independent flood risk management associations should not only be confined to coastal but also inland dike and pumping associations. Stakeholders shall be informed and engaged both as the municipal role of supervisory authority and as responsible for ensuring involvement and commitment to a long-term strategy and development.

An analysis of joint probability of coinciding or concurrent events of extreme precipitation and high sea water levels around Lolland shows that there does not currently appear to be a temporal coincidence between the type of events [16], [10]. Additional flood protection measures are therefore not suggested or explored at the current project state, hence is expected to play a key part in future climate conditions [17].

2.4 Technical proposals for storm surge protection

Comprehensive strategies for coastal flood risk mitigation entailing technical design proposals and variants have been proposed. The strategies include adaptive design principles and possible interventions to further mitigate risks over time, incl. climate resilience and urban development perspectives.

The overall targeted coastal flood protection level for Nakskov is to provide adequate protection against coastal flooding up to water levels of approximately +2.50 m DVR90. Several factors, including future port operations and shipping requirements, influence the range of potential solutions under consideration. As the project develops, design variations may need to be explored further, including phased implementation and adaptive planning options, which could affect the area of impact.

Storm surge protection is dimensioned based on expectations for future water levels and weather conditions, as well as the vulnerability of what the system is to protect. A map indicating the locations of the proposed storm surge protections is shown in Figure 5 and an overview is presented in Table 2.

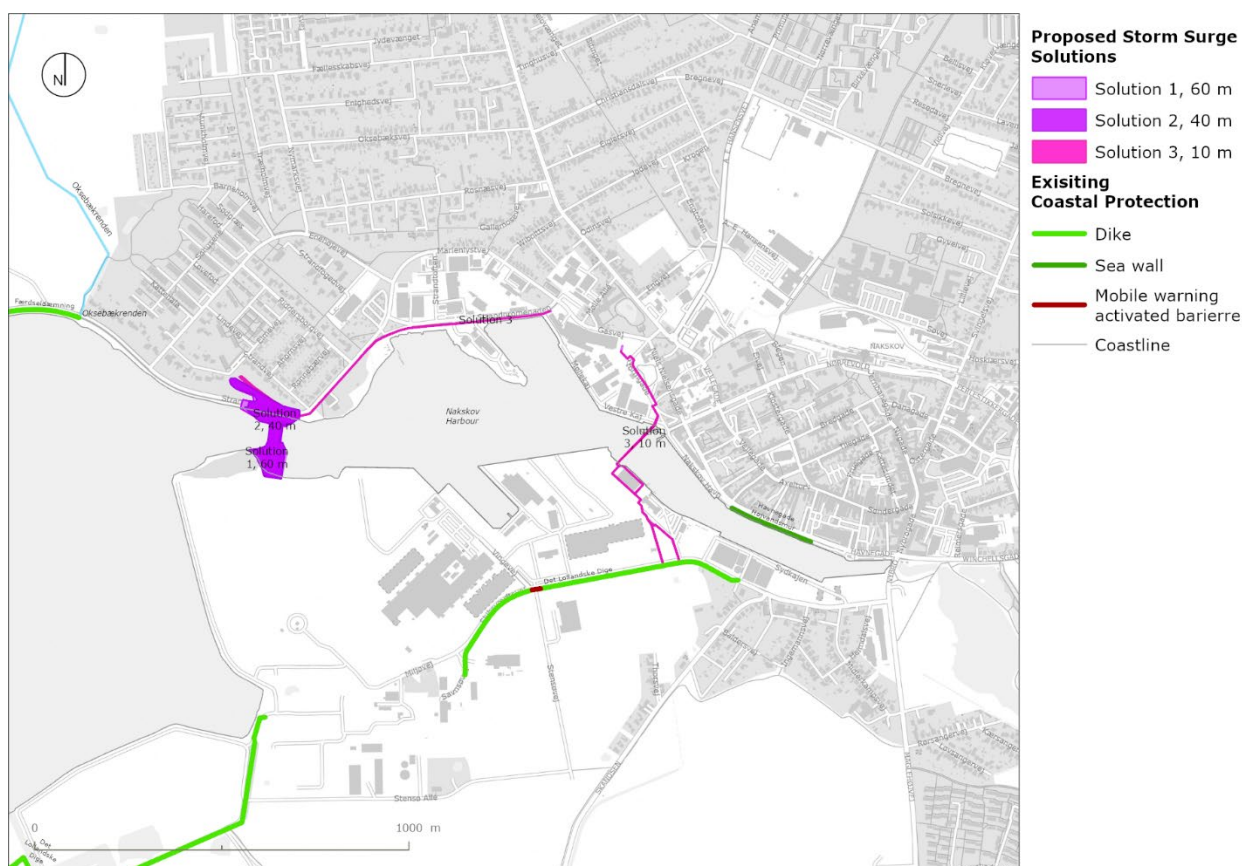


Figure 5: Locations of the three technical proposals for storm surge protection. Note that two alignment versions for solution 3 exist on the southern side of the harbour. Data source: Danish Coastal Authority [13]; Lolland Municipality [10]; and Ramboll [18].

Table 2: Overview of Technical Proposals for Storm Surge Protection

	Variant	Proposal 1 Storm surge barrier incl. 60 m passage with gate "Preferred" [19] (costs updated in [20]) Outer harbour location	Proposal 2 Storm surge barrier incl. 40 m passage with gate(s) "Reduced" [20] Outer harbour location	Proposal 3 Storm surge barrier incl. 10 m opening with 2x6 m gates "Minimum" [21] Inner harbour location
	Technical Proposal, Concept	Dam incl. a rolling or rotary segment gate with supporting structures on land	Dam incl. a rolling or rotary segment gate or with supporting structures on land.	Dam incl. mitre gates and additional supporting structures on land including a pumping station
Design dimensions and description	Existing width from land to land, across water	150 m	150 m	145 m
	Gate, Passage of water Width of opening for water exchange	60 m	40 m	10 m
	Gate, Passage of vessels Navigational width	54 m	32-35 m	8 m
Design Levels [m DVR90]	Design Protection Level	2.5 m	2.5 m	2.5 m
	Design Water Level	Up to +2.35-2.5	Up to +2.35-2.5	Up to +2.5 m
	Construction, Top Level			
	Gate Gate supporting structures Land structures	4.0 m 6.0 m 2.5 m	4.0 m 6.0 m 2.5 m	2.6 m 2.5 to 2.6 m 2.5 to 2.6 m
	CAPEX (2025) (expected +/- 40 % range)	DKK 467 million	DKK 403 million	DKK 136 to 140 million

Initially, it has been looked at whether the system can be adapted to both the known and unknown changes – the adaptive protection system – with a view to ensuring that the system is not oversized in relation to the decided level of protection based on the current and expected flood risk. Not all construction types, design structures, materials, etc. are suitable for or support an adaptive expansion and adaptation infinitely. This sets demands on the construction of the facility, but also on organisation in terms of administrative framework and finances. The establishment of storm surge protection consisting of mobile parts that initiate an automatic shutdown procedure or require the activation of emergency personnel in the event of a warning requires a robust organisation of highly specialised personnel. The type, structure and dimensions of the structure are to varying degrees suitable for adaptively expansion and change, also in relation to the chosen level of protection and the balance of identified impacts, legislation and finances.

The robustness of coastal flood protection can depend on several factors, including design, choice of materials, the degree of safety according to standards, the need for emergency activation, adaptability in relation to expansion and reinforcement, correct operation and efficient maintenance, etc. The lifespan of the proposed solutions is expected to be at least 50 years, but variation occurs within the individual typology. Several measures only have a lifespan of 80-100 years, provided that the right operation and maintenance are carried out.

The proposed solutions are currently perceived to have the same effectiveness as they are all designed to a protection level of +2.50 m DVR90. However, the flood risk reduction effect differs amongst the design proposals, due to different areas benefitting from the implementation, including both surface and subsurface assets, see Figure 6 and Figure 7. The delineation of the risk reduction area according to the effectiveness of a solution must be further investigated and determined, ultimately influencing and determining the outcome of the analysis.

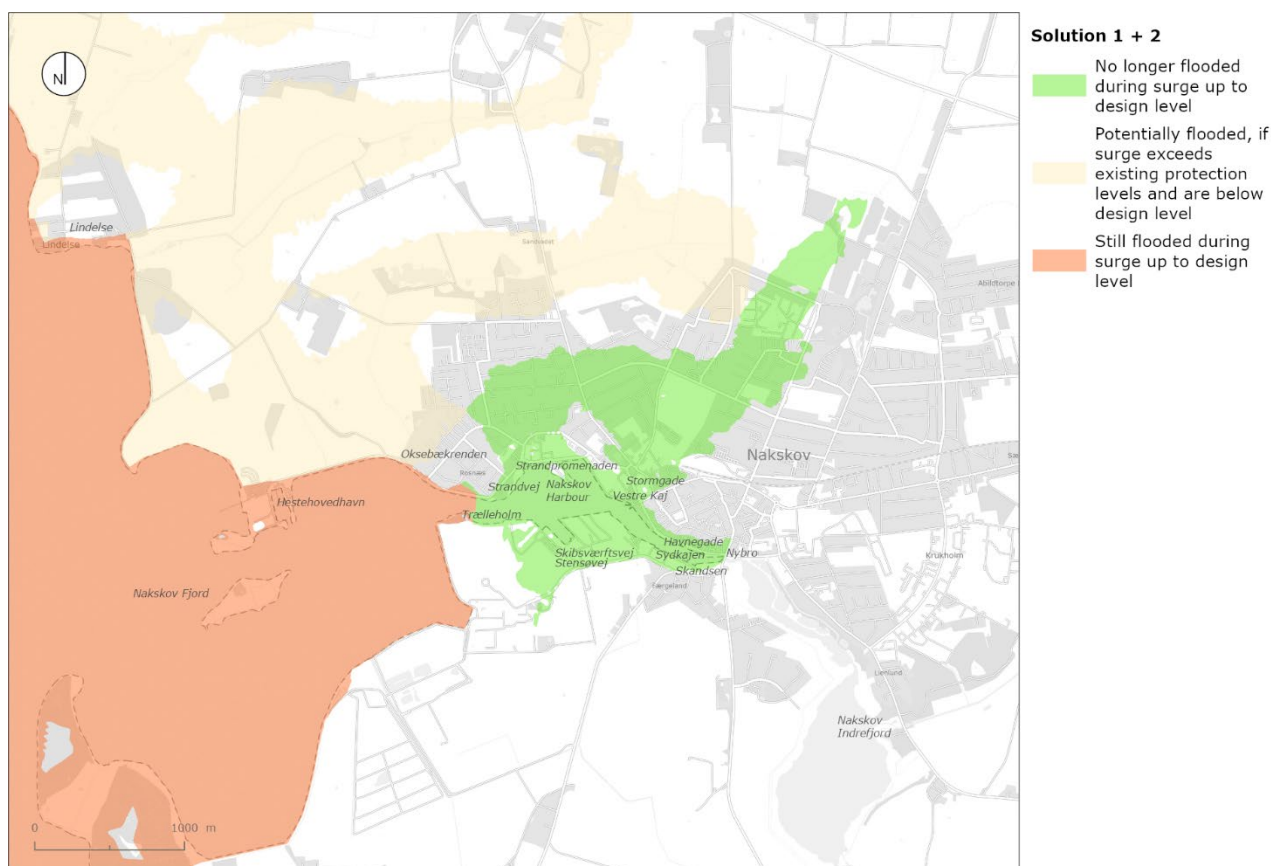


Figure 6: Effectiveness of Technical Proposal, Solution 1 and 2

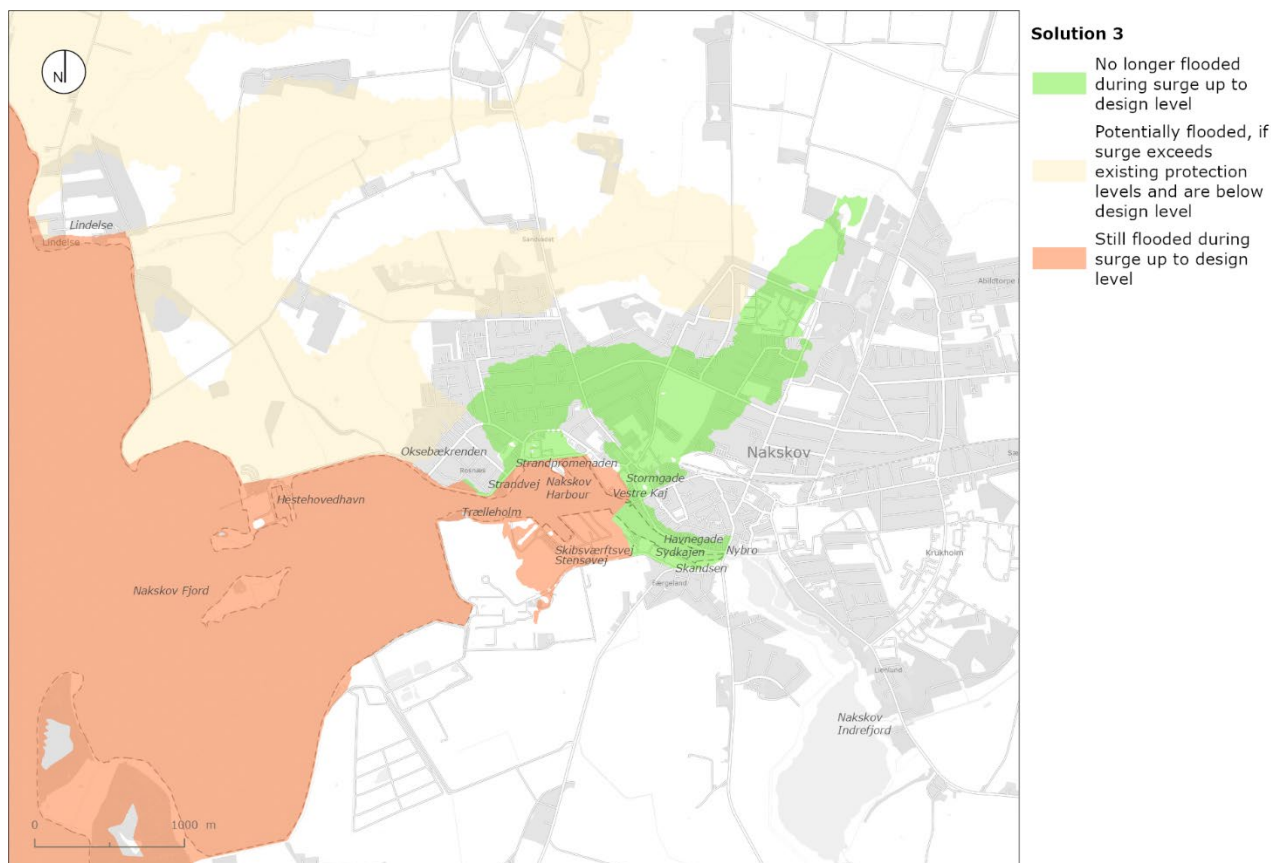


Figure 7: Effectiveness of Technical Proposal, Solution 3

In addition to protecting against flooding from the sea, a storm surge protection will also have to address or integrate any flood risk caused by pluvial sources, e.g. wastewater and rainwater; fluvial sources, e.g. water from rivers and surface run-off, or high near surface groundwater tables, which cannot naturally drain to the sea due to storm surge protection measures. Locally, supplementary measures are usually required as well as the installation of pumping stations and valves. These aspects will be discussed and investigated in more detail as the project progresses and more insights are obtained.

2.4.1 Solution 1: Storm surge barrier incl. 60 m passage with one gate

Solution 1 includes storm surge protection for Nakskov town and port area. It consists of a large-scale storm surge barrier with an open passage width of 60 m and supporting structures, both on water and land. The premise for this solution proposal is that it must be possible to accommodate vessel traffic to and from the Port of Nakskov with slightly larger vessels than those that sail the harbour area today [19].

Solution 1 is located just west of quay 0 [6] near Trælleholm, and includes a dam and a gate across the open water as well as terrain regulations to the north at Rosnæs carried out as road re-levelling of Strandpromenaden and dike construction on the green area in front of the houses at Strandvej. A gate will be activated when high water level warnings are issued [19].

The passage width is defined as the distance between the gate chamber and the supporting dam construction, which is set at 60 m, to minimise the suction between the fixed structures and passing vessels. However, the free navigable passage width is 54 m, as a pile-based guide will be established along the sides of the gate opening [19]. The gate chamber with supporting technical installations and functions will be on the southern side and can be reached by an access road, through an area belonging to the Port of Nakskov.



Figure 8: Conceptual Design Proposal of Solution 1. Source: Ramboll [19]

Immediate advantages and disadvantages of Solution 1 are:

Advantages:

- Support potential growth of Nakskov Port welcoming even larger vessels than today
- Port of Nakskov not flooded during storm surges with water levels up to +2.5 m DVR90
- Little to no influence on ship and boating traffic during operation phase.
- Design can to some extent be adapted over time to increasing threats from sea level rise and storm surges.

Disadvantages:

- Significant interference with Nakskov Port operation during construction phase
- Very high construction and operation cost of the proposed solutions
- Anticipated construction period of approx. 2 years.

2.4.2 Solution 2: Storm surge barrier incl. 40 m passage with one gate

One alternative is referred to as "Reduced open passage width", which essentially is the same as solution 1, but where the opening width has been reduced from 60 m to 40 m. The proposal includes storm surge protection for Nakskov town and port area, consisting of a large-scale storm surge barrier with an open passage width of 40 m and supporting structures, both on water and land.

The premise for solution 2 is that it must be possible to accommodate vessel traffic to and from the Port of Nakskov with no assistance of tugboats. Lolland Municipality likewise wanted to investigate whether the navigational challenges and port operational disadvantages of this solution and the expected high cost of operation is offset by the reduced construction and maintenance costs for the storm surge barrier itself. Additional perspectives regarding further future-proofing of port operations, enabling development of the storm surge barrier to also function as a ship lock, securing the port against climate-related sea level rises [20].

Solution 2 is located just west of quay 0 [6] near Trælleholm and includes a dam and gate across the open water as well as terrain regulations to the north carried out as road re-leveling of Strandpromenaden and dike construction on the green area in front of the houses at Strandvej, Rosnæs. A gate will close will be activated when high water level warnings are issued [18].

The passage width is defined as the distance between the gate chamber and the supporting dam construction, which is set at 40 m, to minimise the suction between the fixed structures and passing vessels. However, the free navigable passage width is 35 m, as a pile-based guide will be established along the sides of the navigational channel and gate opening to minimise coalition and damaging the storm surge barrier [20]. The course of the navigational channel must be alternated a little, including carrying out dredging activities [20]. The gate chamber with supporting technical installations and functions will be on the southern side and can be reached by an access road, through an area belonging to the Port of Nakskov, se Figure 9.

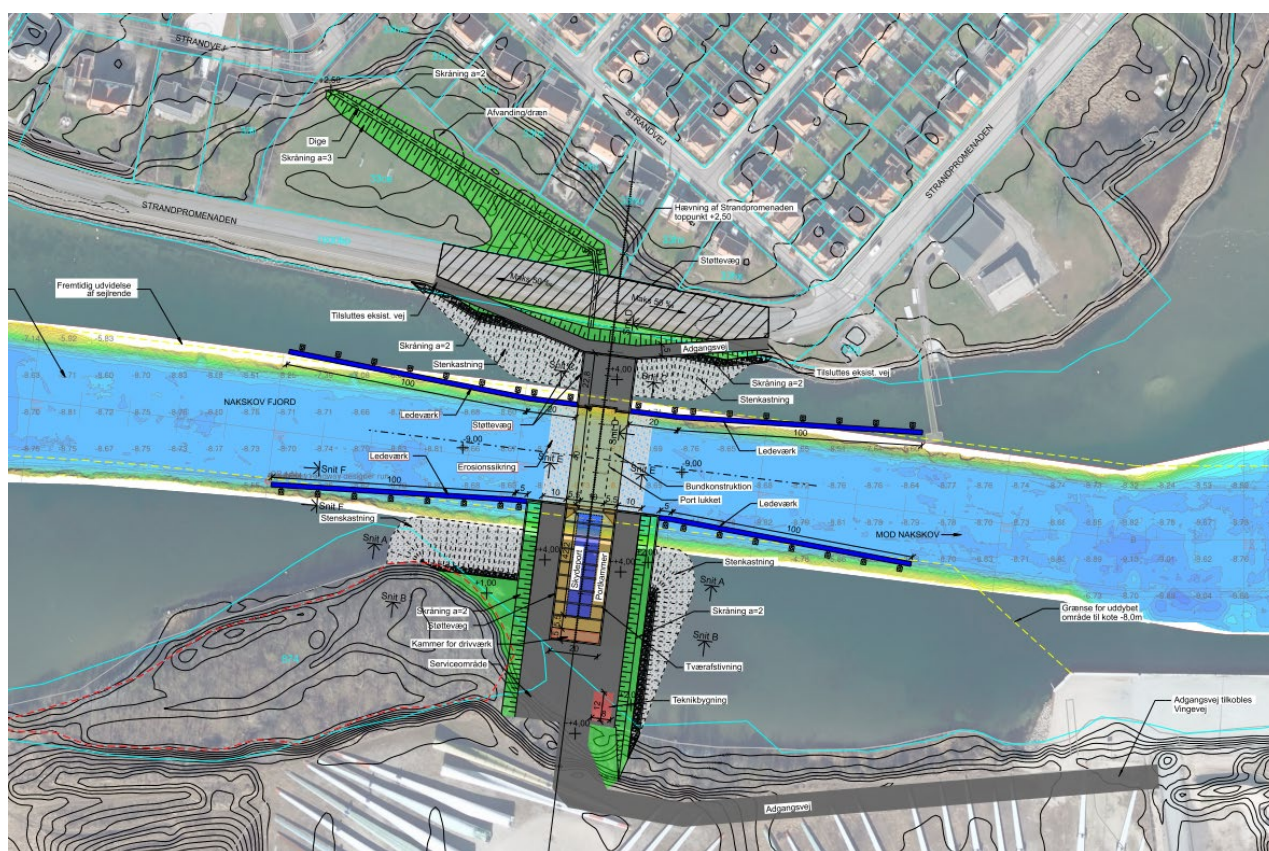


Figure 9: Conceptual Design Proposal of Solution 2. Source: Ramboll [20]

The technical solution may over time be considered retrofitted into a larger sluice gate system as a response to climate change and keeping a high operation frequency of Nakskov Port, see Figure 10.



Figure 10: Conceptual Design Proposal of Solution 2 including possible adaptation to climate change.
Source: Witteveen+Bos [22].

Immediate advantages and disadvantages of the proposal are:

Advantages:

- Support potential growth of Nakskov Port with approximately the same vessel size and capacity as today
- Port of Nakskov not flooded during storm surges with water levels up to +2.5 m DVR90
- Large harbour reservoir for accommodating surface runoff and potential wave overtopping allow for more flexible gate closing protocols as well as no immediate installation of pumping capacity.
- Design can to some extent be adapted over time to increasing threats from sea level rise and surges.
- Design can be combined into a ship lock.

Disadvantages:

- Significant interference with Nakskov Port operation during construction phase
- Partly blockage of navigational channel during construction phases of marine works, potentially impacting leisure boating
- Little influence on known ship and boating traffic during operation phase.
- Little influence on known bathing and boating pier.
- Relative high construction and operation cost of the proposed solutions
- Anticipated construction period of approx. 2 years.

2.4.3 Solution 3: Storm surge barrier incl. 10 m passage with two gates

The second technical alternative is referred to as the "Minimum Solution" (solution 3). The proposed storm surge protection includes establishing stretches with sea walls and dikes on land, as well as a dam with gates across the harbour basin at the middle of Vestre Kaj (Quay 12) towards Quay 6 [21]. The location will require demolition of the old ferry terminal Spodsbjerg – Nakskov [21].

The proposed location is at the narrowest part of the inner harbour, making it possible to simultaneously carry out two relatively simple connections to existing structures on both sides of the harbour basin. Solution 3 is expected to be the cheapest option in relation to construction costs, meeting also the wish not to raise the security bulkhead along Toldbodkaj and Havnegade. Solution 3 will protect the town without significantly changing the port's navigation conditions. It should be noted that this "minimum solution" will leave most of the commercial activities of Nakskov Port areas unprotected [21].

The flood protective structures on land to the north, runs along Strandpromenaden as well as Stormgade and Vestre Kaj. In addition, on the south side, there are flood protection structures from the barrier in the harbour basin to Skibsværftsvej and at the intersection of Stensøvej. On the most north-wester part of the section, the coastal protection consists of a grass covered dike, while on the remaining sections primarily consists of sea wall supplemented by a warning activated temporary mobile barriers at road crossings. The longitudinal extension of the protection structure stops where the existing terrain level reaches the levels of +2.50 m DVR90, see Figure 11.

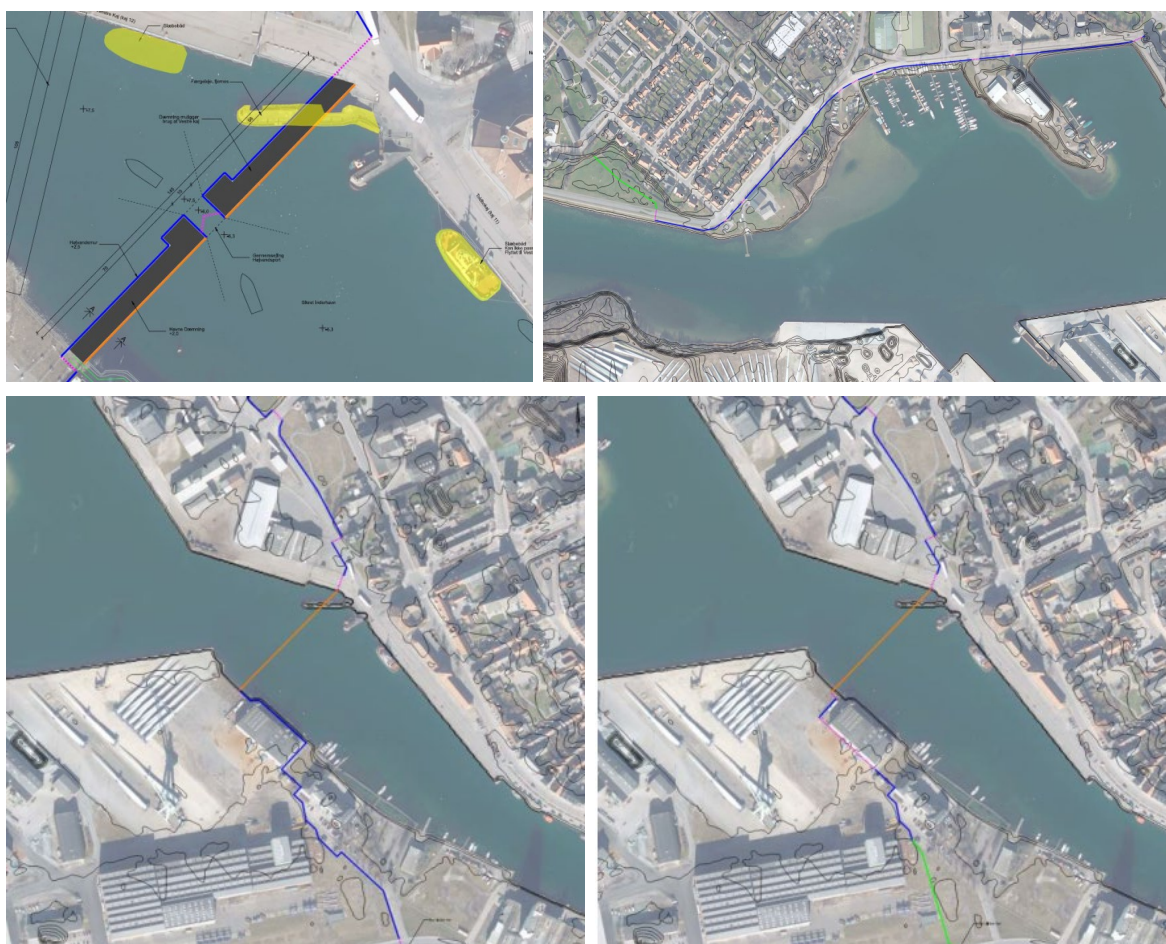


Figure 11: Conceptual Design Proposal of Solution 3. Source: Ramboll [18]

There is a total of 15 locations where the protection consists of a mobile barrier to ensure passage at road crossings. The openings with the mobile barriers vary from approx. 10-15 m. The high-water wall will be built as far as possible so that it follows the cadastral boundaries. The height of the structures is between 0.2-1.1 m [19]. It is accepted that parts of the road infrastructure, as well as the port of

Nakskov is flooded, because of the protection being implemented behind several port buildings and quay areas.

Construction top level is currently estimated up to +2.60 m DVR90, hence no detailed studies of wave action and potential wave activity, which may result in design alterations. The construction height may therefore change if the proposal is further advanced. The technical solution can over time be adapted and retrofitted to accommodate the potential impacts of climate change.

For structures on land, a drain is installed on the back of the flood protection so that surface runoff from the hinterland can exit and any overtopping or overflow from wave impact can be diverted and discharged. It should be noted that the current design proposal does not include any sketched drainage solution, as it was not included in the project work scope [21]. It is therefore assumed that any surface water can be drained by gravity back to the sea recipient, when capacity becomes available in the urban drainage system.

Immediate advantages and disadvantages of the proposal are:

Advantages:

- Little interference with Nakskov Port operation during construction phase
- Port of Nakskov flooded during storm surges exceeding water levels up approx. +2.0 m DVR90
- Possible to install a walking bridge across gate opening passage
- The cheapest construction cost of the proposed solutions

Disadvantages:

- The Vestre Kaj (Quay 12) will be halved from 120 m to 60 m, and a flood protection system will be installed in front of the gates of the quay's two large warehouses.
- The alignment of the sea wall cross infrastructures leading to multiple installation of warning activated measures, increasing overall vulnerability of the flood protection scheme.
- Limited to no protection of Nakskov Port area

3. Review of existing conditions

In this chapter relevant laws and regulations are briefly presented and a review of local spatial and economic development policies and plans pertaining to Nakskov are outlined. Perspectives with perceived relevance for the following project tasks and phases are likewise highlighted.

3.1 Plans and Policies

As part of the first nationally designated municipalities, Lolland Municipality has worked on risk management of flood risk on several occasions. This also applies to the national climate adaptation plans from 2013 and most recently in the DK2020 climate action plans. In addition, in 2018, the Planning Act was amended so that the Municipal Plan must designate the areas in the municipality that may be exposed to flooding, for example, and a decision must be made on remedial measures to protect against flooding.

3.1.1 EU Floods Directive cf. *Oversvømmelsesloven*

The Danish Coastal Authority (DCA) has appointed Nakskov town and port area as an area of Potential Significant Flood Risk. The DCA is on a regular basis reviewing this designation under the EU Floods Directive. The first appointment occurred in 2011, which was later (in 2018) extended and expanded to include the large areas of Rødbyhavn and southern Lolland [23], [10]. The current revision (2024) has included changes in the risk area delineation, limiting the Potential Significant Flood Area to Nakskov and Rødbyhavn [24]. Appointment criteria and Risk Area delineation may be viewed in Table 3 and Figure 12.

Table 3: Appointment of area with Potential Significant Flood Risk cf. EU Floods Directive [25]

	EU's Floods Directive			
	FWC 1 2010 - 2015 [9]	FWC 2 2016 – 2021 [26]	FWC 3 2022 – 2027 [24]	
Risk Area, Name reference	"Nakskov"	"Sydlolland"	"Sydlolland"	
Town(s) at Risk	Nakskov	Nakskov og Rødbyhavn	Nakskov og Rødbyhavn	
Sea Water Level Gauge station	Bagenkop	Rødbyhavn Havn	Karrebæksminde	Rødbyhavn Havn
Flood Exposure Extreme event "Present" "Future"	286 cm, 2012 311 cm, 2060	317 cm, 2015 407 cm, 2115	220 cm, 2024	270 cm, 2024
Affected households/ inhabitants	2,485	20,678	4,025	
Economic value	DKK 3.9 billion			

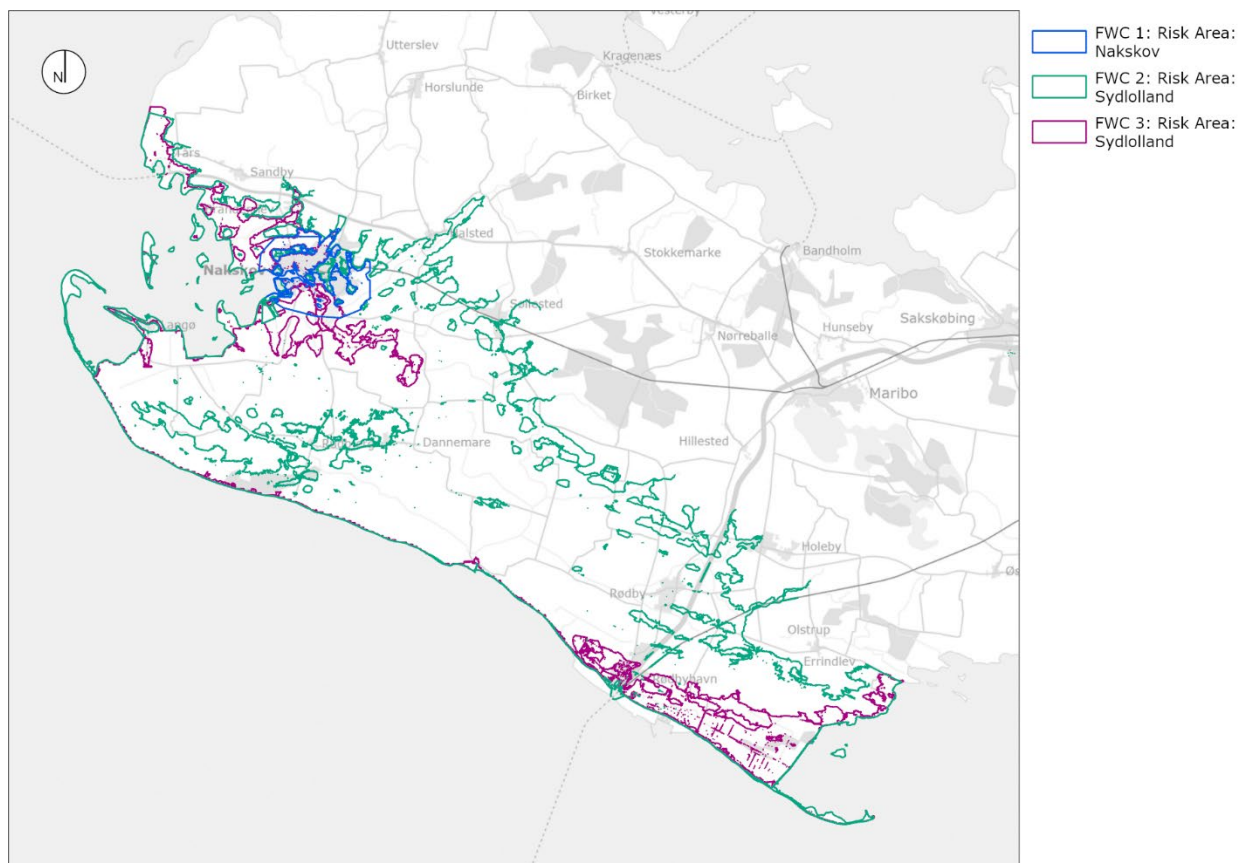


Figure 12: Delineation of the appointed Area of Potential Significant Risk. Source: Danish Coastal Authority

Due to the change in national methodology of appointment criteria, the risk area Sydlolland does no longer fulfil the national criteria for appointment [24]. However, previously appointed areas are kept, and Lolland Municipality must therefore continue to be compliant to rules and regulations related to the EU Floods Directive. Lolland Municipality is therefore responsible for preparing Flood Risk Management Plans under the EU Floods Directive, based on flood hazard maps and risk maps prepared by the Danish Coastal Authority.

3.1.2 Planning Act cf. *Planloven*

The Planning Act defines the framework for land use by creating a hierarchy of plans, and by establishing general principles for sustainable development, including prioritising urban development within existing areas and protecting nature and the environment [27]. It's to ensure a balance between growth and protection by setting a framework for how both local and state authorities plan physical development.

Kommuneplan is the overall municipality's plan for how the municipality is to develop and use its areas, it is important that the data included in the basis for the town plans are suitable to support the long-term planning. This entails a requirement for a high degree of predictability, so that land use, development plans, investments from public and private actors, etc., can be united and constitute a foundation that all citizens, companies, organisations and authorities can act on and count on in the long-term. A number of local plans e.g. *Lokalplaner* set out obligations and guidelines on the basis set by the municipal plan to ensure that its overall goals can be realised in the detailed local planning. The framework specifies general guidelines for the area's use and buildings (e.g. construction height and modification of elevations). Planning schemes are outlined accordingly to their individual use, see Figure 13.

The area of interest is primarily classified 'city zone' e.g. *byzone* within the 'near coastal zone' e.g. *kystnærhedszonen* [28]. In case of extreme storm surge events, flooding may also extent into rural

areas and interlink with exposed flood zones within Nakskov town and port area. Proposed technical solutions are primarily based in areas designated for technical installations, commercial business activity and industries. Permitting may require multiple considerations across sectors according to law to obtain approval.

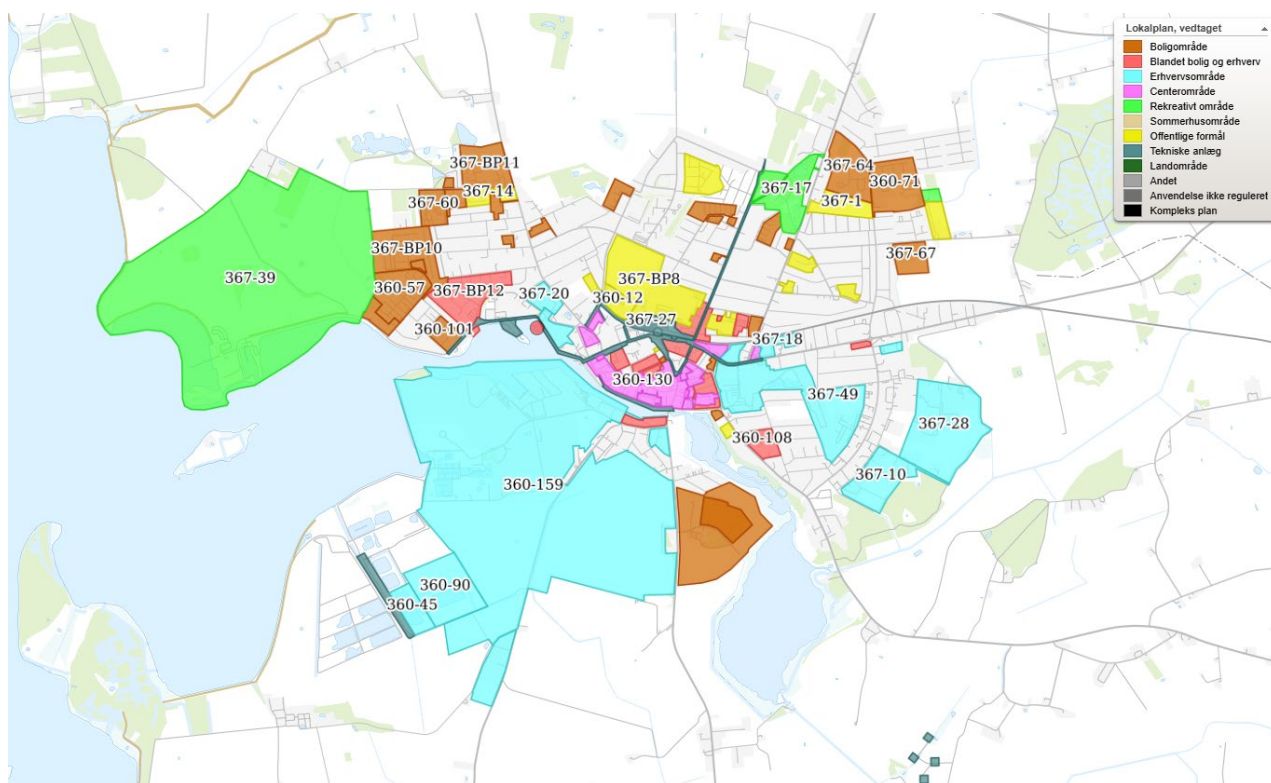


Figure 13: Local planning scheme in relation to Municipal Plan cf. Danish Planning Act [28]

To highlight a few development strategies and initiatives, the following can be mentioned:

Plan- og Udviklingsstrategi 2019-30 - Lolland Lever Livet

The planning and development strategy '*Plan- og Udviklingsstrategi 2019-30 - Lolland Lever Livet*' sets the overall framework for Lolland Municipality's development up to 2030. It is the central strategic and political governing document in the municipality [29].

The vision for the strategy is a strong Lolland, which in 2030 will be mentally and geographically midpoint between Denmark and Germany [29]. A Lolland that has seized the opportunities, created growth and welfare, and that has got everyone on board. How this ambition can be made a reality is addressed in the planning and development strategy in four themes:

- The Fehmarn Belt link and new opportunities for Lolland
- The good life on Lolland
- Growth and development
- Social Transformation

Boligpolitisk Handleplan 2025-26

The strategic action plan for residential housing development and typology composition '*Boligpolitisk Handleplan 2025-26*' sets a direction and guiding principles in relation to prognoses for population composition and potential future development [30]. The residential housing action plan must ensure the necessary attractive housing; ensure relevant housing offers for the municipality's current citizens and retract/demolish outdated surplus housing. The possibility of realising residential housing projects depends on economic activity and development opportunities in the municipality. Maps and project overview of ongoing projects as well as projections of known projects is presented in Figure 5.

Potential development areas at risk is:

- **Sydkajen**, approx. 40 new residential units, by 2025. Private Developer;
- **Tårsvej**, approx. 40 new residential units, by 2025-2026. Private Developer;
- **Engvej**, approx. 73 new residential units, by 2028. Social Housing Development Corporation;
- **Birkevænget**, approx. 33 renovated residential units, by 2027. No square meter reduction, only reduction of 21 units. Social Housing Development Corporation;
- **Klørvænget**, approx. 136 renovated residential units, by 2029. No square meter reduction, only reduction of 96 units. Social Housing Development Corporation;

Over time the remaining developments may become at risk as a result of climate change or mitigation inaction.

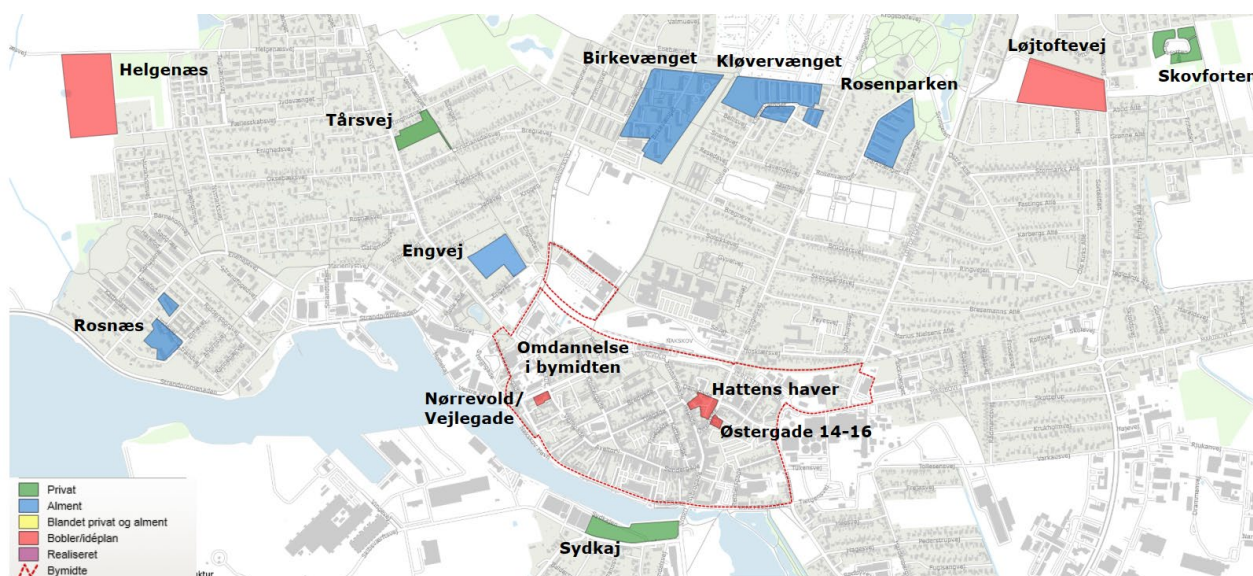


Figure 14: Planned urban development. Source: Lolland Municipality [30]

3.1.3 Climate Adaptation Resiliency Planning and Response

Danish municipalities, including Lolland Municipality, have prepared climate adaptation plans, as well as strategic action plans [31]. In addition, Lolland Municipality has joined DK2020 partnership, where there have been additional efforts focusing on greenhouse gas reduction. Initiatives are summed up and further elaborated in the strategy '*Klima- og Energiplan 2020-2050*' [32].

The climate adaptation plans, including the basis for – and prioritisation of – adaptation efforts, approaches to the overall hydrological cycle, effective multifunctional solutions, and the relationship between rural/urban contexts are crucial for effective resiliency planning [33]. It is therefore of importance to focus on:

- The integration of climate adaptation efforts with urban development and general physical planning, including the relation to development practices and permitting.
- The integration of climate adaptation efforts with the consideration of added value creation to promote sustainable and vibrant urban development and thus better urban life.
- The integration of climate adaptation efforts with preparedness at municipal and possibly regional and state level.
- Implementation of projects synergies

Since 2015, checks with respect to climate risks have systematically been incorporated into the preparation of all municipal plans (e.g. local plans, town plans), strategies (e.g. housing policy, tourism strategy) and projects (e.g. development project "*Lolland's Sydkyst*"). Execution of 'climate check' is

performed to assess the flood risk of an area of interest. The outcome of the assessment is considered in the further process for planning and decision-making [10].

Local emergency response cf. *Beredskabsloven*

Local emergency services and civil protection agencies cooperate to ensure that protection and response are linked in strategic planning. The fundamental principle for contingency planning is sector responsibility. This means that it is the individual municipal sector, utility company and/or other authority that must prepare their own sector contingency plan. And the same applies to companies and institutions.

The duration of a flood can have a major impact on the extent of the damage caused by the flood. The process itself - from the time the water level rises, reaches its peak and has fallen again to around daily water level - is expected to last up to several days. But the duration of the flooding on land will vary greatly locally - from place to place. It can take some time for the water to arrive, but the backflow can also be delayed. In low-lying areas, where it cannot flow away again on the surface, but has to escape through the rainwater pipe system, it can go very slowly, or it can come to a complete standstill if there are pumps that are out of order [9].

In Lolland Municipality, contingency plans have been prepared by the Dike Association of Lolland, by the Lolland-Falster Fire Brigade and by Lolland Municipality, where the Department of Parks & Roads is the key player along with the port master of Nakskov Port. Contingency plans play a role together with the help of a crisis team that is set up urgently with the municipality's political and administrative leaders. Action cards have been prepared that are followed depending on incident developments [10]. Along the harbour area, critical sea water levels are defined as [12]:

- Water levels reaching +1.6 m DVR90 expose black houses at quay 10 along Havnegade 20-22
- Water levels reaching +1.7 m DVR90 expose power outlet in Havnegade
- Water levels exceeding +1.7 m DVR90 will overflow the first quay sites

Flood warning is very important for flood prevention and damage prevention. It is the Danish Meteorological Institute (DMI) that is responsible for high water level warnings and notification of warnings. In 2019, Lolland Municipality purchased a water level gauge approved by DMI for the Port of Nakskov, a model type that contained two measuring devices, both a float and a pressure probe, so that in the future, high water levels statistics and forecasts for Nakskov can be based on real time measurements, much more accurate than recent practice only utilising modelling. Direct alerts can be obtained through various services. An early warning agreement has been made with DMI, so that the emergency services can be notified in the event of an expected storm surge [10].

3.1.4 Ports Act cf. *Havneloven*

The Ports Act defines commercial ports as ports used for commercial expedition of cargo, vehicles, persons and landings of fish [34]. In addition to the Ports Act, the EU Ports Regulation sets out the framework for the ports designated by the Commission as TEN-T ports. The Ports Act generally distinguishes between frameworks for privately organised ports, public owned ports, organised as state ports, municipal ports, municipal self-government ports or municipally owned limited company ports.

Publicly owned ports, such as Nakskov Port, must be responsible for the construction and operation of port infrastructure and lease areas and buildings at the port. They may only carry out other activities to the extent that there are no private actors wishing to carry out the activity and if the activity is also necessary for the operation of the port. This reflects the principle that publicly owned companies should not compete with private actors, which is one of the key principles of the Ports Act. Common to both privately organised ports and publicly owned ports is that the ports' areas must be prioritised for use for port-related activities, i.e., for commercial activities that support maritime transport (cargo handling, storage facilities or bunkering) and for activities that require a location close to the port. In this way, the ports' function as infrastructure is ensured [7].

3.2 Financing coastal protection interventions

Across Europe, municipalities face growing challenges in financing large-scale adaptation infrastructure. Although technical solutions often exist, funding gaps persist due to institutional fragmentation, lack of cost-sharing tools, and public resistance to new changes.

Assessment of risks, costs and benefits are key tools to mobilise sources of funding, which in the Danish regulatory context are the population and businesses at risk as well as other stakeholders who stand to benefit from a common solution to the risk of storm surges.

3.2.1 Danish Coastal Protection Act e.g. *Kystbeskyttelsesloven*

Planning and execution of coastal protection project interventions may follow one of these three forms depending on organisation and level of agreement:

- **Chapter 1c:** Project interventions, both technical and financial in agreeance by all property owners benefitting and landowners subjected to structures and related activities within property.
- **Chapter 1b:** Project interventions, both technical and financial in agreeance by state owners
- **Chapter 1a:** Project interventions, both technical and financial not in agreeance by all property owners benefitting and landowners subjected to structures and related activities within property.

Lolland Municipality is currently in the planning state of a storm surge risk reduction intervention, subjected to chapter 1a as per the definitions outlined above. When planning and executing a project as a "Chapter 1a project", sections 9/9a of the Danish Coastal Protection Act apply to the financial distribution of costs [35].

Joint coastal protection project e.g. Chapter 1a, Danish Coastal Protection Act

The municipality has the authority to impose a distribution of funding contributions among direct beneficiaries, such as property owners and business, required for construction, operation and maintenance and service of financing of a coastal protection project, in conformity with the principles laid down in the law [35].

The cost distribution principles apply to the funding requirement after deduction of possible state or third-party grants from the cost of the risk reduction intervention, as well as any direct contribution from the municipality itself, e.g., funded through general taxation.

The distribution shall follow a principle that property owners benefiting from protection shall contribute to funding the risk reduction project intervention, based on the principle of utility value - principally the primary benefit gained from protection. Property owners otherwise benefiting from the project may also be requested to contribute, based on tangible and intangible secondary benefits – principally area image, reduction of risks to lower probability events, etc.

Normal practice is to keep the distribution as simple and practical as reasonable. Differentiation may take place based on objective criteria such as risk exposure based on location, property value and size, recreational value, etc. Affected parties have the right to challenge.

Good governance

In municipal joint projects, a specific assessment must be made in each individual case to ensure that local and individual circumstances are considered in connection with the decision on the distribution of contributions. The principle of utility is the clear starting point, and based on administrative law, it must be ensured that the requirement to safeguard objective considerations supports the decisions and the reasons for them. If, over time, there are changes in the utility that result in the distribution of contributions not reflecting a reasonable distribution of the utility value for the owners of real property who obtain protection or other benefits, the municipality has the option of subsequently deciding to change the distribution of costs in accordance with the rules, e.g. Danish Coastal Protection Act § 11, stk. 2.

3.2.2 Potential Sources of Funding

Funding can originate from a variety of sources:

- **Flood Risk Reduction Beneficiaries:** Retained “earnings” from prevention of damages and loss serve as a source of funding for investments and ongoing operations.
- **Loans:** Borrowed funds from banks or other financial institutions that must be repaid with interest.
- **Other benefiting parties, because of risk reduction or added value:** Funding of investments from other parties, as a result of obtaining tangible and intangible benefits such as Land Value Capture, increased Sense of Safety and Security, Upholding of Area Image etc.
- **Grants:** Funds provided for a specific purpose that typically does not need to be repaid.
- **Donations:** Gifts of monetary value of resources from individuals or organisations.
- **Investments:** Private funds from sources like venture capital or investors.

Eligible Cost-Contributing Parties

To create a cost distribution model, contributors must be identified in accordance with the Danish Coastal Protection Act. A good starting point for the identification is a mapping of the values that exist in the flood-prone areas in the form of e.g. housing, institutions, workplaces, cultural heritage, etc. This may include any potential negative consequences and/or benefits that can be gained elsewhere as a result of immediate connection and relation to the flood risk area. In this way, decisions about the realisation of a coastal protection interventions are based on the expected benefits of coastal protection and the costs of carrying it out.

The property owners of the buildings, including the plots, are defined as *direct beneficiaries*, due to the potential damage to property and loss of inventory. Other real estate with direct use will be the technical facilities and service providers related to critical infrastructures, such as the utility sector and transport infrastructure. This is a utility that consists of protection against damage, e.g. seepage of water into electrical installations or undermining of roads.

In the case of municipal led projects, there may also be intangible gains or benefits, depending on which coastal protection measures are chosen. For example, greater increased recreational value, increased tourism [36]. This indirect benefit accrues to the municipality, but also to the towns's citizens more broadly.

4. Preliminary Stakeholder Mapping

A preliminary stakeholder mapping is presented in this chapter. The means and dynamics in the engagement of stakeholders will be updated as the project moves forward. The interests of key stakeholders will also be explored further to develop a strategy for their involvement during the project. A complementary Excel file, "Stakeholder Analysis – Engagement and Communication Strategy," is provided alongside the Baseline report. It contains the corresponding stakeholder engagement mapping and should be consulted together with this section for a full understanding of the preliminary assessment.

4.1 Overview of identified stakeholders

There is a wide range of stakeholders involved, each with different roles, responsibilities, and degrees of relevance to the project. Below is a preliminary list of potential stakeholders in Nakskov for each type of stakeholder group.

Table 4: Preliminary Stakeholder List

Public Authority (see section 4.2.1)
Lolland municipality, Admin level
Lolland municipality, Politicians
Danish Coastal Authority (DCA)
Citizens (see section 4.2.2)
Property owners - land and real estate
Citizens of Nakskov
Recreational users, locals and tourists
Local Businesses and Industry (see section 4.2.3)
Port-related industries and companies
Nakskov Port (<i>municipality owned</i>)
Vestas Wind System
Nordic Sugar A/S, Nordzucker
DLG
Other commercial port related businesses: Crispy Food, Krinak A/S
Tourism and service sector
Tourist association e.g. Visit Lolland-Falster
'Skonnerten Johanne'
'Postbåden Vesta'
Nakskov Fjord Camping
Business and trade associations
Nakskov Handel og Erhverv
Business Lolland-Falster
Civil Society and Community Organisations (see section 4.2.4)
Water Management Associations – Land reclamation, Dike Maintenance and Pumping Operations
The Dike Association of Lolland (<i>Det Lollandske Digelag</i>)
The Dike Association of Branderslev/Sandby
Cultural Heritage and Preservation association
Historic and Cultural building preservation association e.g. <i>Bygningsbevaringsforeningen; Slots- og Kulturarvsstyrelsen</i>
Environmental, Recreational and community clubs
Sailing and rowing club(s) e.g. <i>Nakskov Sejlklub, Nakskov Roklub,</i>
Fishing associations e.g. <i>Nakskov Sportfisker Forening</i>

Nature Preservation and Protection e.g. *The Danish society for Nature Conservation (Danmarks Naturfredningsforening, DN)*; *BirdLife (Dansk Ornitologisk Forening, DOF)*

Utility Function and Services (see section 4.2.5)

Utility, 'Lolland Forsyning' e.g. *Lolland Vand A/S, Lolland Spildevand A/S, Lolland Varme A/S, (owned by Lolland Energi Holding A/S)*

Cerius A/S, *Power distributor*

Andel, former SEAS-NVE and Nakskov EI, *Energy supply distributor*

TDC, *Communication utility supplier of fibre cables for Telecom, IT -WIFI*

Energinet, *National Energy supplier and distributor*

4.2 Stakeholder type description

In this section, a brief description of the stakeholder's estimated relation to the project in their respective stakeholder groups will be described.

4.2.1 Public Authority

Lolland Municipality's Department of Planning & Environment is the leader of the project. While the department team for Planning and Mapping has led the development of the technical proposals for storm surge protection, the Technical Secretariat is currently leading this project, with the responsibility of minimising disruptions, ensuring compliance with laws and permits, adhering to the budget, and securing necessary funding. Additionally, they will ensure that public waterfront access is maintained, integrating any chosen storm surge solution with land-use plans and ensuring long-term maintenance.

Lolland Municipality is responsible for facilitating project progress and associated permitting of the project. Project implementation can, depending on organisation and coastal protection structure ownership either be led by the Municipality or a legal entity of an established project association for storm surge protection.

Additionally, politicians and other stakeholder groups within the municipality will be expected to have varying interests in the project, such as ensuring the safety of people and critical sites, protecting habitats and water quality, and ensuring that benefits and burdens are shared equitably, supporting local jobs and business activity, as well as maintaining open communication to build trust with the community.

The Danish Coastal Authority (DCA), under the Ministry of Environment and Gender Balance has several key roles related to coastal zone management, coastal protection and marine spatial planning [35]. DCA has the overall responsibility for implementing the EU Floods Directive in Denmark, including overseeing national flood-risk mapping [9]. Given these responsibilities and its regulatory mandate, the DCA will be a central actor in the assessment and advising the municipal flood risk management plan and the proposed design for storm surge protection.

4.2.2 Citizens

Nakskov town includes 12,600 residents, making Nakskov the largest town on the island of Lolland [37]. Without new protection, large parts of the urban areas of Nakskov are at risk of flooding. A central aspect for citizens in similar cases is fair sharing of costs and benefits across areas. Protecting only some areas can lower values for unprotected properties and raise prices for protected ones; losing scenic views or aesthetic degradation may also alter property values and perceived area attractiveness [38]. Citizens will thus be expected to have an interest in solutions that are beneficial and fair to their own economic interests.

Recreational users of the fjord may be concerned about losing access to the harbour for everyday use and recreation. Recreational users are expected to have concerns on safe entry and exit to the fjord, adequate clearance and depth, as well as wind and stream shelter.

4.2.3 Local Businesses and Industry

Port-related industries and companies

The port area at the inlet of Nakskov provides a major part of Nakskov's job opportunities which the town of Nakskov is highly dependent on [37]. The Nakskov Port is a municipality-led company, and examples of private companies that are in the port area include Vestas, Nordzucker, Crispy Food and DLG Nakskov. Some of these businesses are expected to have an interest in protection from storm surge avoid losses from storms and high water, keep operations and deliveries reliable, hold down insurance costs, keep workers safe, protect local jobs, and provide a predictable setting for future investment at Nakskov Port.

Other commercial businesses and trade associations

Nakskov town houses supermarkets, hotels, real estate etc. Agriculture dominates Lolland, especially on western Lolland, where the landscape is flat and the fields surround the town and the harbour.

Businesses trade organisations such as 'Nakskov Handel og Erhverv' and 'Business Lolland-Falster' represents a major number of smaller businesses with interest in Nakskov and Lolland [39], [40].

Tourism and service sector

Along the coast, the interaction between sea, land, small islands and large reclaimed areas provides many varied views. Many of the businesses which are associated with the water area of Nakskov are linked to tourism. There are some smaller businesses that are directly operating at the Nakskov Fjord, such as historical vessels 'Skonnerten Johanne' [41] and 'Postbåden Vesta' [42]. There has been a discussion about the proposed permanent protections (such as high sea walls along the harbour) potentially hindering the massive loading and unloading that takes place, as well as disrupting industrial workplaces. This highlights the business community's interest in a solution that protects the town without simultaneously complicating the port's commercial activities [9]. Additionally, the organisation Visit Lolland-Falster serves as an important advisor on tourism development, contributing valuable insights on how planned measures align with the needs and attractiveness of the area as a destination.

Additionally, Visit Lolland-Falster serves as an important advisor on tourism development, contributing valuable insights on how planned measures align with the needs and attractiveness of the area as a destination.

4.2.4 Civil Society and Community Organisations

Civil society and community organisations in Lolland play a vital role in representing local interests, preserving cultural and natural heritage, and maintaining a strong sense of community identity. Engagement with these groups will also help build local legitimacy and trust, as they often act as intermediaries between residents, authorities, and other stakeholders.

Cultural Heritage and Preservation Associations

Building preservation associations, such as 'Bygningsbevaringsforeningen' and 'Slots- og Kulturarvsstyrelsen', aim to protect heritage buildings and cultural monuments [2]. They will likely want assurance that vibrations, construction traffic, and other logistics do not harm assets with high conservation value. In addition, they could be expected to have an interest in the project's visual design, including sightlines, materials, and the design of sea walls and embankments.

Water Management Associations - Land reclamation, Dike Maintenance and Pumping Operations

Lolland has historically been hit by several severe floods, especially the storm surge of 1872, which is the worst disaster in Denmark's modern history [43]. Due to this, Lolland has a long history of flood protection work led by dike and land-reclamation associations such as 'Det Lollandske Digelag' and various draining and pumping associations in the hinterland [14]. These entities hold historical knowledge in flooding protection and will potentially have an interest in ensuring that the chosen solution in Nakskov Harbour does not negatively affect their work and align expertise and potential future adaption of practices accordingly.

Environmental and Recreational Organisations

Nakskov Fjord is a beautiful nature area and the inner part of Nakskov Fjord is designated a Natura 2000 habitat:” no. 179 - Nakskov Fjord og Indrefjord”, including H158 cf. Habitat Directive and F88 cf. Birds Directive [44]. Storm surge protection measures could potentially affect and disturb habitat and wildlife dependent on the fjord’s connection to the sea, as well as local opportunities for recreation and tourism. Organisations such as angling fishing association e.g. ‘Nakskov Sportfisker Forening’ [45], and local sailing and rowing clubs e.g. ‘Nakskov Sejlklub’ and ‘Nakskov Roklub’ may therefore have a potential interest in how the project balances ecological integrity with continued public access and recreational use.

Other local nature or outdoor associations, including ‘Naturfredningsforening Lolland’, a part of ‘Danmarks Naturfredningsforening’ (DN) or similar community-based groups, could also be relevant in discussions about biodiversity, nature protection, and recreational access. Engagement with these organisations may help ensure that environmental and community considerations are acknowledged during the design and implementation of the project. Moreover, they could serve as potential communication channels for informing and involving the broader public in later project phases.

4.2.5 Utility Function and Services

It is essential to ensure continuous operation and supply of drinking water, wastewater distribution and treatment, road infrastructure, power, and emergency response access during the construction phase as well as operation phase during future storm surge events. Lolland Forsyning forms part of Lolland Energy Holding, a municipally owned multi-utility company responsible for key infrastructure services on Lolland. Through its subsidiaries, the holding manages: (1) drinking water supply via Lolland Vand A/S, (2) wastewater and rainwater collection, distribution, and treatment via Lolland Spildevand A/S, and (3) district heating via Lolland Varme A/S. These entities together ensure the operation and maintenance of essential water and energy systems across the municipality [46], [47].

Closing of the fjord could potentially have an impact on the water quality, due to insufficient water exchange. The water and sewage system (including the diversion and treatment of wastewater) is a municipal utility service that must be maintained even during a flood. Utility Lolland’s primary interest is to ensure the operation of this critical infrastructure and that the storm protection measures do not negatively affect the water quality and environmental quality standards.

Without protection, the risk of flooding is high. In the event of a storm surge, the electricity supply would be interrupted in large parts of Nakskov due to short circuits, posing a serious threat to businesses and critical infrastructure [19], [9]. Not only may local production and distribution assets be affected, the state-owned company ‘Energinet’ is also at risk. Critical assets and distribution networks can either be directly damaged by floods and/or that their functionality is jeopardised during a storm surge event, which could lead to significant societal consequences [9]. Coordination with the utility owners is necessary to handle the connection of electricity for any potential rerouting of existing systems and to secure energy supply for the intended storm protection surge solution.

4.3 Stakeholder engagement framework and plan

Stakeholder engagement constitutes a core component of the project and will be implemented in a structured yet adaptive manner. To support this process, a stakeholder assessment framework has been established to guide the systematic identification, prioritisation, and engagement of relevant actors throughout all project phases. The framework is designed to ensure that engagement activities are transparent, coherent, and responsive to the project’s evolving context as the funding strategy for storm surge protection is developed.

An integral element of this framework is an Excel-based stakeholder overview, which functions as a practical tool for mapping, documenting, and planning engagement activities. At the current stage, the file should be regarded as a structural template rather than a completed analysis. It provides the basis

for structured stakeholder management and will be progressively refined and expanded as new information and insights emerge over the course of the project.

Section 5.5 describes the full scope of Task 5 (stakeholder engagement, communication, and dissemination), including the methodological and theoretical basis for stakeholder engagement in the project, drawing on established frameworks for effective stakeholder participation and key insights from behavioural science.

4.3.1 Framework Structure and Assessment Dimensions

The Excel-based stakeholder overview serves as a practical tool for organising, analysing, and monitoring stakeholder engagement throughout the project. It consolidates all relevant stakeholders and summarises the factors that guide how engagement is prioritised and tailored over time.

The list below presents the most central analytical dimensions used to assess stakeholder relevance, influence, and the appropriate level of engagement. These dimensions form the analytical core of the stakeholder framework and provide a structured foundation for engagement planning.

Each stakeholder will be assessed across the following dimensions:

- **Assumed/Perceived Interest in Project:** Indicates how affected or invested the stakeholder is in the project outcome (very high to low).
- **Influence (1–5):** The stakeholder's ability to affect decisions, resources, or outcomes.
- **Involvement Necessary (1–5):** The level of engagement required to ensure effective input, support, or acceptance.
- **Influence × Involvement:** A combined indicator used to prioritise which stakeholders require more active engagement.
- **Drivers:** The main motivations or incentives that may encourage active participation.
- **Potential Barriers and/or Risks:** Possible challenges that could hinder collaboration or acceptance.
- **Involvement Level:** The appropriate type of engagement based on the stakeholder's profile and role (inform, consult, involve, collaborate, or empower).
- **Communication and Engagement Methods:** Recommended approaches for interaction, adapted to each stakeholder group.

The analytical dimensions described above are intended as guidelines rather than rigid categories. They serve as a practical tool for structuring engagement efforts and prioritising resources, while allowing flexibility as the project evolves. In addition to these analytical dimensions, the Excel-based stakeholder overview may also include complementary practical information, such as contact details and notes from interactions.

4.3.2 Linking Stakeholder Assessment and Engagement Strategy

Each stakeholder will be assigned a level of engagement corresponding to the intensity and type of interaction most appropriate to their position in the project. This classification provides a practical tool for prioritising engagement resources and designing tailored communication approaches. As a general orientation, the relationship between influence, interest, and engagement can be summarised as follows:

- Stakeholders with **high influence and high interest** should typically be prioritised for **collaboration** or **empowerment** to strengthen ownership and legitimacy.
- Stakeholders with **high influence but lower interest** may best be **consulted** to maintain alignment and prevent opposition.
- Stakeholders with **low influence but high interest** should often be **involved** to ensure inclusion and shared understanding.
- Stakeholders with **low influence and low interest** can be **informed** to maintain transparency.

These classifications should be seen as indicative rather than prescriptive. In practice, engagement needs may shift as the project progresses, and exceptions may be warranted depending on emerging priorities, political considerations, or unforeseen developments.

5. Methodology - Data Availability and Analysis Assumptions

This chapter include outlining the methodology for project execution, including highlighting available data and analysis assumptions.

5.1 Planning scenarios as reference for analysis

In agreement with EIB and Lolland Municipality the reference development scenarios for Nakskov take departure with an emphasis on, not only the development of Nakskov port and of the inner harbour with its commercial areas and the Port, but also the town function and services.

The reference scenarios are to be used as the basis for assessing risks, impacts and opportunities in relation to quantifying direct and indirect climate risks and their mitigation, and hence are very important for the further development in the upcoming project tasks. Three development scenarios are currently proposed, and will be further outlined and detailed in parallel with execution of Task 2:

0. **"Status Quo - Existing conditions prevail"**. No development changes of either positive or negative character. Urban fabric including current spatial extent and ratio between to residential and commercial operations will be kept constant over time.
1. **"Planned Urban Development, Short term"**. Realisation of approved and planned development within the flood exposed area, e.g., the inner harbour with its commercial and residential areas, cf. section 3.1.2.
2. **"Potential Business Developments and Economic Growth, Short-Medium term"**. Port development, e.g., possible business expansion. Including scenario 1 planned and/or approved commercial and residential development. This proposal relies on stakeholder engagement and commitment from key stakeholders related to the ongoing port development strategy c.f. section 2.1.2

5.2 Task 2: Storm Surge and Sea Level Rise Risk Assessment

Building on the existing body of risk modelling, an assessment and quantification of storm surge and sea level risks to Nakskov will be undertaken, including direct, indirect and intangible financial, economic and social effects, extending to the economic and financial impact on Lolland Municipality, considering likely correlated risks to the Municipality arising during storm surge events.

The socio-economic composition is initially mapped as part of implementing the EU Floods Directive, hence will be further outlined as part of the upcoming Tasks 2 and 4, according to available data provided by Lolland Municipality.

5.2.1 Available hazard mapping

The DCA is currently reviewing the designation of Areas of Potential Significant Flood Risk under the EU Floods Directive. This is the third iteration of screening and mapping flood risks, and throughout the iterations, varying methods and data sources, have led to different results of flood risk, see Table 5. Extreme sea level statistics are derived by Danish Coastal Authority [48], [24] and the estimated sea level rise by DMI [49].

Table 5: Key assumptions and results related to assessing the probability of flooding for risk area Nakskov e.g. EU Floods Directive [25].

	EU's Floods Directive: 'Step 2: Flood Risk Mapping'		
	Framework Cycle 1 2010 - 2015 [9] and [50]	Framework Cycle 2 2016 - 2021 [23]	Framework Cycle 3 2022 - 2027
Risk Area, Name reference	"Nakskov"	"Sydlolland"	"Sydlolland"
Sea level statistics Water level gauge Station name	Bagenkop	Rødbyhavns Havn	Rødbyhavns Havn
20-years event return period, 2024 [48]	170 cm (155 cm, 2012)	162 cm (156 cm, 2019)	162 cm (167 cm, 2025)
100-years event return period, 2024 [48]	186 cm (180 cm, 2012)	176 cm (172 cm, 2019)	176 cm (181 cm, 2025)
Extreme event 1872, historical event (approx.1.000-years return period)	250 cm	250 cm	220 - 270 cm
Mean Sea Level Rise Climate change scenario	(RCP 8.5)	RCP 8.5	SSP3-7.0
Mid-range time horizon	26 cm, 2050	33 cm, 2065	-
Long time horizon	70 cm, 2100	83 cm, 2115	53 cm, 2100
Hydrodynamic Flood modelling	DHI MIKE 21 FM	DHI MIKE 21 FM	SFINCS
Total flood maps	6 155 cm 180 cm 181 cm 206 cm 250 cm 251 cm	6 (8) 156 cm 172 cm 201 cm 248 cm 250 cm from west 317 cm from south 327 cm from west 394 cm from south	6 167 cm 181 cm 193 cm 220 cm 235 cm 247 cm

5.2.2 Available impact mapping

As part of the EU Floods Directive, the DCA has also analysed potential storm surge impacts to Nakskov and the greater area. In an impact assessment, potential damages and losses from a specific storm surge event are calculated and evaluated; preferably quantitatively to support effective decision-making, or qualitatively when data is lacking or damages are intangible. To properly assess the risks, it is necessary to integrate these quantified damages and losses over multiple probabilities. In doing so, one must consider that in any given year, storm surges of varying magnitudes may occur. As the impacts by the DCA are expressed in monetary terms (DKK), the risk is expressed as the expected, annual damages and losses in monetary terms (DKK/yr).

The impact analysis for Nakskov in Framework cycle step 2 followed the existing standard approach by the DCA and covered quantified damages and losses to:

- damages to buildings (structural),
- building contents,
- businesses incl. structural damages, contents, and inventory,
- clean up of infrastructure,
- crops, and
- livestock.

Qualitatively the impact assessment included and discussed the impacts of flooding to:

- inhabitants,
- utility supply,
- emergency response locations,
- vulnerable hotspots (e.g., schools and nurseries),
- “high risk” production industries, i.e., facilities where hazardous chemicals and/or waste is stored or used,
- nature, and
- cultural heritage.

There are some concerns regarding the use of the standard approach from the DCA as described by Arnbjerg-Nielsen et al. [51]. First, damages to buildings occupied by businesses are double counted, as they are considered both in “damages to buildings” and “businesses”. Second, the structural and contents damages are calculated as a function of the building value (i.e., the property value minus the land value). This leads to regional disparities and potential inequities across Denmark, where Nakskov may be disproportionately affected. Third, it may be prudent to consider additional damages and losses, e.g., the only damage or loss to infrastructure is the clean-up cost. As storm surges may impact an area for many days with direct water contact, it may be prudent to also consider disruption and delays in the road network and/or rail network. This parameter is typically included in Danish *stormwater* risk assessments. Naturally, it’s impossible to foresee all damages and losses in an event, but inspiration may be drawn from similar, relevant hazard analyses.

5.2.3 ‘Best practices’ and potential ‘Next Practices’

Naturally, effective flood and impact modelling hinges on high resolution and context-specific input data, particularly for land-use, elevation, and damage functions, i.e., the percentage or cost of damage as a function of most often inundation depth, but potentially also flow velocity.

Halsnæs et al. [52] demonstrate that switching from coarse to detailed land-use data or from generic damage-cost functions to locally calibrated ones can alter damage estimates by approximately a factor 4. Even more drastically, the same study showed that moving from a static flood model with a low-resolution digital elevation model (30 m) to a dynamic flood model with more refined elevation data in two Danish case areas produced a difference in flood-area extent by approximately a factor 17. Thus, local context-specific data is important when available and certainly, a dynamic modelling approach that reflects local hydraulic behaviour rather than an overly simplified bathtub model is important.

Obtaining context-specific input data for damages and losses can be a challenge, because a local geography may not have sufficient data for robust and reliable assessments. Furthermore, historic damages and losses may be impossible to extract due to privacy laws such as the General Data Protection Regulation (GDPR). Whilst the Danish Parliament and municipalities are collaborating with insurance companies to make historic data available for researchers [53], more standardised damage functions (from other countries and/or before GDPR) are most often used in Danish flood damage and risk assessments. Standardised damage functions offer the possibility for comparisons across Denmark, but it's important to keep in mind the impacts that may be unique for one’s study area – if not quantitatively, then qualitatively.

To test the robustness of flood damage and risk assessment, a sensitivity analysis is a useful tool. A sensitivity analysis involves systematically varying the input data, parameters or modelling assumptions to see how much outputs such as flood inundation, extent, and damage costs change in response. In this manner, a sensitivity analysis helps to identify which inputs or modelling choices are most influential; if a small change in a damage function yields a large change in overall damage costs, it highlights the need for that particular damage function to be accurate, and hence, investing resources in obtaining that accuracy is well spent. On the other hand, if a significant change in a parameter yields little change in the final results, then resources spent on ensuring the accuracy of that parameter are best spent elsewhere. In addition, sensitivity analyses give transparency and better understanding of the uncertainty in impact assessments. They show decision-makers not just a single value but a range

of possible outcomes depending on data/assumption quality. This supports more robust decision-making for prioritisation, adaptation investments, and dynamic planning.

In the following section an updated approach to a flood risk assessment for Nakskov is proposed.

5.2.4 Methodology proposal and key assumptions

We propose drawing on the existing flood impact assessment and augment and strengthen the analysis for Nakskov Town. As a basis the following applies:

- The existing dynamic flood modelling by DCA is fit for purpose.
- Data used to quantify vulnerability (asset location and damage unit costs) are primarily delivered by Lolland Municipality and publicly available sources.
- Risk defined as the expected annual damages and losses will be calculated for defined development scenarios.
- Risk quantification area for result presentation will be upon agreed delineations:
 - Significant risk area delineation by appointment, EU Floods Directive, e.g. 327 cm DVR90
 - Risk area delineation, potentially receiving flood risk reduction, 2.50 m DVR90

Proposed hazard analysis

Risk planning should include long-term risks, including those affected by climate change. Furthermore, it is a requirement under the EU's Floods Directive (Article 14, paragraph 4) to consider the likely impacts of climate change. Changes in storms and storm intensities during winter in Denmark remain uncertain compared to current conditions, but generally higher storm surge water levels are expected due to the overall rise in sea level. Therefore, no adjustments are made with respect to wind and wave conditions. Probabilities will be estimated utilizing The Danish Coastal Authority's publication on Extreme Level Statistics (2024) [48]. Estimation of future probabilities of flooding to determine risk development over time as a result of climate change will be approximated in relation to the available flood extent and approximate sea level rise estimated by DMI cf. climate scenario SPP3-7.0.

Proposed Impact analysis

First, a systems-based risk assessment will be performed to get an overview of the direct, indirect as well as cascading impacts associated with storm surge in Nakskov and vicinity hereof. The assessment will be qualitatively and conclude on which impacts are relevant to consider in a detailed risk assessment for Nakskov town and port.

Besides impacts included in the existing impact mapping analysis, there are more impacts that may arise when a storm surge occurs and that potentially can be included in an augmented risk analysis. The systems-based risk assessment will consider which damages and losses are relevant to include to strengthen the risk assessment for Nakskov. Other models for flood risk assessments in Denmark such as PLASK [54] and OS2-SkadesØkonomi [55] also include impacts such as costs of power failure, damages and losses to ecosystems and recreational areas, worsened human health, and loss of tourism. In the following, a first step is taken towards identifying potential negative consequences and relevant input data for a spatial risk analysis.

Regarding production loss, it will be determined with the use of database sources of Proff [56] and Virk [57]. An average calculation of the turnover per day is used to quantify the production loss during the period in which the company is not producing as a result of the flooding, [58].

Potential negative consequences							
Theme	Asset	Unit	Impact	Threshold*	Source	Data Input	Data Source
Residential	Building damage and inventory loss (permanent residence)	Quantitative [2022-DKK/m ²]	1167.86 * log(water depth) – 571.21	>20 cm	Skades-Økonomi, [59]	Building footprint	Geo Danmark
	Clean-up	Quantitative [2017-DKK/unit]	4,800	>20 cm	Rambøll, [60]	Building footprint	Geo Danmark
	Rehousing cost	Quantitative [2017-DKK/unit]	148,000	>40 cm	Rambøll, [60]	Building footprint	Geo Danmark
	Power outage	Quantitative [2010-DKK/unit]	1,850	>40 cm	PLASK, [54]	Building footprint	Geo Danmark
	Psychological effects	Quantitative [#]	Unit * 0.62	>20 cm	Skades-Økonomi, [59]	Building footprint	Geo Danmark
Businesses	Building damage and contents	Quantitative [2022-DKK/ m ²] Also, qualitative description of industrial production	1,387.94 * log(water depth) – 881.8	>20 cm	Skades-Økonomi, [59]	Building footprint	Geo Danmark
	Loss of revenue	Quantitative [2014-DKK/unit]	160,000	>10 cm	PLASK, [54]	Building footprint	Geo Danmark
	Clean-up	Quantitative [2017-DKK/unit]	10,300	>20 cm	Rambøll, [60]	Building footprint	Geo Danmark
	Power outage	Quantitative [2010-DKK/unit]	5,551	>40 cm	PLASK, [54]	Building footprint	Geo Danmark
Infrastructure	Road clean-up cost	Quantitative [2013-DKK/m ²]	3	>10 cm	PLASK, [54]	Road center lines with buffer	Geo Danmark
	Road disruptions	Quantitative [2024-DKK/road]	(309 kr./vehicle hour) × AADT** × hrs. delay × duration	>20 cm	Rambøll, [60]	Road center lines with buffer	Geo Danmark
	Rail damage	Quantitative [2017-DKK/m ²]	3,000	>10 cm	Rambøll, [60]	Rail center line with buffer	Geo Danmark
	Loss of ticket income	Quantitative [2025-DKK/rail line]	(900,000 ppl./360 travel days) × 7 days w/o service × 42 kr./ticket	>5 cm	Danske Jernbaner, [61]	Rail footprint	Geo Danmark
	Damages to critical infrastructure	Qualitative		>5 cm		Building footprint	Geo Danmark
	Power outage cost	Quantitative [2010-DKK/unit]	5,551	>40 cm	PLASK, [54]	Building footprint	Geo Danmark
Services	Exposed nurseries, kindergartens, schools, nursing homes, etc.	Qualitative		>10 cm		Building footprint	Geo Danmark
	Tourism	Quantitative	Capacity × missed overnight stays × overnight price	>40 cm	Skades-Økonomi, [59]	Building footprint	Geo Danmark
Environment	Recreational areas	Qualitative		>5 cm		Landcover	Scalgo
	Ecosystems	Quantitative [score]		>5 cm	Skades-Økonomi, [59]	Bioscore	Danmarks Areal Information
Heritage	Cultural significance	Qualitative		>5 cm		Building footprint	Geo Danmark
Agriculture	Loss of crops (sugar beets)	Quantitative [DKK/m ²]	1.4 (price for sugar beets – other crops may be included)	>20 cm	Skades-Økonomi, [59]	Fields	Landbrugs styrelsen, by Lolland Municipality

* Threshold is when a damage or loss is triggered. The variance in thresholds (from 5 cm to 40 cm) is because the damage functions or unit costs are based on different sources. It is important to use the original thresholds, as these were defined in the different sources when the different statistical analyses were calibrated to historic data.

** AADT is an acronym for Average Annual Daily Traffic and refers to the average number of vehicles that pass through a specific location on a road during a full year.

5.3 Task 3: Extended Cost Benefit Analysis

The method and procedure for the cost-benefit analyses (CBA) are based on the Danish Ministry of Finance's guidelines for socio-economic impact assessments from 2023 [62]. In Denmark, it is not a mandatory requirement to carry out CBAs for coastal protection projects, however it is recommended by the EU [63].

The CBA involves a comparison of costs and benefits with the aim of identifying the socio-economic profitability of each of the three proposed solutions. The following factors are considered in the CBA:

- **Costs:** Construction costs, operating and maintenance costs, and possible reinvestments
- **Benefits, reduced risks:** Reduced damage and loss costs, reduced operating costs for any existing coastal protection facilities
- **Co-Benefits, Added Value** (optional): Property value - (maintain or increase)

The result of the CBA is calculated and expressed as net present value (NPV) and in relation to an internal rate of return (IRR). The NPV reflects the overall societal balance between the project's costs and benefits. The IRR indicates the annual socio-economic outcome of the investment and represents the rate at which the net present value is exactly zero. If the internal rate of return is higher than the expected discount rate, the project is profitable from a socio-economic perspective. At the same time, the higher the internal rate of return is above the discount rate, the more attractive the project will generally be.

5.3.1 'Best practices' and potential 'Next Practices'

Application of CBA in Coastal Protection Projects

In 2023, Realise Denmark carried out research regarding experiences with financing, including CBA, of Danish coastal protection projects. The following projects have been reviewed:

- Storm Surge Protection
 - Storm surge protection with the Køge Dike (incl. CBA)
 - Storm surge protection of Kerteminde, Skødstrup, and Munkebo
 - Coastal protection project in Jyllinge Nordmark and Tangbjerg (incl. CBA)
 - The North Funen coastal protection, dike, and pumping association
 - Coastal protection at Enø/Lungshave
- Erosion Protection
 - Erosion protection in the North Coast's future: Halsnæs, Gribskov, and Helsingør (incl. CBA)
- Combined Storm Surge and Erosion Protection
 - Our Coast – coastal protection project at Kelstrup Beach and Hejsager Beach
 - Coastal protection at Struer

The research regarding the use of CBA in Danish coastal protection projects will be updated in Task 3 with the aim of identifying whether there are more recent experiences from Denmark.

Additionally, an examination have been initiated to determine which countries have legal requirements for CBA in connection with coastal protection projects. In this context, initially four countries in the vicinity of Denmark have been screened.

- Sweden [64],
- Germany [65], [66], [67] and [68]
- England [69], [70]
- Netherlands [71], [72]

The preliminary review of experiences from the above-mentioned countries shows that the use of CBA is a legal requirement only in England. As for the other countries that are members of the EU, CBA is a recommended practice and is used most extensively in the Netherlands.

Inclusion of Potential Co-Benefits

Implementing coastal protection may change the property values of the affected properties in the damage-prone area, according to 'Danmarks Nationalbank', the central bank of Denmark (2021) [73]. Their findings indicate that homes located in flood-risk zones sell for about 6% less, and homes in areas at risk of rising sea levels are sold on average 3–4% lower prices compared to similar homes without such risks [74].

5.3.2 Methodology proposal and key assumptions

Costs

Costs will include construction costs, maintenance, reinvestments and potential loan costs. The technical proposals for solutions have thus far only included construction costs. Hence, it is necessary in the following phases to assess the remaining cost components.

Benefits and Co-Benefits

The damage costs and loss will be calculated as described in section 5.2. Implementing coastal protection in Nakskov may change the property values of the affected properties in the damage-prone area, according to 'Danmarks Nationalbank', the central bank of Denmark (2021) [73]. The analysis will therefore include this option and be based on the basis of the 2024 property valuation used is from 'Vurderingsstyrelsen', the Danish Property Assessment Agency [75].

Socio-economic appraisal

The socio-economic discount rate is used to weight future benefits and disadvantages so that they can be directly compared with present values. According to the Ministry of Finance's guidelines for socio-economic impact assessments, the discount rates are as follows [62]:

- 0-35 years: 3.5 %
- 36-70 years: 2.5 %
- >70 years: 1.5 %

Inclusion of uncertainty and analysis sensitivity

Sensitivity analyses will be prepared based on changes in construction costs (e.g., +/- 10-20%). In addition, a sensitivity analysis will be carried out on the project's reduced damage costs (e.g., +/- 10-20%). The opening year is set for 2030, with the mentioned sensitivities and a lifespan of a 100 years. Furthermore, two additional opening years are proposed, 2035 and 2040, and two additional lifespans, 50 and 80 years, with respect to the sensitivity analyses.

Analysis Scenarios

Table 6 indicate the number of CBA analysis being carried out.

Table 6: Analysis matrix including implementation of storm surge protection in three potential future scenarios

		No Mitigation	Coastal Flood Risk Mitigation		
CBA	Scenario	'Do nothing'	Solution 1	Solution 2	Solution 3
Scenario 0	Scenario 0 "Status Quo – Existing conditions" e.g. present-day land use and business activities	Baseline	X	X	X
Scenario 1	Scenario 1 "Short term" Development, cf. approved building permits and planned urban development	X	X	X	X

Scenario 2	Scenario 2 "Short-medium term" Development, cf. approved building permits and planned urban development including growth projections of port activity	X	X	X	X
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5.4 Task 4: Development of a Funding Strategy and Financial Models

The objective of Task 4 is to define a legally grounded, socially acceptable, and economically robust funding strategy for the storm surge protection measures in Nakskov. This includes cost distribution models under the DCA (§9/9a), a modular transparent financial model, and a multi-source financing strategy consistent with EIB, InvestEU, and national frameworks. Assessment of risks, costs and benefits are key investigators to mobilise sources of funding. The cost distribution models will be based on both Danish legal guidance and inspiration from international best practices.

The proposed storm surge protection for Nakskov will be a major investment for the Municipality and the population and businesses of Nakskov. There is therefore a need to consider the issues of affordability and burden-sharing regarding funding for the development of common infrastructure protecting against the risk of storm surges, as well as exploring potential new and third-party sources of funding.

As part of the work on the financing models, previous experiences from Denmark are included. All proposed cost distribution models will be exemplified for each of the three storm surge protection solutions. The following assumptions and premises are the basis for identifying relevant financial models/part distribution models.

5.4.1 Key principles of Cost Distribution and Quantification

Principles of cost distribution are essential for establishing a cost distribution model. Based on the data basis, the principles ensure that the utility principle is uncovered and contribute to ensuring transparency in decisions concerning contributors and quantification of contribution rates. Table 7 provide an overview of the key principles behind cost distribution and quantification.

Table 7: Overview of the key principles behind cost distribution and quantification.

Potential contributors	• Building property owners • Land property owners • Transport infrastructure owners • Utility owners • Other relevant stakeholders
Methods for determining contribution liability and rates	• Based on avoided damage costs • <i>Based on changes in property value, optional</i>
Types of properties	• Buildings • Land plots • Transport infrastructure • Utility infrastructure • <i>Possible other indirect beneficiaries</i>
Possible contributions based on building type	• Residential buildings e.g. damage • Commercial buildings e.g. damage + production loss • Public buildings e.g. damage + loss of public services
Possible contributions based on land	• Land area e.g., loss of property value, loss of land use

	Joint liability (solidarity principle)
Possible contributions based on transport infrastructure	- Road infrastructure e.g. damage, cleanup, restricted access (use), traffic delays - Port infrastructure e.g. damage, cleanup, restricted access (use), traffic delays
Possible contributions based on utility infrastructure	Pipes and/or components (damage, loss of utility services)
Contribution types	- Direct protection benefits (building damage) - Direct other benefits (maintenance or increase in property value) - Direct other benefits (production loss and service loss) - Other indirect benefits
External contributions	- State funds e.g. <i>Statens Kystpulje</i> - Lolland Municipality - With and without external contributions e.g. donations, investment funds

Contributions in relation to properties classified as buildings can be calculated in several ways in relation to whether it should be a total contribution or consist of several sub-contributions, e.g. a building and a cadastral contribution. Within a possible subdivision, buildings can e.g. be assessed based on statements from the Building and Housing Register (BBR) where cadastral asset information related to all buildings in Denmark [76]. There is extensive information available for each building, including its location, purpose, size and age.) building area on the ground floor and possibly other floors. Land for development can, for example, charge a contribution according to flooded areas or collectively for the entire land register. Undeveloped land can be included in the cost distribution, even if a short-term high water level event will not cause damage to the land. However, the function and value of the land can be affected. If plots are built, an extra contribution may be imposed that reflects the value of the building.

Across the selected property forms, types, and uses, contribution rates are typically determined based on the following contribution parameters:

- **Number as the unit of calculation:** When calculated per unit, benefits or advantages may vary in relation to the unit itself, but not necessarily in terms of size or importance.
- **Square metres or length as the unit of calculation:** When calculated per square metre or per metre, benefits or advantages may vary in relation to size, but not necessarily in terms of importance.
- **Weighting of calculated parties:** When calculations are made within or between categories, contributions may be weighted. This may be done according to the level of benefit or other criteria such as importance, exposure and/or risk.

The possibilities for combination are numerous, hence the cost distribution, including the properties listed below, will vary depending on the selected utility principles and method of calculation.

It should be noted that the actual avoided material damage costs for each individual property owner will, to a large extent, be limited by the upper ceiling for storm surge deductibles, as set out in the relevant statutory order [77]. It can therefore be argued that the maximum potential benefit of coastal flood protection for individual property owners cannot exceed the legally prescribed storm surge deductible, as non-commercial insurance companies in Denmark cover damages exceeding the deductible through the national storm surge compensation scheme [58]. This effectively means that, in the cost distribution, no distinction is made between contributors whose damage costs exceed the deductible and those whose costs do not, since the deductible represents the maximum self-insured amount [58].

5.4.2 Methodology proposal and key assumptions

- The Danish Coastal Protection Act remains in force and applicable to the project.
- Financing of the storm surge protection solution is based on a standard assumption that contributions to cover the costs of the installation are collected after the installation has been put into operation, cf. practice in the utilities and infrastructure sector.
- Model proposals will include both direct and indirect costs related to flooded property owners, and examples of inclusion of indirect costs related to nuisance or benefits related to a wider group of none direct flooded property owners and users of the flooded area
- A sensitivity analysis applied to the proposed models will include:
 - the revenues to cover construction costs can be either paid in cash in the year following the entry into operation or through publicly guaranteed debt financing spread over a longer period, e.g. 25 and 40 years.

Ability-to-Pay (ATP) Profiling

A socio-economic analysis will be performed of the area of interest of the affordability of potential cost-sharing mechanisms. The profiling will aim at integrating:

- Income distribution and household economic profiles using available municipal and national datasets.
- Property value data (land registry and cadastral data) to understand asset-based affordability.
- Tax base and local revenue indicators, to gauge the financial headroom for municipal contributions. Commercial sector capacity, particularly port-adjacent industries and SMEs, using business registry and turnover data.

The analysis of ability-to-pay (ATP) will be attempted based upon property owner perspectives of residential and commercial properties. Regarding residential properties, ATP is defined as:

$$\text{ATP} = \text{Income} - \text{Fixed expenses}$$

The households' income will be provided by Lolland Municipality. However, it should be emphasised that data on households' fixed expenditures or wealth levels are not available, why this paper will not include households' ATP. For businesses, the ATP is defined as the company's annual financial result, solvency ratio, and liquidity ratio over a period e.g. the last five years. The data will be sourced through [57] and [56].

Willingness-to-Pay (WTP)

The WTP survey will be implemented after the Ability-to-Pay (ATP). While it's possible to survey both private citizens, business and industries for WTP, they are distinct groups with different drivers and decision-making processes. The different groups of property owners have fundamentally different decision-making drivers. Industries and commercial businesses often focus on operational continuity and return on investment, while households weigh personal, emotional, and perceived utility factors. Attempting a single, undifferentiated analysis will almost certainly lead to flawed conclusions. Fully separate surveys, questions, and analyses would be required.

The insights provided by the WTP survey are often perceived more relevant for private citizens rather than for commercial business, as WTP surveys are excellent at capturing these individual trade-offs among attributes that contribute to personal utility. For businesses or industries, the "buyer" is not an individual consuming the good, but an organisation looking to optimise its operations or profitability. While WTP surveys can identify the value of business-relevant attributes (e.g., uptime, integration capabilities, support), the underlying drivers are less about personal preference and more about quantifiable business metrics, which can be complex to capture solely through hypothetical choices. Given this distinction, it's proposed to limit the WTP survey to primarily private citizens, with business

value attribution addressed separately in the CBA. Thus, industries within the active Port area, may be of separate interest.

There are two main survey-based stated preference approaches for WTP elicitation: the contingent valuation (CV) and the choice experiment (CE) methods. The contingent valuation (CV) method directly asks respondents their maximum willingness-to-pay for a specific change in the quantity or quality of a good or service (Arrow et al., 2013). The choice experiment (CE) presents respondents with hypothetical sets of alternatives, each defined by varying levels of attributes, and asks them to choose their most preferred option to infer the value of those.

Given that the various storm surge protection proposals do not present substantial differences in key attributes that would significantly drive private citizens' choices (e.g., co-benefits like increased recreation, aesthetic impact), a choice experiment (CE) would be difficult to design and implement. Therefore, we suggest that obtaining an overall WTP quantification via the Contingent Valuation (CV) method will be most appropriate, as it is a more direct approach and is expected to be less demanding for both preparation and respondents.

The survey will be co-designed with Lolland Municipality including decisions on target audience and distribution. The planning phase will be initiated alongside task 2 and implemented during task 3 and 4. Key design considerations include:

1. **Distribution Method** – Options include Digital Post (wider reach, faster collection time, but intensive preparation required, including survey distribution costs and GDPR compliance) or in-person (limited reach, but higher response rate, will require dedicated staff), or a combination. It's proposed that that private citizens primarily are reached through Digital Post Service, and the selected industries are done in-person. As a test of the survey questionnaire, selected private property owners may also be considered invited in for an in-person interview and evaluation, before a larger distribution. If the survey is going to be distributed online, it will need to stay open for collection at least one month. Ideally, the respondents will be sent a reminder message after 2 weeks.
2. **Specifics of the WTP scenarios.** The hypothetical scenarios used to elicit WTP are carefully constructed to be as realistic and comprehensible as possible, providing sufficient information about the various options, the payment mechanism, and any relevant context or budget constraints. Therefore, the description of the payment scenario will need to be closely agreed to with the Municipality (e.g., do we need to avoid creating a WTP scenario where the citizens are asked if they would pay higher taxes?).
3. **The presentation of the project** is also to be carefully crafted. For example, visualizations of the planned construction would be a great asset. This step is particularly relevant as the survey could also be a mean to disseminate knowledge about the project to the affected citizens.
4. **The possibility of pre-testing the WTP survey** during one of the stakeholder engagement activities could also be discussed. Pre-testing is fundamental to ensure the quality of a survey, and submitting a draft to the workshop participants could be a good way to get valuable feedback from the same beneficiaries as the survey's target population. At least one month before the date of the survey the questionnaire will have to be tested by a control group. Either during a project workshop or stakeholder consultation, if that option is discarded, by a group from the Municipality/Consultant team not directly involved in the project.

The various analysis results will be compared to identify gaps, contradictions, or reinforcing patterns, and will directly inform the qualitative modifiers in the cost distribution model.

5.4.3 Proposals of Framework for development of Cost Distribution Models

In cooperation with the Municipality, recent relevant examples of models of funding contributions for coastal protection and flood protection projects have been collected. Table 8 lists models that have been identified as relevant for this project and will be based on both Danish legal guidance and inspiration from international best practices. The utility principle mentioned below is a reference to The Danish Coastal Authority's (Kystdirektoratets) guide to cost distribution of the tangible and intangible utility values [78].

Table 8: Cost-distribution models relevant for Nakskov storm surge protection

Financial Model	Sub Set Model Assumptions	
Financial Model 0 Cost distribution according to ATP/WTP in relation to the direct benefit gained from implementing coastal protection.	• Model 0 "Bottom-up" • Contributors: Building owners (private, business, public), infrastructure owners (transport + utilities) • Cost contribution rate: Contribution calculated per square meter based on willingness to pay/ability to pay.	
Financial Model A Cost distribution according to the utility principle (<i>nytteprincip as per Danish regulations</i>) in relation to achieving direct coastal protection.	Model A1 "Top down" • Contributors: Building owners (private, business, public), infrastructure owners (transport + utilities) • Contribution rate: Contributions calculated per square meter, damages: Uniform based on unit, DKK per square meter.	Model A2 "Top down" • Contributors: Building owners (private, business, public), infrastructure owners (transport + utilities) • Contribution rate: Contributions calculated per property value: • Differentiated based in unit, % per value.
Financial Model B Cost distribution according to the utility principle (<i>nytteprincip as per Danish regulations</i>) in relation to achieving direct coastal protection and other benefits.	Model B1 • Contributors: Building owners (private, business, public), infrastructure owners (transport + utilities) • Contribution rate: Contributions calculated per square meter, damages: • Residential: Uniform based on unit, DKK per square meter. • Business: Differentiated based on unit, DKK per square meter. • Public: Differentiated based on unit, DKK per square meter. Contributions calculated based on production loss/service loss: • Business: Differentiated based on gross profit.	Model B2 • Contributors: Building owners (private, business, public), infrastructure owners (transport + utilities) • Contribution rate: Contributions calculated per square meter, damages: • Residential: Uniform based on unit, DKK per square meter. • Business: Differentiated based on unit, DKK per square meter. • Public: Differentiated based on unit, DKK per square meter. Contributions calculated based on production loss/service loss: • Business: Differentiated based on gross profit. • Public: differentiated based on service provider loss
Financial Model C Cost distribution according to the utility principle (<i>nytteprincip as per Danish regulations</i>) in relation to achieving direct coastal protection and other benefits + additional benefits for property owners outside the direct protection zone.	Model C1 • Contributors: Building owners (private, business, public), infrastructure owners (transport + utilities) • Inclusion of "other indirect benefits", such as: ○ Beneficiaries within the boundary of the EU Floods Directive (Potential Risk Area Delineation) ○ Beneficiaries within the Nakskov town and port area (town zone cf. Planning Act or postal code) ○ Beneficiaries within Lolland Municipality (municipal boundary)	Variant The Dike Association of Lolland is replaced by a new organisational structure, e.g. one covering the whole of Lolland with a new cost distribution model.

5.5 Task 5: Support Stakeholder Engagement, Communication, and Dissemination

The objective of Task 5 is to ensure that the overall funding strategy including the storm surge protection solutions are developed and communicated through inclusive, transparent, and effective stakeholder engagement. This task also ensures that findings are disseminated in a way that supports local ownership, political buy-in, and long-term implementation.

Stakeholder engagement and communication must not be seen as a standalone task within this project. Ramboll and the municipality will, on an ongoing basis, determine which party holds responsibility for external communication with stakeholders (e.g., issuing workshop invitations). At the outset of each task, a communication plan will be established specifying the relevant stakeholders, the appropriate form and level of their involvement, the designated sender of all communication, and the participants assigned to each workshop. The plan will also outline the jointly agreed approval process for any material to be distributed, including which party is responsible for reviewing and approving content prior to dissemination.

As a general principle, the municipality will serve as the primary sender; however, Ramboll may, in certain cases, disseminate information directly. For example, in advance of a workshop or prior to the distribution of the willingness-to-pay survey. Ramboll may also, where needed and as jointly agreed, provide input and supporting materials for the municipality's communication activities.

Stakeholder engagement and communication is, on this basis, a guiding principle embedded across all workstreams. Each of the technical tasks (1–4) will be accompanied by dedicated engagement activities tailored to the stakeholder groups and decisions relevant to that phase. These engagement moments are strategically aligned with the overarching aim of the assignment: to lay the groundwork for a feasible, well-understood, and widely supported funding strategy for storm surge protection in Nakskov.

Stakeholder engagement is particularly critical in storm surge protection and resilience planning [38]. These projects involve long time horizons, shared responsibilities, and often contentious cost allocations. Engaging stakeholders early and meaningfully ensures legitimacy by including those affected in the decision-making process; fosters co-ownership, which improves acceptance of funding models and long-term maintenance; supports long-term success by building local capacity and trust; and enables access to local knowledge and lived experience, which can strengthen both the technical and social robustness of proposed solutions.

In this section, we present the definition and conceptual foundation for stakeholder engagement in the project. In Table 9 the five levels of engagement are summarised, describing their primary objectives and the recommended engagement methods applied to each.

Table 9: Overview of level of engagement

Level of Engagement	Objective	Recommended engagement method
Inform	Provide information to ensure awareness and transparency.	Written communication (e.g. email, newsletters).
Consult	Gather feedback on plans and decisions.	Bilateral meetings
Involve	Include stakeholders in discussions and deliberations.	Public meetings, focus groups, interviews
Collaborate	Partner with stakeholders in the design of solutions.	Workshops, seminars.
Empower	Delegate influence or decision-making power.	Participatory design sessions, co-governance mechanisms.

5.5.1 Conceptual Foundations for Effective Stakeholder Engagement

Stakeholder engagement refers to the systematic process of involving individuals, groups, or organisations that may affect or be affected by the project, throughout its development and implementation [79]. Stakeholder engagement is grounded in participatory governance theory, which holds that active involvement of those affected leads to more legitimate and successful policies [80].

A commonly recognised framework for defining degrees of participation is the International Association for Public Participation (IAP2) Spectrum. It distinguishes between five levels of engagement: inform, consult, involve, collaborate, and empower [81]. Representing a continuum from one-way communication to shared decision-making. This project's proposed methodology draws on this model.

When stakeholders move from being passive recipients of information to active contributors or co-decision-makers, they are more likely to view outcomes as legitimate and fair. Conversely, limited or symbolic engagement can reduce trust, weaken perceived fairness, and undermine social acceptance of project decisions.

5.5.2 Behavioural Insights and Practical Implications for the Project

Integrating behavioural insights into stakeholder engagement offers valuable guidance for designing processes that foster trust, cooperation, and long-term support. These perspectives help explain why people respond differently to information and participation opportunities, and how engagement can be structured to encourage constructive involvement in developing the funding strategy.

Behavioural insights refer to an evidence-based approach that draws on findings from behavioural economics, psychology, and cognitive science to better understand how people make decisions and how contextual factors, biases, and social influences shape behaviour. Rather than assuming individuals act purely rationally, behavioural insights explore how real-world decisions are driven by for instance perception, trust, emotion, and social norms [82]. Below, some of the key concepts from behavioural science that have direct practical relevance for stakeholder engagement in storm surge protection are outlined.

Trust and Procedural Fairness

People are more likely to support and comply with funding decisions when they trust the decision-makers and perceive the process as fair. Transparent, inclusive processes that acknowledge diverse perspectives foster perceived legitimacy, even when stakeholders do not fully agree with the final decision [83].

In the context of Nakskov's storm surge funding strategy, this means ensuring that both local businesses at the port and property owners in flood-risk zones can clearly see how their views inform the analysis and proposed measures. During the Task 2 and Task 3, it could be particularly important to communicate how trade-offs between technical feasibility, economic efficiency, and social equity are assessed, and to explain why certain options are prioritised. Demonstrating that stakeholder input is visibly integrated. For example, through transparent summaries after workshops and interviews, helps maintain trust and long-term commitment to the process.

Risk Perception

Perceptions of storm surge and flood risk often diverge from technical assessments. Some stakeholders may underestimate the likelihood or potential impact of flooding, while others may overestimate it, leading to anxiety or mistrust. Engagement that helps make risks both *visible* and *personally relevant* is therefore important for building a shared understanding of local challenges and for fostering informed dialogue about potential solutions [84].

In the context of Nakskov, this will be for example relevant during the Climate Risk and Vulnerability Assessment (Task 2) and later communication activities (Task 4). Approaches such as participatory risk mapping, local storytelling, or visual simulations showing potential flood impacts on key areas, such as

Nakskov Port, residential zones, and local infrastructure, can help residents, property owners, and businesses better understand their own exposure and the rationale for protection measures.

By grounding discussions in locally meaningful experiences and evidence, engagement can help align perceived and actual risk and thus create a stronger basis for cooperation and shared responsibility. While such activities may not directly determine willingness to contribute financially, they can contribute to trust, transparency, and a common understanding.

Social Norms and Collective Action

Human behaviour is strongly shaped by social norms: our perceptions of what others do and approve of [85], [86]. When respected local actors, such as business leaders, associations, or community representatives, visibly support a coastal protection initiative, it could help to establish a cooperative norm that motivates others to engage. In contrast, visible non-participation or scepticism may discourage involvement and foster free riding.

In the storm surge funding strategy context, this dynamic could be relevant for future discussions on shared funding models or voluntary contributions to storm surge protection. For instance, if key port companies or property owners publicly endorse or participate in protective measures, this can signal collective responsibility and normalise participation. Similarly, peer-to-peer communication and visible examples of collaboration. For example, through local business associations or community forums, can help create momentum around collective action.

Communication strategies that highlight positive examples, local leadership, and joint progress may therefore contribute to strengthening shared responsibility. While social norms alone do not determine participation, they can provide an enabling environment that supports trust, fairness, and mutual commitment across stakeholder groups.

Loss aversion and framing

Behavioural research shows that people are typically more motivated to avoid losses than to pursue equivalent gains, a phenomenon known as loss aversion [87]. In the context of storm surge protection, this means that communication and engagement efforts may be more effective when they emphasise what could be lost without action, such as homes, businesses, or community identity, rather than focusing solely on future benefits.

For Nakskov, framing discussions around the tangible risks of inaction (for example disruptions to port operations, damage to residential areas, or loss of local employment) can help make the stakes more concrete and immediate for stakeholders. However, it is equally important to balance this with constructive and forward-looking messages that present protection measures as opportunities to secure long-term stability and economic resilience.

Applied carefully, framing can help make complex cost–benefit discussions, for instance in Task 3, more relatable and comprehensible to diverse audiences. While it cannot replace transparent analysis or inclusive dialogue, thoughtful framing can support better understanding, foster a sense of urgency, and encourage engagement across stakeholder groups.

5.5.3 Recommendations for Stakeholder Engagement Across Project Tasks

Stakeholder engagement activities will be implemented in parallel with the technical progress of the project and continuously adapted to reflect its evolving context. This section provides general guidance on how stakeholder engagement can be approached and integrated across Tasks 1–4. The intention is to highlight key considerations and recommended practices rather than to prescribe specific actions. The following there include general insights on how communication and engagement efforts can be designed and framed based on behavioural insights.

Task 1 – Initial Scoping and Baseline

Engagement during Task 1 focuses on establishing a shared foundation of understanding across the project team and municipal departments. This phase sets the direction for how stakeholders will be identified, prioritised, and engaged throughout the process.

At the workshop the project was align with internal stakeholders, including clarification of roles and expectations, and agree on a coherent approach to storm surge protection in Nakskov. The workshop included introduction to the engagement framework and gathering of early reflections on which stakeholders are most relevant to involve going forward. Complementary activities included preliminary identification and categorisation of stakeholders. Preparation of an initial stakeholder engagement plan has begun, which will serve as a living document updated throughout the project.

The outcome of this task is a common baseline of understanding and a clear internal foundation for subsequent engagement.

Task 2 – Storm Surge and Sea Level Rise Risk Assessment

In this phase, stakeholder engagement becomes more outward-looking and interactive. The objective is to deepen understanding of key stakeholders' needs, motivations, and perceived barriers related to storm surge protection, while also raising awareness of the risks identified.

A workshop, as specified in the Terms of Reference and reflected in our proposal, will be organised to present the preliminary findings, validate results, and discuss the local implications of climate risks and adaptation needs in Nakskov and its port. The specific participants will be decided upon together with the municipality, but may include representatives from Lolland Municipality, high interest/high influence stakeholder such as port industries.

In addition to the workshop, it is recommended that complementary engagement activities be implemented to broaden input and sustain dialogue between formal milestones. These may include:

- Semi-structured interviews with stakeholders who hold high interest or influence, to explore their drivers, priorities, and concerns.
- Bilateral or small-group meetings with to ensure practical insights are reflected.
- Targeted communication materials, such as visual summaries or infographics, to raise awareness and strengthen public understanding.

Insights from these activities will inform an updated stakeholder engagement plan, ensuring that future engagement builds on evidence and emerging priorities.

Task 3 – Extended Cost-Benefit Analysis

Stakeholder engagement in Task 3 focuses on collaboration and transparency around the economic implications of proposed adaptation options. The objective is to create shared understanding of trade-offs and enhance legitimacy around prioritisation and decision-making.

A CBA Workshop will be held to discuss and validate the economic assessment and explore the trade-offs between technical, social, and environmental outcomes. The final list of participants will be determined later, but may include representatives from municipal departments, port operators, major local industries and relevant authorities.

Beyond the workshop, we recommend a range of supporting engagement activities to reinforce dialogue and transparency, such as:

- Briefing sessions or technical dialogues to clarify data, cost assumptions, and uncertainties
- Follow-up meetings with high-influence actors to address specific concerns or gather detailed input on financing implications.
- Communication materials summarising CBA findings in accessible formats to support understanding among non-technical audiences.

This phase provides a critical bridge between technical analysis and funding strategy development, helping ensure that financial discussions in Task 4 are informed by broad and credible input.

Task 4 – Funding Strategy and Communication

The final phase centres on consolidating results and aligning stakeholders around a shared funding strategy. The goal is to ensure that the strategy is both technically robust and socially accepted, supported by those who will be affected by or contribute to its implementation.

A Funding Strategy Workshop will be conducted to present and discuss the proposed strategy, inviting reflections on financing mechanisms, implementation pathways, and future collaboration. The final participant list will be confirmed later, but may include political representatives, local businesses, citizens' organisations, civil society, and key authorities.

To complement the workshop, a broader communication and engagement effort is recommended:

- Visual storytelling and communication materials (e.g., infographics, non-technical summaries, or short videos) to make complex findings accessible to wider audiences.
- Dialogue meetings with decision-makers and interest groups to ensure understanding and buy-in prior to implementation.
- A Willingness-to-Pay (WTP) survey to capture perspectives on financing, fairness, and local commitment to coastal protection.

The phase concludes with a final update of the stakeholder engagement and communication plan, summarising lessons learned, remaining dialogue needs, and recommendations for continued engagement beyond the project's completion.

Glossary incl. English/Danish translations

English	Danish	Description
Ability-to-Pay (ATP)	<i>Betalingsevne</i>	An individual's or company's capacity to meet financial obligations, and is defined by: $ATP = \text{Income} - \text{Fixed expenses}$
Annual financial result	<i>Årsresultat</i>	The profit or loss a company made during a year
Beneficiaries, Primary	<i>Nytteprincip ift. Opnåelse af kystbeskyttelsesfordel</i>	The individual, group, or entity that directly or indirectly gain protection from implemented measures.
Beneficiaries, Secondary	<i>Nytteprincip ift. Opnåelse af anden fordel</i>	The individual, group, or entity that indirectly gain other benefits from a coastal protection measure than coastal protection, e.g. an increase in property values or improved recreational value.
Climate Adaptation	<i>Klimatilpasning</i>	Climate adaptation is often used as a broader term to describe various initiatives to counteract the negative impacts of climate change. This includes different approaches and measures for protection or defense against rainfall and storm surges.
Coastal Protection	<i>Kystbeskyttelse</i>	Coastal protection or coastal protection structures refer to mitigation measures against flooding and/or erosion. Coastal protection is therefore a general term for a range of measures. Examples of coastal protection include seawalls, rock revetments, storm surge gates, dikes, and dune landscapes.
Coastal Protection Act	<i>Kystbeskyttelsesloven</i>	Outlines the law and regulations in relation to permitting, organisation and financing.
Compound events	<i>Sammenfaldende hændelser</i>	There can be a concurrence of events, whether they are combined or derived from one another. They can be caused by errors or actions in systems, technology, people, or weather events. When designing climate adaptation and cloudburst protection, as well as when developing emergency protocols, it must be investigated whether there can be possible concurrence between heavy rainwater diversion and cloudburst, or structural failure while extreme rainfall, etc. may occur. The probability of concurrence varies depending on the variable parameters.
Cost Distribution Model	<i>Bidragsfordelingsmodel</i>	The financial distribution of expenses for a coastal protection. According to the Coastal Protection Act, all property owners who benefit from the implementation of a coastal protection structure, including storm surge protection, may be required to contribute and thereby become part of a broader collective cost-sharing arrangement.
Design Water Level	<i>Designvandstand</i>	The defined water levels used as input for determining the needed protection elevation. The design water level represents the mean high water that occurs during a storm.
DVR90	<i>DVR90</i>	The Danish Vertical Reference 1990, which is the Danish height system used for measuring elevations relative to a reference point.
Dike Association	<i>Digelag</i>	A consortium of property owners who share responsibility for the establishment, operation, and maintenance of a coastal protection structure, including storm surge protection. The association has statutes and a description of the cost-distribution model, as a legally established institution.
to The Danish Coastal Authority	<i>Kystdirektoratet</i>	The Danish Coastal Authority is the official coastal government agency – a division of the Danish Ministry of the Environment and part of the Danish Nature Agency.
The Dike Association of Lolland	<i>Det Lollandske Digelag</i>	The Dike Association of Lolland was established following the storm surge in November 1872. After the storm surge the community came together to build a dike. Today the dike is operated using revenue from 7,243 properties that are subject to a dike tax. In addition, there are minor rental incomes and a payment for the maintenance of the bicycle path. The Association does not receive any subsidies from either the state or the municipality. The highest authority of the dike is the general assembly, which elects a board from among the dike's taxpayers. The board consists of five members.
Emergency response	<i>Beredskab</i>	The immediate response undertaken in situations of danger that have not already been prevented or protected against. Emergency response is typically carried out by public authorities or similar organisations that are prepared to take action to mitigate the effects of events such as storm surges or flash flooding.
Emergency response activated measure	<i>Beredskabsløsninger ift. Varslingsaktiveret tiltag</i>	Temporary mobile solutions for mitigating, e.g., flood damages. These may include water tubes, sandbags, and alu-planks. Depending on the specific task and location such tools, as part of the overall emergency response, can be deployed by both public authorities and private actors. In

		the case of major incidents, first aid and crisis management may also be required.
Financing	<i>Finansiering - Tilvejebringelse af kapital til betaling for omkostningerne forbundet med realisering</i>	Financing refers to the money needed to meet the up-front payments for the NRL-related investment or costs. Financing sources typically consist of a range of "financiers", including commercial banks, institutional investors, development banks, and governments. These sources provide capital through various financing mechanisms such as commercial loans (such as from commercial banks or institutional investors), subordinated debt (such as from development banks or from governments), public-private partnerships (PPPs), equity financing through the issuance of shares, and grants from national governments or EU Funds. Financial solutions may also include innovative financing structures such as blended finance, green bonds, and impact investing, which aim to attract diverse sources of capital while managing risk and achieving sustainable outcomes. Financing leads to the question of creditworthiness.
Funding	<i>Investerings-omkostninger</i>	The ways in which the investments or costs are ultimately paid for. Funding can come from various sources, including external funding such as grants, donations, loans, and investments from partners, as well as internal funding from beneficiaries.
Funding Parties	<i>Bidragssydere (finansieringsyder)</i>	Funding parties take care of the servicing of the invested financial capital, i.e., via paying back any loans with interest and dividend to shareholders (both where applicable) or writing off the assets (depreciation).
Funding Sources	<i>Finansieringskilder</i>	Funding typically comes from taxes, intergovernmental grants, fees, tariffs other mechanisms such as capturing land value, commercial activities.
Funding Strategy	<i>Finansieringsstrategi</i>	A funding strategy leads to answers regarding ability and willingness to pay.
High Water Level / Surge	<i>Højvande</i>	The maximum water level reached during a tidal cycle, storm surge, or flood event. It represents the highest elevation of the water surface relative to a defined reference datum.
Internal rate of return	<i>Intern rente</i>	Indicates the annual socio-economic outcome of the investment and represents the rate at which the net present value is exactly zero. If the internal rate of return is higher than the expected discount rate, the project is profitable from a socio-economic perspective. At the same time, the higher the internal rate of return is above the discount rate, the more attractive the coastal project will generally be.
Liquidity ratio	<i>Likviditetsgrad</i>	Liquidity ratios measure a company's ability to pay its short-term debt obligations.
Lolland Municipality	<i>Lolland Kommune</i>	The municipality geographically covers the western and central parts of Lolland, as well as a number of smaller islands in "Smålandsfarvandet". The municipality has approximately 40,000 inhabitants. About half of them live in the three largest towns: Nakskov, Maribo, and Rødby.
Lolland Municipality, Department of Planning	<i>Teknik- og Miljømyndighed, Lolland Kommune</i>	The municipal sector responsible for planning, nature, water and climate, environment, property/building affairs, and technical secretariat functions.
Lolland Municipality, Department Team Planning and Mapping	<i>Team Planer og Kort, Teknik- og Miljømyndighed, Lolland Kommune</i>	A team under the Department of Planning in Lolland Municipality. The team ensures that land use, development and building activity in the municipality are guided by up-to-date plans, mapped correctly, legally binding where required, and transparently accessible.
Lolland Municipality, Department Team Technical Secretary	<i>Team Teknisk Sekretariat, Teknik- og Miljømyndighed, Lolland Kommune</i>	A team under the Department of Planning in Lolland Municipality that provides administrative and operational support across the department. In effect, the team supplies "back-office" functions ensuring that the technical, planning, environment and climate teams can focus on their specialised tasks with the necessary tools, data and process support.
Lolland Ports	<i>Lolland Havne</i>	A municipal port authority under Lolland Kommune responsible for the operation and development of primary commercial and transport harbours in the Lolland area, notably including Nakskov Havn and Rødbyhavn Trafikhavn, as well as a number of smaller ferry and recreational harbours. The organisation's mandate encompasses maintaining modern infrastructure, supporting the region's industrial, agricultural, and logistics sectors, and aligning harbour development with the municipality's strategy for growth, green transition and connectivity.
Net present value	<i>Nettonutidsværdi</i>	The overall societal balance between the project's costs and benefits.
Planning Act	<i>Planloven</i>	The planning Act serve as the legal framework for the physical planning in both a regional, municipal and local level. Cf. Planloven jf. Bekendtgørelse af lov om planlægning
Property owner	<i>Ejendomsejer</i>	A property owner is an individual or entity that holds legal title to a piece of real estate, which can include land and the buildings on it.
Port Act	<i>Havneloven</i>	Outlines the law and regulations in relation to operating port activities, including ownership, responsibilities and commitments.

Return Period	<i>Gentagelsesperiode</i>	The return period describes the statistical probability of a high-water event occurring.
Sea Level	<i>Havniveau</i>	Sea level a reference to a water level at any given time. Mean sea level often refers to the long-term average, which thereby serve as a reference for the everyday water level observed.
Sea Level Rise	<i>Havniveaustigning</i>	Sea level is rising due to the melting of ice sheets (Arctic and Antarctic) and the thermal expansion of the ocean caused by global warming. Sea level rise is not uniform across the Earth's surface due to gravitational effects between the poles. Denmark is therefore mostly affected by the melting of the Antarctic ice.
Solvency ratio	<i>Soliditetsgrad</i>	A solvency ratio is a measurement of a firm's financial health. It indicates whether a company's cash flow is sufficient to meet its long-term liabilities.
Statistical estimates - percentile	<i>Statistiske estimater og fraktioner</i>	Central estimates are used to describe the best approximation of statistical parameters such as the mean (the 50th percentile) and the 84th percentile, which is an upper percentile. Choosing estimates based on the 84th percentile is more conservative than those calculated for the 50th percentile.
Surge / High Water Level	<i>Højvande</i>	Surge, or high-water level events, is a temporary rise in the mean sea level. Variations in sea level occur daily due to tidal fluctuations, but also as a result of the movement of different weather systems. High water can occur under various wind conditions. Therefore, high water does not always coincide with a storm surge. High water can, however, lead to flooding.
Storm Surge	<i>Stormflod</i>	The temporary increase, at a particular locality, in the height of the sea due to extreme meteorological conditions (low atmospheric pressure and/or strong winds). The storm surge is defined as being the excess above the level expected from the tidal variation alone at that time and place.
Storm Surge Protection	<i>Stormflodsbeskyttelse (Kystbeskyttelse)</i>	Storm surge protection or structures refer to mitigation measures against coastal flooding and rising mean sea levels, only. Examples of protection measures include seawalls, storm surge gates and barriers, dikes, and dune landscapes.
Storm surge protection association	<i>Kystbeskyttelseslag</i>	An association of property owners jointly responsible for the establishment, operation, and maintenance of coastal protection structures, such as dikes, seawalls, or flood barriers. The association is typically formed under the Danish Coastal Protection Act and financed through contributions from the properties that benefit from the protection measures. It operates under approved statutes and is managed by an elected board.
Urban Drainage System	<i>Afløbssystem</i>	Urban drainage system refers to the sub-terrain pipe system in which rainwater and wastewater flows. An urban drainage system can be built as a joint system (wastewater and rainwater together) or a separate system (wastewater and rainwater separately).
Utility principle	<i>Nytteprincippet</i>	Reference to Kystdirektoratet's guide to cost distribution (<i>Vejledning til bidragsfordeling</i>) of the tangible and intangible utility values.

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