National
Risk Profile 2022

DANISH EMERGENCY
MANAGEMENT AGENCY

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FOREWORD

Dear reader,
Welcome to the Danish Emergency Management Agency's (DEMA) third edition of the National Risk Profile. In close collaboration with other Danish authorities and expert organisations, this year's NRP aims to draw attention to 14 incident types that all of Danish society should pay special attention to. A big thank you to everyone that has contributed to NRP 2022.

Since 2020, COVID-19 has illustrated the importance of preparedness and crisis management. Despite NRP 2017's mention of coronavirus variants in the chapter on highly virulent diseases, no one could have foreseen how severe the consequences of the COVID-19 pandemic would be. As we continue to deal with the pandemic and its effects, preparedness and crisis management has earned a higher spot on all of society's agenda.

As a society, as public authorities, and as organisations, we must learn from our experiences. In addition to the pandemic, developments in the risk landscape have created increasingly complex incident types that highlight the need for high quality preparedness. The last few years have been an acute reminder of how crucial investment in preparedness and crisis management capacities are. Such investments are a prerequisite for our society to be able to respond appropriately when the next crisis hits.

Each organisation should read the National Risk Profile from their own perspective and carefully consider how best to handle the risks identified within their own sector, authority, or organisation. In doing so, preparedness actors should be decisive about their roles and continue working towards the development of concrete tools, plans, and activities that increase their organisation's resilience to future crises.

No sector or organisation, however, can handle a crisis alone. The COVID-19 pandemic serves as proof that crises do not respect traditional sector lines. It highlighted the importance of looking beyond one's own sector and working to ensure meaningful cross-sectoral dialogue, collaboration, and decision-making. These are the building blocks for society's collective preparedness and robustness.

Each incident type in this NRP can manifest as crises that extend far beyond what is manageable at a local level or with everyday resources. Only a few, however, can result in a national crisis as long-lasting, complex, and dynamic as the COVID-19 pandemic. Even so, they can all challenge society's robustness.

The next crisis is unknown. It is therefore vital to strengthen generic preparedness plans and crisis management capacities that can be used in any type of crisis.

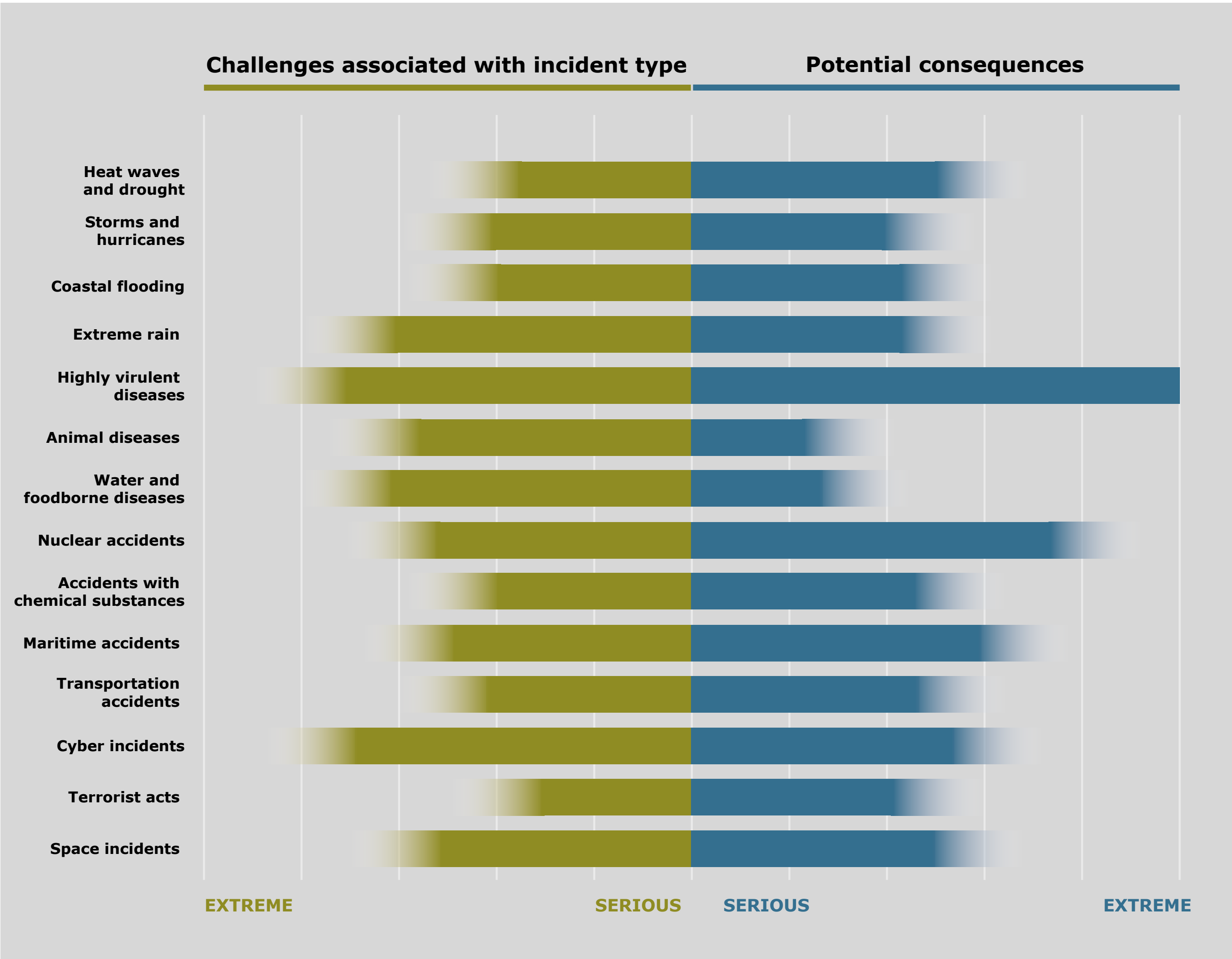
It is my sincere hope that NRP 2022 will contribute to raising awareness about the 14 incident types discussed. Public authorities and organisations can and should take the NRP as a reference point for their ongoing work with preparedness planning and crisis management. The better we know the risk landscape, the better we can prepare for and handle the future's crises – together.

Enjoy!
Laila Reenberg, Director

OVERVIEW

In NRP 2022, DEMA takes account of its ongoing work analysing the largest risks to Danish society. NRP has a medium-to-long-term perspective and outlines the incident types that DEMA assesses warrant the most attention within the next five years from a preparedness perspective.

First and foremost, the goal of NRP 2022 is to create awareness about known risks. The assessment of risks will always be context-dependent. NRP should therefore be used as inspiration for the reader to reflect on the discussed risks from their own perspective.



NRP 2022 is the result of a collaboration with a wide array of experts from sector-responsible authorities and other actors. DEMA, however, is solely responsible for the cumulative content of NRP 2022.

NRP 2022 is a continuation of the work put into NRP 2013 and NRP 2017, which dealt with 10 and 13 incident types, respectively. This time, DEMA presents 14 incident types and assesses – especially against the backdrop of the COVID-19 pandemic, accelerating changes to the climate, intensified cyber threats, and security political tensions – that NRP has never been more pertinent than it is today.

The figure on the previous page illustrates an overview of the risk profile. The figure lists the 14 incident types in the thematic order they appear in the report. This order is not an expression of a ranking. Rather, the figure aims to compare properties across the incident types.

With this relative comparison, keep in mind that the figure in part shows assessments of the 'realistic worst-case scenario' of a given incident type, and in part weights the average of the considerations from the underlying analysis. It is therefore important to emphasise that the figure presents intervals more so than specific values and that the assessment methods are primarily qualitative.

The figure's left side illustrates the extent of the challenges associated with the incident type's characteristics based on four parameters: duration, geographical extent, frequency, and indication/early warning.

The right side of the figure gives an overview of the incident types' potential direct or residual consequences in Denmark based on six parameters: life, health, environment, economy, property, and vital societal functions.

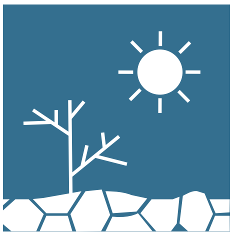
The 14 incident types are not presented in a prioritised order because within each incident type, there is a broad range of possible incidents with very different characteristics and potential consequences if and/or when they materialise. For example, the incident type 'maritime accidents' covers both accidents with passenger ships and with tankers. In the former case, the consequence assessment is primarily concerned with a potentially large number of deaths, whereas in the latter case, the primary concern is environmental consequences.

Each of the 14 chapters about incident types are structured identically in the following way:

- Text boxes with examples of severe incidents that have recently occurred in or affected Denmark;
- Sections regarding the incident type's characteristics, occurrence, consequences, trends, and examples;
- Figures illustrating the challenges associated with the incident type's characteristics and potential consequences; and
- Fictitious 'what if' scenarios with realistic worst-case incidents that encourage the reader to reflect further.

Compared to NRP 2017, an additional chapter features in NRP 2022 entitled 'Heat waves and drought'. The other 13 chapters have been edited and updated with new knowledge and examples, extended with new sections about trends, and supplemented with new 'what if' scenarios. We have also changed the graphic illustrations that accompany each chapter. A description of the report's methodological basis, risk identification, and selection process has been moved to the end of the report.

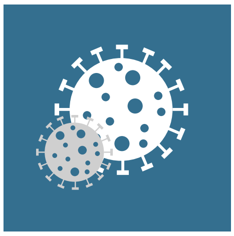
To sum up, we would like to highlight the following from the 100+ pages of analysis.



Extreme weather events have gotten an even larger presence in NRP 2022 with the new chapter on **heat waves and drought**. This addition was made based on experiences from the unusually warm and dry summer in 2018 and indications that similar or more severe situations will occur more frequently in Denmark as the climate continues to change. The Danish population is not used to – and buildings are not well equipped for – extremely high temperatures. Despite good possibilities for early warning, the potential for excess mortality and stress on the healthcare sector gives reason for concern in connection with heat waves. At the same time, higher risks of fire associated with droughts – especially the danger of many simultaneous wildfires – risks putting pressure on rescue services. Heat waves and droughts can also result in damage to plant and animal life, reduced harvest, and challenges to vital societal functions such as water supply, energy supply, road and rail traffic transportation, etc.

Storms and hurricanes, coastal flooding and **extreme rain** continue to feature prominently in NRP 2022. This is primarily because the material damages to property and critical infrastructure, disruptions to vital societal functions, and economic cost of restoration efforts associated with these incident types can be enormous (as seen in e.g., the December hurricane in 1999, the cloudburst over the Copenhagen Metropolitan area in 2011,

and the storms Allan and Bodil in 2013). The risk of death due to flooding is fortunately, however, lower in Denmark than in countries with more hilly terrain (e.g., the deadly floods after severe rainstorms in Germany, Holland, Belgium, and Luxembourg in July 2021). For the first time, NRP 2022 describes the risk of 'consecutive rainfall events' (CREs) – for example, when the consequences of a storm flood are exacerbated by already-high water levels in streams and groundwater due to previous long-term and/or frequent rain events. The impact of climate change on wind strength and the number of storms and hurricanes in Denmark's future is uncertain, but all else equal, the expected temperature and water level rises will translate into more episodes with coastal flooding, cloudburst, heavy rain, and CREs.



NRP 2017's chapter on **highly virulent diseases** explained that diseases with potential to develop into a pandemic occur frequently. In addition to new variants of influenza virus, NRP 2017 named coronavirus as a potential culprit for such a pandemic. Three years later, the pandemic of the respiratory disease COVID-19 caused by a coronavirus became a reality. The pandemic affected Denmark and the rest of the world with consequences far beyond the scope described in NRP 2017. Our assessment was highly accurate in terms of the described characteristics and occurrence, but it underestimated the consequences for life, health, economy, property, maintenance of vital societal functions, etc. Lockdowns and several other events in Denmark in 2020-2021 went far beyond our previous imagination. The 'consequence' section in NRP 2022 has therefore been heavily edited. The end of the COVID-19 pandemic is still uncertain, and the pandemic's consequences will be felt for a long time yet. It is only a matter of time before the next pandemic hits, and no one can say if it will be milder or more severe than COVID-19.

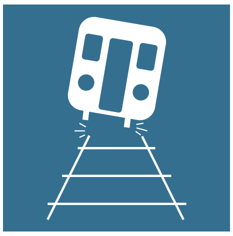
The risk associated with **animal diseases** is assessed to have increased since the publication of NRP 2017. Between 2020-2022, Denmark has experienced its two largest avian flu seasons, and the outbreak of COVID-19 on mink farms leading to the culling of all mink came with large human as well as economic effects. In the same period, Denmark experienced its first ever outbreak of the fish disease infectious hematopoietic necrosis (IHN), and African swine fever has inched even closer to Denmark. An outbreak of the African swine fever in Germany, just a few hundred kilometres from the Danish border, caused the Danish Veterinary and Food Administration to make an appeal in 2021 to everyone able to do so to hinder the spread of the disease due to the threat to animal health and the export of pork. Just a few cases on Danish soil would have potential to cause billions of DKK in economic losses due to lost export income and expenses associated with disease control.

The chapter on **water and foodborne diseases** is lightly revised in relation to NRP 2017, and the risk from the many different diseases is relatively constant. Among the largest individual incidents in recent years was an outbreak of clostridium perfringens that affected 268 persons in 2019. In addition to serious consequences for life and health, the risk is characterised by the fact that per definition, each incident of this type with be without warning. Such incidents can be very protracted, and it can often be difficult to trace the source of the outbreak. Whereas drinking water contamination incidents are typically very localised due to decentralised supply structures, foodborne diseases can occur in groups of consumers everywhere where the contaminated product is distributed and used.

Among NRP 2022's four chapters on accidents, the chapter on **nuclear accidents** has been expanded with relevant information and updated knowledge compared to NRP 2017. Among the 14 incident types in NRP 2022, 'nuclear accidents' tops the list on the environmental and property consequence parameters and ranks second highest on the economy parameter (just after highly virulent diseases). With unfortunate wind and precipitation conditions, an accident at a European nuclear power plant or a nuclear powered vessel in Danish waters could result in long-lasting and geographically widespread radioactive contamination of large areas, buildings, and infrastructure. The likelihood that humans would suffer acute radiation poisoning in Denmark is assessed to be very low, but nonetheless contributes to high levels of uncertainty in terms of psychological consequences and reactions among the population.

The chapter on **accidents with chemical substances** has not been heavily edited, nor have new examples of the incident type occurred since NRP 2017. Catastrophic industrial accidents and transportation accidents with chemical substances are extremely rare in Denmark, and this is not expected to change in light of the trends mentioned in the chapter. Incidents such as the firework explosion accident in Seest (2004) and the transportation accidents with acrylonitrile in Næstved (1992) still serve as reminders of how severe this incident type's risks for life, health, and the environment can be.

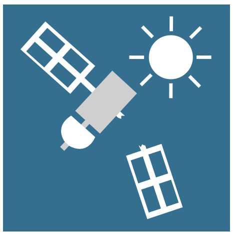
The chapter on **maritime accidents** discusses the risk associated with cruise ship tourism. Before COVID-19 paused the trend in 2020-2021, the number of cruise ships that sailed through Danish waters and anchored in Danish harbours had nearly doubled over the course of 10 years. At the same time, cruise ships became larger to be able to accommodate thousands of passengers and crewmembers. A collision or fire on a cruise ship would therefore result in a much larger maritime catastrophe than previously seen in Denmark. Congruently, all else constant, an increase in the number and size of tankers in Danish waters could increase the risk for contamination accidents of previously unseen extents.



"What if a westward-bound intercity train were to be hit by iron girders protruding from an oncoming freight train […] The left-hand side of the intercity train is torn apart in the accident." This was the 'what if' scenario described in the chapter on **transportation accidents** in NRP 2017. On 2 January 2019, something tragically similar happened on the Storebælt Bridge when an intercity train was hit by a loose semi-trailer from an oncoming freight train. The trailer pushed up on the left side of the front train car, where eight passengers died and 18 were injured. A description of the accident is the introduction to the chapter in NRP 2022 and serves as a reminder of how quickly transportation accidents can occur. The absence of similarly large train traffic accidents in the previous 30 years in Denmark – and the absence of large plane crashes or mass casualty accidents on roads, bridges, and in tunnels – however, means that for now, the incident type's placement in the risk profile has not changed.

Against the backdrop of current threat assessments, the chapter on **cyber incidents** in NRP 2022 has been heavily revised since 2017. This incident type is now placed as one of the most severe in terms of consequences. In recent years, an accelerating increase in the number and severity of cyber-attacks has been observed, and the threat posed to Danish authorities and companies from cyber crime and cyberespionage is currently assessed to be very high. There is an unsettling and increasing trend of cyber-attacks in other countries, including recent examples of destructive cyber-attacks on critical infrastructure. The threat from such targeted attacks in Denmark is currently assessed to be low, but is nonetheless necessary to consider due to the potential indirect consequences of Danish authorities and companies being coincidentally affected as Mærsk was by the NotPetya attack that started in Ukraine in 2017. Trends that can affect the incident type's risk in a medium-to-long perspective include the rolling out of the 5G network, increased coupling of devices to the internet, integration of critical IT systems, outsourcing of IT infrastructure, data centres, and administrative tasks to sub suppliers, potential uses for artificial intelligence, and developments in quantum computing.

The chapter on **terrorist acts** has new text from the newest "Assessment of the Terror Threat to Denmark" (VTD) by the Danish Security and Intelligence Service (PET). The chapter reflects that the threat continues to be serious and primarily stems from militant Islamism. It further explains that terrorist attacks with easily accessible weapons (e.g., knives, batons, arson instruments, or vehicles), firearms, or homemade bombs are still the most likely forms of attack in Denmark. Since NRP is published with longer intervals (every 4-5 years) than VTD, readers are encouraged to refer to the current VTD on PET's website for the most current threat assessments. The chapter has been expanded with DEMA's assessments of various potential consequences, including residual efforts that can place significant pressure on police, the healthcare sector, and rescue services as well as consequences for society in a more general sense.



The report's final chapter has a new name – from 'space weather' in NRP 2017 to '**space incidents'** in NRP 2022. The chapter now includes incidents caused by solar flares (space weather) as well as unexpected collisions between the fast-growing amount of manmade space objects such as satellites, space probes, space vehicles, and 'space junk' (e.g., decommissioned satellites, pieces of satellites, fragments from rockets). Both types of incidents can put satellites completely or partially out of commission, and in the worst-case, they can pose a general risk for modern human activity on Earth, including in Denmark. This is because of our dependence on satellite-based infrastructure for navigation, accurate synchronisation of time, communication, financial transactions, and an endless list of other digital processes.

PURPOSE, TARGET AUDIENCE, AND POTENTIAL USE

The primary purpose of NRP 2022 is to generate awareness about known risks. Any assessment of risk is context-dependent. NRP is therefore also intended to help readers reflect on the mentioned risks from their own perspective.

NRP 2022 has several target audiences: top executives and preparedness planners in central, regional, and municipal authorities, public and private companies with responsibility for vital societal functions, the cross-sectoral fora of Denmark's national crisis management system, emergency management actors in the volunteer sector, teachers and students within emergency management-related education tracks, and the general population.

DEMA recommends that authorities and other organisations use NRP as a starting point for their own work with preparedness, security, and crisis management capacity regardless of the fact that a concrete crisis' character, longevity, scope, and consequences are rarely known beforehand. NRP can be used as inspiration for:

- Creating or updating an organisation's own risk profile. The organisation's risk profile should include its own selection of risks assessed to be most relevant to the organisation's area of responsibility. The risk profile does not need to be similar to NRP 2022 in format, method, or scope. Alternative titles for such risk profiles could be: risk catalogue, scenario bank, risk analysis, risk assessment, risk and vulnerability analysis, or similar. An organisation-specific risk profile can be an important part of an organisation's planning base for comprehensive preparedness planning. Increased understanding of the risks that can threaten an organisation strengthens the basis upon which to assess the need for more preventive and mitigating efforts.

- Creating or updating preparedness plans as a supporting element of the organisation's crisis management. When an organisation has a risk profile, it also paints a picture of what the organisation should be aware of in its general preparedness plan and what should be described in associated sub-plans, contingency plans, and instructions/action cards. Seeing across risks paints a clearer picture of what to describe and plan for in the organisation's set of plans.

- Formulating strategic goals or points to note for specific incident types for use in internal or cross-sectoral crisis staffs. These goals or points are then ready when and if a crisis occurs. This can be a useful tool in the time-sensitive beginning phase of a crisis. These goals and points, however, should naturally be adapted to the concrete incident(s) and response(s).

- Working with continuity planning and increasing the robustness of the organisation's segments that can be affected by crises (e.g., IT or logistics and supply chains).

- Planning exercises, for example with the help of the historical examples and fictitious 'what if' scenarios presented in each chapter of this NRP. If necessary, the scenarios can be scaled down to less serious incidents based on local conditions while still maintaining a scenario that could be catastrophic for the local society or individual organisations.

- Education and training activities to build up crisis management skills, exchange emergency management knowledge and experiences, etc.

- Preparation of teaching programs.

The NRP should also be seen in connection with thematic national risk and threat assessments published by other authorities, such as:

- "Assessment of the Terror Threat to Denmark" from the Centre for Terror Analysis (CTA) in the Danish Security and Intelligence Service (PET).

- ”Assessment of the Espionage Threat to Denmark" from the Danish Defence Intelligence Service (FE).

- "Intelligence Risk Assessment" from the Danish Defence Intelligence Service (FE).

- "The Cyber Threat Against Denmark" from the Centre for Cyber Security (CFCS) in FE.

- "The Biological Threat Assessment – Risks and Prevention" from the Centre for Biosecurity and Biopreparedness (CBB) in Statens Serum Institut (SSI).

DELIMITATION

The 14 incident types in NRP 2022 are far from an exhaustive list of risks facing Denmark. Since this is a national risk profile, the selection process is based on the following criteria:

Each incident type must have potential to manifest as incidents, understood as a delimited sequence of events that has significant and immediate consequences for society and requires an acute need for coordination and crisis management within Denmark's borders at a level that is not merely local.

Incident types that can be handled within the framework of daily emergency management efforts and that occur relatively frequently or incident types that only affect limited parts of Danish society are therefore not included. These types of incidents can still be relevant to include in regional, local, or organisational risk profiles (e.g., complex but isolated building fires, which are a permanent element of municipal rescue services' risk-based dimensioning).

Incident types that are unlikely to occur in or near Denmark (e.g., large earthquakes) are also not included despite the fact that such incidents would have consequences for Danes and Danish interests overseas. Diplomatic and security policy crises, e.g., the evacuation of persons to Denmark after acts of war overseas, are also not included in NRP.

The same is true for so-called 'megatrends' and 'risk drivers' of more global character and/or with more protracted timelines (e.g., climate change, biodiversity loss, scarcity of natural resources, population growth, urbanisation, irregular migration, technological development). Such phenomena can influence the occurrence of incidents in Denmark – also within NRP 2022's five-year perspective – and could very well cause tomorrow's most challenging crises. Even so, these phenomena are not themselves incident types.

Finally, potentially existential risks for humankind (e.g., extinction due to nuclear war, massive asteroid hit, or eruption of a super volcano) are not included.

In selecting the 14 incident types, attention has been given to incident types where there is sufficient information such that the underlying analysis of characteristics, occurrence, possible consequences, and trends is considered reliable. The likelihood for specific incidents within each incident type varies so much that NRP 2022 does not venture a guess. Of course, the selection of these risks is also not a guarantee that unforeseen large incidents of other types will not occur within the report's five-year perspective.

To conclude, it is important to emphasise that the focus throughout NRP is primarily on risk. NRP 2022 is not a national capacity analysis, and its goal is not to create an overview of Denmark's collective resources or ability to combat and handle the 14 incident types. Thus, specific examples of robustness or vulnerabilities are not covered in NRP 2022, and concrete needs for preventive and mitigating initiatives are not identified. The responsibility to create such an analysis follows the principle of sector responsibility and rests, in accordance with Emergency Management Act §§ 24 and 25, with the individual ministers, regional councils, and local councils. We therefore encourage readers – especially those at the strategic decision-making level – to read the report while drawing on their own reflections regarding their resilience to incident types that occur in Denmark.

More information about preparedness planning and crisis management can be found at brs.dk/en. Interested readers are welcome to write to brs@brs.dk insofar as they may desire more information.

HEAT WAVES AND DROUGHT

Summer 2018

From May to August 2018, Denmark experienced local, regional, and nation-wide heat waves and the longest drought ever measured by the Danish Meteorological Institute (DMI). There were a record number of dehydration- and heat stroke-related hospital admissions. The heat was estimated to have caused an excess mortality of 250, primarily among elderly individuals. There were 2,000 wildfires, leading to extraordinarily busy days for rescue services. In the agricultural sector, grain harvest yields were historically low, and the water supply, energy, and transport sectors also faced challenges. These all caused significant economic loss and put intense pressure on authorities' resources. Consequences for the environment (i.e., for plant and animal life) were extensive, including but not limited to widespread fish death.


MASKINSTATION I/S

CHARACTERISTICS

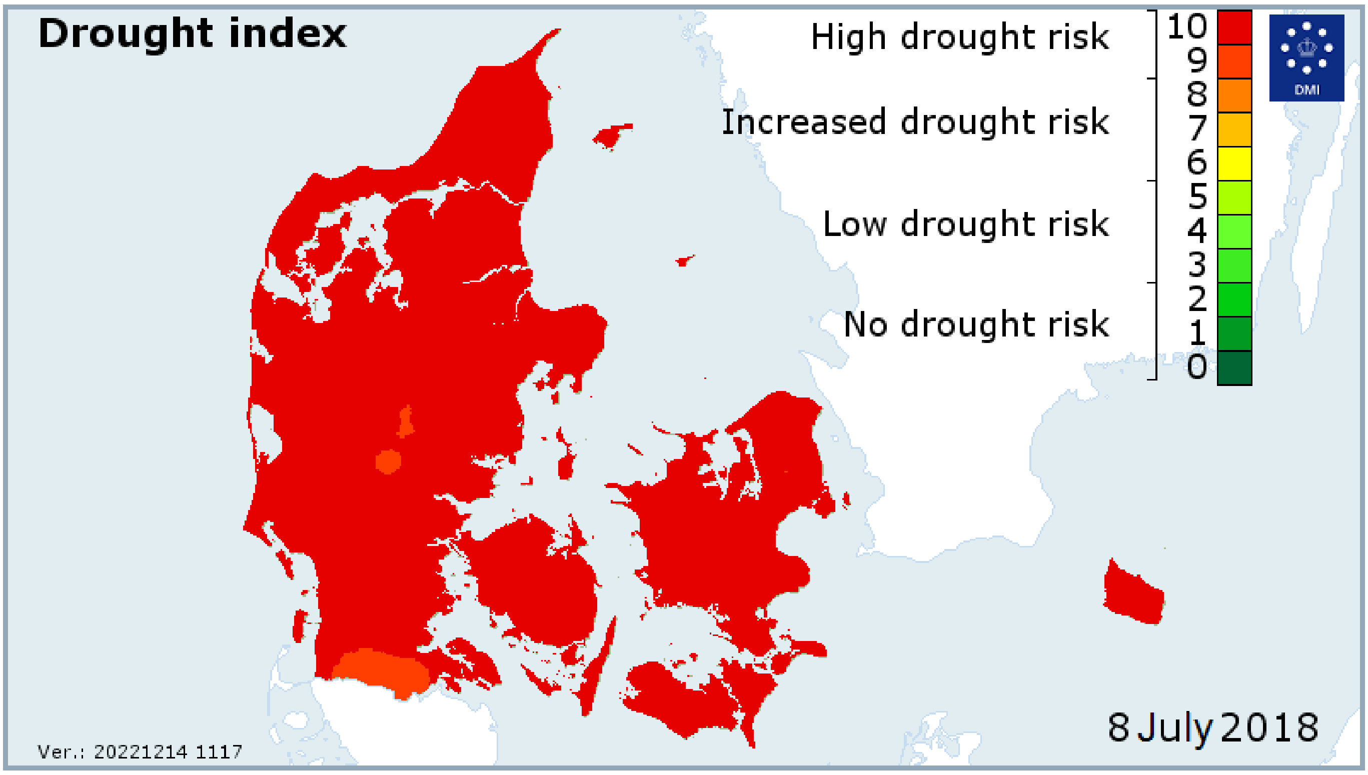
Heat waves and droughts occur in combination with various meteorological conditions. Static weather patterns with stagnant high and low pressure, weak wind, significant solar radiation, sparse precipitation, and significant evaporation are important contributors to heat waves and droughts.

In a meteorological context and as a warning criteria, DMI defines a heat wave as a period where the highest registered temperatures measured exceeds 28 ºC over three consecutive days. The same definition applies to the term 'warm waves', but with a temperature limit of 25 ºC instead.

Heat waves therefore last at least three days. So long as the average temperature over those days exceeds 28 ºC, the heat wave is not interrupted by temporary lower temperatures during any given day. Daytime temperatures can also be significantly higher. The heat record in Denmark of 36.4 ºC was measured on 10 August 1975. On that day, the temperature was between 30 and 36 ºC across almost the entirety of the country. This was the warmest summer day ever measured by DMI. High daytime temperatures are often accompanied by so-called tropical nights where the temperature does not fall below 20 ºC at any point.

Heat waves can be nation-wide or regional (i.e., occur in one of the eight regions that DMI divides Denmark into) when 50 per cent or more of the country's or region's land area fulfil the criteria, respectively. It is usually possible to issue a warning for heat waves before they begin. Typically, DMI creates a five-day forecast for dangerous weather conditions that is later replaced by a warning.

DMI does not have an official meteorological definition of drought, but their website describes the phenomenon as a "long-lasting and abnormal lack of water due to lack of precipitation". Since



2005, DMI has maintained a national drought index with a scale from 0 to 10 and uses the value 9 as a baseline for news articles about drought.

The drought index is based on a water balance model that estimates the amount of water in aquifers available to plants across Denmark. The calculations are based on three parameters: access to water (precipitation), evaporation from soil and plants, and seepage from underlying ground layers.

In addition to 'meteorological drought', in some contexts (e.g., agriculture and drinking water supply), other descriptions of drought are used such as 'agricultural drought' (when there is too little humidity for crops in a certain area to develop normally for an extended period of time) and 'hydrological drought' (when the volume of water reserves in groundwater, lakes, and streams fall under the statistical average for an extended period of time).

OCCURRENCE

Heat waves are relatively seldom in Denmark as compared with more southern parts of Europe. Often, several years go by between nation-wide droughts. Over the last 16 years, there have been nation-wide heat waves in 2006, 2008, 2014, 2018, 2019, and 2020.

Heat waves most often occur during late summer when there is stable high pressure to the east of Denmark and warm air flows up from the European continent. Most heat waves are short-lived (typically 3-4 days), but they can occur in quick succession during a long warm summer. The longest continuous nation-wide heat wave lasted eight days from 4-11 August 1975. The longest continuous local/regional heat wave lasted 13 days in Copenhagen from 21 July to 2 August 1994.

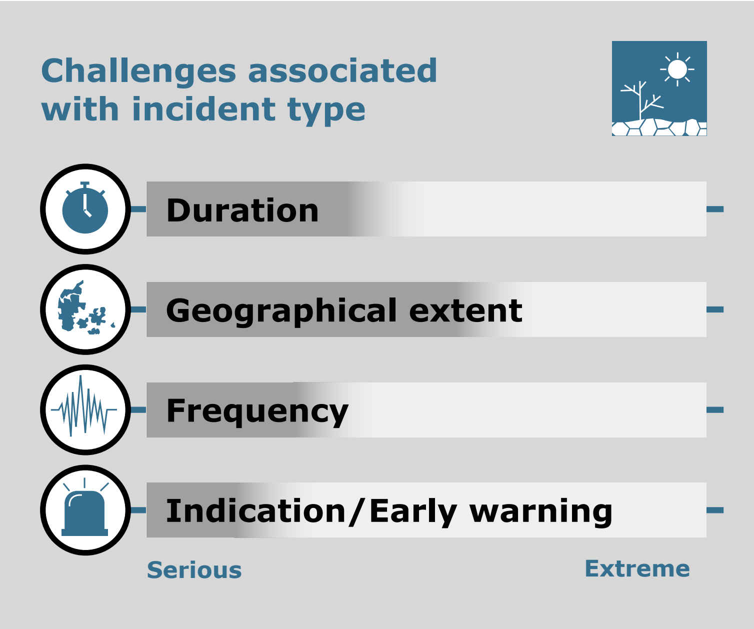
Droughts are also relatively seldom in Denmark, but in contrast to heat waves, they can last for months. The longest continuous nation-wide drought in Danish weather history lasted from the middle of May to the middle of August 2018, beating the previous record from the summer of 1992.

Although the causes of heat waves and drought are normal meteorological conditions, new climate research indicates that global warming has already increased the occurrence of heat waves in most land areas, including Denmark. There is a high level of uncertainty regarding droughts. In Europe, the only areas certain to experience more frequent droughts are those surrounding the Mediterranean Sea.

DMI's climatologists are not able to conclude anything based on data from a – seen from a climate perspective – relatively short period (i.e., since 2005, when the national drought index was established). In 2018-2020, there was an extraordinarily high number of days with a drought index value of 9 or more. Even so, this data set is far too sparse to document an increased incidence of droughts. The numbers for 2005-2020, for example, vary greatly from year to year.

# of days with drought index value >= 9			
2005	**0**	2013	**13**
2006	**16**	2014	**0**
2007	**0**	2015	**0**
2008	**29**	2016	**0**
2009	**2**	2017	**0**
2010	**0**	2018	**58**
2011	**0**	2019	**34**
2012	**0**	2020	**49**

It is notable that heat waves and droughts can mutually influence likelihood, frequency, and duration. If there is a drought during a heat wave, the temperature naturally rises further since less energy is used to evaporate water from the land's surface. Accordingly, high air temperatures during a heat wave can increase



evaporation, which – depending on the amount of precipitation – can exacerbate the conditions for a drought.

CONSEQUENCES

Heat waves can result in more summertime illnesses and deaths than normal due to dehydration, heat stroke, and heat syncope. Symptoms can appear slowly and for some, it is difficult to notice them before critically overheating. At-risk groups include elderly individuals, young children, obese individuals, and individuals with certain chronic health conditions, physical handicaps, or users of medicines that cannot withstand high temperatures. Individuals who drink alcohol, exercise rigorously, or conduct physically demanding labour in extreme heat are also vulnerable.

An especially vulnerable group is elderly individuals with dementia who require reminders and assistance to consume necessary amounts of fluids and salt. Heat waves can thereby also increase the work burden on home care workers, assisted living homes, nursing homes, hospitals, etc. Education, training, and increased awareness of correct storage of medicine are necessary to prevent and treat heat-related illnesses.

The risk for life and health are the largest in the case of outdoor recreation and in buildings, rooms, or vehicles without air conditioning, effective ventilation, or sun protection. The risk can be larger in densely populated areas with many high buildings, concrete, and asphalt surfaces, where temperatures can be multiple degrees higher than the surrounding land. This is because black asphalt, grey concrete, and black roofs absorb the sun's light and warmth and retain the heat. This so-called 'urban heat island' effect is exacerbated by heat emissions and air pollution from traffic, heating, and industrial activities. High temperatures, sunlight, and stagnant air can worsen air contamination, thereby causing excess mortality among those with respiratory illnesses.

Drought generally leads to a higher risk of fire, and especially wildfires (i.e., fire in all types of vegetation). This is primarily because the amount of flammable material on the forest floor and in wild nature increases during droughts, especially if the weather is warm, dry, and windy, as wind both helps to dry out vegetation and contributes to quicker fire spread. Human activities and behaviour are also significant. In sunny and dry weather, the number of people visiting natural areas tends to increase. This includes overnight camping where cookware and grills are used and torches are used to burn weeds while tending gardens. During the harvest season, an increase in the number of field fires also tend to increase (e.g., ignited by friction from the harvester or straw baler).

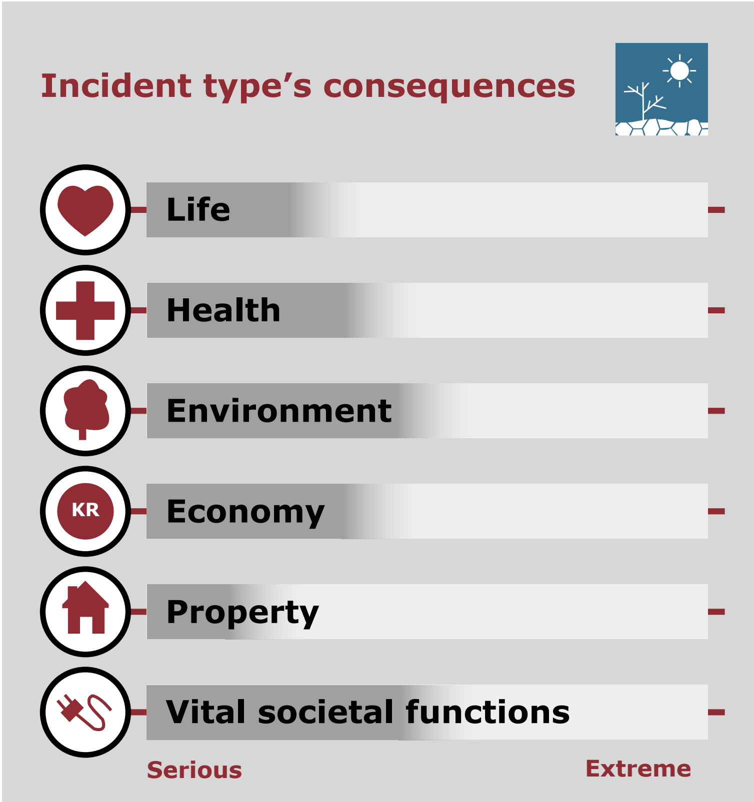
Most wildfires in Denmark are relatively small, but if the number of fires is sufficiently high during a drought, the work burden can overwhelm rescue services. At the same time, the risk of large fires increases during a drought. These wildfires could be, for example, a dune fire near a summerhouse area or a treetop fire in a forest where the fire spreads quickly from treetop to treetop. Another especially serious type is underground fires in moorlands and marshes, which have potential to last for weeks or months. By definition, such wildfires are more resource-intensive to extinguish and can result in large economic and environmental loss depending on if an affected area is designated for farming, forests, or recreation. The risk for loss of human life is, however, much lower in Denmark than in parts of southern Europe, where densely populated areas are in close proximity to wild nature and/or in hard-to-access areas, making evacuation and rescue more challenging.

For agriculture, drought during the summer growing season can drastically reduce harvest outputs and cost billions in lost revenue, leaving many farmers vulnerable to bankruptcy. If there is a simultaneous heat wave, the agricultural sector can be especially overwhelmed if authorities' regulations regarding animal welfare cause restrictions on the import and export of live animals. Problems with regards to slaughtering of animals and cooling capacity can also arise within food production.

Water supplies can face significant challenges during heat waves and droughts, when the demand for water generally increases. Water companies can be forced to reduce the pressure in the pipe framework and municipalities may issue partial or general watering bans.

Heat waves can cause road traffic accidents and traffic jams. Extreme heat can also cause problems for heavy vehicles when heat causes asphalt's binding agent, bitumen, to weaken, thereby making roads' coatings too soft. The Danish Road Directorate can implement a curfew for heavy special transport on certain stretches of road or throughout the entire country during the summer (i.e., from 1 May to 1 October).

On train tracks, high temperatures can cause iron rails to extend, necessitating a reduction in the speed and number of trains on the tracks. Travel plans can therefore be disrupted and transport capacity reduced. Train traffic also risks being completely stopped if overhead contact lines become overheated and thus less effective.



Many components in the electricity sector can be affected by high temperatures. High temperatures can cause increased wear and tear on cables, leading to lower transmission capacity, overwhelmed systems, and power outages. This can affect many areas of society highly dependent on electricity and critical installations that have a special need for cooling. During heat waves, cooling and freezing needs throughout society can also place pressure on providers.

Finally, heat waves and droughts can have negative consequences for plant and animal life (e.g., increase in tree death and fish death due to high water temperatures, reduced aeration and oxygenation in lakes and streams). In some cases, the affected nature can take several years to restore.

TRENDS

Danish summer weather will continue to vary significantly from year to year, but there is wide consensus among climate researchers that summers will become warmer as global warming continues. This also means that there is a risk for more frequent, warmer, and more protracted heat waves in Denmark.

This trend was further confirmed in 2020 and 2021 when DMI's Climate Atlas was updated with more information about extreme temperatures and specialised knowledge about wind conditions, solar radiation, and evaporation. Data from 2021 indicate that if greenhouse gas emissions remain the same, at the end of the decade, Denmark can expect:

"The number of heat wave days to increase from 2 to 9 days per year. Warm waves can become very normal during the summer. We can expect approximately 30 days with warm waves in the future, compared to just 9 days today."

With such warming, Danish summers will become more reminiscent of those of southern Europe with longer drought periods and more frequent short but intense downpours. When DMI's Climate Atlas was updated in June 2020 with new knowledge about future torrential rain, the forecasts for the summer season were the most shocking. DMI's best guess for the end of the century – based on the assumption that greenhouse gas emissions remain as they are – is that the aggregate amount of precipitation will be relatively unchanged during the summer, but that there will be 7 per cent more dry days (with less than 1 mm of precipitation per 24 hours) and the longest consecutive dry period will be increased by 10 per cent (approximately 36 hours longer).

The 2020 and 2021 updates to the Climate Atlas also highlighted that the growing season (i.e., where soil is most fertile in Denmark) will become almost three months longer than it is today by the end of the century. Conversely, there will be more dry periods and rain will be increasingly torrential. A 5 per cent increase in potential evaporation from the ground's surface is expected alongside rises in temperature, thus contributing to the risk for drought.

All other things constant, more frequent, long-lasting, and warm/heat waves and droughts can exacerbate each of the consequences above. From a health perspective, climate change can also be worrying, especially when seen in combination with demographic trends such as population ageing (since the elderly are especially vulnerable to high temperatures) and urbanisation (since heat waves are often more intense in cities due to the mentioned 'urban heat island' effect). Although Denmark has only experienced a relatively limited number of heat-related deaths, it is worth noting that heat waves globally and in Europe claim just as many lives as storms, floods, and other natural disasters. Among the most extreme was the 2003 heat wave in southern Europe, which is estimated to have cost more than 40,000 lives.

With respect to wildfires, climate change should be considered alongside with changes in wildlife care. Firstly, in the last 50 years, Denmark has become greener with a larger land area of forest that extends towards coasts. This trend increases the amount of flammable material on forest floors and wild nature during dry periods. Secondly, the 2016 Nature Act (*Naturpakke*) mandated that approximately 20 per cent of state-owned forests are to be 'untouched', and trends indicate that this share will become greater, both out of respect for biodiversity and in order to improve outdoor recreational opportunities. A larger share of dead trees benefits biodiversity, but also increases the risk of fire.

Finally, in forest management, there is a trend toward less maintenance of roads, ditches, and fire belts in order to foster biodiversity, which can both increase the risk of fire and hinder future access for fire extinguishing vehicles. Together, these consequences can lead to dramatic increases in the number of natural fires during Danish summers as in 2018.

Information about the risk of fire in nature can be found on brandfare.dk, which is managed by DEMA, Danske Beredskaber, and KL. Brandfare.dk provides a fire risk index created in collaboration with DMI, a map with current fire bans, and advice on how to avoid fires in nature. Brandfare.dk can also inform decisions about controlled burning, as nature management might need to be planned differently during extreme heat and dry summers.

EXAMPLES

The summer of 2018 was – tied at first place with the summer of 1997 – the warmest summer in Denmark since nation-wide temperature measurement started in 1874. There were widespread local, regional, and national warm and heat waves, including an especially intense heat wave in Copenhagen from 25 July to 4 August with a high daytime temperature of approximately 32 ºC. With less than a sixth of the normal precipitation, it was also one of the driest summers since 2013. From the middle of May to the beginning of August, the longest continuous drought in Danish weather history was recorded.

The health-related consequences cannot be aggregated, but according to an analysis by Statens Serum Institut, the heat caused an excess mortality of 250 over the course of the summer, primarily in weeks 30 and 31. These people were primarily elderly. Across the healthcare, caregiving, and social sectors, the work burden increased due to efforts to prevent and treat dehydration and heat stroke among high-risk groups. Hospitals reported record-breaking numbers of admissions. At Aarhus University Hospital, temperatures around 30 ºC led to discomfort among patients and employees because an energy-efficient ventilation device was installed during the building's construction instead of air conditioning.

There were 2,091 1-1-2 calls regarding wildfires across the country from May to July – three times as many as the average of the previous five years and in July, six times as many as the previous July. 95 per cent of these calls were assessed to be actual alarms, and the number of natural fires is therefore estimated to have been 1,990 in the period from May to July. The drought also led a wave of fire bans. From 4 July to 13 August, there were fire bans in all of Denmark's municipalities.

Individual fires stood out in terms of size and duration. Among the exceptional fires were the fire at Randbøl Hede and Lundgård Plantage near Billund in July 2018. The response to both fires required about 100 firefighters. At Randbøl Hede, approximately 7 km^2 burned during the course of one day. At Lundgård Plantage, only about 1 km^2 of forest was burned, but the fire still required a response on difficult-to-access terrain in order to prevent the fire from reaching the treetops and becoming much worse. The response was complicated by a persistent temperature of 32 ºC for more than four days.

A third significant example was a field and marsh fire in Dokkedal in northern Jutland. The fire lasted 120 hours. The fire spread quickly, first as a field fire, then spreading to the layer of sphagnum moss and threatening to spread to Lille Vildmose and Tofte Skov, one of Denmark's largest connected natural forests. In addition to thermal cameras on drones and an all-terrain airport crash tender from Air Station Aalborg, specially made hollow water spikes were used in order to pump water into underground pockets of fire. It took approximately 75 firefighters to extinguish the fire, and the local operational staff in northern Jutland's police was activated.

Most of the other reported wildfires were relatively small, but the number and wide geographical and temporal distribution challenged rescue services' capacity. During some periods, rescue services conducted more than 20 responses per day. The additional stress on personnel and material damages caused extraordinary costs and temporarily put training and legally mandated oversight on hold. In addition to national tasks, that summer, Denmark provided international assistance to forest firefighting efforts in Sweden by dispatching 215 persons. The assistance effort was led by DEMA with participants from several municipal rescue services.

Coastal rescue services also had a busy summer in 2018 as extraordinarily large numbers of people sought to cool off at the beach. TrygFondens coastal rescue services conducted 88,355 responses in 2018 as compared to about 50,000 in 2017's coastal rescue season. Most were for educational purposes, but 52 rescue actions were life-saving.

In the agricultural industry, harvest yields were significantly reduced since the drought was at its worst during the growing season from May to July. At one point, 15 bankruptcies were reported per week. The wheat harvest fell to about 6.5 million tonnes, 25 per cent less than the average for the preceding five years, and were the smallest since 1983. Denmark had experienced a drought of the same scale since 1992, when agricultural yield fell by 23 per cent.

Water supply companies also encountered problems trying to meet extraordinarily high consumption levels. Several water companies had to get water from neighbouring companies and discouraged consumers from watering their gardens and/or issued partial or general watering bans. The capital region's water supply company (HOFOR) issued a ban on watering public spaces in the region's eight municipalities in July 2018 due to water consumption being 15-20 per cent higher than normal.

In the agricultural sector, drilling for water in fields occurred 24/7 and exceeded the municipal allowances. Meanwhile, municipalities were overwhelmed by applications for short-term licences for further use of such drilling and for retrieving water from open streams. The Danish Society for Nature has since described 2018 as a "nightmare example" in regards to the handling of water from streams and groundwater in the agricultural industry. Built-up nutrients in streams and groundwater were released into freshwater in strong pulses when a strong downpour of rain ended the drought. This contributed to a partial ecological collapse of Filsø (Jutland's second largest lake), where fish with a combined weight of 80 tonnes died as a result of massive loss of oxygen.

Energy supply security was not pressured, but in the energy sector, the heat triggered an unanticipated energy need for cooling. Danish wind turbines could not keep up and solar panels could not compensate for the missing wind. The energy demand was therefore met by imported energy, causing energy prices to rise by 66 per cent in July as compared to the previous year. Energy could not be imported from Denmark's Scandinavian neighbours since they were also affected by the drought: Norwegian hydropower plants had issues adapting to the lack of water in aquifers, and Swedish atomic power plants reduced their operation since the ocean water was too warm to cool the reactors. Instead, Denmark's import of energy from German coal plants more than doubled.

Finally, in Funen and Jutland, houses were damaged by fissures as a result of the clay soil cracking due to lack of water during the summer months.

What if...

... in early May, a stagnant high pressure comes over Scandinavia and traps warm, dry weather in Denmark until the end of August. The period comes with an unprecedented number of heat waves, daytime temperatures of 32-37 ºC, and many tropical nights. This causes 1,000 heat-related deaths and places immense pressure on personnel in the healthcare, social, and caregiving sectors, especially during the warmest weeks, which coincide with vacation periods. An additional 30 deaths are attributed to the heat, partially due to traffic accidents because of soft road surfaces and partially because of drowning accidents in the ocean and lakes. Despite quick implementation of comprehensive fire bans, 4,000 natural fires occur, 10 of which are especially destructive dune fires, fires in spruce and fir tree plantations, and underground peat and marsh fires. In several cases, summerhouse communities and tourist attractions are evacuated due to fire and smoke spread. In one case, 12 tourists are trapped and die in a fire in a dense state-owned forest.

There is a drought from May to August, and the water supply sector is hard hit. The agricultural sector experiences a 50 per cent decrease in productive land area, causing hundreds of bankruptcies and an expected loss of almost 10 billion DKK. This cost puts pressure on the government to implement an economic stimulus package far larger than the one from 2018, which totaled 380 million DKK. In nature, there is widespread fish death, and thousands of trees are so significantly weakened by the drought that they will not be able to survive this year's fall storms. In public transport, discomfort due to heat is widespread and train operation is drastically reduced. Many older refrigerators and freezers temporarily shut off, and companies that deliver and service cooling systems cannot keep up with increased demand. The effects of the heat on the energy sector causes local power outages that occasionally affect critical infrastructure that requires cooling. Widespread fissures on buildings, especially older houses, occur.

STORMS AND HURRICANES

The December hurricane, 1999

On 3 December 1999, most of Denmark was hit by the strongest hurricane in the preceding 150 years of meteorological measurement. With an average wind speed of 40 metres per second (m/s) and wind gusts of up to 50 m/s, the hurricane had a destructive effect on everything in its path. The hurricane caused seven deaths and left more than 800 injured and in need of medical attention. Close to four million cubic metres of timber were lost in forests due to the storm, and at Lindø Wharf near Odense, a 114-metre-high gantry crane fell onto a container ship holding at the dock. About 400,000 households were without power for varying amounts of time. The material costs were estimated to be approximately 13 billion DKK, making the hurricane the most economically expensive extreme weather event in Denmark to date.

CHARACTERISTICS

Storms and hurricanes are caused by large differences in pressure and temperature between the atmosphere's low and high pressure systems. When Denmark is hit by a storm or hurricane, it usually happens on the polar front, where a barrier is created between cold, polar air from the north and warm, humid air from the south. Where the cold and warm air masses meet, there is a front. A disruption (vortex) to this front can lead to a low pressure system that can quickly intensify and turn into a large, cohesive, rotating system of clouds. The larger the difference in temperature between the cold and warm air, the more extreme the development of the low pressure system and resulting wind strengths are.

When the average wind speed exceeds 32.6 m/s (equivalent to 117 km/h), the event is classified as a hurricane. Average wind speeds between 24.5 and 32.6 m/s are categorised as storms.

During strong storms, gusts of hurricane strength wind can occur without the storm then being defined as a hurricane. Regardless of the category, isolated wind gusts can therefore have the same destructive potential during a storm or hurricane.

If more than 30 per cent of Denmark is affected, meteorologists describe the event as a national storm/hurricane. A regional storm or hurricane covers 10-30 per cent of the country.

OCCURRENCE

DMI continuously updates the 'Storm list for Denmark' where all Danish storms and hurricanes since 1981 are classified according to strength and geographic scope. In 2013, DMI began naming individual strong storms and hurricanes to make them easier to distinguish from one another.

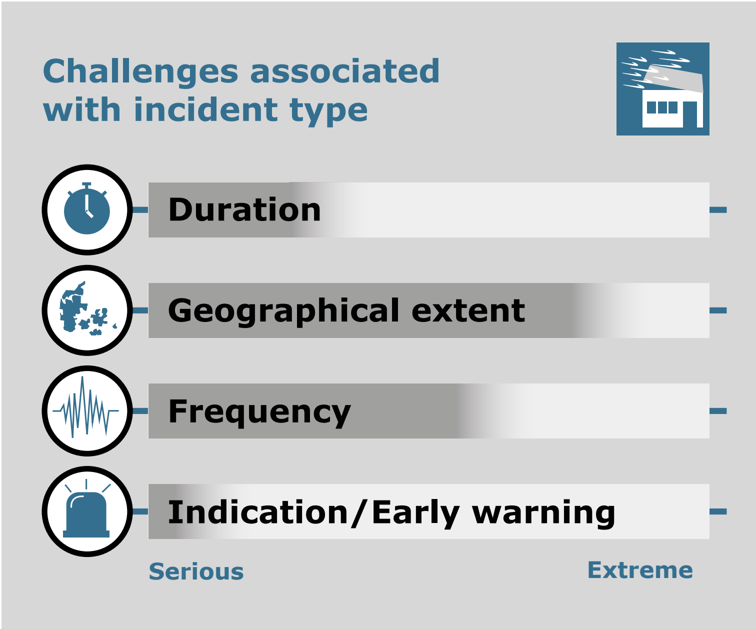
In Denmark, statistics on storms and hurricanes are based on data dating back to 1873. In the past 100 years, only five actual hurricanes have been registered in Denmark, but there have been several strong storms with hurricane-speed wind gusts. Strong and destructive wind is thus frequent in Denmark.

The conditions for such storms are almost exclusively present during autumn and winter months. Between 1950 and 2021, DMI registered 46 storms and hurricanes in Denmark. 45 of these occurred between September and February.

There can be periods of several years where Denmark experiences no storms or hurricanes, like between January 2005 and November 2011. Prior to the storm of June of 2021, no storms had been registered since December of 2016 (the 'Urd' storm). Since then, there have been multiple storm warnings. These warnings, however, were subsequently classified as strong gales[1] that had potential to develop hurricane-strength wind gusts.

Nonetheless, storms have occurred in quick succession in Denmark before. It is not unlikely for storms and hurricanes to occur within only a few days or weeks of one another.

The geographic scope of storms and hurricanes can be so large that all of Denmark is affected simultaneously. The intensity can vary greatly between regions. The duration of such incidents is typically up to 48 hours.



Storms and hurricanes rarely come without warning in Denmark. It is usually possible to give warning and predict the development of extreme low pressure systems with a relatively high degree of precision. The precision of such predictions and warnings correlate with the development of weather models and large

[1] Wind speeds between 20.8-24.4 m/s

amounts of observation data from radars and satellites. It is still challenging to precisely predict storms' and hurricanes' course and intensity.

CONSEQUENCES

Storms and hurricanes are among the weather events that affect society most. The trajectories of storms and hurricanes, however, are typically very similar. This means that storms and hurricanes will occur during a limited time period and will likely have some of the same consequences.

Storms and hurricanes can cause injuries and death due to flying objects, falling trees, falling roof tiles, and traffic accidents. Outdoor recreation and traffic can therefore be life-threatening, both during and immediately after storms and hurricanes. Humans and animals can be killed, injured, or trapped if weak buildings collapse.

In addition, there can be residual consequences for life, health, and welfare if logistics and transportation, access to acute services from the police, rescue services, health preparedness, and/or municipal home care services are affected by difficult driving conditions and/or partial breakdowns of infrastructure. In the ocean, wind can create extremely high waves that can make sailing dangerous, thus complicating rescue efforts at sea after maritime accidents.

Storms and hurricanes can cause substantial material damage to buildings as a direct consequence of high-speed winds and indirectly due to flying or falling objects and debris. Complete destruction whereby entire roofs and/or outer facades collapse is not uncommon. Clean up work and restoration of buildings, infrastructure, etc. can be extensive and protracted.

Often, hurricanes and storms will cause widespread damage to nature, as entire forests can be hit by storms. The extent of the damage and subsequent costs of clean up, reparation, and replanting can lead to significant economic loss. Since the 1999 hurricane, however, there has been a conscious effort to replant more diverse forests with higher shares of leaved rather than coniferous trees, since the former are more robust against high-speed winds.

Storms and hurricanes typically have significant effects for the transportation sector since bridges, airports, and ferry routes are often forced to close and important roads and highways may be closed off. On land, transport often has to be stopped due to risk of flying and falling objects. In the ocean, winds can create very high waves (up to 14 metres in the case of a hurricane), posing a danger to maritime traffic.

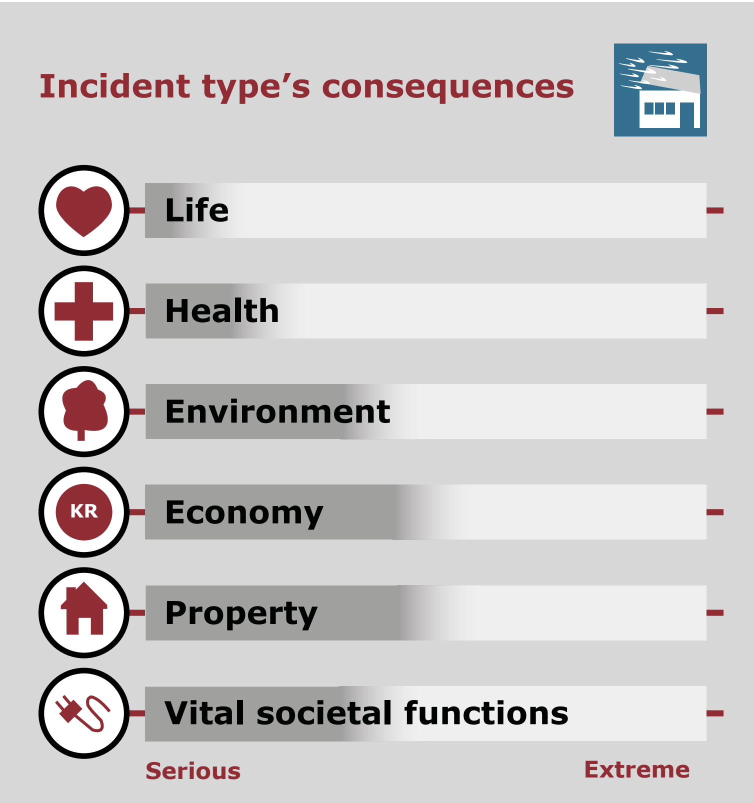
Storms and hurricanes can also cause IT and telecommunication services to be interrupted or overwhelmed by many users, leading to residual consequences for many other vital societal functions. Power supply interruptions can also occur, causing widespread and serious consequences in many areas of society. Restoration of power will often take longer than usual because of the storm or hurricane. The risk for widespread and/or long-lasting power outages as a result of falling objects with electric cables, however, has been drastically reduced during the last decade as the power distribution grid has been placed underground.

Finally, storms and hurricanes can cause large floods from the ocean and be a part of combined incidents. Such incidents will be further explored in the coming chapters about coastal flooding and extreme rain.

TRENDS

Climate change can affect typical wind patterns. The wind, however, also has a strong natural variability. A look at DMI's list of storms shows that in the beginning and end of the 20th century, there were more storms than today, whereas in the period from the 1930s to the 1960s, like the first decade of the 21st century, there was relatively less wind. Three hurricane-like storms (in October 2013, December 2013, and November 2015) changed the overall picture of that decade. Even so, these events are not a sufficient basis for general conclusions regarding future wind conditions in Denmark.

Discrepancies between climate models reflect uncertainty as to whether wind strengths and number of storms and hurricanes in Denmark will increase, decrease, or remain the same towards the end of the century. In December 2020, DMI's updated Climate Atlas stated that:



"The variable weather in Denmark makes future wind trends uncertain. The best guess is that there will not be any significant changes. Small increases or decreases in the average wind strength, however, cannot be ruled out. The number of storms may increase a bit in west-facing coasts (especially Jutland), but this is also extremely uncertain."

EXAMPLES

The hurricane on 3-4 December 1999 was undisputedly the largest in Denmark's recent history. 100 kilometres of coastline along Southern Jutland and the Wadden Sea were especially hard hit, though the hurricane affected the entire country. Aside from northern Jutland, in most places, wind gust speeds reached up to 40-51 m/s. On Rømø, a national average wind speed record was set, measuring over 40 m/s with wind gusts of over 50 m/s, all measured before the wind measurement instrument was blown down. At the time, these wind speeds were assessed to be near the maximum possible speeds for a low pressure storm system in and around Denmark. The consequences of the storm are summarised in this chapter's introductory text box.

On 8 January 2005, Denmark experienced another storm with hurricane-strength wind gusts and average wind speeds like that of a hurricane in the northern and western parts of the country. The storm – known in Scandinavia as 'Gudrun' – cost four lives. Two people died after being hit by a torn off roof and two others died when their cars were hit by falling trees. In large parts of the country, there were significant consequences for traffic: bridges were closed and routes for trains, busses, the metro, and flights were changed. An estimated 4,000 people were left at bus stops and train stations. In several cases, people were forced out into the dangerous weather, as stores and warehouses closed and public transportation routes were unexpectedly adjusted. About 200,000 users were affected by power outages. These outages were of a smaller scope than during the 1999 hurricane, however, partially because large-scale low-voltage net cables were laid in the time between the two storms. Multiple telephone centrals were out of service alongside large parts of the mobile telephone network. In forests, more than two million cubic metres of timber were blown over. The storm's damages are estimated to have totalled about four billion DKK.

On 28 October 2013, there was a strong storm with wind gusts of unprecedented speed in Denmark. The storm, dubbed 'Allan', had the highest recorded average wind speeds at 39.5 m/s measured at Røsnæs Fyr. Storm Allan also had wind gusts of up to 53.5 m/s near Kegnæs Fyr, constituting a national record. Allan primarily hit Southern Jutland, Funen, and Zealand, resulting in significant damage to property and infrastructure. Train traffic operation was paused in large parts of the country for more than 48 hours due to fallen trees and torn-off roofs lying on the tracks. Three people died because of flying debris from roof constructions and a collision with a fallen tree.

Just two months later on 5-6 December 2013, Denmark was hit by a hurricane-like storm once again. Storm 'Bodil' covered a large land area and hung over Denmark for longer than 'Allan'. Average wind speeds met the definition of storm in many coastal areas, strong storm in several places, and hurricane in one location. Average wind gusts in coastal areas were almost unanimously over hurricane speeds. One person was killed and several were injured. Almost all of the country's bridges were closed because of the strong wind and traffic hubs like the Storebælt Bridge, Øresund Bridge, and the Lillebælt Bridge closed down completely. Ferries remained in harbours were harboured and planes stood still on the asphalt of the Aalborg, Billund, and Copenhagen airports.

Note: Many of the above mentioned storms and hurricanes resulted in simultaneous large-scale flooding. Examples of this will be discussed in the next chapter about coastal flooding.

What if...

... on 22 December, there is a storm warning in Germany for Christmas Eve. The storm is also projected to produce a strong gale over southern parts of Denmark. During the night of 24 December, the storm changes course. On the morning of 24 December, a warning is issued stating that the storm will hit southern parts of Denmark, Zealand, and Funen in full force in the middle of the afternoon.

Despite warnings from authorities that Christmas guests should be sure to get to their destination no later than 2:00 pm and that ferry and train operation as well as bridges will be closed at 1:00 pm, there are many people on the roads when the storm hits at 3:00 pm. This results in a need to evacuate and provide emergency shelter to up to 10,000 people, including many children and elderly individuals. Further, it causes a large number of vehicular accidents, leading to more deaths and injuries across southern Denmark than in previous storms. Rescue efforts are complicated by fallen trees and debris on roads as well as the continuing stormy weather.

Since several areas are experiencing power outages, mobile phone networks and internet connections (and therefore many residents' channels by which they communicate with and receive information from authorities) are interrupted.

COASTAL FLOODING

The storm surge of 1981

On 24-25 November 1981, all of Denmark experienced winds of hurricane strength, leading to drastic rises in sea level in the Wadden Sea and North Sea. On the Wadden Sea island of Mandø, the rising water levels occurred at the same time as high tide, causing 90 per cent of the island to flood. The island's 300 sheep drowned and the island's dykes were seriously damaged. Several other dykes along the Wadden Sea's coasts collapsed due to the pressure from the water. In Esbjerg Harbour, the highest water level ever measured was recorded, exceeding normal levels by 4.33 metres. The harbour flooded, and the economic costs of this event alone amounted to tens of millions of DKK, in part because 15,000 full fish crates were washed out into the harbour.

CHARACTERISTICS

Coastal flooding occurs when the ocean's sea level rises to such a degree that city and land areas are suddenly flooded. Rises in ocean water levels can be a result of several factors, though primarily due to strong winds or the bathtub effect[2] from the eastern part of the Baltic Sea.

Strong winds can push large amounts of ocean water onto land. This is called elevated water levels, and if these water levels exceed a set threshold, the Danish Storm Council can declare a 'storm surge'. Elevated water levels and storm surges can be influenced by several factors including the wind's direction and strength, the shape of coastal land areas, air pressure, the course of a low pressure system, and the tide. The most serious storm surges occur due to unfortunate combinations of these factors.

When there is inland wind, water levels rise along coastlines, and when there is offshore wind, coastal water levels decrease. In the event of average wind speeds of 20.8-24.5 m/s winds,

[2] In a Danish context, the 'bathtub effect' refers to the phenomena whereby water forced into the Baltic Sea by wind reverses its course and channels into narrow waterways once the wind changes direction or ceases, potentially causing extremely high water levels in Danish waters.

the equivalent of a strong gale, water levels can increase to the point of a storm surge. The risk is even higher for inland wind in the case of a storm (average wind speeds of 24.5-32.6 m/s) or hurricane (average wind speeds of over 32.6 m/s).

Wind-induced water level rises have the largest effect on shallow waters. Because of this, the shape of coastal areas matters. Low-lying areas such as marshlands and fjord areas will therefore experience flooding from the ocean more often when wind gusts push ocean water onto land.

In addition, Baltic coasts are at risk for flooding because of the bathtub effect. Such flooding can happen if storms from the northwest first push water from the North Sea into the Baltic Sea and the Gulf of Bothnia and then push water into the Little Belt strait, the Great Belt strait, or parts of the Øresund sound. This can cause water levels along Denmark's inner coasts to rise up to three metres.

In addition to the wind's direction and speed, air pressure and tides have significant implications for water levels. The average air pressure in Denmark is 1013 hectopascals (hPa), but during storm weather, the pressure typically falls to 970-980 hPa, leading water levels to increase by 0.3-0.4 metres. Tides are daily events, but during certain constellations of the Sun, Moon, and Earth, high tide can be higher than average. This is called a spring tide and occurs approximately every 14 days. If strong wind coincides with high tide, the risk for coastal flooding increases. The strongest tide in Denmark can be found along the Wadden Sea, where the difference between high and low water can be up to two metres.

Another factor that can increase the risk of coastal flooding even with low wind speeds is the amount of rain that has fallen during the preceding period. Already-high water levels in rivers and streams increase the risk for inland flooding if these bodies of water are not able to flow into the ocean. Similarly, an increased flow of rainwater to the ocean can increase the risk of coastal flooding if water levels are already higher than normal.

Coasts can also be exposed to flood waves caused by seismic activity such as landslides and underwater earthquakes. The resulting flood waves are called tsunamis. A tsunami's strength depends on its height and speed. Its speed lessens as the wave approaches the coast and more shallow waters, but at the same time, the wave becomes taller. The risk for this type of coastal flooding in Denmark is, however, very low.

OCCURRENCE

Denmark's landmass lies an average of only 31 metres above the ocean's surface and is surrounded by approximately 7,300 kilometres of coast. Many large Danish cities are located near coasts, making them potentially vulnerable to coastal flooding.

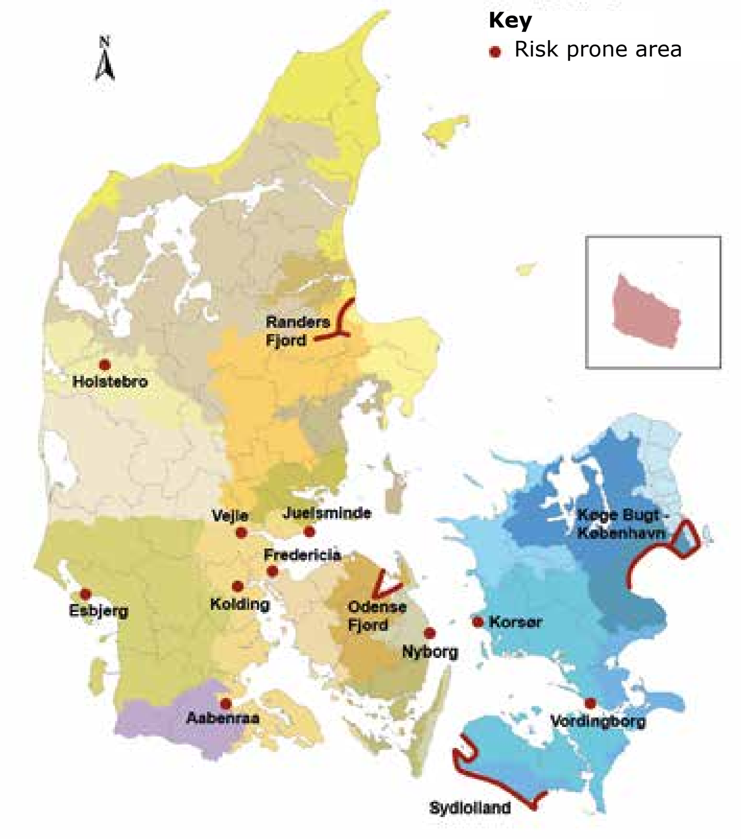
Almost annually, Denmark experiences coastal flooding and storm surges. In the period 2000-2020, for example, there were 20 incidents large enough to be classified as storm surges according to the Danish Storm Council. Some years have no storm surges, whereas others have several.

The frequency of coastal flooding also varies seasonally. Flooding occurs most often during cold months when low pressure systems often pass over Denmark, causing strong winds.

Geographically, local areas can be more or less vulnerable to coastal flooding depending on the strength of coastal dykes and the difference in elevation between the coast and nearby inland areas.

Because of this, there are important differences between Denmark's outer and inner waters. The outer waters are the North Sea and the Wadden Sea, while the inner waters cover the Kattegat and eastern parts of the country. The entire coast of western Jutland is vulnerable to strong westerly inland winds as well as large differences in tides. The Wadden Sea area is comprised of flat marshland that can quickly flood. To protect cities in southern Jutland in particular, coastal dykes have been erected along large parts of the Wadden Sea coast.

In Denmark's inner waters, the water levels and wave heights cannot accumulate as much energy as along the western coast of Jutland. The areas along fjords in inner Danish waters, however, are often less protected by natural barriers against flooding and high water levels. These areas are

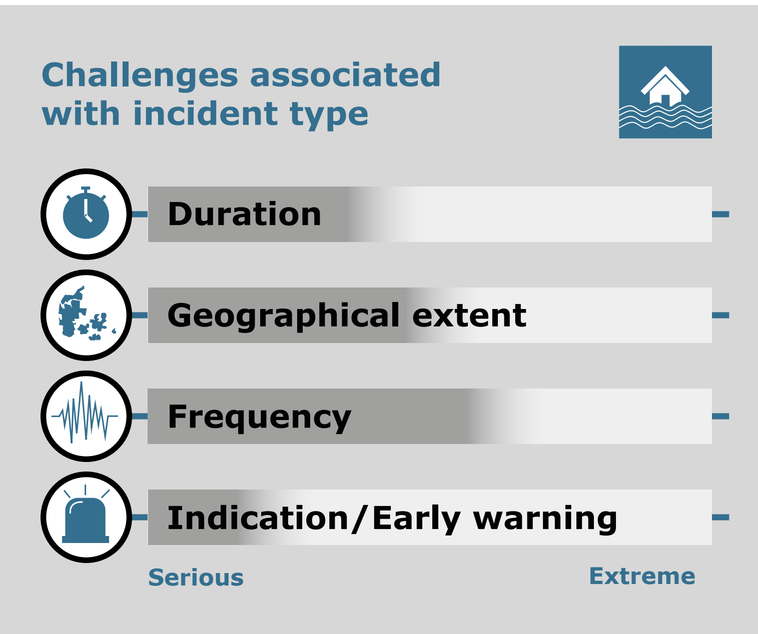


therefore generally more vulnerable to flooding than the west coast. For example, fjord areas on Funen and Zealand and the east-facing fjords in Jutland have experienced several storm surges resulting in large-scale flooding.

In recent years, there has been an increased focus on preventing these floods based on the implementation of the EU's flooding directive. In 2018, Denmark identified 14 risk prone areas especially threatened by flooding. 12 of these are along a coast or fjord in the inner Danish waters and an additional one of these areas is in the Wadden Sea area (covering Esbjerg and the city of Nordby on Fanø). These 14 areas affect a combined total of 27 municipalities.

The most recent identification of risk prone areas in 2020 gave municipalities updated damage and risk maps showing potential damage and loss of buildings, infrastructure, and agriculture in various flood scenarios. More information can be found on the Danish Coastal Authority's website, kyst.dk/english.

The distribution and types of seismic zones in the North Atlantic Ocean mean that tsunamis caused by seismic activity are extremely rare. Smaller waves that move quickly, however, can still hit coasts in outer as well as inner Danish waters.



CONSEQUENCES

The potential consequences of coastal flooding heavily depend on structural protective constructions such as dykes or flood walls, city planning, climate adaptation, preparedness planning, acute preventive and mitigating measures, and measures and behaviours enacted by the general population.

Along the majority of vulnerable coastal areas on Denmark's west coast, dykes or coastal cliff strengthening with the help of beach nourishment (i.e., adding sand where it otherwise has eroded away) have been put in place. Although there are dykes most places along inner Danish waters, there are still many flood-prone areas without dykes.

Dykes are essential to protecting life and property in low-lying areas. If dykes are not inundated and do not collapse, their protective function persists and there will be no damage behind them. Each incident of increased water levels temporarily puts pressure on these dykes, which can cause erosion to the surface of the dyke, making it vulnerable to collapse. Although dykes are maintained and erosion damage is fixed, dykes can collapse.

Incidents with significant loss of human life in Denmark, such as those on the west coast and in Falster, occurred before dykes were erected. This also illustrates, however, what a collapsed or inundated dyke can mean – especially today, when societal assets (and thereby vulnerabilities) behind dykes have grown significantly over the last 100 years due to city development in coastal zones.

Another protective measure that contributes to a reduction of the consequences of coastal flooding are so-called 'high water walls'. High water walls are especially utilised in densely populated urban areas with significant economic activity such as harbour areas, where there is either not space for dykes or where a high water wall is more fitting for the city environment.

In addition to dykes, coastal cliff strengthening, and high water walls, a storm surge readiness system has been established near the Wadden Sea and the central part of the west coast. This means that upon warning from DMI, the readiness system is ready to carry out evacuations if necessary. Evacuation can also be necessary in other places, such as near inner waters.

Although the risk posed by coastal flooding is assessed to be limited in terms of loss of human life, coastal flooding can have health and welfare-related consequences if wastewater plants and sewage systems are flooded. If this were to happen, humans could come into contact with disease-causing microorganisms through contaminated water. Flooding can also result in psychological consequences for the affected residents, such as stress due to evacuation or lost private property.

The material extent of flood damages depends on which areas are affected. If a densely populated area floods, there will be significant damage to property, such as buildings and inventories. Basements and ground floors of homes and commercial facilities can be affected by standing water such that they are unusable for long periods of time while under renovation. Economic consequences can be large, especially when flooding affects several parts of the country simultaneously.

Coastal flooding can cause problems for critical infrastructure and continuity and restoration of vital societal functions. Harbours, coastal roads, and train tracks near coasts can be temporarily closed or destroyed as a result of flooding. Flooded areas and areas close to flooding can experience power outages, catalysing several cascade effects such as companies being unable to operate for a period of time.

Coastal flooding can also affect the supply of drinking water if saltwater contaminates drinking water. Water treatment plants can flood, and following floods, ocean water can settle as small pools in indents in terrain and slowly infiltrate groundwater. Decontamination of wells and water purification can be very costly.

When freshwater sources are flooded with ocean water, the freshwater becomes salted. This can cause substantial disruptions to local ecosystems since both animals and plants require freshwater. Salt can also be a problem for agricultural areas flooded with ocean water. Salt hinders plants' osmosis by depriving them of freshwater, thereby preventing them from growing. Thus, salted soil cannot be used to grow crops, and can thereby cause significant financial loss for the agricultural sector.

Many areas at risk of flooding have industrial buildings, including potentially hazardous facilities. In this case, floods can cause leaks of chemical substances that can then spread over large areas. In addition to the potential health and environmental risks this may pose, the clean-up of the affected areas can be protracted and costly.

TRENDS

Changes in climate are expected to cause a rise in the ocean level due to melting icecaps and ocean water's thermal expansion. As a result, the coming years will see more and more instances of the ocean's water level exceeding the normal level.

December 2021 updates to DMI's Climate Atlas gave a 'best guess' as to conditions at the end of the century (2071-2100) compared to today if CO_2 emissions remain high (RCP8.5 scenario):

- Average water levels increase, and at an accelerating rate. Water levels increase least in northern Jutland and most in southwestern Jutland. The difference correlates with the land level rises since the last ice age. The average increase of average water levels will be approximately half a meter.

- Storm floods become significantly more severe. When average water levels rise, a storm flood can have much more serious consequences since water is pushed high up over terrain.

- What is considered a 20-year storm flood today begins occurring every year or every other year.

It should be noted, however, that there is naturally a certain degree of uncertainty in predicting future water levels – especially with respect to the most extreme storm surge events, where relevant data is limited.

In recent years, there has been an increasing focus on adapting and securing constructions near coasts, which could contribute to a reduction of the consequences of coastal flooding.

EXAMPLES

The hurricane of 3 December 1999 caused a storm surge along coastlines of the Wadden Sea and North Sea. In the Wadden Sea, water levels were 4-4.5 metres over their normal levels. Measurement devices on Ribe, Esbjerg, and Højer's dykes were damaged, and even though the measured water level (5.12 metres by Ribe Beach) was a record, the water levels were likely even higher when the hurricane was at its strongest. The water levels peaked during low tide. If water levels had peaked just six hours later when the tide was high, the water would have been 1-1.5 metres higher and the dyke in Ribe likely would have been inundated.

On 5 December 2013, storm 'Bodil' hit Denmark. When the storm reached the coasts, the wind rotated northwest, pushing large amounts of water from the North Atlantic into the Kattegat. From the Kattegat, water was pushed southward toward Zealand's northeastern coast. There was large-scale flooding in populated areas around Roskilde Fjord, where water levels were more than two metres over normal levels. In Frederikssund and Jyllinge Nordmark, approximately 600 families lost their homes for a period of time, and in Roskilde, the Viking Ship Museum (as well as other sites and buildings) was at risk of being flooded. Similarly, large-scale flooding and destruction occurred around Holbæk Fjord, Odense Fjord, Isefjord, and Copenhagen. The incident cost more than 900 million DKK in insurance claims alone.

On 4-5 January 2017, a smaller storm pushed large amounts of water from the North Sea to the Baltic Sea via Skagerrak and Kattegat. Northerly winds in the Baltic Sea exacerbated the problem, pushing the excess water towards southern Denmark. The storm resulted in historically high water levels and flooding from the old Lillebælt Bridge, around southern Funen and Zealand, and up to Copenhagen's Nordhavn as well as Bornholm. On the evening of 4 January 2017, the water level prognoses led the Copenhagen Police to warn residents that it could be necessary to evacuate coastal areas on Amager if the dykes were inundated, which they ultimately were not.

What if…

…a strong winter storm from the west pushes water from the North Sea into the Baltic Sea via Kattegat and Øresund. Following the low pressure system, the wind pushes the water back from the Baltic Sea towards Køge Bay and the southern part of Øresund. The bathtub effect puts such pressure on the dykes on the coasts of Lolland, Falster, Møn, Køge Bay, and Dragør that several dykes collapse. This causes widespread flooding, necessitating acute evacuations of several thousand residents. There are power and heating outages in the flooded areas, and it quickly becomes critical to evacuate especially vulnerable residents from their homes/ nursing homes as quickly as possible because of very low temperatures. The ongoing storm and difficulty accessing flooded areas complicate evacuations. At the same time, water levels continue to rise and pose a danger to the inner harbour of Copenhagen.

EXTREME

Cloudburst over Greater Copenhagen, 2011

In the early evening of Saturday, 2 July 2011, Greater Copenhagen experienced a cloudburst on an unprecedented scale with little warning. In the areas most severely affected, the equivalent of two months' rain fell in just a few hours. It became the most expensive natural incident in Denmark since the hurricane of 1999, costing 6.2 billion DKK (spread over 90,000 damages) in insurance claims alone.

The material damage consisted primarily of water and humidity damage to buildings, but there was also a widespread breakdown of infrastructure. About 10,000 households were without power for up to 12 hours, and about 50,000 indoor heating customers lost heat and warm water for up to a week. Several of the most trafficked highways were closed off for 1-3 days. Train traffic was disrupted by flooded stations, tracks, and technical installations, a 100 metre landslide, lightning-struck electrical equipment, and disrupted IT systems. Some stretches of train tracks were closed for several days, and it took a week for operations to fully normalise.

Further interruptions included DMI's supercomputer and website, the Danish Road Directorate's traffic map, a telecommunications central, Copenhagen Police's telephone system, Vestre Prison's IT systems, and Copenhagen Municipality's emergency monitoring devices for the elderly. It is estimated that 70 per cent of Copenhagen Municipality's cross-sectoral critical IT systems were on the verge of destruction. At the Greater Copenhagen alarm central, flooding in technical rooms caused outages for some communication technologies and the dispatch system and there was a risk of a complete system

RAINFALL

breakdown. The emergency number 1-1-2 still worked, however, and received almost 5,000 calls in the busiest hour between 8 and 9 pm.

There were no deaths during the cloudburst, but afterwards, five cases of leptospirosis were reported. Two of the infected individuals were hospitalised, one of whom died. A 257-participant survey of individuals exposed to contaminated rainwater showed that 22 per cent of respondents had gotten sick. There were a few injuries due to flood-related traffic accidents, and at least nine people suffered burns from scalding vapour released from grates over flooded heating and vapour lines.

The risk of serious health consequences and/or death was compounded by the fact that ambulances and acute medical vehicles had difficulty reaching sites, and operations at several of the Capital Region's hospitals were affected by flooding. Rigshospitalet was hardest hit, where the trauma centre and radiology hall were flooded. The trauma centre's reception of severely injured people had to temporarily be moved to Herlev Hospital. Due to a short circuit, the supply grid for prioritised electricity supply to Rigshospitalet broke down, affecting several intensive care units and a surgical unit. Emergency power supply was only partially functional. Intensive care patients were moved internally and power was restored, but there was a risk that the power outage would recur and require a large number of patients to be evacuated.

CHARACTERISTICS

Extreme rainfall describes episodes where the volume of rainfall exceeds that which can be absorbed into the ground or otherwise drained, thereby causing flooding. The term extreme rainfall covers three phenomena: cloudburst, heavy rain, and consecutive rainfall events (CREs).

DMI defines cloudburst as short-lived rainy weather with a precipitation intensity of more than 15 mm in 30 minutes locally (within the area to which the warning applies).

Heavy rain is defined as a precipitation event with an intensity that exceeds 24 mm over the course of six hours locally (within the area to which the warning applies).

Consecutive rainfall events are precipitation events with differences in geographic scope, duration, and intensity, but where the resulting aggregate precipitation falls in such a short time period that the water cannot naturally drain.

For all three types of extreme rainfall, the aggregate number of millimetres of precipitation is not what determines the potential extent of damages from resulting flooding. The amount of precipitation should instead be seen in combination with other factors such as the time interval precipitation is measured over and where the rain falls (e.g., in relation to the ground's condition, topography, building density, water drainage systems, etc.).

The development of cloudbursts and heavy rain is affected by many factors in the atmosphere, including the distribution of warm and cold air masses. When local atmospheric conditions are especially unstable, rain clouds can become especially large and precipitate heavily, resulting in heavy rain and/or cloudburst often supplemented by lightning, thunder, strong wind speeds, and/or hail.

Cloudbursts and heavy rain are always geographically limited phenomena, and cloudbursts are typically very local. Some clouds stand still over an area while others move and spread rain over several large areas. In both cases, however, the extent of the affected area is limited in comparison to normal rainy weather from passing front systems.

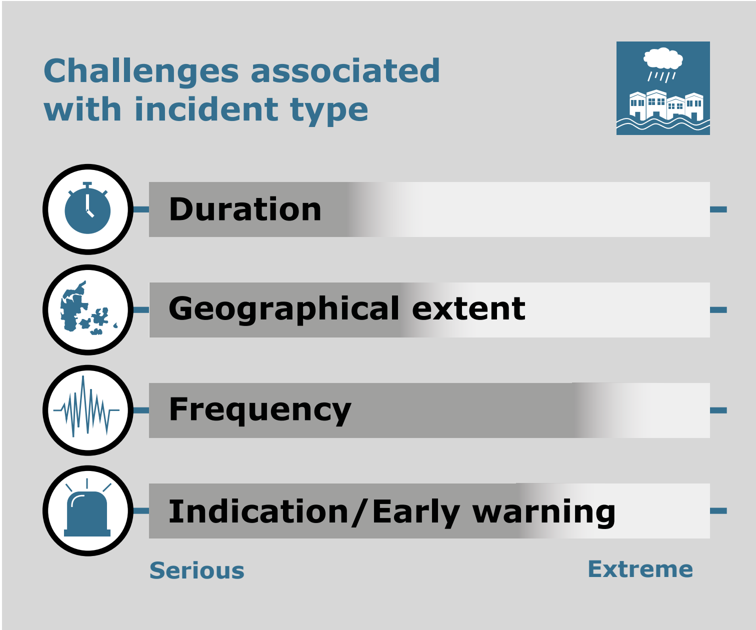
Cloudbursts are especially characterised by an abrupt start and end as well as quick and large fluctuations in the amount and intensity of rain over a short period of time and over short distances. It is therefore often not possible for meteorologists to predict precisely where, when, and with what intensity cloudbursts and heavy rain will occur.

A consecutive rainfall event (CRE) is an event whereby several rain events occur shortly after one another. These events can replace one another with short or no intervals in between, such that the amount of precipitation can exceed that of both cloudburst and heavy rain over time. Soil and drainage systems (canals, streams, lakes, basins, and groundwater zones) can be saturated with water and the ground's capacity to absorb water and delay runoff of excess rainfall can be reduced or completely eliminated. Afterwards, even small rainfall events could lead to consequences that are on par with or exceed those of very intense rainfall.

Modern weather models are better equipped to offer high-quality prognoses for CREs and normal long-lasting rain events than cloudbursts and heavy rain.

OCCURRENCE

Since 1990, Denmark has experienced an average annual rainfall of approximately 745 mm. In the last 150 years, this number has risen about 25 per cent and has especially accelerated since the 1980s. An increase in the number of episodes with cloudburst and heavy rain are more challenging to document, however, since DMI's precipitation measurement only started continuously measuring rainfall intensity in 2011. Rain gauges are set up in strategic places and do not cover the entire country. Today, cloudbursts can be seen on radar data, but this technology is not yet fully operationalised. The foundational data are therefore relatively weak in terms of assessing whether cloudburst and heavy rain occurs more often today than in previous years. Since these phenomena are predominantly local, many cloudbursts are presumably never officially registered.



Cloudbursts and heavy rain can occur at any time of year, but the conditions necessary for such events are most often present in conjunction with warm weather, making summer the high season for heavy rain and cloudbursts. A DMI summary for the period 2011-2020 showed that there was an average of 22.6 days per year where a cloudburst occurred in at least one place in Denmark, almost 75 per cent of which occurred between June and August, and 90 per cent of which occurred between May and September. In summer 2021, July stood out with 12 days of cloudbursts as opposed to the 10-year average of 4.9 days for the month of July.

Showers that result in cloudburst and heavy rain are usually created during the day due to warming from the sun, but they can also form at night if there is significant cooling at the top of the clouds.

Geographically, cloudbursts and heavy rain can occur anywhere in the country. In addition to atmospheric conditions, however, their development is also affected by the ground's surface. Large cities can be more vulnerable to these events than smaller cities and countryside areas. This is due to the so-called 'urban heat island' effect caused by, among other things, high population density and dark coloured surfaces (e.g., asphalt) that absorb heat from the sun. During summer periods with still air, air temperatures over large cities can therefore exceed those of the surrounding areas by several degrees.

CREs can also occur throughout the year and at any place in the country since the phenomenon encompasses several long-lasting or frequent rainfall events. In contrast to cloudbursts and heavy rain, the conditions for CREs are most often present during autumn and winter months. CREs have a more significant effect on groundwater levels and water flows in streams than cloudbursts since the infusing of rainwater with groundwater and streams occurs over a longer period of time. When groundwater levels (especially those near terrain) rise, the ground's ability to absorb rainwater is reduced, increasing the risk of flooding.

CONSEQUENCES

There is a distinction between pure 'hydrological floods', which occur in natural areas without causing significant consequences for society, and 'damaging floods', which affect populated areas and infrastructure. Flooding in city areas can have especially wide-ranging consequences, both direct and indirect. These depend on:

- The number of buildings and infrastructure exposed to flood risk.
- Volume of buildings and the degree to which surfaces are covered with asphalt and similar materials that inhibit absorption.
- Whether terrain is flat or hilly (i.e., the degree to which water can settle in low-lying areas).
- How saturated the ground in the affected area was before the incident, which affects the ground's absorption capacity and the fullness and saturation of nearby lakes, streams, soil, and other natural drains or reservoirs.
- Preventive measures including the effectiveness of sewage systems, excess water basins, drainage areas, and other mechanisms that transport, delay, or hold back water masses.
- Preventive and mitigation measures from landowners and emergency management actors in terms of pumping water away, clearing rain gutters and grates, moving items from cellars, laying out sand bags, making acute reparations, etc. Rescue services' capacities (i.e., high-capacity water pumps and fire hoses for water transport, etc.) and prioritisation of pumping efforts can be significant factors in determining the ultimate scope of the consequences.

There can be an acute risk of personal injury in connection with cloudbursts and heavy rain in traffic situations due to reduced visibility, hydroplaning, or lack of traffic regulation at traffic light stops in places affected by flood-induced power outages. Potentially dangerous situations can also arise if people must go through deep water or climb on installations if, for example, they must leave their car at a low-lying point on a road.

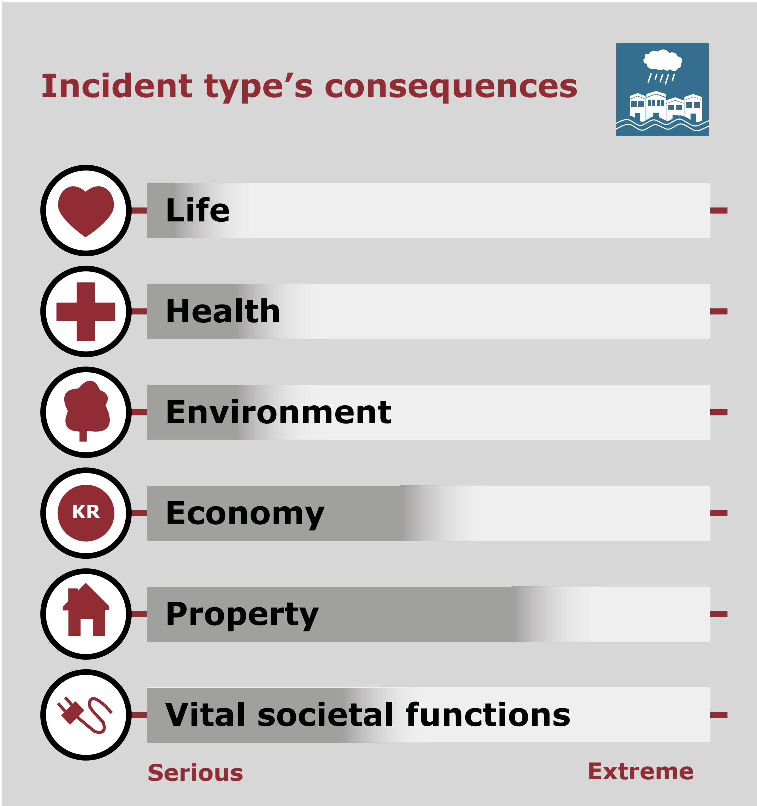
Experience further shows that heavy rain and cloudbursts can create anxiety and insecurity among chronically ill persons and patients that use oxygen at home who are especially dependent on power supply. Likewise, anxiety and insecurity can also arise in patients that have a special need or wish for evacuation in the event of flooding or power outages.

The floodwater that pools in cellars and on roads can be composed of rainwater mixed with wastewater. Human contact with wastewater poses a serious health risk even when diluted by otherwise clean rainwater. For example, the bacterial infection leptospirosis can spread if drowned rats are washed out of waste water pipes. The most common symptoms of leptospirosis are diarrhoea, common cold-like symptoms, sore throat, and headaches, but in some rare cases, leptospirosis can cause jaundice and fatally affect kidneys and lungs.

Non-purified wastewater can also leak into harbour basins, oceans, lakes, and streams, but since bacteria die quickly in saltwater and only slightly more slowly in freshwater, the contamination will typically resolve itself over the course of a few days.

Although the potential health consequences of extreme rainfall should not be underestimated, the largest challenges posed by such events are material damages and related economic losses. Events with extreme rainfall can have especially extensive consequences for property. According to the reinsurance company Swiss Re, the cloudburst over Greater Copenhagen on 2 July 2011 was the single most expensive event in Europe that year. In addition to the economic consequences, some losses were difficult to quantify, such as water and mould damage to archives, museum articles, and other items with value to cultural heritage.

Extreme rainfall can also affect critical infrastructure and the provision of vital societal functions. On roads, flooding can affect ease of access and cause roads to be closed for several days. Train operations can also be interrupted if low-lying tracks, cables, track changes, etc. are flooded or if IT services critical to traffic regulation are interrupted due to flooding or lightning. Roads, rails, and railway dams can also be weakened and collapse, posing a risk for personal injury, long-lasting disruptions to traffic, and large repair costs. Because of the underground infrastructure (stations, tunnels, and technical installations), the Copenhagen metro risks long-term disruptions to operation in the event of water damage. An increased focus on prevention and ongoing updates on the part of infrastructure administrators and operators within road and train sectors, however, have reduced the risk of long-lasting interruptions to operations as compared with previously. In addition, there is an increased focus on protecting transport infrastructure as early as in the project design phase.



In the energy sector, flooding and lightning strikes can cause power outages. In addition, flooded steam wells and district heating pipes can lead to lack of heating and warm water.

Within the IT sector, servers and other IT equipment, server cooling systems, power relays, and emergency power generators placed in cellars can fail due to water and/or humidity damage, short-circuit, and fire. Telephone centrals and cell phone towers can also be disrupted by flooding or lightning.

In relation to food supply security, extreme rainfall's effects on infrastructure can also affect production, stock, and distribution of food to affected areas. Food inventories impacted by flooding can only be reused after thorough cleaning and disinfection. Potential disruptions to the supply of drinking water can also affect companies' ability to produce safe food.

For police, rescue services, and healthcare emergency services, flooding can make it difficult for first responder vehicles to drive and threaten power supply, emergency generators, servers, and other IT systems critical to the operation of alarm centrals, hospitals, etc. Experience has shown that rescue services can be put under stress due to blind dispatches as a result of emergency fire alarms, which are activated far more often during flood incidents than usual. This is in addition to a large number of normal, everyday responses (removal of water, personal rescue operations, etc.).

TRENDS

As mentioned, the basis of data necessary to assess whether cloudburst and heavy rain has become more frequent in Denmark is weak. There is, however, wide consensus among meteorologists and climate researchers that the long-term risk for cloudburst and heavy rain in Denmark increases as air temperatures rise due to global warming.

Changes in precipitation patterns are expected, including summers with longer dry periods and more intensive precipitation events (cloudbursts and heavy rain) despite the aggregate precipitation levels remaining more or less unchanged. Updates to DMI's Climate Atlas from 2021 indicate that with a continued high level of greenhouse gas emissions (RCP8.5 scenario), the number of cloudbursts could increase by 70 per cent. In contrast to summer weather patterns, winter precipitation could increase by 25 per cent by the end of the century. A relatively large share of this precipitation will fall as rain due to increased temperatures. There is therefore also a larger risk for consecutive rainfall events during the winter.

Most extreme rainfall events can be predicted by weather services with relative precision, and these capabilities are continuously improving. Nevertheless, it will continue to be difficult to give precise warnings as to where and with what intensity a cloudburst will occur. Thus, cloudburst prognoses in the near future will be faultier than other meteorological prognoses.

The increased focus on securing cities against the consequences of extreme rainfall via planning where water masses can be diverted to cause the least disruption possible and setting up cities accordingly is expected to continue. This could potentially reduce material damage and economic costs of future extreme rainfall events. Further knowledge about examples of relevant initiatives can be found at en.klimatilpasning.dk.

In addition, rescue services have invested additional material for use in acute mitigation responses that can reduce the consequences not able to be addressed by climate adaptations implemented by authorities and private actors. These investments have been in, among other things, stronger high-capacity water pumps, sandbag fillers, and mobile dams (so-called 'water tubes').

EXAMPLES

The cloudburst over Gråsten and the surrounding areas in southern Jutland on 20 August 2007 was likely the strongest short-lasting precipitation event in Denmark since 1877. DMI's rain gauges in the area did not capture the worst of the incident, but a recently decommissioned measurement station registered 142 mm of precipitation over the course of approximately 1½ hours near Fiskebæk, two kilometres from Gråsten. A radar estimation indicated 152.6 mm of precipitation in Fiskebæk with a maximum 10-minute precipitation level of 53 mm. These are extreme values, and DMI described the event as a 'convective bomb' – a short, extremely intense, and very local rain event where the vast majority of the rain fell over hilly terrain. No one was injured, but one railway dam between Gråsten and Sønderborg was destabilised, causing the tracks to hover freely. One train just made it past the track's weak point before the track broke apart. Near Adsbøl, a piece of road was washed away by the storm and several other roads were closed off. In addition to the rain, strong winds and large hail caused much material damage and about 1,000 lightning strikes were registered, leading to power outages and a field fire.

Although meteorologically speaking, the Gråsten cloudburst was the most intense in recent years, its consequences pale in comparison to those of the cloudburst over Greater Copenhagen on Saturday, 2 July 2011. The cloudburst occurred due to an unusually meteorologically explosive development of thunder clouds over Øresund. During the day, DMI had updated a message warning of the risk of cloudburst over Zealand, but the message was only upgraded to an actual warning less than 15 minutes before the cloudburst reached land along a southwestern course toward Copenhagen. The majority of the rain fell between the event's 30 minute and two hour mark. The rain was accompanied by large hail and thousands of lightning strikes. Areas in central Copenhagen were hardest hit with measurements of over 80 mm, but all the way to Lyngby to the north, Taastrup to the west, and Greve to the south, more than 30 mm of rain fell. In the Botanical Gardens, 135.4 mm of rain were measured, the highest registered value in Greater Copenhagen in at least 65 years. By Landbohøjskolen, the precipitation intensity was measured to be 4.5 mm over the course of one minute, and at Ishøj Varmeværk, 31 mm of precipitation were measured over 10 minutes and 63 mm over 30 minutes. Never before had such high 1, 10, and 30 minute rainfall intensities been measured in Denmark. The consequences are summarised in this chapter's introductory text box.

On 15 and 16 October 2014, large parts of northeastern Jutland were hit by an extraordinarily strong and long-lasting rain event. At DMI's measurement station in Lendum, 148.1 mm of rain fell over 48 hours, and in some places, more than 100 mm rain fell over just 24 hours. This caused widespread flooding of buildings, roads, and railroad tracks as well as destabilising of road foundations and railway dams. In Vendsyssel, especially around Hjørring and Frederikshavn, the flooding was the worst in decades and reparations took more than a month.

In November of 2015, almost double the normal amount of rain fell (171 mm as opposed to the usual 94 mm) over parts of mid- and western Jutland. The amount of rain caused high waters in Storå (Denmark's second-longest river) near Holstebro, but did not cause the city to flood. After a long period of time with rain, the soil was so saturated that the additional 32 mm of precipitation that fell on 5 and 6 December near Storå could not be absorbed. This resulted in the majority of the water streaming to Storå, which, just a few days after, caused intense flooding in Holstebro.

February 2020 was the wettest February since DMI started registering precipitation measurements in 1874. The relatively evenly distributed rain over a long period combined with little evaporation caused widespread flooding from streams and creeks that collected rainwater from surrounding fields. This was especially the case in southern and mid-Jutland, where water from, e.g., Ribe River caused a flood wall to collapse. Several areas near Silkeborg were flooded by the overflowing Gudenåen River. In several places across Jutland, authorities warned of a high risk of hydroplaning after several traffic accidents.

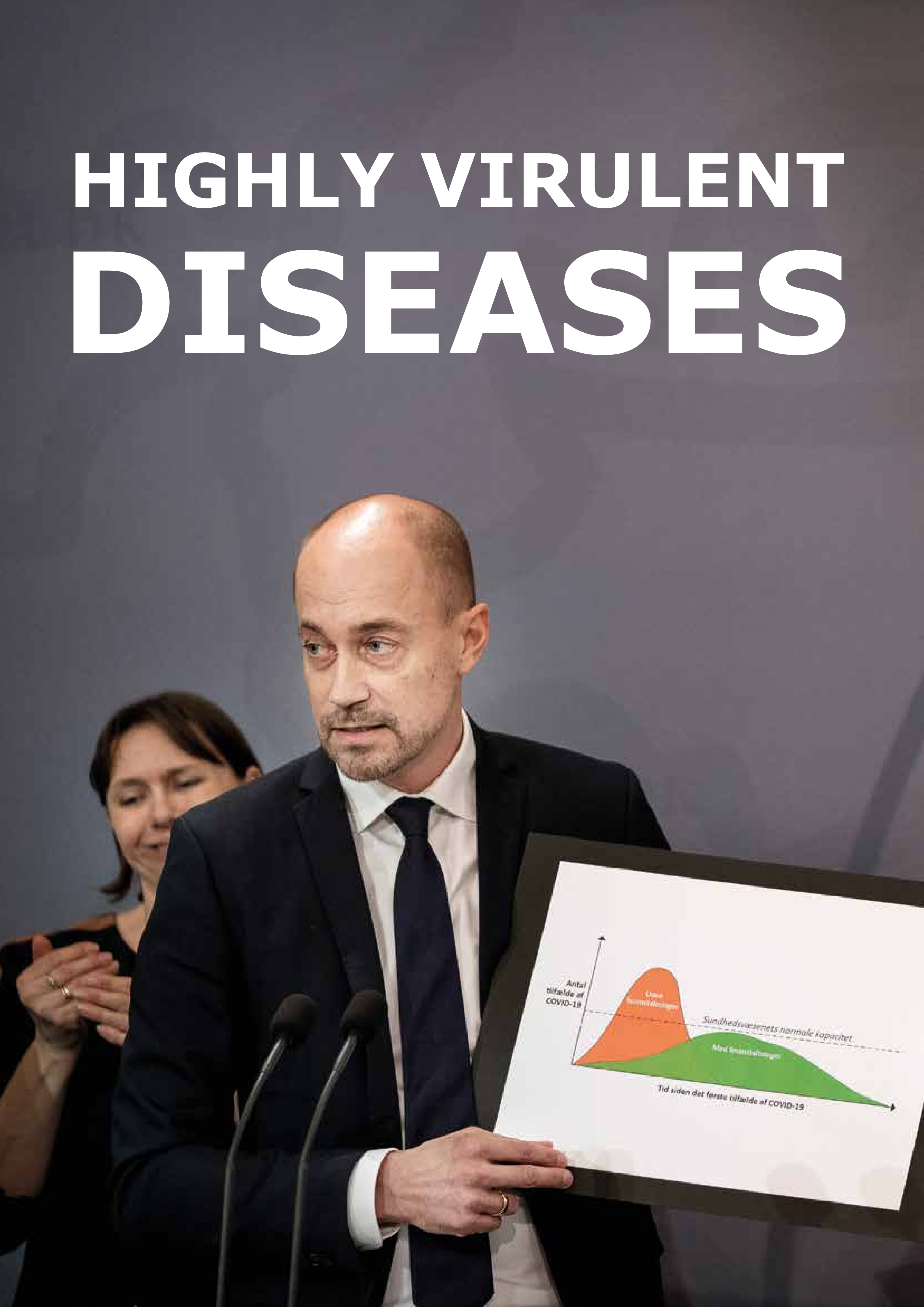
What if...

... large parts of eastern Jutland are hit by CREs and a storm flood simultaneously. For the last while, it has rained so much that the ground is completely saturated, and streams are struggling to drain and incorporate the ongoing precipitation. In several places, creeks start to exceed their banks while emergency services work to contain and remove water that has primarily flooded fields and smaller roads up to this point.

After just a week, there is a storm with an average wind speed of 25.5 m/s and a storm flood in Randers Fjord. Although the storm flood in the fjord is relatively limited, it prevents the water in Gudenåen River and adjacent streams from running off into the ocean. Instead, the water builds up in the streams, resulting in massive inland flooding. Meanwhile, cities along fjords are struggling to hold the water back.

Protecting these cities is complicated by the fact that rescue services' capacity to handle flooding is already tied up near the streams that threatened to flood over their banks earlier in the week. The combination of these two factors means that the flooding spreads and affects places that are not used to nor prepared for floods.

HIGHLY VIRULENT DISEASES



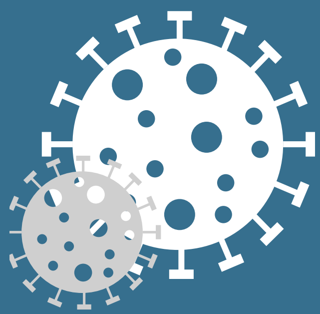
The COVID-19 pandemic

At the end of 2019, a viral disease (later named COVID-19) broke out in China. Two weeks into 2020, the Chinese authorities shared the genetic sequence of the pathogen with the rest of the world. The virus proved to be a novel coronavirus (called SARS-CoV-2), leaving significant uncertainty regarding the virus' characteristics, contagiousness, and mortality. Through until the end of January 2020, the Danish health authorities assessed that the risk for enduring spread of the virus in Denmark was low. The disease, however, spread quickly, and on 30 January 2020, the WHO declared an international public health emergency. In Denmark, the first case was registered on 27 February 2020, and the number of infections continued to rise sharply thereafter, primarily among ski tourists who had returned from Italy and Austria. On 7 March 2020, the first instance of community spread within Denmark was confirmed, and enduring spread became a reality.

On 11 March 2020, the WHO declared a global pandemic. At that point, more than 118,000 cases were registered across more than 114 countries, including 514 cases in Denmark. On the same day, the Prime Minister's Office held a press briefing announcing a partial lockdown of society. The Danish health authorities went from a strategy of disease containment to one of mitigation, aiming to limit and delay the spread of the virus and thereby avoid a potential breakdown of the hospital system. At the same time, the government launched the first of many economic stimulus packages.

A year and ten months later – on 11 January 2022 – there had been a total of more than 1 million COVID-19 infections and 3,408 deaths related to COVID-19 in Denmark*. On a global scale, there have been 308 million infections and 5.5 million deaths. In addition, there have been enormous health, economic, and social consequences as lockdowns have been periodically tightened and loosened in Denmark and other countries. With unprecedented speed, vaccines have been developed and approved. The vaccination effort has been ongoing since December 2020, but limited vaccine production capacity, complex distribution of vaccines, and mutations in the SARS-CoV-2 virus continue to make the outlook to the end of the pandemic uncertain.

*In Denmark, deaths related to COVID-19 are defined as a confirmed COVID-19 infection whereby the infected person died within 30 days of testing positive for COVID-19. COVID-19 is not necessarily the immediate cause of death.



CHARACTERISTICS

In the context of the National Risk Profile, 'highly virulent disease' denotes any disease with the ability to spread easily or cause serious harm to infected individuals. The cause of the given disease is called a pathogen, which is typically a virus or bacteria.

Some pathogens spread from one human to another through air, liquids, or physical contact while others can spread via a temporary carrier such as a mosquito or an animal.

A pathogen's ability to spread between individuals and its ability to induce serious symptoms or death in infected individuals are two separate elements of virulence. One pathogen can be especially infectious and spread quickly and easily among a population (i.e., epidemically), but cause relatively mild symptoms, while another pathogen can require close and long-term contact to infect a new host, but be fatal. Both pathogens and the diseases they cause are considered highly virulent.

In a Danish context, highly virulent diseases are divided into three groups:

1. Diseases rarely occuring in Denmark
2. Recurrent diseases in Denmark
3. New diseases

The first group covers diseases that continue to cause problems on a global scale, but have been eradicated or are only rarely seen in Denmark. These are diseases such as diphtheria, cholera, polio, measles, and tuberculosis.

The second group are recurrent and sometimes frequently recurring in Denmark, such as seasonal influenza, which can be caused by various influenza viruses. Seasonal influenza viruses mutate quickly, and there are therefore continuously new variants of it. The mutations can either be small changes, which can be seen from year to year (antigenic drift), or large changes (antigenic shift).

In addition, influenza viruses are also widespread in animals such as swine, poultry, and other birds, which increases the risk for mutations of influenza viruses that enable spread from animals to humans. In these cases, virus variants that humans have not been exposed to and therefore do not have immunity to can infect humans via human to human contact. Such mutated viruses can thereby spread freely among populations and give rise to global influenza epidemics – so-called pandemic influenza.

Although we know much about influenza diseases, handling new types of influenza is both difficult and resource-intensive. Among various influenza viruses, there is significant variation in terms of severity of symptoms and which demographic groups are hardest hit. Regardless of whether the new virus is especially virulent or not, the creation of a specifically tailored vaccine for each type of virus is an important tool in handling disease outbreaks.

The third group – new highly virulent diseases – covers diseases that appear either as an epidemic or a pandemic for the first time or as a recurrence of an old disease that has not broken out in decades. The pathogen may appear in a mutated form or something may have changed in the population's resistance to the pathogen, allowing the disease to run rampant.

This group also includes diseases caused by new variants of coronavirus (CoV). Recent examples include:

- SARS-CoV-1, which caused more than 8,000 cases of the disease SARS (Severe Acute Respiratory Syndrome) and just under 800 deaths across 37 countries in 2002-2003 (none of these deaths were in Denmark).
- MERS-CoV, which was first noticed in 2012 and caused more than 2,500 cases of the disease MERS (Middle East Respiratory Syndrome) and just under 1,000 deaths across 27 countries (none in Denmark).

- SARS-CoV-2, which caused the pandemic with the disease COVID-19 and had caused more than 308 million infections and just under 5.5 million deaths spread across the entire world (3,408 deaths and more than 1 million infections in Denmark) as of 11 January 2022.

OCCURRENCE

The first of the previously mentioned disease groups – the rare highly virulent diseases – do not pose an immediate significant risk to Denmark. This is because of several factors, including that the population's general standard of hygiene is high, the general housing situation is good, and the healthcare sector is well-functioning. In addition, Denmark has an effective childhood vaccination program, which is the most significant reason why most highly virulent diseases occur very seldom in Denmark. In addition, there is generally a high level of confidence in the Danish health authorities, which significantly impacts the degree to which the population abides by authority-issued recommendations.

Participation in Danish vaccination programs, including childhood vaccination programs and influenza vaccinations, is high and growing. Even small decreases in participation, however, could reduce the so-called 'herd immunity' and reintroduce vulnerability to diseases that are otherwise not widespread in Denmark. Herd immunity is a term that describes when members of the population that are not vaccinated against a certain disease for whatever reason are nonetheless protected by the fact that the disease cannot flourish in the population because of the population's collective immunity. The more contagious a given disease is, the higher vaccine participation rates are required to achieve herd immunity. As such, lacking participation in vaccine programs can compromise the ability to control otherwise well-known highly virulent diseases, allowing them to break out and cause significant damage.

The second group – recurring highly virulent diseases – typically have the most disease cases during the winter months, partially because more people gather close together indoors. Since seasons are opposite on the Earth's northern and southern hemispheres, countries south of the equator experience influenza season during the Danish summer months. During this time, the virus can mutate into new variants with changed characteristics by the time they return to countries in the northern hemisphere.

The seasonally dependent movement of influenza is closely monitored in Denmark as well as by the EU and the UN's World Health Organisation (WHO), and it is therefore sometimes possible to meet new variants of influenza viruses with a vaccine before they break out. Vaccines developed before the coming influenza season are produced based on assumptions about the properties of the new virus that will come into circulation. Because the vaccine development is based on assumptions, albeit well-informed ones, such vaccines do not always offer full protection. Each winter, the incidence of influenza increases in periods of 6-10 weeks, where 5-10 per cent of the Danish population will be infected. Statistically, about every fourth year, seasonal influenza infects about 20 per cent of the population and the disease develops into an epidemic.

Occasionally, completely new forms of influenza viruses emerge that no humans have immunity to. These can spread globally regardless of season and cause a pandemic. Historically, pandemic influenza has occurred three to four times per century, most recently in 2009 and 2010 in the form of the so-called 'swine flu'.

Some types of influenza are primarily found in animals such as swine or birds, but can infect humans in rare cases. This has especially been seen in Asia, where some avian influenza viruses have caused serious illness in humans. The avian influenza is particular in that it can easily travel long distances through wild migratory birds that can then spread the pathogen to stocks of domesticated birds that are in closer contact with humans. In the fall of 2020, the highly pathogenic avian influenza H5N8 began to circulate amongst wild and tame birds in Europe – including Denmark – and in February of 2021, the first case of human infection with H5N8 was recorded on a poultry farm in Russia. Human to human spread was not observed, so it is unlikely that the H5N8 virus would be able to cause an influenza pandemic.

The third group – outbreak of new diseases – also occur regularly. This is primarily the normal and constant mutation of existing microorganisms that sometimes manifest themselves in highly virulent variants. Examples of this, as mentioned, include the new variants of the coronavirus (CoV) that caused the current COVID-19 pandemic, the MERS outbreak in 2012, and the SARS pandemic in 2002-2003.

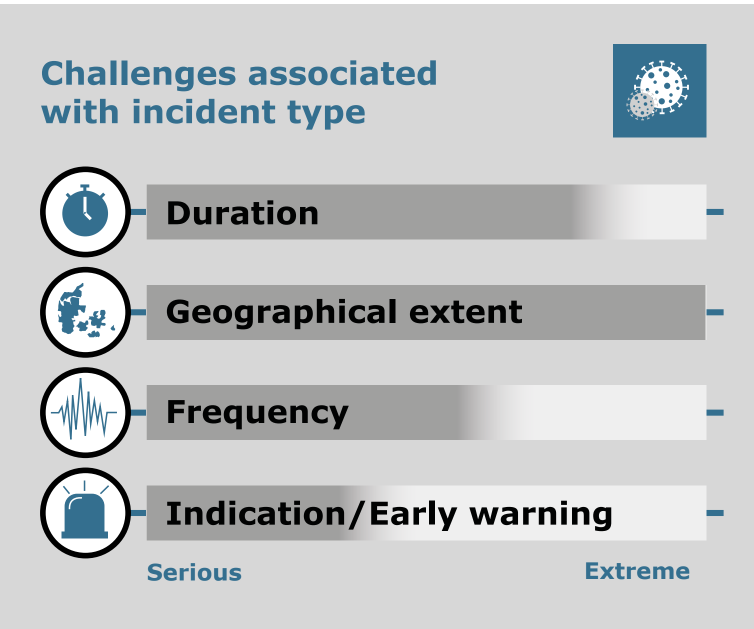
Finally, it should be noted that very deadly (though not very contagious) viral haemorrhagic fevers such as Ebola and the Marburg virus have not yet reached Denmark. If isolated cases occurred because of return travel from other parts of the world, these viruses would likely not be able to spread widely thanks to good diagnostics and handling of the disease (isolation, treatment, contact tracing, hygiene, etc.) within the Danish healthcare emergency management system.

CONSEQUENCES

Highly virulent diseases have direct consequences for life and health among those affected. Factors such as which population groups are predominantly affected, mortality, disease spread, and consequences for society as a whole depend on several parameters.

One parameter is the pathogen's properties, including the manner by and degree to which it spreads as well as the disease's severity and mortality. The recurring seasonal influenza, for example, infects individuals through droplets and typically lasts less than one week followed by one to two weeks of coughing, fatigue, and reduced physical capacity. Longer-lasting, more serious infections can also occur if the viral infection directly attacks the lungs or paves the way for a bacterial infection. Each year, an average of 1,000-2,000 persons die of complications from seasonal influenza in Denmark. Excess mortality primarily occurs among chronically ill patients and elderly individuals, but there can also be a significant disease burden on children and young adults that have not built up the same immunity through previous exposure to a similar pathogen as older individuals may have. A new disease can have properties that make it different and more virulent than normal influenza. This applies to both the degree of severity of symptoms as well as mortality and spread. Diseases that can be transmitted from one person to another prior to the onset of obvious symptoms are especially difficult to control.

Another parameter that affects how long-lasting a disease outbreak will be and how much the disease will spread is the population's behaviour, especially the



degree to which the recommendations of health authorities are followed. Typically, these recommendations will be about which symptoms to be aware of, guidelines regarding socialisation with other people at work, school, or other institutions, and advice regarding how to minimise the spread of the disease (e.g., wash hands, use hand sanitizer, and thorough cleaning).

A third parameter that can affect the scope and type of consequences of a given highly virulent disease is the political strategy chosen to handle the disease. This can be regarding the implementation of restrictions on large gatherings, closure of certain institutions, or the chosen contact tracing strategy, testing strategy, and vaccination strategy.

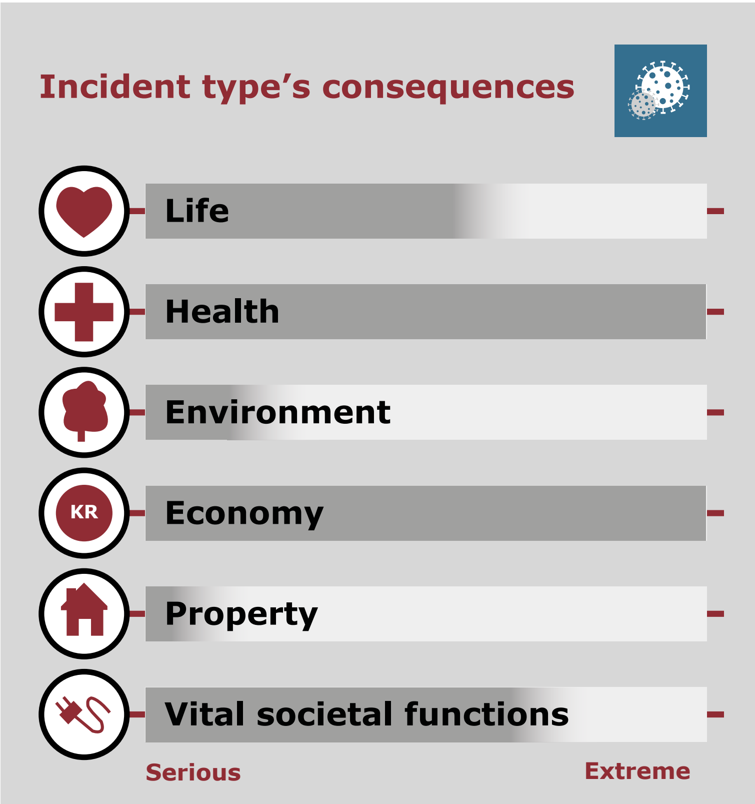
A serious pandemic can – depending on these three parameters – put pressure on all of society. This is especially true for the healthcare sector, where a large increase in the number of physician consultations, hospital admissions, intensive treatments, etc. can be expected. A large number of people infected that experience complications would require treatment, and even more individuals than usual may seek medical attention due to a fear of developing a serious complication. At the same time, healthcare personnel can also be infected, reducing the healthcare sector's capacity. There is also an additional task of tracing infection sources and isolating contagious disease carriers. In the long term, a pandemic can also deplete resources in the healthcare sector if the disease causes long-term effects that require treatment in infected individuals.

In addition, general public health can be negatively impacted since a pandemic can cause capacity problems in the healthcare sector, making it difficult to treat more frequently occurring diseases. Routine check-ups and treatments may be postponed to make time and space for treatment of acutely ill patients, prolonging the time patients are sick while also increasing the length of waiting lists. In periods of lockdown, social distancing, and remote working and learning, individuals may experience mental health challenges, including but not limited to depression. Worries about the future, family, and job security have a significant impact on the population's general mental health and resilience.

At workplaces, pandemics can cause a significant amount of personal absences among sick employees or employees that stay home to care for sick or quarantined family members. Requirements, rules, and recommendations regarding lockdowns, working from home, travel restrictions, etc. may also be implemented. The increased lack of and uncertainty about personnel capacity can pose a risk for interruptions to the supply of vital societal functions.

Further, political decisions may be taken that affect the everyday workings of specific industries or entire sectors: e.g., prohibitions on gathering, keeping the workforce home, and limits on freedom of movement across national borders in order to reduce contagion. Hindrances to workforces' free movement could directly lead to losses in production in several sectors and thereby lack of services such as cleaning at hospitals, slaughtering of animals, and food production. Lockdowns of entire branches such as liberal professions, the concert and festival industry, or the hospitality industry can ultimately lead to a higher level of layoffs and more bankruptcies. The tourism industry can be especially hard hit by both a ban on Danes entering other countries as well as bans on foreigners entering Denmark.

Global supply chains can also be affected by widespread lockdowns and limited transport capacity including civil air transport. Shortages of products such as personal protective equipment (PPE), hand sanitizer, and specific pharmaceuticals can also occur. This can also affect the parts of the healthcare sector that deals with especially vulnerable groups, such as the care sector, or sectors that frequently use PPE, such as rescue services or the food industry. A shortage of goods that are not necessarily part of battling a pandemic can also occur. For example, reduced air cargo capacity can reduce capacity to transport special spare parts or critical components from non-local markets.



In addition, a long period with uncertainty, lack of predictability, and interruptions to production can more generally affect business demand and tenders for goods or services, thereby affecting other branches by forcing layoffs and bankruptcies. Highly virulent diseases can also have enormous and long-term consequences for society's economy. Potential national stimulus packages to help affected branches and industries can total billions of DKK.

TRENDS

It is certain that a new pandemic will occur, but no one can say when, which pathogen will cause it, how serious it will be, which population groups will be at the highest risk for serious illness or death, or which tools will prove most effective in battling the pandemic nationally and internationally.

Today, large parts of the world are closely connected. With international air transport, people and goods move quickly around the world. Although there was a large decrease in transnational tourism in 2020 and 2021 as a result of COVID-19, the current trend of increasing travel activity is expected to continue. Global interconnectedness creates the foundation for a quick spread of pathogens and thereby potential for pandemics. This means that diseases that would not normally occur in Denmark can suddenly appear anyway.

The occurrence of new highly virulent diseases (or recurrence of old ones) can also be connected to changes in the population's composition, behaviour, use of space, food sources, interactions with animals, etc., which weaken general resilience to and bring us into contact with new pathogens. At the same time, urbanisation means that humans around the world are living increasingly close together in cities and thereby increasing the risk for disease spread.

Changes to the climate can also affect conditions for insects' and animals' seasonal migratory patterns, meaning that some vector-borne diseases can spread to areas where they have not previously been. A vector is a disease carrier that carries a pathogen from a living organism to another (e.g., to a human). Examples of vectors can be mosquitos, lice, and ticks.

EXAMPLES

History's most infamous highly virulent disease is the plague caused by the bacteria Yersinia pestis. During the worst of many outbreaks in the Middle Ages, it is estimated that up to half of Europe's population died of the plague. There is no exact number of deaths in Denmark, but it is estimated that 30-40 per cent of the population died during the first and worst outbreak in 1349-1350. Subsequent outbreaks did not kill as many thanks to improved methods of dealing with epidemics, such as quarantining. The most recent plague epidemic hit Denmark in 1711.

Although accounts of widespread influenza-like outbreaks exist dating back to the 1500s, it was not until the late 19th century that it was biologically possible to document influenza-like pandemics. In the last 100 years, there have been four actual influenza pandemics (all caused by influenza A virus subtypes) that have also affected Denmark:

- The Spanish Flu in 1918-1919 (H1N1)
- Asian Flu in 1957-1958 (H2N2)
- Hong Kong Flu in 1968-1970 (H3N2)
- Swine Flu in 2009-2010 (H1N1 pdm09)

Of these four influenza pandemics, the Spanish flu was the most catastrophic. It is estimated that about one third of the world's population was infected and about 10-20 per cent of those infected died, corresponding to 3-6 per cent of the population at the time (i.e., 50-100 million people). The disease killed quickly and hit younger people unusually hard. About 80 per cent of those that died were between 15 and 45 years of age. In Denmark, it is estimated that more than 14,000 people died.

Another example of a highly virulent disease is AIDS caused by HIV (Human Immunodeficiency Virus). From the start of the 1980s and onward, AIDS has killed tens of millions of people globally. Since a breakthrough in treatment of HIV in 1996, the number of fatal AIDS cases has stagnated, especially in Western countries. It was not until 2019, however, that Statens Serum Institut assessed that the curve of case numbers was broken based on recent data regarding newly diagnosed HIV infections in Denmark.

Most recently, COVID-19 has affected most of the world dramatically since the start of 2020. On 11 March 2020 – the same day the WHO declared COVID-19 a pandemic – Prime Minister Mette Frederiksen held a press meeting and announced the shutdown of large parts of Denmark, including schools, public workplaces, cultural institutions, etc. and further restrictions on gatherings in order to prevent contagious spread in society. Over the following days, the Ministry of Foreign Affairs advised against all non-essential travel to the entire world, and the Danish borders were closed for incoming travellers without a 'worthy purpose'.

In the time since March 2020, various restrictions have been loosened and tightened as disease spread developments and changes in the population's behaviour have occurred.

New mutations of the SARS-CoV-2 virus also emerged. The B.1.1.7 variant (Alpha, first registered in the United Kingdom) proved to be significantly more contagious than the original virus. It was introduced to Denmark at the end of 2020, and by February of 2021, more than 60 per cent of aggregate infections were due to the Alpha variant. Other variants include Beta (B1.351, first registered in South Africa) Gamma (P.1, first registered in Brazil), and Delta (B.1.617.2, first registered in India), which arrived in Denmark in the spring of 2021 and became the dominant variant over the course of the summer. In November 2021, Denmark had its first registered case of Omicron (B1.1.529, first registered in South Africa), and by the end of 2021, it had overtaken Delta as the dominant variant.

Since the pandemic is ongoing as of the time of publication, it is not possible to give an exhaustive summary of the multifaceted health, economic, and social consequences of COVID-19 in Denmark. It was already clear in the beginning of the pandemic, however, that all parts of society would be affected in some way. For example, in March and April 2020, 52,000 fewer medical operations were performed than during the same period the year before due to the diversion of the healthcare sector's resources in order to prepare for potentially large numbers of COVID-19 patients.

At the end of December 2020, authorities began vaccinating the first Danes with the newly developed vaccines against SARS-CoV-2. In June of 2021, the effects of the vaccination program were clear: there was a decrease in illness and mortality among the population, especially among people above the age of 50. As of 11 January 2022, 4.8 million people in Denmark had received their first vaccine, just under 4.7 million had received their second, and almost 3.2 million had received their third.

As a result of high vaccination rates and the assessment that disease spread was under control in Denmark, the final COVID-19 restrictions from the reopening agreement of June 2021 were lifted on 10 September 2021, 548 days after the first lockdown. Over the course of December 2021, the quick spread of the Omicron variant led Parliament's Epidemic Committee – based on recommendations from the Epidemic Commission – to instate new activity-limiting restrictions, which entered into effect 19 December 2021.

What if...

... the COVID-19 pandemic is contained in Denmark, society is fully reopened, travel is no longer advised against, and the population is living life as normal. Suddenly, human to human transmission of a new type of the influenza A virus is confirmed (swine flu G4 variant) with an unknown origin in wild or tame birds. The virus proves to be not only extremely contagious, but also more challenging to treat, and leads to a high number of serious illnesses and deaths – higher than with SARS-CoV-2 and associated variants. Illness caused by the new influenza virus is – unusually and in contrast to COVID-19 – more serious among young people. In Denmark and the rest of Europe, the number of new cases soars, hospitals fill up with seriously ill patients, and the death toll rises exponentially. The development of the first vaccines happens relatively quickly, as was the case with the COVID-19 pandemic, but the virus mutates quickly, weakening the vaccines' effectiveness.

ANIMAL DISEASES

Avian flu H5N8 outbreak, 2020-2021

On 30 September 2020, the European Center for Disease Control (ECDC) issued a warning describing several outbreaks of highly pathogenic avian flu H5N8 in western Russia and Kazakhstan. Annual bird migrations brought the disease to Denmark and several other European countries, leading to the culling of millions of birds. In Denmark, the first case was detected in November 2020. In March 2021, the Danish Veterinary and Food Administration confirmed that the outbreak of avian flu was the largest ever in Denmark. Between November 2020 and July 2021, approximately 195,000 hens, turkeys, geese, ducks, pheasants, and other birds were culled in 16 locations across the country.

The outbreak had enormous consequences for animal health and imposed significant costs on bird farmers and associated industries. The outbreak also put intense pressure on the Danish Veterinary and Food Administration as well as DEMA, who assisted in the decontamination and logistics of the culling effort as well as collection of the many hundreds of dead wild birds in order to monitor the spread of the disease. The stress on resources was exacerbated by the fact that several responses were simultaneous with Denmark's first outbreak of the fish disease infectious haematopoietic necrosis (IHN) and the handling of the COVID-19 spread in mink farms in Denmark.

In February 2021, Russian authorities reported the first known case of bird-to-human spread of the H5N8 virus to the WHO. Seven workers, all of whom were involved in the culling and handling of dead, sick birds, were infected. They only had mild symptoms, however, and there was no indication of a risk for the disease to spread person-to-person. The risk of infecting the general public – and thereby for a pandemic the likes of the avian flu H5N1 pandemic in 2008 – was also assessed to be very low by both the WHO and the ECDC.

In August 2021, Denmark recovered its status in the World Organisation for Animal Health (WOAH) as a country free of the avian flu. In the fall of 2021, however, the highly pathogenic avian flu H5N1 came to Denmark again, and the 2021/2022 avian flu season surpassed the 2020/2021 season with the culling of 228,000 birds in eight locations as of 10 January 2021.

CHARACTERISTICS

Production of animals and food products can be affected by outbreaks of various serious and contagious diseases among animals. Some disease outbreaks can be limited to a specific species of animal while others can spread across species. When the number of infected animals increases drastically, a disease outbreak is called an epidemic or an epizootic development.

Animal diseases are primarily a threat for animal stocks, but in some cases, disease can spread to people via either living or dead animals. Such a disease is called a 'zoonosis'. A zoonosis that causes illness in people does not necessarily do so in animals. In other words, animals can be disease carriers without exhibiting symptoms themselves. Some zoonoses, however, can cause serious symptoms in both animals and people.

The Danish agricultural industry is heavily focused on food security and quality control. Denmark is under the jurisdiction of EU regulations transposed into Danish law. Denmark also works closely with the World Organisation for Animal Health (WOAH) to ensure high standards for animal health. Given the extent of Danish animal production and the relative proximity of animal stocks, disease outbreaks can spread quickly depending on the method of transmission despite constant efforts to minimize risk factors.

In Denmark, 87 animal diseases are required to be reported to the Danish Veterinary and Food Administration upon suspicion or detection, depending on the severity of the disease. Since 17 July 2020, COVID-19 has been added to this list.

OCCURRENCE

Several serious animal diseases have not been detected in Denmark before. There are also, however, several serious animal diseases that have occurred or occur regularly in or near Denmark and therefore constitute a significant risk for Danish animal production. This is especially pertinent in the case of highly pathogenic avian flu, foot-and-mouth disease, classical swine fever, and African swine fever.

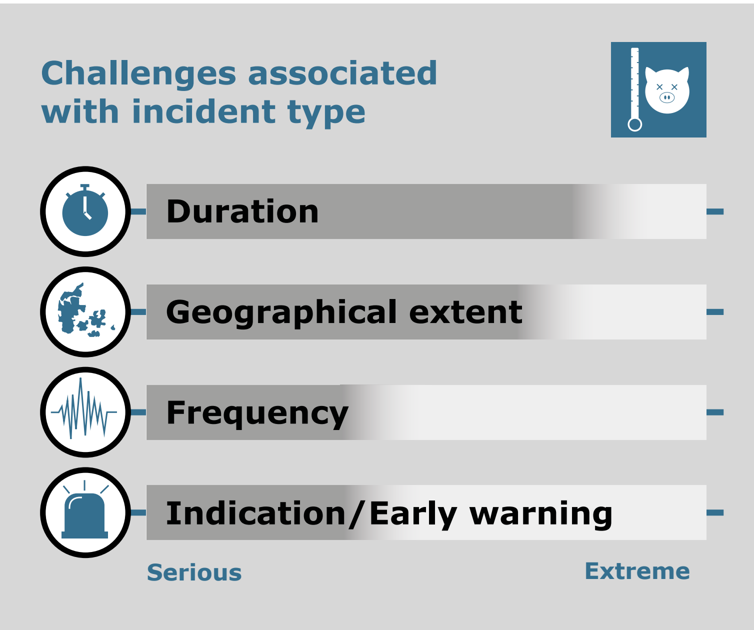
Avian flu ('bird flu') is an infectious viral disease caused by the influenza A virus that can afflict all species of birds. Avian flu can be split into two groups: highly pathogenic avian flu (which causes especially serious illness) and low pathogenic avian flu (which causes more mild illness in birds). Both types occur regularly in Denmark. Low pathogenic avian flu has the ability to mutate and become the highly pathogenic type, which is why veterinary authorities cull poultry flocks infected with low pathogenic avian flu. Wild birds, especially migratory water birds, can spread disease to different parts of the country and across national borders. Wild birds in Europe are now a reservoir for highly pathogenic avian flu year-round. Humans and animal species other than poultry (e.g., pigs) can also be infected with avian flu.

Foot-and-mouth disease is a serious infectious viral disease that can infect all species of cattle, pigs, wild ruminants, sheep, and goats. The disease can infect new hosts through direct animal-to-animal contact, via the air, and secretions from infected animals. Infected animals can secrete the virus for several days before blisters appear. Transportation instruments or people that have been in contact with infected animals can also spread the virus. An outbreak of foot-and-mouth disease has not been detected in Denmark since 1983, but there are sporadic outbreaks in the EU, most recently in Bulgaria in 2011. The infection cannot be transmitted to humans.

Classical swine fever and African swine fever are viral diseases that can infect all breeds of pigs, both tame and wild. Infection is transmitted within a flock from animal to animal through direct contact and indirect contact via bedding, feed, and water. Infection between flocks can occur through trading of pigs or via persons that have been in contact with infected animals. Humans cannot be infected with swine fever.

Classical swine fever in wild boars can lead to a transfer of disease to tame pigs without a sufficient infection barrier between them. This is one of the reasons why African swine fever has been such a large problem in Europe for years. It has also been a topic of discussion in Denmark in recent years with regards to migrating wild boars from Germany. In 2021, outbreaks of African swine fever were detected in wild boar or tame pigs in 10 EU countries including Germany, where a flock of tame pigs in Rostock just 236 kilometres from the Danish border were infected in November 2021. African swine fever is expected to spread to large parts of the world and to new European countries in the coming years.

In addition, Danish aquaculture (i.e., fisheries, shellfish farms, and other water organisms) can be affected by disease. In May 2021, an outbreak of the fish disease infectious hematopoietic necrosis (IHN) was detected in Denmark for the first time. The outbreak affected eight fish farms and three fishing lakes in 2021. IHN is fatal to fish but cannot infect humans.



CONSEQUENCES

Animal diseases can have serious health consequences for animals as well as humans. The health-related consequences for humans infected with a zoonotic animal disease are discussed in the chapter on highly virulent diseases as well as the chapter on water and foodborne diseases.

Health consequences for infected animals can vary from mild symptoms to widespread fatalities. Even animal diseases that are not directly fatal can result in permanent harm to the infected animal. Since the risk of transmission of highly infectious diseases is often large, flocks often have to be culled, and the areas previously occupied by the flocks must be thoroughly cleaned and disinfected.

Outbreaks of certain animal diseases can have large economic consequences for Danish farmers and other industries involved in the production and export of animals and related food goods. In turn, this can be expensive for the Danish economy as a whole. These economic consequences can be loss of production, fees associated with diagnostics, treatment, culling, cleaning, and disinfection of contaminated flock areas, temporary restrictions on transport, and other disease outbreak containment measures.

Long-term outbreaks can also strain the resources of authorities involved in processes of combatting the disease. This is especially the case for the Danish Veterinary and Food Administration, which has the primarily responsibility for responding to animal diseases. This can also be the case for, for example, DEMA, who will often assist the Veterinary and Food Administration in large-scale responses.

The direct costs of combatting an animal disease can be high, but are usually less than the commercial costs. For example, estimates calculated by the Technical University of Denmark (DTU) based on simulated outbreaks of foot-and-mouth disease in Denmark showed a decline in exports ten times the amount of the cost of combatting the disease through the examined strategies. The estimates further show that the total economic loss in the event of a foot-and-mouth disease can vary between 3 and 8.5 billion DKK.

In the case of outbreaks of certain animal diseases in Denmark, other countries' bans on imports of Danish food goods can be substantial and long-lasting. With food exports contributing more than 150 billion DKK to the economy annually (accounting for 25 per cent of Denmark's total exports of goods), the potential impact of import bans on specific Danish animals or foods is large.

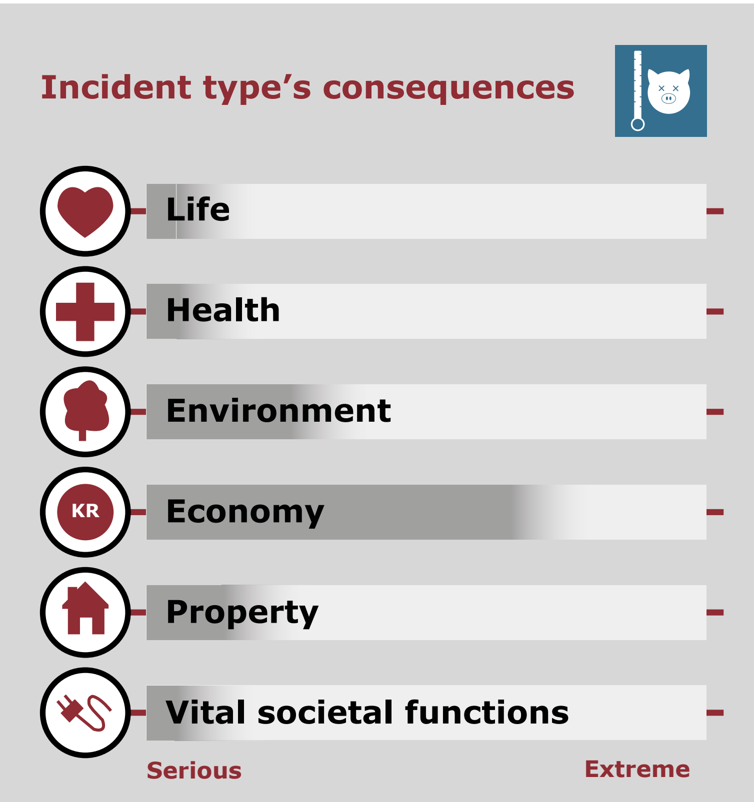
For example, export of pork and living pigs amounted to 35.8 billion DKK in 2020, making up 5.1 per cent of Denmark's total goods exports for that year. The estimated costs in the case of an African swine fever outbreak in Denmark are between 2 and 10 billion DKK. The outbreaks of African swine fever in Germany in 2021 led the Danish Veterinary and Food Administration to ask everyone involved in the pig and pork industries to assist in preventing the disease from reaching Denmark. Furthermore, information materials have been made and signs have been put up at Danish rest stops with reminders not to litter animal products in nature or feed them to pigs.

TRENDS

In Denmark and the rest of Europe, there is a constant effort to improve the surveillance, prevention, and combatting of outbreaks. In addition, collaborations between responsible authorities and the agricultural and food industries are continuously being strengthened. Even so, the risk of introduction of serious infectious animal diseases in all Danish animal flocks and reintroduction of already-known diseases in Denmark could increase in the coming years.

On a global level, increases in commerce and international relations as well as the growth in the animal and food production to provide for a growing world population contribute to a higher risk for infectious animal diseases to spread across national borders. International revenue from animals and animal products is increasing. Combined with increases in tourism and the ability to take pets across national borders, this further increases the risk for animal disease. In addition, the agricultural industry's increasing duration of transportation of living animals also increases the risk for disease spread.

In terms of climate change, even small increases in temperature and humidity can make it possible for insects to survive in new, previously inhospitable environments and allow explosive propagation during warm periods. Especially during summer months, insects could spread exotic infectious diseases to both animals and humans. For example, the vector borne viral disease West Nile Fever has spread in Europe since 2008 and was



detected in birds and horses in mid- and northern Germany in 2018. There is also a risk for the introduction of the disease in Denmark.

Similarly, higher water temperatures in the winter allows year-round aquacultural fish production. This creates new risks in terms of outbreaks of severe infectious diseases among farm-raised fish such as viral haemorrhagic septicaemia (VHS), which was declared eradicated from Denmark in 2013.

New viruses and bacteria are constantly emerging in different parts of the world, and the risk that these will spread increases – as with current and known diseases – alongside the increased movement of animals and humans across national borders.

EXAMPLES

In the middle of the 1960s, viral haemorrhagic septicaemia (VHS), also known as Egtved disease, peaked in Denmark with more than half of Danish fish farms infected (i.e., 300-400 farms). The disease was a serious issue in the following 50 years, especially for trout farms. VHS is a viral disease with a mortality rate of 20-95 per cent in infected fish, while the surviving fish become immune disease carriers. Each time a fish farm is infested, all fish must be destroyed and the facility must be disinfected. VHS is estimated to have cost Danish fish farms up to 50 million DKK per year from the middle of the 1960s to 2013, when the disease was declared eradicated from Denmark.

The most recent outbreak of foot-and-mouth disease in Denmark occurred in 1982-1983. The epidemic started on Funen in the spring of 1982 and was then transferred to southern Zealand via a sheep flock that was moved from southern Funen to Zealand. The outbreak was the last in a more widespread epidemic that originated in Ukraine and spread via Germany. The incident caused import restrictions in Japan, Canada, the US, and other countries, resulting in large economic loss.

The United Kingdom experienced a serious outbreak of foot-and-mouth disease in 2001. In total, 2,030 outbreaks were detected and about 6 million animals were culled, costing the UK approximately 40 billion DKK. Offshoots of the outbreak also affected Ireland, France, and the Netherlands, and there was suspicion of an outbreak in Denmark, though this was proven not to be the case. Despite this, Denmark was still affected by import restrictions since Japan, Russia, and the US implemented import bans on meat from the EU.

For many years, bluetongue was conceptualised as a vector borne disease limited to Southern Europe (i.e., south of the 50th parallel north). The disease spreads through biting insects and afflicts cattle, sheep, goats, deer, and other ruminants. In October 2007, the first outbreak was confirmed in Denmark, and there were 15 outbreaks in the country. The outbreak triggered a comprehensive vaccination program in Denmark that lasted from 2008-2010. The most recent outbreak of bluetongue in Denmark was in November 2008, and the disease was declared eradicated in Denmark in 2011.

In 2003, a highly pathogenic avian flu (H5N1) broke out in parts of Asia and subsequently spread to Europe and Africa. In addition to causing problems for poultry production, this virus was also a significant threat to humans, and the outbreak ended up causing several hundreds of deaths across the world. There was also worry that this avian flu could develop into a virus with pandemic potential. In Denmark, the highly pathogenic H5N1 was detected three years later in 2006 in wild birds and within a hobby poultry farm.

In 2016-2017, another variant of a highly pathogenic avian flu (H5N8) was found among wild birds and farm poultry in Denmark, and in 2018, the new highly pathogenic variant H5N6 was detected. In this case, Denmark was the country with the most infected and dead wild birds in all of Europe. Most recently, Denmark was hit by H5N8 again in 2020-2021 (see the introductory text box) and was hit by H5N1 in 2021-2022. Between 1 November 2021 and 10 January 2022, 228,000 hens, turkeys, pheasants, ducks, and geese were culled across eight farms, making it the largest outbreak of avian flu in Denmark to date.

In June 2020, COVID-19 infection was detected among mink on three farms in northern Jutland. The infection of the mink was due to a mutation of the SARS-CoV-2 virus (Y453F), the so-called 'mink variant', which infected both mink and humans. Despite comprehensive attempts to contain the outbreak, the virus spread, and by the end of November 2020, 289 mink flocks in Denmark were infected. As of 5 February 2021, all mink in Denmark were culled. Combatting COVID-19 in mink required a substantial effort across several authorities in close collaboration with the mink industry, and the associated cost including costs associated with mink farmers' own contributions to the effort was calculated to be 610 million DKK in 2020. In addition to this, destruction of dead mink, costs associated with exhumation and cremation of the previously buried mink in two locations due to environmental concerns, remedial measures, and compensation and damages to mink farmers and associated industries were all costly endeavours. In the political agreement regarding culling of mink from 2021, these costs alone are estimated to total 15.6 to 18.7 billion DKK.

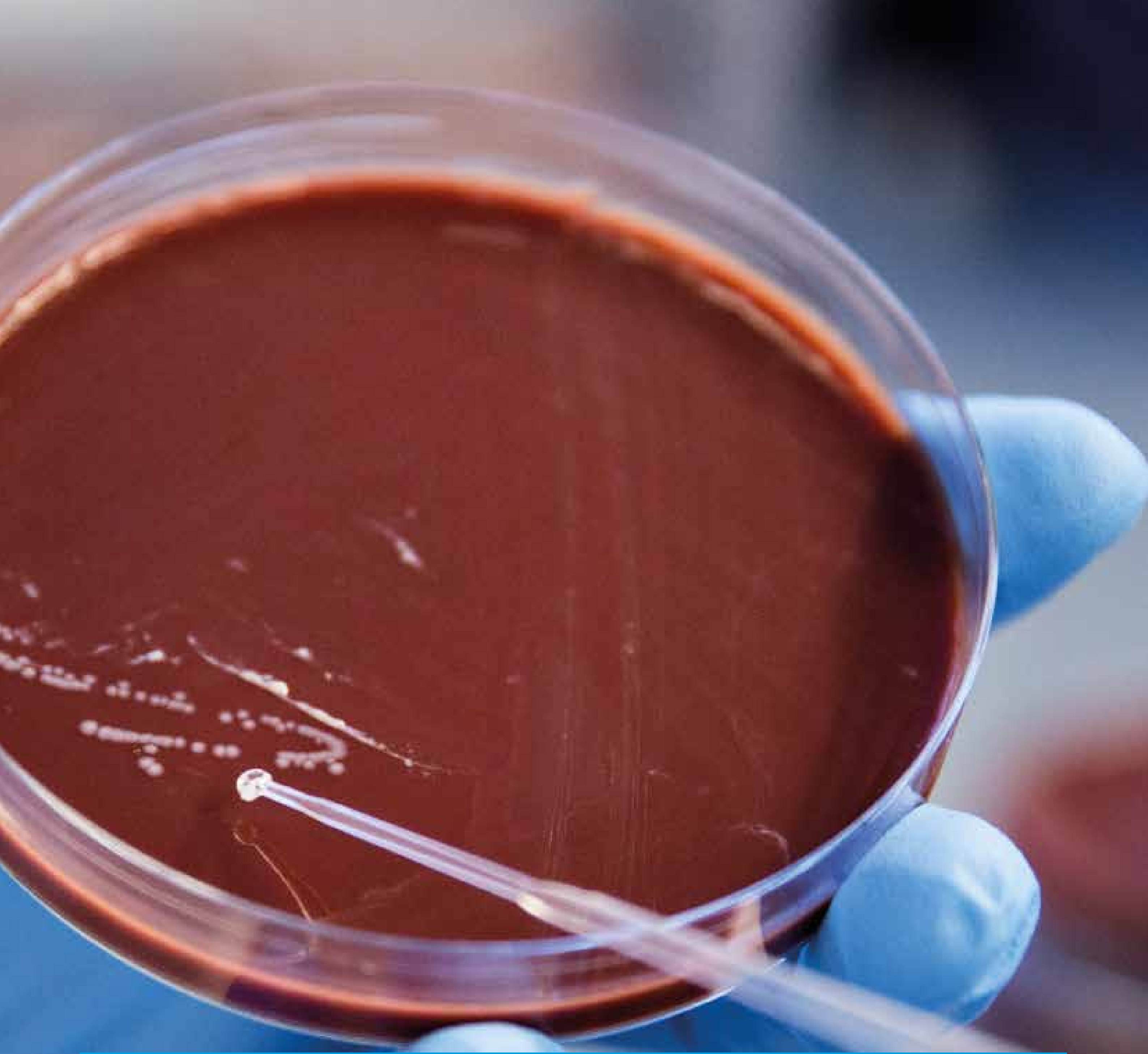
What if...

... several human deaths occur in Europe, primarily outside of major cities, that can be directly linked to animal production. In Denmark, four people die after having been seriously ill with influenza-like symptoms. After some time, research shows that a previously unknown form of swine fever that had become zoonotic caused all of the deaths. The illness therefore afflicts pigs and can be transferred to humans in some cases. In the short term, the source of the outbreak cannot be identified, but Denmark is assessed to be especially hard hit.

Danish and foreign consumers begin to avoid Danish food goods connected to pig production. At the same time, several of Denmark's most important export countries implement a ban on import of Danish pigs and pork. Billions of kroner in export income are lost, and it is uncertain how long the ban will be in effect. In addition, a significant demand for information emerges among residents that want to know the extent to which the disease constitutes a risk for humans.

At the same time, Danish authorities' resources are heavily strained due to the long-term response including tasks such as culling of flocks, cleaning and disinfecting of flock areas, restrictions on transport of pigs, and other measures aimed at containing the outbreak.

WATER AND FOODBORNE DISEASES



Listeria outbreak, 2013-2014

The most deadly outbreak of a foodborne disease in Denmark began in September 2013. The breakout lasted for over a year and was not under control until October 2014. Listeria infection was detected in 41 patients, 17 of which died as a result. The patients were relatively evenly distributed over the country's regions. Because it primarily affects individuals with pre-existing conditions that have significantly weakened immune systems, listeria has a high mortality rate among those infected.

The main source of the 2013 listeria outbreak turned out to be a meat product from a producer in Zealand. Other companies had purchased and used the meat product to make sliced cold cuts. Listeria bacteria were then transferred to those businesses' equipment, and it could therefore not be ruled out that other products produced in the same facilities could be contaminated with listeria. The products were sold in supermarkets and were also delivered to canteens.

CHARACTERISTICS

Water and foodborne diseases can be caused by contaminated water and food, covering a wide array of chemicals and microorganisms such as bacteria, viruses, parasites, and fungi. A foodborne infection is caused by the microorganism itself while food poisoning is attributable to toxins produced by bacteria, fungi, or chemical substances.

Waterborne diseases refers to infections with bacteria, viruses, algae, and parasites that enter the body via consumption of contaminated water, inhalation of contaminated aerosols, or contact with bodily cavities or open wounds. In Denmark, drinking water quality is generally very high. The Danish drinking water supply is based on groundwater extraction and is highly decentralised. This means that in the vast majority of cases, a waterborne illness outbreak would be relatively local.

Waterborne disease can be a consequence of flooding if the flood causes wastewater to come up from sewers or if a water purification plant is exposed to flooding. In addition, there are health risks connected to swimming in water contaminated with waste water.

Foodborne diseases are typically bacterial infections or poisoning caused by toxin-producing bacteria and can vary in severity.

The risk for foodborne infection depends on – other than the microorganism in question – the population's resistance. Generally, children, elderly, immunocompromised individuals, and pregnant women are especially vulnerable.

Norovirus, campylobacter, salmonella, listeria, and STEC (Shiga toxin-producing E. coli) are disease-causing microorganisms assessed to have potential to be seriously threatening to public health in Denmark.

Norovirus, also known in Denmark as '*roskildesyge*', is very contagious and spreads via surfaces or droplets in the same manner as common cold viruses. Only very few virus particles are required to infect a person, enabling mass infection when people are gathered large numbers.

Infection with campylobacter causes gastrointestinal illness. The bacteria is typically found on the surface of raw chicken meat, but has also been identified in contaminated drinking water sources. Campylobacter can also be transferred via contact with contaminated water during leisure activities and contact with animals.

Salmonella is a bacteria that causes gastrointestinal illness. Infection occurs almost exclusively through food. The risk for salmonella infection from eggs and poultry in Denmark is reduced thanks to special rules for these products. Even so, beef, pork, fish, vegetables, etc. can also cause salmonella infection.

Listeria is found both in animal and vegetable products and can therefore also be introduced to food production facilities. Listeria is a very robust bacteria that can survive in both dry environments and temperatures all the way down to 0 ^{0}C. If listeria is present in a food production facility, it can be very challenging to get rid of. Only few healthy people get sick from the bacteria, but for immunocompromised persons, mortality is high.

In some cases, STEC infections can be very serious and cause organ failure due to the poisonous toxins produced by STEC bacteria. These bacteria are primarily found in healthy ruminants, such as cattle, goats, sheep, and venison. STEC primarily infects hosts through contaminated drinking water or food, but infection can also occur via contact with ruminants, colostrum, or ingestion of contaminated water during leisure activities such as swimming.

As far as poisoning goes, food poisoning caused by bacterial toxins are considered especially problematic. These toxins can cause severe but short-lived illness with diarrhoea or vomiting, but for some, the poisoning can be long-lasting and potentially life threatening. Botulism, also known as 'sausage poisoning', is especially dangerous to human health. Botulism is caused by poisonous neurotoxins produced by the bacteria Clostridium botulinum. Neurotoxins are some of the most potent and dangerous poisonous toxins in existence. Botulism is often attributable to consumption of poorly conserved food.

Most often, the cause of a foodborne illness is contamination of food due to insufficient production hygiene in food production, failures in cooling equipment, insufficient heating or cooking, bad kitchen hygiene, or cross-contamination due to handling of raw meat. Vegetables and fruit washed with contaminated water can also be sources of infection.

Another reason can be production and sale of illegal food items. This is on the rise in the EU, and this development is expected to continue. The danger of food fraud is that neither the consumer nor authorities can know with certainty which substances the product contains or where and under what hygienic conditions it was produced. In addition, repacking, insufficient cooling conditions, and fraud with regards to expiry dates increase the risk of infection. The health risk connected to consumption of illegal food can therefore be high, and tracing of the disease outbreak can become more difficult because of the unreliable tracing information inherent to food fraud.

In some cases, dietary supplements have been proven to contain undisclosed illegal and dangerous substances or ingredients. Dramatically increased intake of vitamins and minerals as a result of production mistakes or poor labelling can be dangerous for human health.

OCCURRENCE

All foodborne disease outbreaks in Denmark are registered in the Foodborne Disease Outbreak Registry (FUD). In 2019, 51 foodborne disease outbreaks were registered with a total of 1,929 illness cases. 33 of the 51 outbreaks were local or regional, and the remaining 18 were national outbreaks. In 2020, there was a significant decrease in the number of registered foodborne disease outbreaks – from 51 to 35 – which DTUs Food Institute's annual report attributes to the COVID-19 pandemic. This is partially because of the drastically reduced travel activity in 2020 (many illnesses occur on international trips), and partially because Danes were less likely to seek medical attention for mild symptoms during the COVID-19 pandemic. Because COVID-19 was still a significant factor in 2021, the following text primarily refers to data from 2019.

The actual number of water and foodborne disease cases can be assumed to be higher than what is reported. This is firstly because symptoms of these infections overlap with several other diseases, and secondly, because those with more mild infections typically do not seek medical attention.

In Denmark, norovirus and campylobacter are the most common cause of water and foodborne disease. In 2019, there were 19 norovirus outbreaks with a total of 932 infected persons. This was an increase of more than 10 per cent from 2018 and more than a tripling as compared with 2017. Between 2014-2019, the annual number of people with laboratory-confirmed infection with campylobacter has varied between 4,348 and 5,389.

In the years leading up to the turn of the century, salmonella infections were more frequent than infections with campylobacter. Increased awareness about salmonella amongst the general population combined with preventive and mitigation efforts by authorities, however, have contributed to a significant decrease in the number of salmonella infections, which have been relatively constant around 1,000 cases a year in recent years. The effort to eliminate salmonella from meat-producing and egg-laying chickens is especially notable. In 2019, there were nine outbreaks of salmonella that aggregately infected a total of 1,120 persons.

In the last five years, the number of annual listeria infections has remained stable at around 50 infections per year. In 2019, 62 people were infected with listeria.

The number of people found to be infected with STEC has increased each year since 2015 (228), reaching a total of 630 persons in 2019. In 2018, 21 cases of haemolytic-uremic syndrome (HUS), a complication of STEC, were registered. This was the highest number of HUS cases ever registered in Denmark. During the most recent outbreak between 3 December 2021 and 10 January 2022, 13 persons were infected with STEC, including three children that suffered acute kidney failure (HUS).

Each year, a few cases of botulism (primarily infant botulism) are recorded in Denmark. In 2019, 10 botulism outbreaks were registered as a result of Clostridium perfringens, infecting a total of 551 persons. This was an increase, both in the number of outbreaks and illness cases as compared with 2016, 2017, and 2018. One outbreak caused 268 infections, making it the largest foodborne illness outbreak in 2019.

Water and foodborne diseases caused by infection by parasites are rare in Denmark.

CONSEQUENCES

Water and foodborne diseases can cause unpleasant and serious symptoms and can in the worst case be fatal.

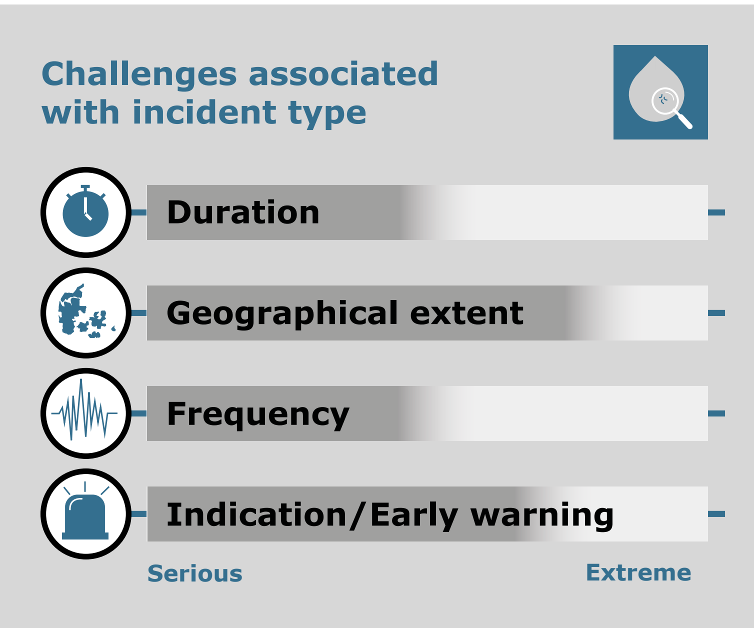
The most common health-related consequence of water and foodborne infections is gastrointestinal illness with symptoms such as stomach pain, diarrhoea, and vomiting. These symptoms can be so severe that they require treatment and hospitalisation. Examples of such infections are norovirus, campylobacter, and salmonella.

Listeria infections in vulnerable groups (i.e., immunocompromised patients or pregnant women) can cause life-threatening complications such as sepsis or meningitis.

STEC often causes serious stomach pain and bloody diarrhoea and, in serious cases, can cause HUS, which can be life-threatening and cause permanent kidney or neurological damage. HUS as a result of a STEC infection most often afflicts children and is the main cause of acute kidney failure in this group.

Similarly, botulinum poisoning can have very serious consequences. The bacteria toxin attacks the nerves and creates paralysis. Botulism can thereby cause permanent damage. In the most serious cases, if chest muscles are paralyzed, the infection can be fatal. Treatment of a botulism infection can take several months.

Sale of illegal food can have significant consequences for food security in Denmark. Consumers risk ingesting products with



poisonous substances or ingredients that can trigger allergies without such substances or ingredients being declared on the product. The consequences of this can range from minor irritation to death.

Contamination of drinking water supplies can be long-lasting. In addition to risk of disease, drinking water contamination can disrupt businesses and the population in the affected area (e.g., in the form of a boil water advisory). Larger and long-term contamination events can further pressure local water supply companies.

Both water and foodborne diseases can lead to an increase in hospitalised patients requiring special treatment, which can exceed hospitals' existing capacity. Authorities and actors in the health and food sector can also experience pressure as a result of a large demand for information from citizens.

Water and foodborne diseases can also have serious economic consequences if entire production batches are recalled. In some cases, even suspected contamination is enough for a recall. Sometimes, production facilities, cafeterias, restaurants, etc. must close down after identification of disease-causing foodborne microorganisms. Such closures can impose large costs and threaten companies' reputation and existence.

Further, water and foodborne diseases can cause import and export bans on specific ingredients or processed goods. This can have a significant impact on producers and risk hurting aggregate Danish food exports to specific countries, leading to large economic costs.

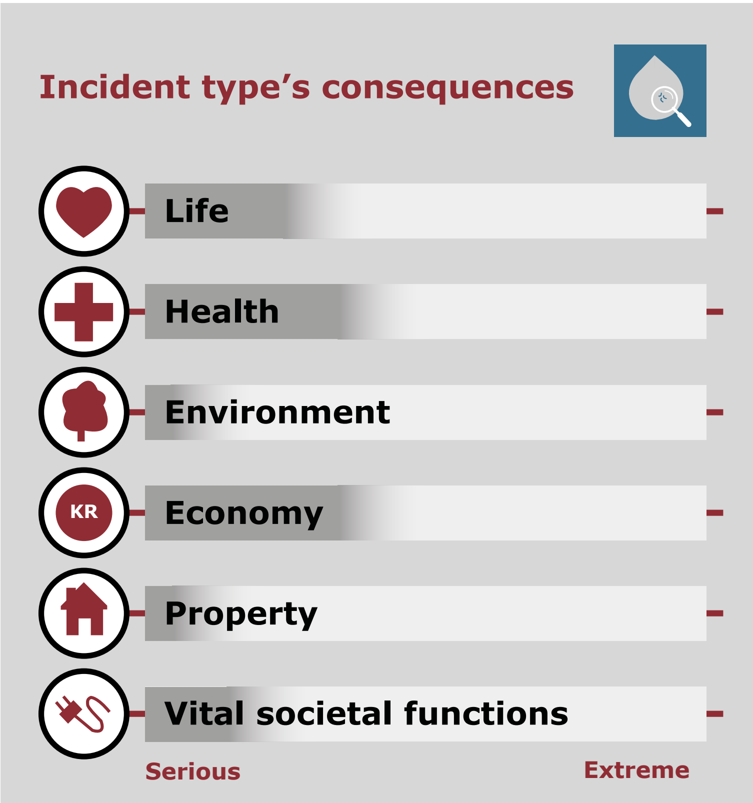
TRENDS

As of now, there is a trend towards healthier eating and consuming less meat and more diverse products than previously. Therefore, in the coming years, people are expected to eat more fresh ingredients. All other things constant, this increases the risk for foodborne disease. Fresh products are not cooked, conserved, or otherwise treated by the producer in a way that destroys disease-causing microorganisms. Ingestion of these products without first being cooked by the consumer can therefore be connected to a higher risk for foodborne disease. There is also, however, a trend towards eating more local products. This means there is a greater chance that outbreaks will be able to be traced and contained quickly, leading to fewer total cases of illness.

There is an ongoing focus on increasing food security, including efforts such as surveillance and control programs at the national, EU, and international (e.g., WHO) levels.

EXAMPLES

At the beginning of 2007, 7,000 Køge residents' drinking water was contaminated. A mistake at a purification plant caused waste water to be linked up to and leak into drinking



water pipes. 140 people fell ill due to various microorganisms including E. coli, campylobacter, and norovirus. In June 2010, Køge experienced another drinking water contamination incident that left several individuals ill due to infections with campylobacter.

In the beginning of 2008, Denmark experienced its largest salmonella outbreak since outbreak tracking began in 1980. Despite a large-scale effort, it was not possible to trace the source of the outbreak. From the outbreak's start until 1 September 2009, 1,206 cases of salmonella U292 were registered. The cases were evenly distributed across the country.

In summer 2011, Germany experienced a very large outbreak of STEC with HUS. 3,168 cases of STEC and 908 cases of HUS were reported, resulting in 53 deaths. In Denmark, 26 cases caused by the same bacteria were identified, most of which were infections that occurred in connection with vacation in Germany. Ten Danish patients developed HUS. Fenugreek sprouts produced by Egyptian fenugreek seeds were identified as the most likely source of the outbreak, though several other food products were identified as potential sources, including cucumbers, tomatoes, and lettuce. These suspicions and warnings from authorities led to a de-facto import ban on Spanish cucumbers and large economic losses (i.e., close to 80 per cent of revenue for multiple German companies).

In July of 2016, a product with vitamin D drops for infants and small children was recalled from stores throughout Denmark. The producers' calculation error caused the drops to contain 75 times more vitamin D than they should have. Poisoning with vitamin D causes vomiting, headaches, and in rare cases, cramps and kidney failure. The product was immediately recalled, but approximately 500 bottles had already been sold. A total of 150 children were examined, and 80 children showed signs of poisoning. Of these, six children were seriously poisoned.

In July 2017, through the European Rapid Alert System for Food and Feed (RASFF), it was announced that fipronil was found in samples of eggs and poultry from several farms in the Netherlands and Belgium. Fipronil can have acute health effects in certain concentrations. The case developed in the following months, and fipronil was ultimately found in eggs from 180 hen farms in the Netherlands. Eggs and products containing fipronil were recalled and removed from shelves throughout the EU and in several countries in the rest of the world. Fipronil is approved as a veterinary medicine, biocide, and pesticide, but may not be used on food-producing animals. Studies showed that a company had illegally added fipronil to the legal insecticide DEGA-16, which is distributed and used to combat red mites in hens. The insecticide builds up in the hens and thereby in their eggs. Fipronil was not found in Danish poultry and egg production, but some products and foods were contaminated with fipronil because they contained eggs from the Netherlands and Belgium. In total, the case is estimated to have cost 33 million EUR.

From September to November 2018, 38 people were infected with STEC during an outbreak in Denmark. Of the 38 infected, 33 were children of primary school age. Illness cases were spread throughout the country with heavier concentrations in and around large cities. In collaboration, the Danish Veterinary and Food Administration, Statens Serum Institut, and DTU Food at the Technical University of Denmark (DTU) suspected a beef salami from a specific food producer as the cause of the outbreak. It was not, however, possible to identify how the salami became contaminated with STEC.

In May and June 2020, 203 people living in Bornholm and people who had recently visited the island were infected with campylobacter. The Danish Veterinary and Food Administration took samples of several ready-to-eat locally produced foods but did not find campylobacter. Statens

Serum Institut conducted a study comparing answers from confirmed infected individuals and answers from randomly selected non-infected persons with the same postal code, age, and sex. The results showed a strong correlation between illness and consumption of milk. As a consequence, the local dairy was shut down and thoroughly cleaned. The dairy then took samples of their water, which revealed bacteria levels that exceeded maximum acceptable levels.

What if...

...there was a serious outbreak of a special kind of HUS-inducing STEC in Denmark. Illness cases are limited to the Capital Region, and many employees in ministries and authorities in Copenhagen are infected. A study of the infected patients raises suspicion that public authorities' canteens may be the source of the outbreak.

After two weeks, 300 patients with STEC and 40 with HUS are identified. The source of infection turns out to be ingredients from a supplier responsible for the operation of several public authorities' canteens. The healthcare sector in the capital region reaches its maximum capacity for treatment of HUS patients, and patients are transferred to other parts of the country. At the same time, the affected authorities' operations and work stand still.

NUCLEAR ACCIDENTS

Fukushima accident

On 11 March 2011, Japan was hit by an unprecedentedly strong earthquake measuring 9.0 on the Richter scale. The earthquake was subaquatic and created a 10-metre-high flood wave (tsunami) that submerged Japan's northeastern coast, hitting the nuclear power plant Fukushima Daiichi. The earthquake cut off the plant's power and emergency generators responsible for keeping the reactors stable were flooded. This caused three of the plant's six generators to melt down, explosions and fires in reactor buildings, and a series of radioactive spills in the subsequent days. Radioactive contamination affected eight per cent of Japan's landmass. Up until this point, handling the aftermath in the last almost 11 years has cost over 1 trillion DKK, and efforts are expected to last at least an additional 30 years. No known deaths or illnesses have been directly attributed to the radiation released during the accident, but due to other reasons, the evacuated population has experienced excess mortality.

Due to the distance between Japan and Denmark, there was no risk of radioactive contamination in Denmark, but the accident nonetheless triggered a need for intensive and comprehensive crisis management. After the situation at the Fukushima Daiichi plant worsened in the days after the earthquake and tsunami, Danish authorities were extremely busy clarifying the accident's consequences, aiding each other with advice and expertise, and communicating relevant measures to Danish citizens and companies domestically and abroad.

CHARACTERISTICS

A nuclear accident is an accident that occurs in connection with production, processing, use, transport, storage, or deposit of nuclear material. Here, nuclear material refers exclusively to plutonium and enriched uranium. This distinguishes nuclear accidents from radiological accidents, which occur with various other radioactive materials used in industrial or medical facilities.

The threat of a serious nuclear accident with substantial consequences for Denmark primarily comes from nuclear power plants in Europe. Nuclear power plants occupy a special status as potential sources of nuclear accidents because of the large volume of fissile material they contain. Under adverse wind conditions, this can potentially lead to airborne spread of radioactive radiation over large areas.

The biggest danger posed by nuclear power plants is the risk of radioactive materials being released and spread from reactors. Leaks of large amounts of these materials require both damage to the fuel and that the reactor container fails to fully contain the released materials. This can happen if control over the chain reaction in the reactor core is lost or if it is not possible to cool the reactor core effectively. Similar things can happen if decommissioned fuel in the fuel basins (typically placed outside of the reactor containment) cannot be cooled. Other catalysts can include technological vulnerabilities, human error, natural disasters, or failures in the energy grid.

Nuclear accidents can also occur on board nuclear powered vessels. Nuclear powered icebreakers, cargo ships, and naval vessels (hangars and submarines) can release radioactive materials into the air and water if the reactors or security systems are damaged in a collision, grounding, or other accidents. The vessels' reactors are significantly smaller than those used in nuclear power plants on land, but the reactor containment is also proportionately smaller and are therefore not able to withstand the same physical and mechanical impacts.

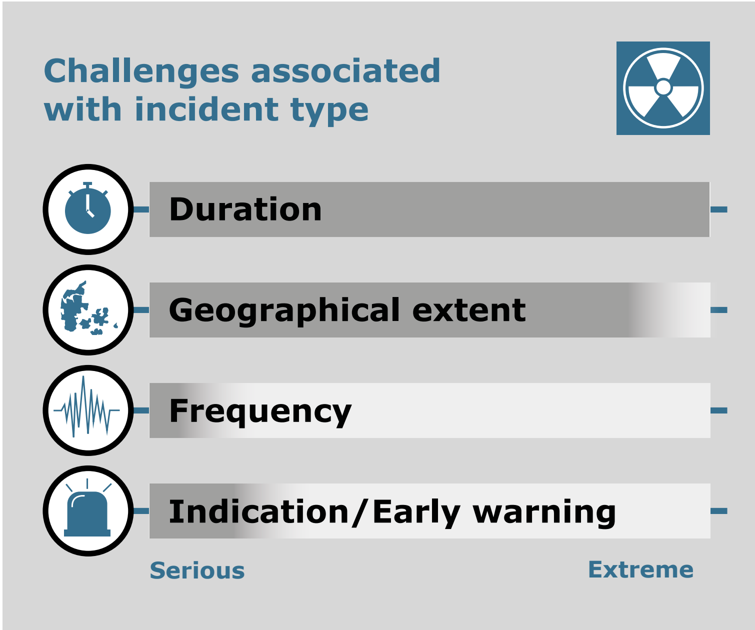
Finally, nuclear and radiological accidents occur during production, use, or handling of reactor fuel, during transport or storage and deposits of used fuel and radioactive waste, or during handling of strong industrial sources (e.g., radiographic sources).

Nuclear and radiological accidents are categorised with the help of the International Nuclear and Radiological Event Scale (INES). The scale consists of seven levels, where 1-3 is an 'incident' and 4-7 is an 'accident'. The authorities in the incident's or accident's 'host country' are responsible for assigning a level. Like the Richter scale that defines the strength of earthquakes, the INES scale is logarithmic, meaning that severity increases by a factor of 10 for each level. In contrast to the Richter scale, however, the INES scale is not an objective scale. This means that incidents and accidents can be upgraded or downgraded on the scale over time as the scope and consequences of the event become clearer. For example, the 2011 Fukushima accident was initially categorised as an INES 3 incident and was gradually upgraded to an INES 7 accident.

OCCURRENCE

Large reactor accidents are rare. The total number of accidents, incidents, and 'close calls' that have occurred at nuclear plants is unknown, but there have been four especially serious reactor accidents: at the military reactor Windscale in the UK (INES 5) in 1957, at the nuclear power plant Three Mile Island in Pennsylvania, USA (INES 5) in 1979, at the nuclear power plant Chernobyl in Ukraine (INES 7) in 1986, and at the nuclear power plant Fukushima Daiichi in Japan (INES 7) in 2011.

The likelihood for direct consequences in Denmark after a reactor accident at a nuclear power plant abroad depends on the security of individual plants, but also on the number of plants and their relative distance to Denmark.



The active nuclear power plant closest to Denmark is the Ringhals plant in Sweden. The plant is located in Gothenburg, about 55 kilometres from Læsø. Within a radius of 300 kilometres from Danish land area, there are also active nuclear power plants in Emsland in Germany and Oskarshamn in Sweden. An accident at one of these plants could cause radioactive fallout over significant parts of Denmark. Since the distance from the western part of Sweden or northern part of Germany is relatively short, the amount of time between a radioactive leak to the arrival of radioactive clouds and potential fallout in Denmark can likewise be short.

The closest Dutch, Belgian, French, and British plants are about 500-600 kilometres from Denmark. In total, there are just under 100 nuclear power plants with a total of approximately 180 operative reactors in Europe. Of these, just over half operate in EU Member States (Belgium, Bulgaria, the Czech Republic, Finland, France, Germany, Hungary, the Netherlands, Romania, Slovakia, Slovenia, Spain, and Sweden). The remainder are outside of the EU in countries such as Russia, the UK, Switzerland, and Ukraine. About 75 per cent of the European reactors are closer to Denmark than the Chernobyl plant in Ukraine where the world's largest-to-date nuclear accident occurred in 1986.

In recent years, several of the aforementioned countries have re-evaluated the size and setup of preparedness zones surrounding the nuclear power plants. German and Swedish authorities (among others) have conducted new analyses with advanced calculation tools and comprehensive weather data indicating that preparedness measures for vulnerable groups can be necessary within a radius of up to 300 kilometres from a nuclear power plant in the event of an accident. For agriculture and water supply, the corresponding radius can be up to 500 kilometres.

Although there are no nuclear power plants or active reactors in Denmark, it is possible for a nuclear accident to occur on Danish territory. This is because nuclear powered vessels frequently pass through Danish waters. As mentioned, the vessels' reactors are significantly smaller than those of an onshore reactor, and the size of a leak following an accident is therefore expectably smaller. DEMA assesses, however, that a radioactive leak from a nuclear powered vessel can release a sufficiently high concentration of radioactive material that acute and more long-term preparedness measures could be necessary in Denmark. A leak from a vessel in passage under the Storebælt bridge, for example, can occur with less warning than an accident abroad.

CONSEQUENCES

The potential consequences of a nuclear accident at a nuclear power plants in Europe or a nuclear powered vessel in Danish waters for Denmark are very difficult to estimate. The consequences partially depend on the specific accident – e.g., the duration of the leak into the atmosphere and the amount and type of radioactive material, which vary greatly in terms of hazardousness.

Some of the most dangerous are radioisotopes such as caesium-137, iodine-131, strontium-90, and plutonium-241, which spread via dust particles and can therefore be inhaled and deposited in soil and water, whereby they can contaminate the food chain via plants and animals.

The consequences also depend on the direction of spread, wind speeds, fallout, and precipitation. Under certain circumstances, an airborne leak can travel long distances with relatively limited fallout followed by a strong rinsing effect from downpours. For example, after the Chernobyl accident, there was significantly increased radioactivity in parts of Sweden and Norway more than 1,500 kilometres from Chernobyl, while other, much closer areas measured insignificant amounts.

It is therefore not possible to give a definitive, generalised distance across which contamination can spread, just like it is hard to predict if – and if so, where – precipitation will fall and cause a rinsing effect on radioactive clouds passing over Denmark.

Regardless of distance, meteorological conditions, and the properties of radioactive materials, humans and animals in Denmark are not expected to suffer acute radiation-related injuries from direct radiation from air contamination, inhalation, or consumption of radioactive materials through food and drinking water. A preparedness response would therefore focus on minimising the radiation dose to the general population as much as possible to minimise the risk for long-term effects (typically cancer). The best way to do so is by pursuing indoor protection, preventing consumption of contaminated fluids and foods, stable iodine prophylaxis for selected parts of the population, and potential evacuation.

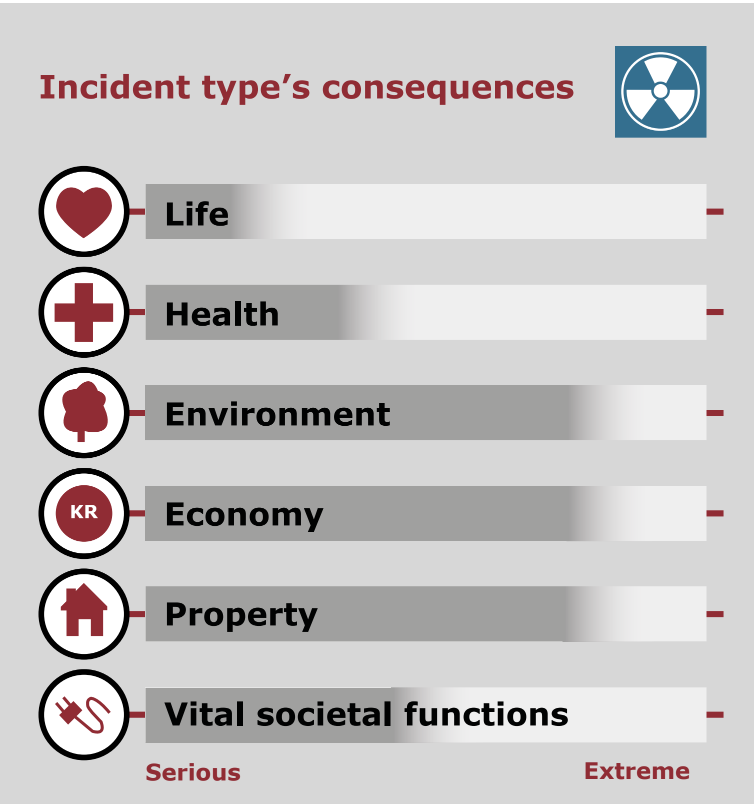
At the same time, a radioactive leak could lead to consequences for psychological well-being, both short- and long-term. This can be because of trauma or general anxiety triggered by the accident or stress and insecurity in connection with evacuation, uncertainty regarding the contamination of private property, etc.

Since a serious nuclear accident can contaminate very large land areas, the economic costs connected to clean-up can be enormous and potentially spread over months, years, or even decades. This can especially affect agriculture, where it may be necessary to destroy crops, rotate soil with cultivation tools, and contain and/or cull livestock in order to avoid food contamination. Certain supply chains can be disrupted as a result. In the case of nuclear contamination in Denmark, other countries may place a ban on Danish imports, causing large long-term income loss. This can happen even without formal restrictions if Danish and foreign consumers try to avoid contact with food products from Danish agriculture, fisheries, aquaculture, and fish farms.

A further consequence can be radioactive contamination of buildings and infrastructure, which can be costly to decontaminate and cause a significant drop in the value of property and land in the contaminated city, industry, and farm areas. Very serious contamination can necessitate temporary or permanent relocation of the local community. This would come with substantial costs and legal challenges. In addition, even a smaller-scale contamination – or suspicion of one – could cause tourists to stay away for a period, leading to collateral consequences for the tourism industry and the overall economy of the affected local society.

Because Danish drinking water comes from wells that draw on water that fell as rain many years ago, there would likely not be an acute need for restrictions on water. Drinking water companies' infrastructure on land, however, can be affected and, in turn, affect the security of the supply chain.

Road and train transport in impacted areas can also be affected due to rerouting of transportation, which can affect logistics, supply chains, and personal transport. Airspace can be temporarily closed due to potential contamination of aeroplanes, but air traffic would likely not be as impacted since aeroplanes can change course and filter air for radioactive materials. The same would likely apply to ship traffic, but if the leak comes from a ship reactor, the area of danger could temporarily affect several important sailing routes.



A nuclear accident could also put significant pressure on Danish authorities, even if the accident in question happened so far away from Denmark that none of the aforementioned consequences occur. Danish interests can be affected by an accident at a faraway nuclear power plant if there are citizens and/or business interests in the affected area or if Danish citizens demand high volumes of information.

These factors can necessitate a long-term communication response regarding local health-related measures, travel guidance, import of food, etc.

TRENDS

It is difficult to conclude anything regarding the risk for nuclear accidents based on the widespread nature of nuclear power in Europe. Some countries, such as Germany, try to reduce their use of nuclear power, while others rely on expanding and increasing it, sometimes based on the argument that nuclear power is a green energy source.

Today, new nuclear power plants are being built especially in Asia, where more than 30 are under construction – primarily in China, India, South Korea, and eastern parts of Russia. New nuclear power plants are also being built in Europe – for example, in western parts of Russia, Belarus, Finland, and Poland. Poland's current government, for example, is planning to build six new reactors leading up to 2043. Some of these reactors could be placed less than 200 kilometres from Bornholm.

Additionally, there are many countries (e.g., Sweden, Belgium, the Netherlands, the UK, Finland, and Russia) that chose to extend the lifetime of existing nuclear power plants, typically by 10-20 years. Such lifetime extensions are accompanied by requirements from authorities, including increased component control and improvement of security systems to compensate for the potentially increased risk as a result of ageing.

Several countries have started or have concrete plans to build new nuclear powered vessels (i.e., icebreakers and naval vessels). If built in the Baltic Sea area such as at the Baltic Wharf in Saint Petersburg, these vessels must pass through Danish waters on their way to their final destination (e.g., Murmansk). There are also annual naval parades with nuclear powered vessels that pass through Danish waters. One nuclear powered transport ship, Sevmorput, passes through Danish waters annually on its way toward Saint Petersburg. Russia has also started producing floating nuclear power plants, and in 2018, one of the plants (albeit without fuel) was towed through Danish waters.

EXAMPLES

Two nuclear accidents abroad have caused temporary, limited direct or indirect consequences in Denmark: the Chernobyl accident in Ukraine and the Fukushima Daiichi accident in Japan.

The Chernobyl accident began during the night of 26 April 1986 at the nuclear power plant Chernobyl in Ukraine when an uncontrollable chain reaction caused a vapour explosion that caused the upper part of the reactor to blow off and set the reactor core on fire for 10 days. In those 10 days, 400 times as much radioactive material as the atomic bomb that impacted Hiroshima was released.

At the accident site, it is presumed that 30-60 people died immediately or in the following days. 100-200 others suffered radiation damage, and it is estimated that approximately 4,000 people in Russia, Belarus, and Ukraine that lived close to the accident site in 1986 have since developed thyroid cancer. This type of cancer can be treated, however, and is rarely lethal. Increased frequency of other kinds of cancer and/or genetic defects in children whose parents were exposed have not been proven. The then-Soviet authorities evacuated about 115,000 people from the area and since 1986, 220,000 people in Belarus, Russia, and Ukraine have had to leave their homes and move to areas less exposed to the radiation. Almost 36 years later, the decommissioning and work to limit the leak of radioactive materials from the plant are still not finished. These tasks are expected to take several more decades and cost many billions of DKK.

Throughout the 10 days during which the reactor core burned in 1986, large amounts of radioactive material was sent over 1.5 kilometres up into the atmosphere and was sent over the majority of Europe by changing wind patterns. In the beginning, it was uncertain where the radiation was coming from, as the Soviet news bureau TASS sent out the first press release regarding the accident on the evening of 28 April 1986. In areas of Europe where it rained during the course of the accident and its aftermath, radioactive material was washed out of the atmosphere, causing contamination. Among the hardest hit were areas in Central Europe, southern Finland, and the middle of Sweden and Norway. In the parts of northern Scandinavia where populations eat reindeer, the caesium-137 contaminated rain posed a special risk since the substance built up in the reindeers' feed. Several hundred thousand reindeer and elk were therefore euthanized in the most affected areas.

In Denmark, however, only a slight increase in the amount of radiation was measured, and there was no significant contamination since there was fortunately very little rain during the time when the radioactive cloud travelled over Denmark. Even so, Denmark's authorities were confronted with an extremely high workload with little warning, and the organisation of the preparedness system was delayed due to several factors. Measurements of radioactivity in the air, the ground's surface, in rainwater and drinking water, in crops, and in milk were significantly intensified. Near the borders, controls were put in place to check if people, trains, cars, and airplanes arriving from eastern Europe were contaminated. The most contaminated cars and ships (i.e., fishing vessels) were decontaminated. Guiding thresholds for radioactivity in food were established, and from 6-11 May 1986, there was a ban on grazing of dairy cows after an observed increase in the amount of iodine and caesium in grass samples due to rainy weather from the south. Declarations regarding Danish food

products' suitability for human consumption had to be issued to representations abroad through the Ministry of Foreign Affairs.

The Fukushima accident started on 11 March 2011 when a strong underwater earthquake triggered a 10-metre-high tsunami that hit the nuclear power plant Fukushima Daiichi, located approximately 250 kilometres northeast of Tokyo. Of the plant's six reactors, three were in operation while the other three were closed down for maintenance. The used fuel from the closed down reactors were in fuel basins. When the earthquake occurred, the operating reactors automatically shut down, stopping the chain process while diesel generators ensured emergency power to the plants. When the tsunami hit the plant, the cellars housing the diesel generators and the main components of the electrical equipment were immediately flooded. The emergency power was therefore cut off and with it, the cooling of the reactors and functioning of the fuel basins. Because most of the surveillance systems also went out, it was not possible to get a sufficient overview of the situation.

Due to the excess heat, the temperature in the reactor container rose and caused the reactor fuel to melt. The rise in temperature also led to the development of hydrogen, causing three explosions in the reactor buildings. At the same time, the pressure in the reactor confinements increased so much that it necessitated release of air and vapour in order to prevent further damage. With air and vapour, however, large amounts of radioactive material were also released until the reactors and fuel basins were supplied with the necessary water for cooling.

Since the accident, it is assessed that there were no direct health consequences for the local population linked to the radioactive leak. The evacuation of tens of thousands of people from cities within a 20+ kilometre radius and the aftermath of the accident have, however, potentially cost more than 2,000 lives due to stress, anxiety, depression, PTSD, other psychological ailments, diabetes, substance abuse, and suicide. Many Japanese residents did not know if they had been exposed to radiation or when they could return to their homes for several years.

The contamination affected approximately eight per cent of Japan's land area including areas up to 200 kilometres from the nuclear power plant as well as parts of the Pacific Ocean. In the years since, the clean-up – including containment and collection of radioactive material, cleaning up and storing contaminated water and soil, and decommissioning the nuclear power plant – has cost over 1 trillion DKK. Clean-up is expected to last at least 30 more years.

Because of the distance to Japan, there was no risk of radioactive contamination in Denmark. Even so, Danish authorities, companies, and residents had to face the accident's residual consequences. DEMA was extraordinarily busy in collaboration with the Danish Health Authority, Risø DTU, DMI, the Danish Veterinary and Food Administration, the Ministry of Foreign Affairs, and Denmark's embassy in Tokyo. The International Operative Staff (IOS) was activated in the Ministry of Foreign Affairs, and at DEMA's headquarters, a crisis staff, expert group, and call centre were established and tasked with answering citizens' and businesses' questions.

DEMA and the Danish Health Authority also consulted with the Ministry of Foreign Affairs regarding travel guidance for Japan. DEMA sent experts to Japan as part of an EU mission and to the Danish embassy in Tokyo to advise regarding preparedness- and radiation-related circumstances.

In the following years, the Fukushima accident drew intense international attention to the safety and security of nuclear power plants. In the EU, in 2011 and 2012, all nuclear power plants were stress-tested with special attention to the consequences of potential natural disasters.

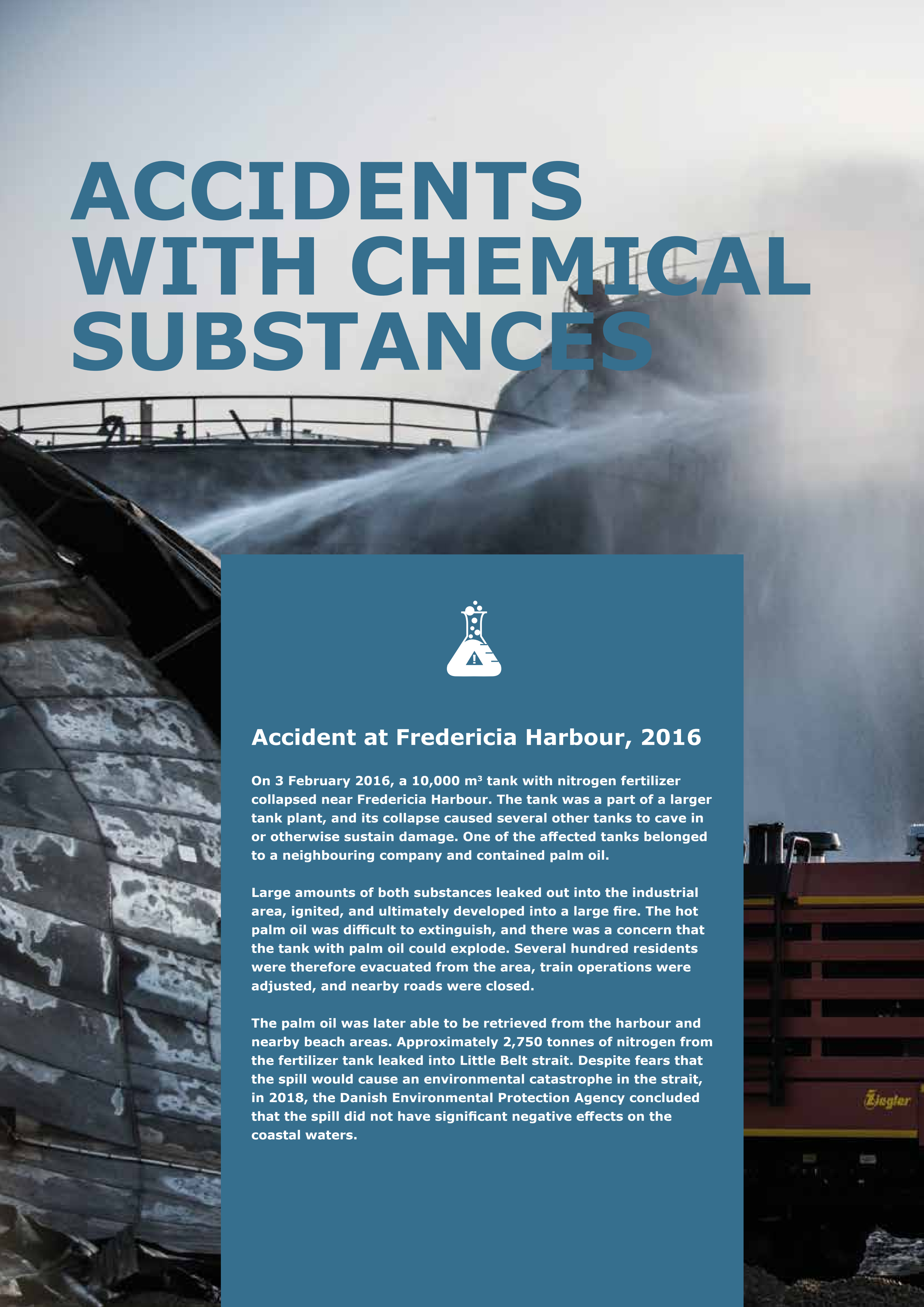
Authorities in several countries have since carried out many improvements based on concrete action plans. In Denmark, the accident drew increased focus to preparedness planning and training of specialists in DEMA to conduct more detailed measurements of radioactive contamination.

What if...

... a nuclear powered vessel violently collides with a large container ship. Fire breaks out on the vessel and smoke develops in the reactor room. To better control the accident, the captain grounds the ship a few kilometres from the Danish coast. It is immediately apparent that the reactor confinement and cooling system is much more severely damaged from the collision than initially assumed. Although there is not a lack of cooling water, airborne spread cannot be stopped. The reactor becomes uncontrollable and the majority of the crew leaves the vessel. After a few hours, the reactor room explodes, and a large radioactive leak moves over land with the speed of the wind. Since it is windy and raining heavily, radioactive contamination occurs in a large number of areas ('hotspots') spread across an area of 100-1,000 km^2. The contamination affects populated areas, industrial buildings, transportation, crops, natural areas, and marine environment.

Danish authorities initially encourage those in the affected area to go inside and begin a comprehensive information campaign to inform and reassure citizens across the country. The radiation level is assessed as not immediately life-threatening, but anxiety and insecurity nonetheless spread. Many residents self-evacuate and are caught in traffic jams on roads in areas that risk being impacted by radioactive rain. Even more people try to contact authorities and doctors to get personalised advice. The accident does not directly cost lives or cause radiation poisoning, but many people in the affected area (including response personnel) are later diagnosed with stress, anxiety, depression, PTSD, and similar ailments. The long-term effects on the society, environment, and economy are substantial due to the cost of soil and building clean-up, restrictions on food products, destruction of crops, culling of livestock, bans on fisheries, falling housing prices, and decreased tourism in the affected areas.

ACCIDENTS WITH CHEMICAL SUBSTANCES



Accident at Fredericia Harbour, 2016

On 3 February 2016, a 10,000 m^3 tank with nitrogen fertilizer collapsed near Fredericia Harbour. The tank was a part of a larger tank plant, and its collapse caused several other tanks to cave in or otherwise sustain damage. One of the affected tanks belonged to a neighbouring company and contained palm oil.

Large amounts of both substances leaked out into the industrial area, ignited, and ultimately developed into a large fire. The hot palm oil was difficult to extinguish, and there was a concern that the tank with palm oil could explode. Several hundred residents were therefore evacuated from the area, train operations were adjusted, and nearby roads were closed.

The palm oil was later able to be retrieved from the harbour and nearby beach areas. Approximately 2,750 tonnes of nitrogen from the fertilizer tank leaked into Little Belt strait. Despite fears that the spill would cause an environmental catastrophe in the strait, in 2018, the Danish Environmental Protection Agency concluded that the spill did not have significant negative effects on the coastal waters.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CHARACTERISTICS

Accidents with chemicals are most often industrial accidents or transportation accidents where the involved substances' dangerous properties can pose significant danger to humans, property, and the environment in the case of fire, explosions, or spills. This is primarily the case with flammable, explosive, toxic, and/or environmentally hazardous substances. This chapter focuses exclusively on accidents on land. Accidents on water are discussed in the chapter about maritime accidents.

Accidents with chemical substances occur in connection with uncontrolled incidents during production, transportation, storage, or use. Large stocks of chemical substances are usually found in industrial plants, but significant accidents can also occur in other places and due to other things, such as an ammonia spill from a large air conditioning unit at a shopping mall or other non-industrial buildings.

Companies with large stocks of combustible and fire hazardous substances are categorised as risk businesses. There are many types of risk businesses, but in Denmark, oil storage plants and refineries are among the largest. The rules for risk businesses are administered by several authorities in Denmark and are anchored in the EU directive called the Seveso Directive. This and other sets of rules (e.g., the EU's REACH ordinance and pesticide and biocide directives) identify a long list of chemical substances with dangerous properties.

The causes of industrial accidents with chemical substances can generally be separated into categories of human error, technical error, and external reasons, though in most cases, the cause will be a combination of these factors.

Human error covers operator mistakes (e.g., intentional or unintentional violations of security procedures or inattentiveness). Human errors can also be systematic, stemming from an insufficient culture of security, lack of auditing, poor maintenance or poorly suited facilities. Cost-cutting measures with regards to staffing or facilities can also increase the risk for systematic human errors.

Technical errors such as unnoticed wear and tear, ageing, building up of static electricity, or unintentional presence of other ignition sources can occur in equipment or systems.

External risks come from circumstances or events outside of the company (e.g., extreme weather events, accidents at neighbouring companies, or sabotage of physical installations or IT systems).

Land transport accidents with chemical substances can also occur during commercial transport of dangerous goods in tanker vehicles, tanker train cars, shipping containers, and other containers. The potential causes of such accidents can be collisions, impact, derailing, or improper handling of goods during packaging and transportation, which can cause leakages.

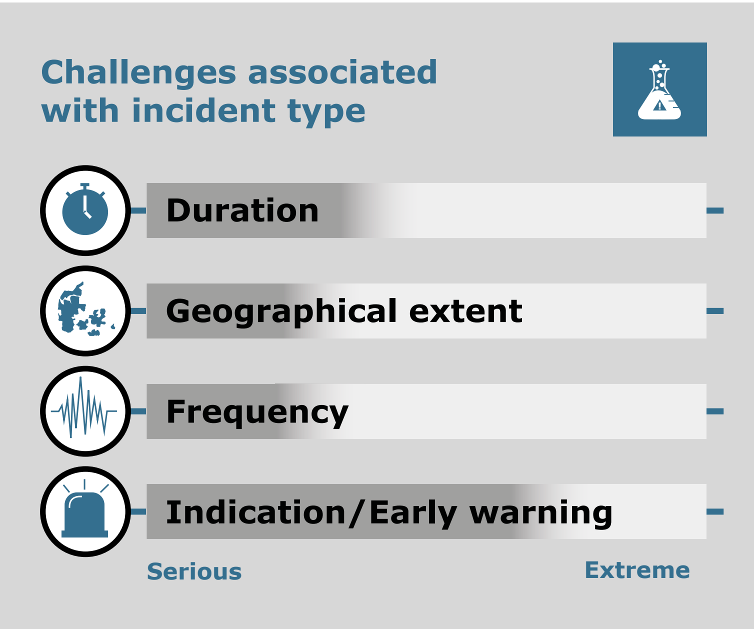
OCCURRENCE

Industrial accidents and transportation accidents with dangerous chemical substances can occur in many places. In Denmark, there are approximately 150 risk businesses, some of which are located near populated areas such as harbour areas. Railroad networks and road traffic carrying dangerous goods can also be located close to densely populated areas unless transport of certain chemical substances on certain roads is specifically forbidden.

Storage companies that temporarily store goods for further transportation and distribution can also have stocks of substances that can pose a danger if leaked or ignited. When combined with other substances, relatively common substances such as chemical fertiliser, oil products, strong acids, or chlorine can become explosive, flammable, toxic, and/or environmentally hazardous.

In addition, ammonia is one of the most common types of gas in Denmark and can come from sources such as biological waste gas purification plants and refrigeration equipment in food production. Ammonia is stored as a liquefied gas under pressure. If a tank, hose, or similar is punctured, ammonia is quickly released. Ammonia gas is poisonous when released into air.

Large amounts of chlorine and products containing chlorine are used in the production of plastic, paint, and nylon. Such products are also used as a cleaning and disinfection agent in swimming pools. Chlorine is transported in large pressurised tanks. If these tanks are punctured in an accident or otherwise, toxic corrosive chlorine clouds can spread over a large area.



Across Denmark, approximately 10 large commercial depots with oil products are part of the everyday supply chain of fuel. These depots are generally located in harbour areas near large cities. Accidents at these depots can therefore have substantial consequences.

CONSEQUENCES

Because of a strong focus on security and prevention, accidents with chemical substances seldom have catastrophic consequences, though there are exceptions.

Chemical accidents can pose a direct danger to life and health via inhalation of gases or contact with dangerous liquids. Chemical accidents can also cause explosions and intense fires that can result in many deaths and severe injuries to people in the accident site's immediate surroundings. As a result, shock waves, flying fragments, strong radiant heat, collapses, and spread of smoke and toxic gases can occur. Airborne spread of large amounts of dangerous chemical substances in densely populated areas can have serious consequences for public health. Typically, this manifests as problems breathing and eye irritation.

Depending on an accident's complexity and extent, the accident site can contain many hazards for the dispatched personnel, such as secondary explosions, uncontrollable fire spread, sudden collapses, unexpected chemical spills, etc. Rules necessary to protect response personnel can therefore affect the performance of acute response measures, such as evacuation of the accident site or prevention of further danger of fire and explosion.

Personal injuries can also occur if residents do not follow the recommendations and instructions given by authorities such as remaining inside, closing windows, respecting security distances, etc.

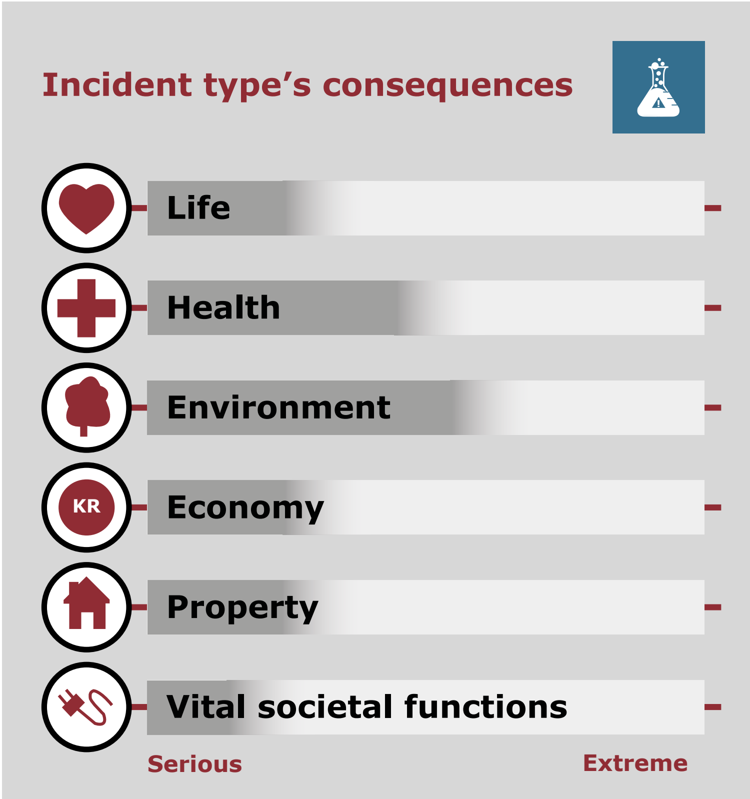
In addition to the immediate danger to people, accidents with chemical substances can pose long-term danger. The consequences of a spill for the surrounding environment (i.e., animals, plants, soil, aquatic environment, groundwater, etc.) have potential to be very significant, and in some cases, it can take several years to rehabilitate the contaminated environment.

On top of the consequences for life, health, and environment, accidents with dangerous substances can also be economically costly. If an accident causes a fire, explosion, collision, or the like, significant material damages can be inflicted on nearby buildings, transportation, and infrastructure. At the same time, decontamination and subsequent removal of contaminated water and soil can be costly. Potential resettlement and compensation processes for affected residents can also be protracted and costly.

Finally, accidents with chemical substances can have consequences for the accessibility of certain vital societal functions. Local drinking water supplies can be seriously affected if dangerous chemical substances permeate into the groundwater. Likewise, in the transportation sector, it can become necessary to reroute traffic for a long period of time. An accident at a depot with oil products can affect the supply chain of fuel in the impacted region, which can then affect transport infrastructure, among other things.

The nature and extent of the possible consequences are very situationally dependent and can be affected by factors such as:

- The volume of the substance, its toxicity, environmental hazard, location of the accident, and the substance's flammability and explosiveness.
- Number and reliability of security measures in place in compliance with regulatory prevention requirements.
- Weather conditions at the time of the accident, including wind strength, wind direction, and amount of precipitation.
- Number of persons in immediate vicinity of the accident and distance between the accident site and the nearest residences and companies.



- The surrounding environment's vulnerability to contamination, including the ecosystem's ability to adapt.
- Available knowledge about the chemical substance and local conditions at the accident site.
- The effectiveness of warning systems, the limiting and mitigating measures in place with regard to life-saving responses, containment and enforcing safety distance, and decontamination.
- The effectiveness of the subsequent clean-up, restoration, and environmental decontamination.

TRENDS

Production, storage, use, and transport of dangerous chemical substances is limited in Denmark as compared with other European countries, but will continue to be necessary since

such substances are used in many industrial processes.

To some extent, more stringent rules and phasing out the most dangerous and environmentally hazardous substances can contribute to the presence of fewer dangerous chemical substances in Denmark, thus reducing the risk for certain kinds of industrial accidents. It should also be noted, however, that certain chemical substances not used at a large scale in Denmark are nonetheless transported through Denmark. Generally, all else constant, an increase in the amount of traffic also increases the risk for transportation accidents with dangerous chemical substances.

In addition, changes in Danish weather conditions due to climate change can also potentially increase the risk for accidents with chemical substances caused by extreme weather conditions.

The risk can also be influenced by the expansion of cities if construction occurs closer to existing risk businesses. This emphasizes the significance of a sustained focus on risks in authorities' city planning. In the last decade, authorities have generally improved the administrative practices regarding risk businesses and transportation of dangerous goods. This development is expected to continue.

Conversely, the general development towards more complex systems with increased mutual dependence between companies and increased use of sub-suppliers makes it more difficult to maintain an overview of such dependencies and processes. This can increase the risk for large industrial accidents with chemical substances.

Finally, in recent years, there has been an increase in the production and consumption of flammable gases, especially hydrogen, biogas, and liquefied natural gas (LNG). This trend is expected to continue and be accompanied by the establishment of hydrogen plants, larger biogas plants, and more stocks of LNG around Denmark. The general increase in production, transport, and consumption of flammable and explosive gases increases the risk of accidents.

EXAMPLES

Fortunately, accidents with chemical substances at an industrial scale are fairly rare in Denmark. The largest industrial accident in recent history in terms of the scope of the material damages occurred on 3 November 2004 at a firework factory in Seest near Kolding. The accident is presumed to have started when an employee dropped a box of firework rockets during a routine emptying of a container. The rocket fireworks then ignited. The fire quickly spread to the rest of the factory within the container and to fireworks on palettes outside in an open neighbouring container. Approximately 1½ hours after the fire started in the one container, the fire spread and caused an explosion in an area where over 800 tonnes of fireworks were being stored. Afterwards, three more explosions in the factory area occurred, causing the entire factory and buildings in the surrounding area to catch on fire.

About 800 people participated in fighting the fire – approximately 350 firefighters, 150 police officers, 300 National Guard members, and personnel and crash tenders from the Danish Air Force. One firefighter died in the response and two were seriously injured. Among the area's residents, 17 persons were injured. About 2,000 people from 760 residences and employees of nearby businesses were evacuated. In total, 12 business dwellings were subsequently demolished and about 350 homes were either completely burned down or burnt to the extent that they were uninhabitable.

The most serious Danish transportation accidents with dangerous chemical substances in recent history occurred on 25 September 1992 when a freight train hit a passenger train parked at Næstved station. Several train cars were derailed and damaged. When the liquid spill was first observed, it was assumed that the liquid was merely diesel gas from a tank. It turned out, however, that liquid was also flowing out from an overturned tanker that contained acrylonitrile. Acrylonitrile is a very toxic and flammable chemical that can cause explosive fires upon contact with air. It can poison humans both via inhalation and through contact with skin. When acrylonitrile burns, it can become an even more toxic substance called hydrogen cyanide, also known as prussic acid. The area around the overturned tanker was therefore sealed and covered in flame retardant foam in order to prevent ignition and poisoning. In total, 400-600 litres of acrylonitrile leaked onto the ground. Initially, the accident resulted in 52 hospital admissions. The environmental clean-up, which entailed the removal of more than 300 m^3 of acrylonitrile-contaminated soil and 155 m^3 og oil-contaminated soil, was completed in November of 1996, more than four years after the accident.

Other examples of large industrial accidents in Denmark include:

- The contamination accident in Simmersted in 1972. A tanker fell over and released a large amount of toxic phenol near the Simmersted water plant, which was forced to close and never reopened.
- The explosion at an extraction plant at Dansk Sojakagefabrik in Copenhagen in 1980. 23 people were injured and the explosion required a thorough long-term decontamination of the soil and caused damages of 200 million DKK.
- The explosion at Lindø Wharf in 1994. Six employees were killed and 15 were injured after 900 litres of diesel gas leaked and nebulised in a fuel tank that then ignited during the welding of a supertanker.

What if...

... tonight, a hole forms in a tank with nitric acid at a food company. Nitric acid is a strong acid used to clean production equipment. The leaked nitric acid reacts with the building's concrete floors, creating very toxic nitrous gases that can affect airways when inhaled. When the first shift of employees comes to work in the morning and opens the storage building, the nitrous gases flow out, entering the factory and adjacent areas.

Rescue services are called and work as quickly as possible to stop the leak. Rescue services also begin misting water in order to control the spread of the gases and thereby minimise the area of danger as much as possible. The yellow-brown hue of the nitrous gases can already be seen in a large area and the nearby interstate and train track is closed to traffic. This causes problems with morning traffic and the police are worried about the people in the many waiting cars inhaling the toxic gases. At the same time, the healthcare sector begins to receive many inquiries from worried residents.

MARITIME ACCIDENTS

Capsize accident in Præstø Fjord

On 11 February 2011, a five-metre-long canoe with two teachers and 13 boarding school students capsized in Præstø Fjord, triggering a large scale rescue effort in the air, on water, and from land. One teacher died. The other teacher and the 13 students were saved, seven of which were in critical condition due to extreme hypothermia. The teacher who died was an experienced canoeist but was not wearing a lifejacket. The other 14 on board were fairly inexperienced, but were all wearing lifejackets.

When they sailed out, there was a reportedly light wind and no notable waves. Wind and waves formed fairly quickly, however, and after 22 minutes of sailing, the group decided to return to the harbour. While turning the canoe around, the canoe capsized as a result of wind, rough waters, the movements on board, and the boat's structural stability properties. The boat's underside turned face up, and all 15 on the boat ended up in the cold winter water (approximately 2 ºC) about 600 metres from land. The accident was not seen from land, no one was able to reach the fjord's floor, and panic quickly ensued.

After a failed attempt at turning the boat over, a few students managed to climb onto the keel while the rest swam toward the nearest coast. One teacher helped a girl who was severely weakened and possibly unconscious up onto the boat's keel. Several students saw him sit on the keel with her afterwards. After this, he was lost from sight. With great difficulty, three students succeeded in swimming to shore and called 1-1-2 respectively 80, 84, and 106 minutes after the capsize. This was essential for the initiation of the rescue effort. About half of the victims were recovered lifeless, some in cardiac arrest and with body temperatures as low as 16 ºC. Seven of the students were put in artificially induced comas by doctors.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CHARACTERISTICS

The term 'maritime accidents' covers all large accidents at sea that cause loss of life, personal injury, damage to property, and/or environmental damage to such a degree that a significant coordinated rescue or clean-up effort is required. This type of incident often involves vessels transporting goods or persons, fishing vessels, or offshore installations. Seen from the perspective of rescue efforts, an aeroplane or helicopter crash over a body of water would also constitute a maritime accident.

Accidents that happen at sea have specific challenges. Reaction time can be longer due to long distances between the accident site and land, limitations imposed by adverse weather conditions, and the difficulties and dangers associated with evacuation of a large number of people.

Running aground, collisions, and fires are some of the obvious dangers associated with ship traffic. Besides these, accidents that cause large-scale pollution of marine ecosystems also constitute a risk.

Large ships often sail with significant amounts of fuel on board – so-called bunker oil. Oil pollution is therefore a potential consequence of accidents, even if the implicated vessels are not transporting oil as their cargo. In addition, the extraction and transportation of oil can cause much larger pollution accidents.

Other chemicals are also transported by sea, but in smaller quantities than ships transporting oil. Even so, many chemical substances are more harmful to health and marine environments than oil. In such cases, even smaller leaks could cause large environmental problems in inner waters.

Maritime accidents can occur as a result of human error, technical error, external causes, or a combination of these. Human error refers to operator errors such as intentionally or unintentionally ignoring security procedures or not paying attention to hazards. Human error can also be more systematic, such as lack of maintenance over a long period of time, insufficient security culture, or intentional cost-cutting measures in relation to staffing or facilities.

Technical errors can occur in equipment or systems, such as unnoticed deterioration or spontaneous failure of IT, communication, or navigation systems.

External causes are reasons for accidents that cannot be attributed to equipment nor to human error. This can be, for example, extreme weather. In the North Sea especially, weather conditions are volatile and often severe. An intentional effort to cause damage to people or property (e.g., arson, cyber attacks, or sabotage) can also be seen as an external cause. The same goes for intentional or unintentional disruption to the GNSS (Global Navigation Satellite System) signal by either military actors or other ships that wish to obscure their positioning. Space incidents can also disrupt GNSS signals.

OCCURRENCE

On all metrics, Denmark is a large maritime nation. The Danish trade fleet is the world's fifth largest and has grown over recent years. Only few Danish trade ships, however, regularly enter Danish ports. Even so, the waters surrounding Denmark are heavily trafficked by vessels of other nationalities. This is especially due to Denmark's placement next to the most important navigable access route to the Baltic Sea and, from there, many important harbours. The Kattegat is characterised by narrow sailing routes and passages through the Great Belt and Øresund straits. This contributes to an especially high traffic density in certain areas.

Each year, 36,000 trade ships pass through the Øresund sound while 24,000 pass through the Great Belt strait. Of these, about 5,000 are tanker ships that typically carry crude oil out of the Baltic Sea. On an average year, more than

375,000 ships enter Danish ports, of which, about 20,000 are freight and tanker vessels.

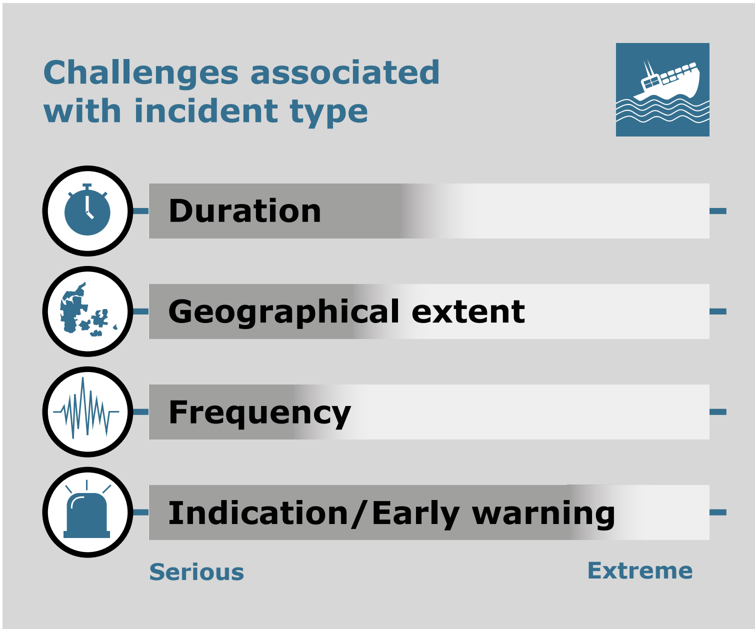
In addition to transportation of goods and industrial fishing, leisure sailing and ferries are part of the day-to-day maritime traffic. There are daily passenger ferries travelling between Denmark and the Faroe Islands, Norway, Sweden, and Germany as well as several domestic ferry routes that primarily serve to connect the many smaller islands to the mainland.

In the years before the COVID-19 pandemic, cruise ship tourism was increasing sharply. Danish harbours saw an almost doubling of the number of cruise ships received over the course of 10 years. As a reference, 608 cruise ships passed through the Great Belt strait in the period 2018-2020, very few of which were in 2020 due to the COVID-19 pandemic, which continues to affect the industry.

Since 1972, multiple operators have produced oil and gas from Danish fields in the North Sea. Today, there are 21 oil fields in the Danish part of the North Sea which house a total of 55 permanent extraction platforms. There are additional mobile platforms that are primarily used for housing, research, and test drilling. Denmark's oil and gas extraction in the North Sea will increase up until 2027, at which point a gradual end to production is planned to start. Several other countries including the United Kingdom, Norway, and the Netherlands also have active oil fields in the North Sea close to Danish ones. The total number of offshore installations that could cause environmental catastrophes in Danish waters or near Danish coasts therefore extends beyond just those in the Danish fields.

Along with other goods, large amounts of oil are shipped from the harbour terminal Primorsk northwest of Saint Petersburg. Oil arrives in Danish waters via oil tankers with a capacity of up to 150,000 tonnes. After the ships have passed the Great Belt or Øresund, in the Kattegat, the tankers are filled to maximum capacity or oil is transferred to larger, more cost-efficient tankers. Transfer of oil happens directly from ship to ship on the sea.

The incidence of serious maritime incidents in Danish water has been low throughout the last two decades, both in terms of accidents that endanger humans and pollution accidents. This is due to a generally increased focus on security, better organisation of proactive assistance, and substantially improved maritime traffic surveillance systems. Additionally, in 2020, new international sailing routes and routing systems were implemented to improve traffic management in Skagerrak and Kattegat. These new routes aim to separate oncoming ship traffic and thereby increase the predictability of sailing. Despite the low incidence, however, the risk for large maritime accidents and catastrophes is still present.



CONSEQUENCES

Maritime accidents always place the life and health of those involved in imminent danger. This can be a direct consequence of the specific accident – for example, an explosion, collision, or fire. The danger of drowning or hypothermia also poses a risk to the person(s) involved, especially in cold waters such as those surrounding Denmark and especially during the winter months. Accidents involving ferries and cruise ships can therefore put many people at risk even after initiation of evacuation efforts.

When large ships wreck in inner waters and harbour areas, some degree of damage to infrastructure may occur. Such damage or blocking of transport routes can cause disruptions to supply chains. Collisions between ships and bridges are rare in Denmark, but when they do occur, they are typically smaller collisions that do not cause structural damage to the bridge. After a Finnish freight ship collided with a railway bridge over Limfjorden near Aalborg in 2012, however, train traffic to Vendsyssel was interrupted for more than a year until the bridge was finally repaired.

Oil and chemical pollution accidents damage both the marine and the coastal environment and can have serious consequences if they affect especially vulnerable areas or areas that are especially important for the natural ecosystem. Accidents involving the spill of oil or chemicals are especially difficult to contain and manage when they occur at sea.

Depending on weather conditions, spilt crude oil and refined oil products can spread over large areas of the sea's surface and disperse over long distances. In the case of oil spills, response efforts generally aim to collect the oil into a tank and contain it or chemically break it down on the spot.

If oil pollution affects a coastal stretch, it can also cause large-scale damage to animal and plant life. Birds are especially vulnerable to even small amounts of oil. At the same time, beach areas can be rendered unusable for recreational purposes, causing great harm to the tourism industry. The tourism industry contributes almost 130 billion DKK to the Danish economy each year, of which coastal and nature tourism account for almost half. Local economies in several of Denmark's smaller coastal societies are also directly dependent on income from seasonal tourism. An oil pollution incident that occurs immediately before or during a high season for tourism could therefore have very large economic consequences.

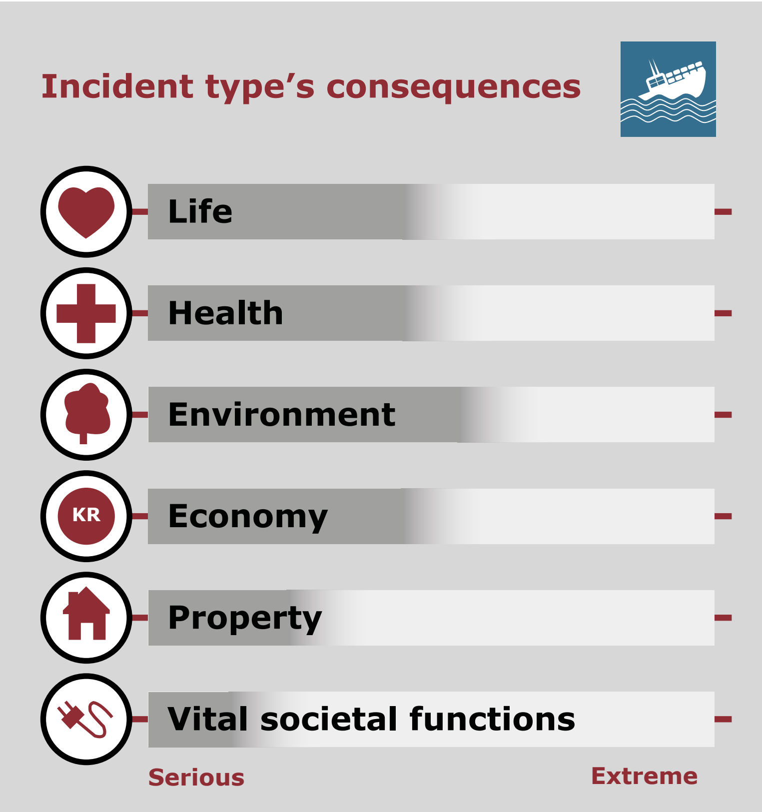
Collection of oil, whether on land or at sea, is a very costly, labour-intensive, and protracted task. It is necessary, however, since it can take decades for oil to naturally break down and thereby cease to disrupt the ecosystem. Depending on the location of the oil spill and the scope and duration of the control and clean-up work, ship traffic can also be disrupted due to blocked off sailing routes or harbours.

Chemical spills are generally very challenging to handle, as chemicals vary greatly in terms of properties. Sinking (i.e., chemicals with a higher density than the surrounding water) and water-soluble chemicals are not possible to remove and can therefore catalyse damaging changes in the marine environment (e.g., poisonous algae blooms). Other chemicals react with salt water and can create toxic corrosive gases. Compared with the number of oil transporters, there are only a few chemical transporters in Danish waters. Conversely, experience with such chemical spills and the multifaceted challenges they pose is also more limited.

Finally, oil or chemical spills can also affect fisheries and marine aquaculture. In addition to production losses, oil or chemical spills can threaten food security such that a large-scale effort from authorities is required.

TRENDS

Pollution accidents with oil and chemicals in Danish waters have been relatively limited. The risk for more and/or larger spills is, however, not expected to diminish in the future.



Climate change could also impact the risk for maritime accidents. Strong winds and high waves increase the danger for shipwrecks and can cause increased wear and tear on maritime infrastructure. Climate models regarding extreme wind conditions are still uncertain, but a general intensification of western wind in the northern part of the North Atlantic has been observed, making the North Sea especially vulnerable to such conditions.

Updated international rules for maritime security, technological development, guidance from pilots with local knowledge, and initiatives to improve the oversight of ships will all increase capacity to guide ships through difficult or highly trafficked passages. This could contribute to a decreased risk for future accidents in Danish waters. International cooperation, information exchange, and agreements about maritime assistance in the case of large accidents will also remain vital.

The number of ships passing through Danish waters has generally increased. In the period 2015-2020, there were an average of 18,500 oil and/or freight vessels transiting between Bornholms Gat and Skagen through Øresund sound and the Great Belt strait. All else constant, an increase in maritime traffic in Danish waters and use of larger ships translates into an increased risk for maritime accidents.

In addition, the size of ships is expected to further increase, which will primarily put pressure on the passage between the Great Belt and Skagerrak. Combined with the fact that Danish waters can be challenging to navigate through, this will increase the risk for a collision that results in unprecedentedly extensive oil pollution in Danish waters. The same can be said about the risk for larger chemical spills.

The ongoing project regarding the establishment of two energy islands in Danish waters will mean – both in the construction and the operation phases – increased ship traffic around the islands and the associated windmill parks. In the long run, however, the energy islands will contribute to a phase-out of oil and gas dependency. Thus, in time, there will likely be fewer oil transporters and pipeline constructions that pose a risk for oil spills and contamination of the marine environment.

EXAMPLES

The worst accident with ferries or other passenger ships in Danish waters occurred on 8 July 1959 at Haderslev Dam, costing 57 people their lives. After an engine failure shortly before arriving in the city of Haderslev, the people onboard the leisure boat "*Turisten*" tried to fill the boat's gas tank with improvised rubber tubes. One of the tubes flew off, causing oil to flow directly onto the hot motor. The oil ignited, and the boat burst into flames. There were 95 people on board despite the boat only being approved to carry 35, contributing to panic. Many jumped overboard and fought to get away from the burning boat, pushing and stepping on other passengers. Of the casualties, 20 died of burns and 37 people drowned despite the water being so shallow that most passengers could touch the sea floor.

The worst accident near Danish waters occurred the night of 7 April 1990 when a fire ignited on the Danish-owned passenger ferry MS Scandinavian Star. The ferry was in Skagerrak on its way from Oslo to Frederikshavn. 159 of the 482 passengers on board died as a result of the fire – most due to carbon monoxide poisoning or inhalation of toxic smoke while they slept in the ship's cabins. It was not until after the ferry was towed to the Swedish coastal city of Lysekil that the fire could be fully extinguished. Subsequent investigations showed that the fire was started deliberately.

The biggest oil pollution incident to date occurred on 29 March 2001 when the oil tank Baltic Carrier collided with the freight ship Tern at Grønsund in the waters southeast of Falster. The collision resulted in an estimated spill of 2,350 tonnes of fuel oil from the Baltic Carrier's total load of approximately 33,000 tonnes. Difficult weather conditions complicated the collection of the oil on open waters, and much of the oil flowed into the east-facing coasts of Møn and Falster as well as in Grønsund. After a two-week effort, about 3,950 tonnes of oil and oil-contaminated material were collected. Grønsund is an important breeding area for birds, and it is estimated that up to 20,000 birds died as a result of the pollution.

Another large oil spill in Danish waters occurred on 31 May 2003 when the Chinese freight ship Fu Shan Hai sunk in the waters north of Bornholm after a collision with the container ship Gdynia. Fu Shan Hai was loaded with synthetic fertiliser, and upon the collision, a portion of the approximately 1,680 tonnes of bunker oil in the ship's fuel tank flooded out into the Baltic Sea about three kilometres from the nearest coast. The oil spread to coastal stretches around Ertholmene and large parts of southwestern Skåne, resulting in the death of 1,000-1,500 birds.

On 3 March 2005, the freight ship M/V Karen Danielsen set a wrong course on its way from Svendborg to Finland. The ship collided with the western part of the Storebælt Bridge and became wedged under the bridge's lower level. The ship's entire wheelhouse was bent astern in the collision, killing the chief officer. Two of the ship's cranes were knocked overboard and a fire broke out. The bridge connection was closed for approximately five hours until technicians could confirm that the collision had caused superficial but no structural damage to the bridge's construction.

On 28 March 2012, a Finnish container ship, Ramona, collided with the railway bridge between Aalborg and Nørresundby. This caused such extensive damage that a new bridge leaf had to be built, and for more than a year, there was no railway connection over Limfjorden. The bridge is one of Denmark's most trafficked bridges for both trains and ships, and the long-term interruption and new decisions regarding passage had significant consequences for train passengers and businesses up until the bridge's reopening on 29 April 2013. The accident was likely due to a communication error between the bridge guard and the ship, but a maritime accident report could not entirely attribute fault to either party. In a 2014 settlement, Banedanmark accepted four million DKK from the Finnish firm that owned the ship, but the collision ended up costing Banedanmark 46.6 million DKK.

On 23 September 2020, a Russian naval vessel collided with the 145-metre-long freight vessel Ice Rose. The collision occurred just south of the Øresund Bridge. The naval ship was sailing without an activated automatic identification system (AIS) even though visibility was at 50 metres due to dense fog. The Danish Maritime Accident Investigation Board concluded that navigation errors on board both ships were to blame for the accident. Both a Danish patrol ship and Swedish authorities came to the site. No one was injured in the collision.

What if...

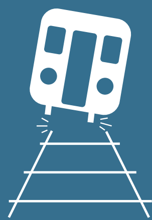
... on its way to the Baltic, a smaller freight ship does not navigate east to pass through Øresund and Falsterborevet due to lack of attention from the ship's command. At the same time, a small cruise ship with 1,000 passengers is on its way from the eastern Swedish archipelago towards Lübeck. The two ships collide severely. It is a January night with extremely cold water and air temperatures. At the same time, the wind is blowing hard, creating waves two metres high in the Baltic Sea.

The collision causes several deaths and serious injuries to some passengers as they fall out of their beds and hit the ground and fixtures in their cabins. The freight ship incurs serious damage to the hull and breaks out in flames. The cruise ship incurs damage to its rudder and can no longer manoeuvre in the strong wind. The cruise passengers and crew are evacuated to naval rescue boats shortly after the collision and escape into the dark through the cold waves.

Danish Defence's rescue helicopters and several ships have gathered around the accident site to assist with rescuing the many hypothermic passengers and passengers requiring treatment from the water. The high waves cause several naval rescue boats to capsize, complicating efforts to rescue the many passengers. The rescue effort is protracting and as more and more passengers become critically hypothermic, pressure on hospital capacity increases drastically.

TRANSPORT ACCIDENTS

Train accident on the Storebælt Bridge, 2019



On 2 January 2019, as the wind blew with almost storm speeds, an empty semi-trailer from a cargo train collided with passenger train ICL 210 on its way across the lower bridge of the Storebælt Bridge. A locking mechanism on the cargo train that should have secured the semi-trailer to the rest of the train was not working, thus allowing the wind to break the train car free. At the time of the collision, both trains were moving with speeds of about 120 kilometres per hour. The bed of the trailer was pushed up against the passenger train's left side and hit the passengers sitting on that side of the train's front most car. The semi-trailer hit the passenger train and was wedged up against the cargo train's other cars and semi-trailers as the trains passed each other. This caused damage to the passenger train's subsequent cars. Of the 134 persons on board, eight were killed and 18 were injured, four of whom were seriously injured. The rescue operation was complicated by the wind, near-freezing temperatures, problems with radio communication, the severe structural damage to the train, fallen overhead contact lines on both train tracks, and goods spread out over several kilometres, both on the train tracks and on roads, complicating driving conditions surrounding the accident site. The accident was Denmark's worst train accident in more than 30 years.

CHARACTERISTICS

The term 'transport accidents' describes accidents with transportation instruments involving transport of people or goods, both via air and land (i.e., on roads or train tracks) as well as accidents that affect related transport infrastructure. Transport accidents at sea are discussed in the chapter on maritime accidents.

Causes of transport accidents grouped into three categories: human error, technical error, and external factors. Most accidents, however, are due to a combination of these. Human error refers to direct operator error (e.g., intentional or unintentional disregarding of security procedures or lack of attention). Human error can also be more systematic (e.g., insufficient security culture, lacking audits and maintenance, or intentional cost-saving measures that compromise personnel, education, or facilities). Technical errors can occur within the transportation instrument itself or within the systems used to control and/or oversee them. Examples of such errors are material failure, short circuits, computer failures, and IT breakdowns. External factors refer to conditions or events such as weather phenomena as well as deliberate actions such as vandalism or cyber incidents.

Transport accidents in the air traffic sector can occur on-board planes as a result of collision in the air or on the take-off and landing strips in airports. The largest potential risk is an accident involving large passenger aeroplanes. Aeroplane accidents typically occur during take-off and landing, but they can also occur during taxi. Aeroplane accidents can occur due to collisions with other objects, such as other aeroplanes, helicopters, drones, or bird flocks. Aeroplane accidents can also be caused by motor or navigation failures or other technical errors. Unintentional human error and intentional actions can also lead to aeroplane accidents. Leading up to take-off, aeroplanes typically carry a large amount of fuel, which can increase the risk of explosive fire in the event of an accident.

Transport accidents on land can occur on train tracks, roads, and connected infrastructure such as bridges, tunnels, stations, parking areas, cargo hubs, etc. The potential risk for many personal injuries is largest in the case of transportation accidents where many people are present (i.e., train and metro). Collisions between trains driving on the same track or crossing one another's track can occur due to faulty disposition, negligence at control centres or command posts, or if a locomotive driver ignores signals due to carelessness.

In addition, damaged train tracks and security apparatuses can cause a train to derail either in an open area or in a place where it can collide with other trains, buildings, bridges, or other infrastructure. Material errors with trains themselves, on the train track, or track changing system can have the same consequences. Trains could also run over construction equipment and machines working on or near train tracks. Weather incidents such as extreme rain or storms and hurricanes can erode material from under the tracks or cause trees to fall onto the tracks and thereby derail trains. In such cases, the victims of an accident would not necessarily be limited to the passengers and crew on the train, but could also include persons in the immediate vicinity of the accident site.

A collision between a train and another vehicle in a road crossing is usually most detrimental to the latter (e.g., if a car driver does not notice a warning at a train crossing). Depending on the train's speed and the other vehicle's size and weight (e.g., freight truck, construction machine, etc.), the collision can, in the worst case, derail and turn over the train and thereby cause a large accident. Examples of this have been seen abroad several times.

On roads, accidents can occur in the case of a collision between buses, freight cars, personal cars, etc. and running over of people, such as bicyclists and pedestrians or in connection with road work. Traffic accidents on roads are frequent, but in relation to this National Risk Profile, these are the least serious type of transport accident. In some cases, however, the consequences of such an accident can be large, such as bus accidents involving many passengers or multi-car collisions on motorways. Complicated accidents do not necessarily lead to loss of human life, but if they occur in tunnels or on bridges, such accidents can cause long-term interruptions to critical infrastructure, causing serious economic consequences.

OCCURRENCE

Statistically speaking, air transport is the safest form of transport – significantly safer than transport via train, bus, or especially personal car. This is due to a strong culture of security, internationally standardised rules, and good coordination and control of air traffic. Large aeroplane accidents with casualties are rare in Denmark. The most recent incident occurred in 1989 when a Norwegian charter aeroplane crashed into the strait of Skagerrak. All 55 passengers on the plane died.

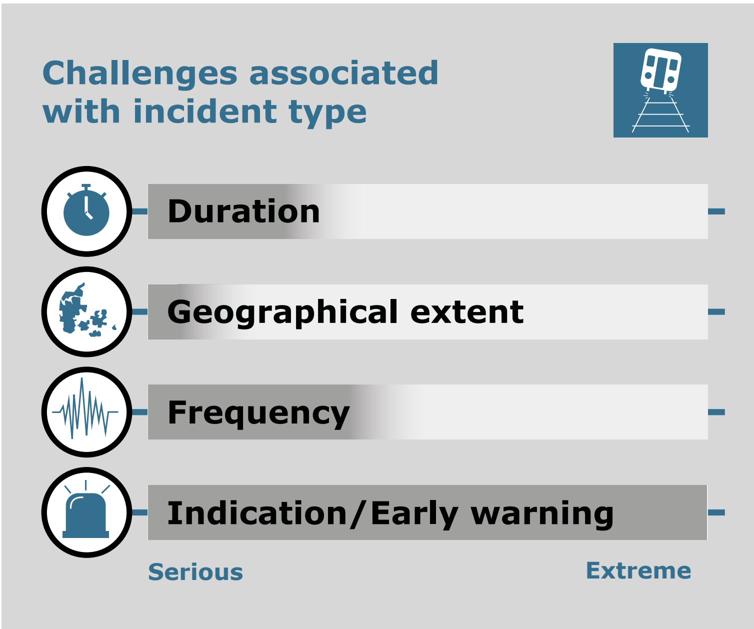
Train traffic in Denmark is characterised by a high level of security and a low number of casualties and injuries as compared with other EU countries. The Storebælt accident (described in this chapter's introductory text box), however, significantly inflated the number of traffic-related deaths in 2019. The overall high level of security in the sector is at least in part thanks to the fact that the majority of train infrastructure is monitored by automatic train control (ATC) and that trains' speeds are reduced automatically when the ATC system is not active for whatever reason. For passenger trains, a large share of traffic follows its own course without crossing other traffic or large external objects. The Metro is automatically driven (driverless operation), ruling out the potential for human error or lack of attention.

The highest number of annual casualties on Danish roadways (1,213) was registered in 1971. Since then, this number has fallen drastically. From 2010 to 2019, the number of traffic-related deaths decreased from 255 to 199. In 2020, 163 traffic-related deaths were recorded, the lowest number since the 1930's. This can be partially explained by the limited traffic activity during the lockdown during the COVID-19 pandemic. This downward trend continued in 2021 (120 traffic-related deaths were recorded as of the end of November 2019).

The total number of traffic-related deaths includes many smaller incidents with few dead or injured. Such incidents are handled locally. Traffic accidents with more than two casualties are not common on Danish roadways. Speed limits, controls, speed-reducing measures, improved signage, and an increased general level of security in buses, lorries, cars, etc. have had a positive effect on this downward trend of the number of traffic-related deaths.

CONSEQUENCES

Whenever many people are transported, an accident can lead to a large number of casualties and injuries. Aeroplanes and trains can transport more people than cars and buses, and as such, an accident involving these can have more



victims. Sites of complex transport accidents can also include many hazards for response personnel and rescue services.

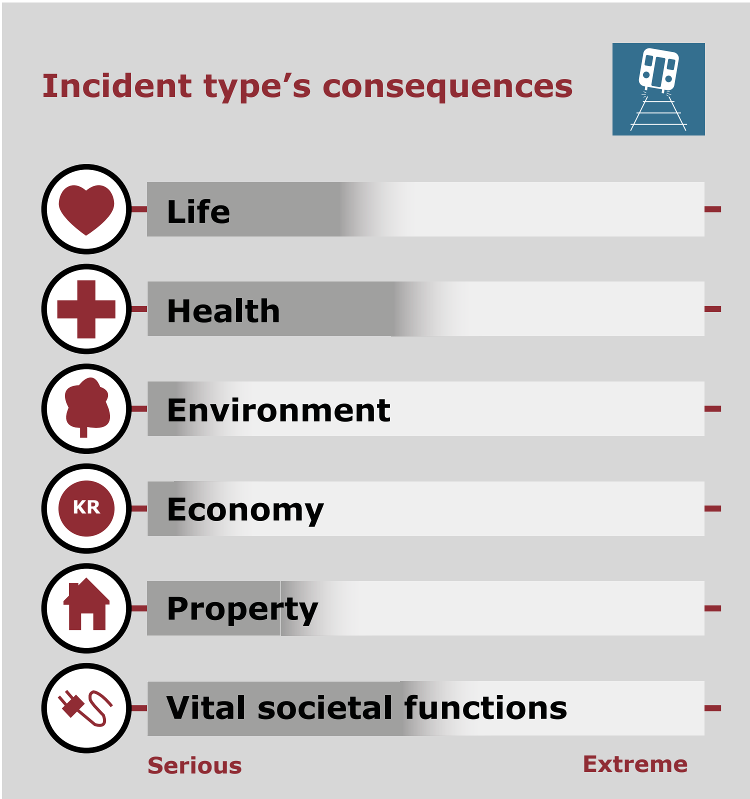
Victims of aeroplane accidents over land are not necessarily limited to the passengers and crew members on board the aeroplane, as wrecked parts and explosive fires can also kill and injure people on the ground.

Large transport accidents can also cause significant material damage to infrastructure and buildings hit by the vehicle or wreckage in the case of aeroplane crashes, derailing accidents, or collisions with trains.

In addition to personal injury and material damage, transport accidents can have environmental consequences in the event of contamination. Transport accidents involving dangerous goods are discussed in the chapter regarding accidents with chemical substances and in the chapter regarding maritime accidents.

Reparation and clean-up after transport accidents can be costly endeavours. If the damage necessitates a long-term rerouting of traffic or organisation of alternative transport solutions, economic costs will typically be high. Transport accidents can also be costly for transport operators if operation is interrupted for a long period of time. Operation may be halted due to obvious damage to infrastructure or as a result of precautionary measures. For example, the use of a certain type of aeroplane or train may be suspended following an accident pending a thorough investigation that can rule out mechanical design faults.

Finally, there can be significant residual consequences for maintenance of vital societal functions if a large transport accident affects critical infrastructure (e.g., airports, harbours, sailing routes, bridges, tunnels, stations, important train tracks or motorways) for a long period of time. A disruption to road and train traffic over the Storebælt or Øresund Bridges can affect large parts of the population, impact businesses, and can even take on an international dimension by negatively impacting transport across Scandinavia and the European continent. Similar effects could occur if a large aeroplane accident were to lead to a temporary closure of Copenhagen Airport, which functions as a major hub for all of Scandinavia.



TRENDS

The risk of transport accidents in air traffic can develop in the coming years due to an expected increase in the number of private-owned and commercial drones in the air for various purposes. Drones continue to become more affordable and remain equipped with functions for surveillance, inspection, photography, and measurement. Drones are also increasingly easy to control, which, combined with the other listed factors, will increase their popularity and usage.

On 1 January 2021, however, new EU rules aiming to increase security regarding drones were implemented.

All else constant, increased air traffic also means an increased risk for accidents. From 2016 to 2019 (i.e., before COVID-19 led to a drastic reduction in air traffic), large airports in Denmark were experiencing a slowly increasing number of departing passengers. This number rose from 17.3 million in 2016 to 18.2 million in 2019. The European organisation for air security, Eurocontrol, assessed that the number of commercial passenger flights could increase to levels at or above those seen before the COVID-19 pandemic within the next few years.

If the foreign security tensions between the West and Russia remain at their current level or escalate, the risk for transport accidents in the air will increase. This is due to risky activities such as interruption or blocking of GNSS signals and military flights with switched off transponders. For civilian flights, this can lead to an increased risk of colliding with military flights since flights with switched off transponders are more challenging to identify.

Within train traffic, there is a continuous effort to reduce the number of train track intersections across Denmark. For example, there have been recent measures to renew rails and signal systems.

As for roadway traffic, there is a trend towards more bus and freight car transportation (both for persons and goods) than previously. Permanent bus lines have established themselves as alternatives to train connections. All else constant, more buses and freight cars on roadways means a higher risk for more casualties or injuries.

Although fully self-driving cars are not expected to be on the Danish market for several years, many cars on Danish roadways will have semi-automated functions and an increased use of driving support systems. Whether this will impact traffic security positively or negatively is not yet clear.

At the end of November 2021, there were over 60,000 electric cars in Denmark, corresponding to 2.2 per cent of the approximately 2.78 million registered personal cars. This is a quadrupling over the course of just two years, and the number of electric cars is expected to continue to increase sharply. Electric cars use lithium-ion batteries, which can cause severe and long-lasting fires with very toxic smoke. These fires can be very difficult to extinguish. If several electric cars were to burst into flames at the same time (e.g., in a parking garage or tunnel), a very complex incident could develop.

EXAMPLES

The worst aeroplane accident in Danish territory occurred on 8 September 1989. A privately chartered aeroplane full of passengers from a Norwegian shipping company was on its way from Oslo to Hamburg. Shortly after the plane had entered Danish airspace, it crashed into the ocean 18 kilometres north of Hirtshals. The crash was found to have been caused by parts in the aeroplanes tail that did not meet the requirements regarding strength and hardness, leading the tail to fall apart. All 55 passengers on board died.

The second worst aeroplane accident occurred on 28 August 1971 when an aircraft from the Hungarian company Malév crashed on its way to Budapest shortly before a stop at Copenhagen Airport. 31 died and only three survived.

In terms of air traffic with Danish commercial interests, the worst aeroplane accident in SAS' history occurred in Linate Airport outside of Milano on 8 October 2001. As the SAS aircraft was taking off, a smaller German-registered Cessna aircraft drove into the side of the SAS aeroplane, which was then pushed into a baggage claim hall. All 110 passengers on board the SAS flight died, including 16 Danish passengers and two Danish crew members. Four persons on the Cessna aeroplane and four persons in the baggage claim hall were also killed.

The worst train traffic accident in Denmark in recent years occurred on 25 April 1988 when an Intercity train crashed outside of Sorø. Several train cars were derailed and fell on the tracks shortly before the train reached Sorø Station. Eight people were killed and 72 were injured. An investigation after the crash revealed that the accident was due to too high speed. The train was going 120 kilometres per hour in an area where the speed limit was 80 kilometres per hour.

A notable road traffic accident occurred on 27 February 2001 when a double decker bus drove into Knippelsbro in Copenhagen. The driver was driving too fast and did not notice the warning signs about the bridge's maximum height allowance. The roof of the bus was peeled off. The accident resulted in two deaths and ten severe injuries.

What if...

... an electric car breaks down on a suspension bridge due to a technical error. The driver of a tanker filled with flammable material notices the broken down electric car too late and is not able to brake in time. After the collision, the tanker falls over and bursts into flames. As a result of the collision, four people in the electric car and the tanker die, and seven more people in other vehicles on the bridge are injured.

The fire in the electric car's battery fuels the tanker's fire even more, and a self-feeding fire called a 'thermal runaway' ensues. The fire quickly reaches a temperature of more than 1,000 ºC. The fire lasts for several hours and damages the suspension bridge to such a degree that the first estimates indicate that it will have to be closed for 6-12 months before a reopening would be safe.

CYBER INCIDENTS

NotPetya attack, 2017

On 27 June 2017, A.P. Møller-Mærsk was the victim of a destructive malware cyber attack called NotPetya. NotPetya was masked as a case of ransomware (i.e., where the attacker demands a cash ransom), but in reality, it had destructive intent. From Ukraine, the NotPetya attack spread to banks, hospitals, companies, etc. in over 60 countries within hours. Among the hardest hit companies was Danish-based Mærsk. Denmark and a long list of likeminded states have attributed the attack to the Russian state.

For Mærsk, the cyber attack meant multiple days of interrupted operations. Containers stood still, clients could not get information about their cargo's placement, and new orders could not be placed. Mærsk was forced to shut down all of its IT systems, including all communication services. Mærsk estimates that the aggregate loss due to the attack was between 1.3 and 1.9 billion DKK.

CHARACTERISTICS

The term ‘cyber incidents’ describes incidents that negatively affect the accessibility, integrity, or confidentiality of information technology (IT) or indirectly affect cyber security by degrading security measures.

These three concepts are defined as follows:

- Accessibility: the property of being available and usable upon request from an authorised entity.
- Confidentiality: the property of not allowing information to become available or be revealed to unauthorised persons, entities, or processes.
- Integrity: the property of being accurate and complete.

Cyber incidents can be divided into cyber attacks and technical failures.

Cyber attacks are actions whereby an actor intentionally tries to disturb or gain unauthorised access to data, systems, digital networks, or digital services. For example, cyber attacks can be used to make IT systems unusable, seize control of a system, or forcibly gain access to confidential data in order to share, delete, or alter it. Cyber attacks can thereby undermine accessibility, integrity, and confidentiality of IT systems and data alike.

In most cyber attacks, geographical distance between the attacker and the victim does not play a significant role since the attack usually takes place over the internet. Actors that perform cyber attacks can be individuals, small groups, large networks, states, or state-sponsored groups. It is primarily organised state and criminal hacker groups that possess the capabilities necessary to perpetrate an attack serious enough to necessitate a national response. In most cyber attacks, it is difficult to precisely identify the responsible actor.

Cyber attacks can be split into five categories:

- Cyber crime is an umbrella term for when hackers use cyber attacks to commit crimes motivated by a desire to gain economic wealth. In some cases, however, there can be an overlap between cyber criminals’ and states’ interests.
- Cyber espionage is a form of espionage wherein the offender steals information from IT systems, electronic entities, software, or internet services such as emails or social media platforms. Foreign intelligence services use cyber espionage to try to gain access to classified and sensitive information from Danish authorities, companies, and research institutions. Intelligence services are constantly developing their capacity to listen in on tele- and data traffic. Non-state actors that engage in cyber espionage for their own benefit are typically affiliated with organised crime rings. Industrial espionage can also be perpetrated by commercial firms.
- Destructive cyber attacks are attacks where the desired outcome is death, injury, substantial damage to physical objects, or the destruction and/or manipulation of information, data, or software so that they cannot be used. When foreign intelligence services deliberately attempt to sabotage an authority or company, their efforts would also fall under this category.
- Cyber activism aims to create the most possible awareness surrounding a cause. Cyber activists achieve this goal through various means, and the method of attack can vary greatly in terms of complexity.

- Cyber terrorism includes cyber attacks that are part of an asymmetric war tactic with the aim of creating the same effect as more conventional terrorism (e.g., cause physical harm to people or extensive disruptions to critical infrastructure).

In addition to cyber attacks, technical failures can also create large cyber incidents. These can occur when specially developed IT solutions are no longer compatible with newer systems. If solutions are lacking the necessary adjustments, updates, upgrades, and maintenance, systems can be more vulnerable to system failures as well as attacks.

Weaknesses in equipment are usually due to technical vulnerabilities and erroneous code. In rare cases, system failures can be attributable to malware or other remote entries exploitable by hackers built into software and hardware during production. This can be intentional on the part of the developer or manufacturer, but it can also occur without the producer's knowledge. Another reason for weaknesses in systems can be incomplete installation or setup (e.g., not changing the default password). There is also always a chance that technical parts of systems simply break down due to short-circuiting, overheating, or defects.

The Centre for Cyber Security (CFCS) under the Danish Defence Intelligence Service (DDIS) is Denmark's national IT security authority. The Centre's up-to-date assessment of the general cyber threat against Denmark as well as cyber threats for individual sectors can be found on CFCS's website.

OCCURRENCE

CFCS generally assesses that the cyber threat against Denmark is very high, meaning that there is a specific threat and that malicious attacks are very likely.

Cyber incidents can affect anyone that uses or depends on IT equipment and systems. Every day, there are many cyber attacks and system failures in Denmark that cause small cyber incidents. Most of these incidents remain at a level that is manageable at a local level and do not cause consequences for society as a whole.

Cyber threats are not limited by geography. Systems, networks, and computers are generally linked via the internet, making it possible for hackers to affect victims across national borders. In addition, technological developments mean that threats are constantly changing.

Cyber crime poses a large threat to authorities, companies, and citizens in Denmark. Whereas cyber attacks from criminal groups have typically been targeted at many potential victims, during recent years, there has been an increase in the number of ransomware attacks targeting authorities and companies.

Cyber criminals work together and mutually exchange services, tools, and infrastructure. This cooperation occurs both through purchase and sale of services via the internet and through established cooperation agreements. This exchange of services is also called 'crime-as-a-service'. Among other things, such cooperation mean that criminals support one another's cyber attacks and enable less resourceful hackers to commit cyber crime.

In recent years, there has been an increase in the number of countries that perpetrate cyber espionage. In 'The Cyber Threat Against Denmark' from June 2021, CFCS assessed that the threat from cyber espionage was very high. This means that it is very likely that Danish authorities and companies will be exposed to attempts at cyber espionage within the next two years. Denmark is vulnerable to both politically and commercially motivated cyber espionage from state actors.

It is especially countries like Russia and China that use cyber espionage to advance national trade opportunities, gain competitive advantages, and avoid strategic surprises in the changing foreign affairs environment. Several publicly known cyber attacks against European foreign affairs ministries show that knowledge about foreign affairs decisions and dispositions is a priority for several countries' cyber espionage.

Authorities and companies that possess information and/or knowledge which other states have an interest in are also targets for cyber espionage. Such organisations' suppliers and partners can also be exposed to attempts at cyber espionage that aims to use them as a stepping stone to gain access to the primary target. For example, a compromised software or hardware supplier can be used to spread malware to their clients via infected system updates.

In recent years, there has also been a focus on hidden built-in 'back doors' in new technology that could give foreign intelligence services direct access to spy on citizens, authorities, and companies. This debate has been especially visible regarding the launch of the 5G network. A highly referenced example of this is a Chinese security law by which the Chinese intelligence authorities can force Chinese companies to collaborate with the Chinese state.

According to CFCS, the threat from destructive cyber attacks against Danish authorities is low. Although the threat is small, it is necessary to address since a skillfully conducted attack can have serious consequences. In addition, several states have significant capacity to wage a destructive cyber attack and are constantly developing this capacity. The threat can increase in parallel with more political or military conflict and tension involving countries with the ability to carry out destructive cyber attacks.

Destructive cyber attacks are relatively rare. According to CFCS, it is state actors that have carried out the vast majority of the known destructive cyber attacks in connection with inter-state conflicts or geopolitical tensions. It is less likely that foreign states have an intention to attack Denmark directly. Even so, it is possible that Danish companies and authorities with activities in conflict areas can be vulnerable to the effects of a destructive cyber attack. At present, the majority of destructive cyber attacks have occurred in Ukraine and Saudi Arabia. State actors, however, are also responsible for cyber attacks that are severely disruptive, although not outright destructive.

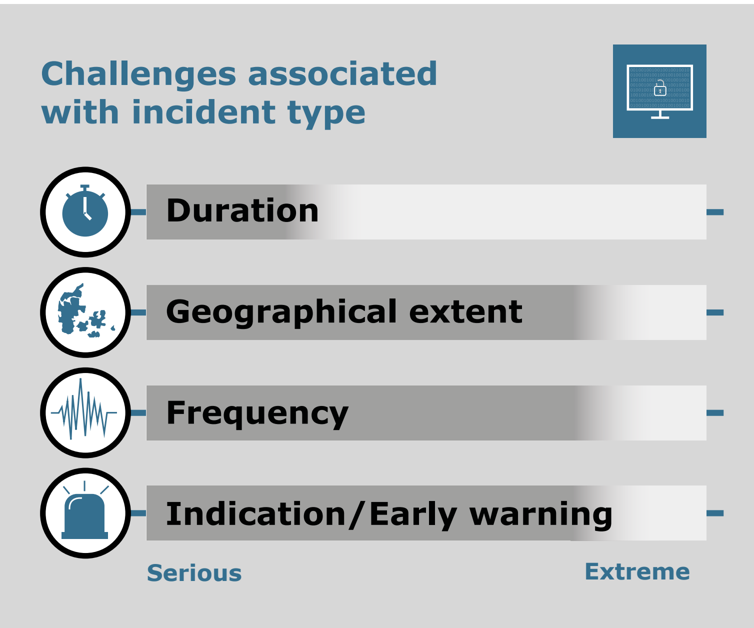
The threat to Danish companies or authorities from cyber activism is assessed by CFCS to be low. At a global level, the number of activist cyber attacks has dropped in recent years. The threat mainly comes from events or individual causes that attract the attention of cyber activists. The number of such attacks can therefore quickly increase if Danish authorities or companies fall under activists' spotlight.

According to CFCS, cyber terrorism is currently unlikely since militant extremists do not have the technical expertise and organisational resources to commit such attacks. Additionally, established terrorist organisations do not see cyber attacks as an effective way of creating fear and chaos as in the case of conventional terrorist attacks. The threat from cyber terrorism can increase, however, if militant extremists succeed in radicalising and recruiting skilled hackers or insiders with access to critical IT systems.

As authorities', companies', and organisations' use of IT increases, so does their vulnerability and the risk of technical failures. Tasks and processes that were not previously reliant on IT are increasingly dependent on physical and software-based IT components. Pairing of more and more everyday electronic components to the internet, also called 'Internet of Things' (IoT) is an example of this. A specific challenge with these components is that they are often not developed to receive security updates, meaning that if a vulnerability is identified in the product post-production, this can be exploited by hackers as long as the product is in use. For example, a security loophole can be used to reprogram devices in order to be a part of a larger coordinated cyber attack.

Although it is certain that a large number of cyber incidents occur in Denmark each year, it is not possible to exhaustively document these incidents. Not all incidents are reported to the authorities. It is therefore assumed that there are a large number of unknown/unreported cyber incidents that are never brought to the attention of authorities or the public.

Denmark has not yet been affected by a cyber incident that has caused significant direct consequences for society. In recent years, the Danish state has built up capacity and allocated resources to cyber security. Increased attention and regulation has meant that cyber security is no longer exclusively a topic for IT departments, but now also for senior management levels in Danish companies and authorities. The COVID-19 pandemic brought with it a sudden change in the patterns of use of online services and systems. This has also contributed to an increased focus on cyber security.



CONSEQUENCES

Consequences of cyber incidents depend on many factors, including how long the incident remains unnoticed, which data and systems are impacted, and potential cascade effects. In many cases, cyber attacks and technical errors can cause similar consequences.

Cyber crime can have significant economic consequences. Losses can be inflicted through theft, fraud and embezzlement, extortion, violation of immaterial property rights, and sale of sensitive data. The affected companies can be hit with additional costs due to lack of production or revenue, and re-establishment of IT systems can also be quite costly.

Cyber crime can also lead to disruptions to vital societal functions and critical infrastructure. In the beginning of May 2021, the USA experienced a ransomware attack on a pipeline that transports gas, diesel, and jet fuel. The pipeline is amongst the most important in the USA and supplies 45 per cent of the USA's east coast. The pipeline was taken off the grid for several days, leading to lack of oil products as well as price increases in some areas.

Although cyber crime is often targeted at companies, there have been several instances of Danish authorities being affected. This can cause a reduction in the services offered to citizens. Public services can also be secondarily impacted by incidents that affect sub-suppliers of IT solutions.

In cases of cyber espionage, information about Denmark's relations with other countries can be used against Denmark and against countries that Denmark cooperates with. It is likely that foreign states use cyber espionage as a means of gaining knowledge about Danish interests, deliberations, and decisions regarding large international issues or foreign negotiations and thereby gain leverage. This knowledge can be used by states to undermine Danish interests, put pressure on Danish negotiators and decision-makers, or generate knowledge about bi- or multilateral decisions.

Cyber espionage against Danish companies or research institutions – especially in areas where Denmark has competitive knowledge – can damage Denmark's competitiveness and lead to loss of income and jobs. In addition to the economic costs, companies affected by cyber espionage can also suffer damage to their reputation if the espionage becomes publicly known. This is one reason why companies rarely choose to report cases of cyber espionage.

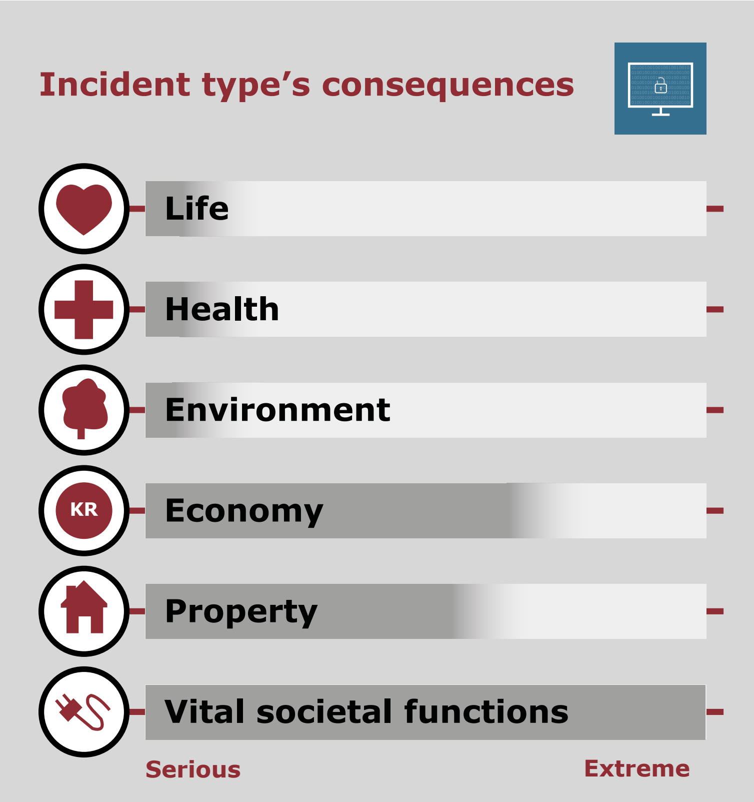
Cyber attacks still have primarily economic and political consequences. With the continued digitalization of vital societal functions, however, the potential for cyber attacks to cause serious, tangible consequences is expected to increase.

Cyber incidents do not yet pose a general threat to life and welfare, though isolated examples show that cyber attacks can pose a residual threat to life and well-being. This was exemplified by a ransomware attack on a German hospital in 2020 which ultimately led to emergency patients not being able to receive treatment and instead being referred to another, more remote hospital. One emergency patient died as a result of the increased transport time. There are also several examples of cyber attacks from other countries that have targeted elevator control systems in hospitals, which can be fatal in emergency situations. Highly technological medical equipment is increasingly connected to the internet to enable things such as distance diagnostics. If this equipment suffers due to a cyber incident, it may become unusable and impact patients' ability to receive treatment.

Rescue services are increasingly dependent on IT systems. A breakdown of an alarm centre would constrain the courses of action available to rescue services significantly, especially if several alarm centres are affected simultaneously. Attacks that aim to overwhelm alarm centres can come from malicious actors in the form of distributed denial-of-service (DDoS) attacks, but also from unintentional failures in smartphone apps whereby emergency numbers are contacted autonomously by the app. In addition, inaccurate information from position, navigation, and time management services (GNSS) can cause serious disruptions to rescue responses, complicate crisis management efforts, and thereby threaten public security. GNSS services are based on a large number of satellites in orbit around the Earth, and a disruption to these can occur due to human or technical errors, cyber attacks, and/or space incidents.

IT systems that support telecommunication, energy and water supply, control systems in industry or transport infrastructure are highly significant for several vital societal functions. As more and more infrastructural areas make use of digital solutions and pair with the internet, vulnerabilities and the potential impact and scope of attacks or failures increases. Failures in SCADA systems (i.e., industrial management and surveillance systems used in multiple sectors) have especially strong potential to affect society in a substantial way. Through these systems, electricity, heating, and water supply as well as internet, mobile networks, etc. can be affected by cyber attacks and in turn cause cascade effects for vital societal functions. Operation of trains, ships, and aircrafts can be forced to adjust somewhat or completely due to serious failures or attacks on management and surveillance systems. Motor traffic can also be affected by control issues with light signals and/or electronic roadside signs.

In addition, digital public services and financial transactions can be disrupted or postponed as a result of cyber incidents. In these cases, consequences can affect payment of wages and/or pensions, personal registration, central registration of companies, public registration, tax levying, etc. Communication of payments, bank transfers, stock exchanges, etc. can also become inaccessible for a period of time.



TRENDS

Over the coming years, the remaining rollout of the 5G network is expected to be completed in Denmark. This will increase internet speeds by a factor of up to 100, expand encryption, and enable networks to handle multiple users and devices simultaneously. This will open up new opportunities for automation and robotics as well as enable a closer pairing between the physical and digital world as more and more devices that have not traditionally been connected to the internet are connected.

The increase of online devices and the integration of critical IT systems will also, however, expand hackers' potential reach. Thus, it may also exacerbate the consequences of an attack since IoT devices still largely control physical systems. The EU Commission and the European Agency for Cyber Security have assessed that the 5G network is vulnerable in and of itself.

Another trend expected to affect the consequences of future cyber incidents is authorities' and companies' increasing outsourcing of IT infrastructure, data centres and operational tasks to sub-contractors. On one hand, this can result in better cyber security, as sub-contractors may choose to invest in improved protection against cyber attacks to gain a competitive edge. On the other hand, this means that an effective cyber attack on one sub supplier can potentially affect a large number of authorities and companies simultaneously, thereby causing a large aggregate effect on society. The fact that a few large actors continue to dominate the cloud computing market can further exacerbate this problem.

Research on artificial intelligence (AI) is being conducted around the world, and there is already an increase in use of machine learning for specific analytical tasks. AI is expected to play an increasingly large role in developments involving self-driving cars, autonomous industrial systems, and diagnostics and distribution of medication in the health sector. As AI is increasingly used in routine decisions and to complete tasks previously completed by humans, certain systems can become especially vulnerable to attacks.

Additionally, quantum computing is advancing. Quantum computers can potentially pose a cyber security threat to Denmark, as quantum computers' extremely increased processing power can be exploited in cyber attacks. In Denmark, further development of quantum computers will especially challenge data security on the internet, where communication is currently encrypted and thereby protected by a very complicated calculation that a traditional computer would take thousands of years to break.

Recent technological and geopolitical developments mean that the threat of cyber espionage against Denmark is significantly larger and more serious than just a few years ago.

Foreign powers are generally driven by a desire to gain critical knowledge and information from authorities, companies, and organisations. Some states use cyber espionage very actively and there is no indication that the threat from these states will subside.

To address some of the potential future developments and increase Denmark's digital security, in December 2021, the Danish government launched a national strategy for cyber and information security.

EXAMPLES

In April 2018, CFCS issued a warning confirming that in 2017, an actor had tried to access information (i.e., data and log-in information) from several Danish authorities via a vulnerability in their Cisco equipment. CFCS assessed that this was an attempt at cyber espionage from a state-sponsored hacker group.

One of Denmark's largest companies, Demant, which produces hearing aids (among other things) was the victim of a ransomware attack in September 2019. This led the company to close down several IT systems across the company to prevent the virus from spreading. Afterwards, Demant shared that it had been possible for them to restore their data from a backup. Even so, Demant estimated that the attack caused a loss of up to 650 million DKK.

In April 2020, agro-industrial company Danish Agro was hit by a ransomware attack that affected aspects of production and delivery of feed, fertilizer, etc. and created problems with orders. The attack started as a so-called 'email thread hijacking', whereby the hackers took over a supplier's IT systems and sent a phishing email in an ongoing correspondence between Danish Agro and the supplier. Approximately two months after the attack, the company estimated that the attack had cost them between 20 and 40 million DKK.

In May 2020, the Danish company GlobalConnect experienced a ransomware attack that affected multiple customers' IT systems. Among others, the company Amgros, a supplier to Danish hospital pharmacies, was affected, and hospital pharmacies and suppliers could not buy or sell pharmaceuticals via the shopping system Naviline for several days. The attack did not, however, cause a shortage of pharmaceuticals at public hospitals.

In the spring of 2020, CFCS confirmed an increase in phishing emails and false domains related to COVID-19 where criminal actors attempted to exploit Danes' demand for information about COVID-19. It is also likely that the hackers attempted to exploit the increased need for remote access, VPN solutions, and communication platforms among Danish authorities and companies as a result of changed working patterns during the COVID-19 pandemic.

The SolarWinds attack was a global software supply chain attack that became publicly known in December 2020. A state-sponsored hacker group had hidden a specially developed backdoor in legitimate updates to the widely used IT management system Orion from the IT company SolarWinds. According to SolarWinds, the backdoor was distributed to up to 18,000 organisations worldwide. The attack is one of the largest publicly known cyber espionage attacks ever. CFCS assesses that the hackers only used the backdoor to gain access to the most interesting targets among the victims of the attack. The group used specially constructed malware and advanced attack methods to attack these selected targets. Although more than 50 Danish organisations received the backdoor, CFCS assesses that the hackers primarily exploited the backdoor to gain access to data from American authorities and companies.

What if...

... Denmark experiences a serious health crisis. Hospitals are under pressure and all outpatient appointments and scheduled operations are cancelled. In the midst of the crisis, an electronic health records system in one of the Danish regions experiences a ransomware attack that encrypts data and locks users out of the system. In addition to having stolen encrypted patient data, the hackers threaten to publish all of the data unless the region pays a ransom before a designated time. While the region's hospitals work to activate their emergency procedures, it is necessary to reroute ambulances with acute patients to hospitals outside of the region. This leads to prolonged ambulance transportation times for many patients since there is only limited treatment capacity left throughout the country. In four cases, patients die either on the way to the hospital or shortly after arrival.

TERRORIST ACTS

Terror attack in Copenhagen, 2015

At 15:30 on Saturday, 14 February 2015, a young man fired several shots from an automatic weapon into the cultural venue 'Krudttønden' in Østerbro, Copenhagen. One person died as a result of the shots, and four police officers were either hit by bullets or shards of glass. The perpetrator fled the scene and after midnight, he appeared near the synagogue on Krystalgade. There, he shot at the guards and police present. A volunteer private guard was killed at the scene and two police officers were shot. Later that same morning, the presumed perpetrator was sighted in Nørrebro. Following an exchange of gunfire with the police's Special Intervention Unit, the perpetrator was killed. The perpetrator was later found to have declared his allegiance to the Islamic State shortly before the attack. He was also known by the police for several criminal actions including violence and violations of firearm laws. Two weeks before the attack, the perpetrator was released from prison. He was also known to be associated with a criminal gang.

CHARACTERISTICS

Terrorism refers to a range of serious offences (murder, bombing, arson, kidnapping, hijacking, etc.) covered by § 114 of the Danish Penal Code. Terrorism is committed with the intent "*to seriously intimidate a population or unlawfully compel Danish or foreign public authorities or an international organisation to do, or to abstain from doing, any act or to destabilise or destroy the fundamental political, constitutional, economic, or social structures of a country […]*".

The Centre for Terror Analysis (CTA) in the Danish Security and Intelligence Service (PET) evaluates the terrorist threat against Denmark and Danish interests abroad annually. The current Assessment of the Terror Threat to Denmark (VTD) can be found on PET's website.

In March of 2021, CTA assessed:

- That militant Islamism continues to constitute the most serious terrorist threat to Denmark and that this threat is at the level 'serious'.[3]
- That the terrorist threat from right-wing extremists is at the level 'general'.
- That the terrorist threat from left-wing extremists is at the level 'limited'.

The following assessments under the headings 'occurrence' and 'trends' originate from CTA's 2021 VTD. Since DEMA's National Risk Profile is published with longer intervals (approximately every fourth year), readers are encouraged to refer to the current VTD for the most up-to-date threat assessments, including potentially changed or entirely new assessments.

[3] *CTA's threat assessments are given based on a scale with the following threat levels: minimal, limited, general, serious, and very serious.*

OCCURRENCE

The conditions that make up the terror threat picture against Denmark are constantly changing. This necessitates authorities' ongoing adjustments of their security and preparedness-related efforts and measures against terrorism.

PET initiates ongoing operations to contain or prevent potential terrorist threats against targets in Denmark. Terrorist attacks can occur without preceding intelligence indications even if perpetrators can be known to have shown sympathy for militant Islamism or political extremism. Persons who have undergone a relatively short radicalisation process and persons excluded or rejected by environments, possibly due to their extreme behaviour or beliefs, are especially concerning.

Terrorist threat from militant Islamists

According to CTA, there are persons in Denmark and abroad with sympathy for militant Islamism that constitute a terrorist threat against Denmark. The threat comes from persons that sympathise with and are inspired by foreign militant Islamist terrorist groups, especially the Islamic State (IS) and al-Qaida (AQ). The threat comes from both persons in Danish Islamic environments and from other radicalised persons in Denmark and abroad. International virtual communities where propaganda is spread and extremist beliefs are shared across national borders often play a large role in radicalisation processes.

As outlined in the 2021 VTD, in 2020, there have been events in Denmark and abroad that have been perceived as offensive to Islam. These events continue to have significant potential to be a driving force for militant Islamists. Since the Muhammad comics in 2005, Denmark has had a reputation for being offensive to Islam. When Denmark or Danes are named or highlighted in militant Islamist propaganda, Denmark's reputation as an offensive country gains momentum. Reactions to offensive events abroad and especially in France have contributed to focus on historical and current offensive cases in Denmark. The extent of the negative reactions to offensive cases in the West varies from case to case. Some cases never gain attention, while others – such as was the case in France in the fall of 2020 – gain significant negative attention, including planning and execution of a militant Islamist terrorist attack.

The most likely target for a militant Islamist attack in Denmark is a symbolic target or an unprotected civil target, such as large crowds in public places. Symbolic targets are generally persons, institutions, and events that militant Islamists can perceive as offensive to Islam. Other potential symbolic targets are Jewish targets, police, and military – especially in connection with guarding tasks. A threat could also be directed towards other authorities or political representatives.

The most likely militant Islamist terror attack in Denmark is an attack that is conducted with easily available equipment (e.g., knife, batons, arson instruments, or vehicles), guns, or homemade bombs made by smaller groups or a solo terrorist inspired by militant Islamist propaganda. Attacks with readily available equipment can be conducted spontaneously or after a short planning period.

Terrorist threat from right-wing extremists

CTA assesses that the terror threat from right-wing extremists is at the level of general. In relation to PET's definition, this means that there is a general threat – there is capacity and/or intent and potential planning.

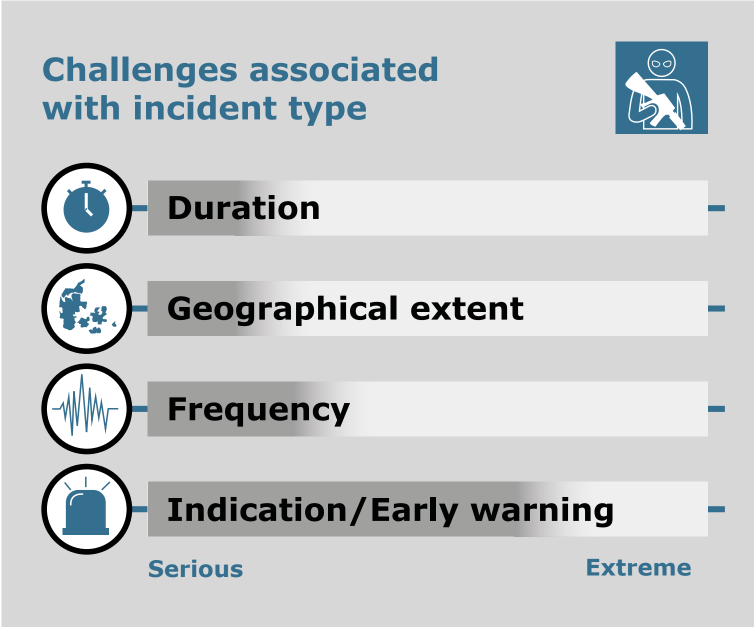
The threat of right-wing extremism in the West comes from a broad spectrum of organisations, groups, and individuals inspired by various political and ideological agendas, including conspiracy theories. The ideological basis for right-wing extremism can stem from Nazism, fascism, or national conservatism, but various conspiracy theories are increasingly considered to be the driving force behind right-wing extremists in the West.

CTA assesses that in coming years, the threat from right-wing extremism in the West will come from individuals and small groups whose primary venue for gathering, engaging in radicalization, and finding inspiration will be virtual communities and networks. In Western countries, there is an increasing trend towards internationalisation of right-wing extremist narratives through the sharing and consumption of right-wing extremist propaganda as well as via virtual transatlantic and European communities. CTA assesses that the increased international exchange of propaganda and extremist ideas can exacerbate the threat posed by right-wing extremism in Denmark.

A right-wing extremist terror attack in Denmark would most likely target mosques, asylum seekers and asylum centres, Jews and synagogues, and persons of non-Danish ethnicity, including areas where such individuals and groups are perceived to gather. Other potential targets are perceived political opponents, especially left-wing extremists, LGBTQ+ persons, and some authorities and political representatives.

The most likely right-wing extremist terror attack in Denmark is one carried out by a solo terrorist or a small group on the periphery of or outside of a right-wing extremist environment. The most likely weapon in such as an attack would be bludgeons/assault weapons and small firearms, especially hunting rifles, shotguns, pistols, and homemade firearms. Other possible weapons include arson instruments, homemade bombs, and vehicles.

Terrorist threat from left-wing extremists
The threat from left-wing extremists is evaluated by CTA to be limited. According to PET's definition, this means that there is a potential threat. There is limited capacity and/or intent.



CONSEQUENCES

From DEMA's perspective, the potential consequences of a serious terrorist action would primarily concern individuals killed and injured. In addition, serious health consequences can present in survivors, even those who did not suffer serious physical harm. This can manifest as trauma, anxiety, stress, and fear, which can emerge immediately or long after the attack. Such effects can be passing, long-term, or permanent. Victims' loved ones can experience similar psychological symptoms. DEMA further assesses that terrorist attacks can have a fear-inducing and behaviour-changing effect on the general public. This is evident in populations in other European countries that have experienced repeated and violent terrorist actions.

Terrorist actions can result in large-scale damage to or loss of property, especially in the case of a bombing attack. Even if the actual target is humans, the blast wave (also known as overpressure), heat from the blast, fire, and smoke can cause significant damage to the attack site and the immediate surrounding areas.

Terrorist actions can also put significant resource pressure on police, healthcare preparedness, and rescue services, especially during and immediately after an event.

Terrorist actions that aim to kill and injure as many people at one or more attack sites can trigger a need for a large number of response actors, imposing a large-scale coordination and leadership task. There is an immediate need to support first responders and facilitate and assist pre-hospital preparedness.

After bomb explosions, there can be completely or partially collapsed buildings and infrastructure where survivors can be stuck or trapped. When the immediately accessible injured are found and brought away from the site, it can be necessary to secure the attack site against further collapse with the help of reinforcements to search for persons who are injured or stuck in the wreckage. It can also be necessary to break through walls and other obstacles in order to reach injured individuals. This work requires the expertise of specially trained personnel, rescue dogs, and technical listening equipment. Heavy contractor equipment and specially built rescue cranes can also be required to rescue trapped individuals.

There can also be a potential need to extinguish fires after bomb explosions, which can be complicated by completely or partially collapsed buildings. People moving in and around the ruins must exercise the utmost caution to avoid further collapse. Water used to extinguish fires can move through the ruins and be potentially dangerous for persons still stuck in the wreckage.

Uncertainty about whether toxic, corrosive, radioactive, or otherwise dangerous substances were used in a terror attack necessitate identification of potentially dangerous substances in order to ensure the correct protective equipment is worn by response personnel. Alternatively, the absence of such substances must be confirmed in order for protective equipment to be taken off.

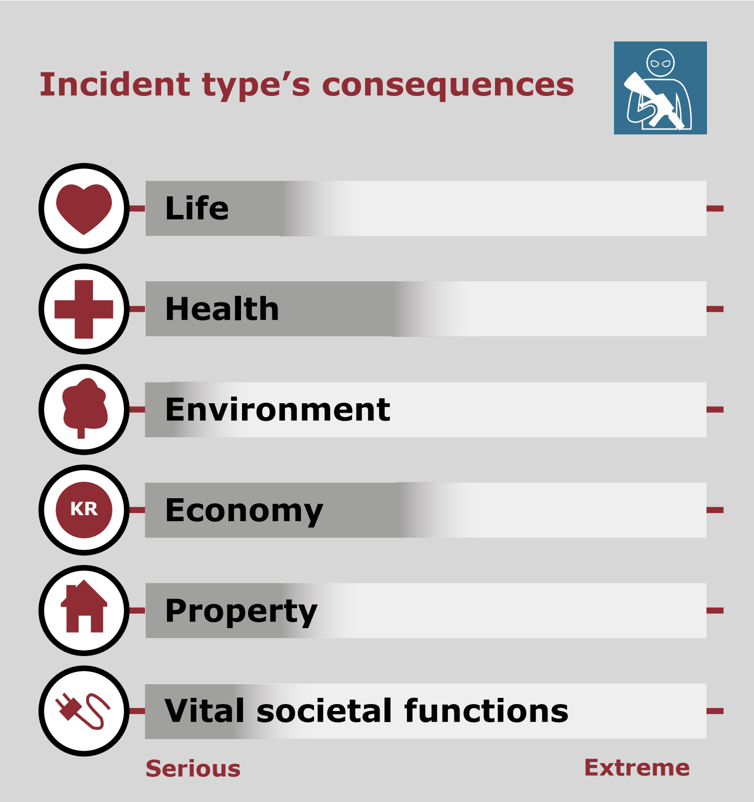
There can also be other potential hazards at an attack site after a bomb explosion (e.g., technical installations that have not been shut off and therefore are leaking gas, cables and cords that are still electrically charged, etc.).

In connection with the initial terror attack, an additional danger can be posed to response personnel if there is a risk for contact with armed perpetrators or if more terror attacks are planned in immediate succession of one other (i.e., sustained shooting or subsequent explosions).

The time after a terrorist attack with massive material damage can be extremely economically costly due to potentially long-term clean-up and reconstruction. This is especially the case if large buildings or critical infrastructure are damaged. Such damage can impact logistics, transportation, and other vital societal functions.

Terror attacks and attempts are usually followed by an overall higher level of preparedness. Maintenance of high terror preparedness can, according to DEMA's assessment, involves high economic costs for society. Physical security installations, staffing, and special security procedures all contribute to this. In periods where there is a special need for visible guarding and patrolling, many working hours are required from the police and defence. Such a peak workload can lead to economic and administrative consequences that last well beyond the duration of the actual response.

Finally, several other residual consequences can emerge in the short- or long-term. For example, a public authority or company can – regardless of whether it is hit as a selected terrorist attack target or as collateral damage due to its location close to the actual target – experience staff absence due to fear of further attacks, damage



to the organisation's reputation, or decreased revenue due to reduced trust from external partners.

TRENDS

The global threat landscape is dynamic and riddled with new trends and challenges that also affect the terror threat against Denmark. The number of terrorist attacks in the West in 2020 was substantially lower than in the period 2015-2017 despite increases in the number of attacks carried out in the West, especially in France since the reprinting of the Muhammad comics in a French satirical magazine, Charlie Hebdo, on 2 September 2020. There has also been a decrease in the number of fatalities. This tracks with the fact that the majority of terrorist attacks perpetrated in the West from 2018-2020 were carried out by solo terrorists.

As previously mentioned, CTA assesses that the number of events perceived as offensive to Islam still has significant potential to be a driving force for militant Islamists.

According to CTA's 2021 VTD, several other developments in Denmark and internationally could significantly impact the terror threat against Denmark. These developments include certain conspiracy theories, anti-state movements that are not illegal but can have a propensity to develop into violent threats that, seen from a legal perspective, can be of a terrorist nature.

In terms of forms of attacks, CTA assessed in the 2021 VTD that terror attacks with easily available equipment (primarily knives, batons, arson instruments, or vehicles), firearms, or homemade bombs continue to be the most likely forms to be perpetrated in Denmark.

In terms of other weapon types, CTA assesses that:

- Capacity to perpetrate a chemical terror attack with something other than unprocessed material in Denmark is low.
- Capacity to weaponise biological instruments such as anthrax to perpetrate a biological terrorist attack in Denmark is very low.
- Capacity to perpetrate a terror attack with radioactive instruments against people in Denmark is very low, and that there is not capacity to commit terror with the help of nuclear instruments.
- Capacity to perpetrate terror attacks via cyber attacks that cause physical damage to humans or large-scale disruptions to critical national infrastructure or similar targets in Denmark is low.
- Challenges of using drones as an attack weapon in Denmark are still very significant in relationship to the damage that such a weapon could inflict.

- Technologies and AI, 3D printing, and synthetic biology is not well-suited or sufficiently accessible to have an independent effect on the terror threat in Denmark.

EXAMPLES

Perpetrated attacks

The only attack perpetrated in Denmark in recent history is the militant Islamist shootings on 14 and 15 February 2015, which is described in the introductory text box.

The only large terror attack with explosives that has occurred in Denmark was carried out on 22 July 1985 in central Copenhagen. First, a bomb went off at the American airline Northwest Orient Airlines' office on Vester Farimagsgade. A few minutes later, another bomb exploded by the synagogue on Krystalgade. A third bomb was found in Nyhavn and was likely intended to go off at the Israeli airline El Al's office. On Vester Farimagsgade, a few were injured, one of whom died a few days later due to injuries sustained from the attack. On Krystalgade, 27 people were injured. Three perpetrators from the Palestinian terrorist organisation Islamic Jihad were sentenced to life in prison in 1989.

Foiled attacks

Since 2007, militant Islamists have planned and attempted to carry out several terrorist attacks against people and places in Denmark. The following are selected examples of these foiled plots.

In the fall of 2009, two people with American-Pakistani and Canadian-Pakistani background were arrested in Chicago for planning a terror attack against Jyllands-Posten. The two men had acquired information about potential attack targets, and one had visited and filmed Jyllands-Postens offices in Aarhus and Copenhagen and reconnoitred alternative targets.

On 29 December 2010, three men arriving in Sweden with Tunisian, Lebanese, and Egyptian background were arrested by PET's action force at an apartment in Herlev. They were suspected of having imminent plans to break into Jyllands-Postens/Politikens Hus in Copenhagen and kill as many people as possible. Upon their arrest, they were in possession of a machine gun, a pistol, ammunition, and 200 zip ties that could be used as handcuffs. In June of 2012, the three men and one co-conspirator were all sentenced to 12 years in prison in Sweden.

In November 2016 and December 2017, two Syrian refugees residing in Sweden and Germany respectively were arrested for planning to conduct a terror attack on an unknown target in Denmark with a knife and a homemade bomb. In December of 2020, one of the suspects was found guilty for attempting to commit terror in the so-called 'toothpick case' in Denmark while the other was sentenced in Germany in 2017. According to the Danish Prosecution Service, both sympathised with the Islamic State.

In December 2019, a 26-year-old man was arrested after buying pistols, silencers, and bullets to be used in a terror attack in Denmark or abroad. Afterwards, in November 2021, he was sentenced to 10 years in prison for attempting to commit a terrorist attack. A 27-year-old co-conspirator was also found guilty of violating § 192 a, section 1, clause 1 regarding financing of the purchase of firearms and was sentenced to two years and nine months in prison. Both verdicts were appealed to the Danish High Court.

In April 2020, a 24-year-old man was arrested after buying a firearm, two magazines and 50 bullets to be used in a terror attack in Denmark or abroad. In September 2021, he was sentenced to 10 years in prison, revocation of his Danish citizenship, and permanent deportation from Denmark for attempting to commit a terrorist attack. The case is set to be heard in the High Court in the end of 2022.

In addition to these examples, the following recent examples can be noted:

- Terror cases from Glasvej in Copenhagen, Vollsmose in Odense, and Glostrup where militant Islamists were given long-term sentences in 2007-2008.
- Case from 2010 where a Chechnyan-Belgian man traveling to Denmark unintentionally detonated a bomb in a restroom at Hotel Jørgensen in Copenhagen.
- Case about a 15-year-old girl from Kundby that was arrested in 2016 and was sentenced to eight years in prison in 2017 for attempted terror for planning a bomb attack on two schools.
- The drone case from 2019 where two of the three defendants were found guilty in 2020 for assisting a terror organisation by sending drone parts to the Islamic State over the course of four years.

What if...

... a large-scale terror attack hits the centre of a large Danish city. The attack begins on a Friday at 21:20 and lasts about three hours. The attack consists of three detonations of homemade explosives, six shooting attacks with automatic weapons, and a hostage-taking episode. The targets are coincidental masses of people outside a stadium and in several of the city's restaurants, cafes, and bars as well as a concert venue. Fleeing masses of people create chaos for traffic in the city's narrow roads resulting in bottlenecks and creating challenges for the police's and rescue services' response. Witnesses report that the perpetrators are shouting Islamic slogans and messages about revenge against Denmark. There is an exchange of gunfire between the perpetrators and the police. While the police have strength in their superior forces, there is still uncertainty about the number of attack sites and perpetrators. Later, it becomes clear that the perpetrators had split up into three groups, each consisting of three men. Seven of the perpetrators are killed by the police or commit suicide with a bomb vest. The last two flee, but are killed a few days later during police actions in Denmark and abroad. An international militant Islamist terror organisation later claims responsibility for the attacks.

(This fictive scenario is inspired by the terror attack in Paris on 13 November 2015.)

SPACE INCIDENTS

The Halloween storms, 2003

At the end of October and beginning of November 2003, the Earth was hit by one of the largest solar storms to date with significant effects. The so-called 'Halloween storms', as the series of storms was later named, made communication and navigation systems unreliable. Near the polar regions, transatlantic and polar flight routes had to be rerouted or cancelled, causing many and significant delays. The Japanese space agency permanently lost contact with and control of two satellites, one of the American space agency's (NASA) satellites was damaged, and many other satellites, including the Danish Ørsted satellite, were temporarily unreachable or unreliable. In the southern part of Sweden, the electric grid experienced disruptions that led multiple transformer stations to suffer from overload due to overuse. In and around Malmø, up to 50,000 people were without power for ½ to 1½ hours. In the USA, several individual transformers were also damaged and there were losses of power in wide-ranging areas for several hours. These outages are estimated to have cost the USA at least four billion USD. Similar problems also occurred in other countries, including South Africa.

CHARACTERISTICS

In this National Risk Profile, the term 'space incidents' is used to describe incidents that originate outside of the Earth's atmosphere but constitute a risk for human activity on Earth, including Danish society. In this chapter, 'space incidents' covers incidents caused by space weather and unintentional collisions between satellites, space probes, space vehicles, and space junk (also known as space trash, defined as non-functional items such as out-of-commission satellites, broken fragments of satellites, and fragments from launchers). Though collisions or shooting down of space objects may also occur intentionally, this chapter does not address potential political security risks associated with militarisation of space.

This chapter also does not discuss risks that stem from near-Earth objects such as asteroids and comets. Still, it is notable that this topic has received increased attention since an asteroid explosion over the Russian city Chelyabinsk in 2013, which caused the injury of 1,150 persons and damage to approximately 3,000 buildings. The likelihood of a similar air explosion or impact in Denmark is, however, minimal, when considering the size of the Earth's aggregate surface area and how rarely these types of incidents have occurred. This is why these incidents are not included in the National Risk Profile. The consequences of such an incident, however, could range from the creation of a crater in an uninhabited area to annihilation of a large city to the end of our civilisation.

Space weather is a term used to describe the variable physical conditions in space. The Sun constantly radiates a large number of electrically charged particles to the space surrounding it. The electricity of these particles is called the solar wind. The solar wind makes up the majority of the particle radiation that affects the Earth. This radiation is harmful to human health in high doses, but the Earth's magnetic field and atmosphere protects life on Earth against the vast majority of the solar wind's harmful effects.

When there are oscillations in the intensity of solar wind, the magnetic field partially mitigates the effects, keeping the radiation level on Earth more or less constant.

The conditions on the Sun's surface are currently very volatile. This can be observed from Earth and by satellites, for example in the form of sun spots (temporarily darker spots on the Sun) and solar flares. Solar storms are violent explosions on the Sun whereby energy is released and particles are propelled outward. The phenomenon of a solar storm is also commonly called a sun storm.

Solar flares are when large amounts of energetic electromagnetic radiation (i.e., gamma, x-ray, and ultraviolet radiation) is released during a solar storm. Since electromagnetic radiation travels at the speed of light, the radiation is the first observable mark of a solar flare.

Depending on the local configuration of the Sun's magnetic field, a flare can be followed by a Coronal Mass Ejection (CME) where the explosion shoots electrically charged particles from the Sun into space. Moving away from the Sun, a CME will meet previously released particles from solar wind and merge into a shock front. When such a front hits the Earth's magnetic field, it can create strong disturbances called a 'geomagnetic storm'. A shock front from a solar storm will typically hit Earth one to two days after the explosion on the Sun's surface. Such particle radiation associated with flares and CMEs is called a Solar Particle Event (SPE).

How a solar flare manifests itself on Earth is dependent on several factors. A flare of a certain size will not always create a flare with the same level of consequences on Earth. This is because the Earth's magnetic field will interact with the shock front created by the CME and solar wind and mitigate it in different ways. A visible (and completely harmless) result of such an interaction is aurora, or polar light (also commonly known as northern lights).

Because the Earth's magnetic field varies with latitude, the negative consequences of a solar flare will be experienced differentially on Earth even though flares, SPE, and CME affect the entire planet as well as manmade objects in space. Among potential consequences are interruptions to electricity supply, breakdown of electronic equipment, or disruption to space-based infrastructure for communication, magnetic navigation, Earth observation, and space weather observation.

In addition to space weather, space incidents can also be caused by satellites, space probes, space vehicles, and especially space junk generated over the course of more than six decades of space activity. Although there is a lot of room in space and these manmade objects are in orbit with different trajectories and at different heights, collisions still occur.

The risk of these collisions is increasing as the number of objects quickly grows. At the time of publication of the last National Risk Profile in January 2017, there were 1,300 operative satellites in orbit around the Earth. In January 2022, that number had risen to 4,900 in addition to 3,000 satellites that had either been phased out or stopped working.

As of January 2022, the European Space Agency (ESA) estimated that 36,500 pieces of space junk larger than 10 cm, 1 million pieces larger than 1 cm, and 330 million pieces between 1 mm and 1 cm orbit the Earth. Approximately 30,600 of these objects are monitored from Earth. Although large satellites have the ability to avoid large traceable pieces of space junk, smaller fragments are almost impossible to notice. Small satellites like the so-called CubeSats are not able to steer around the space junk and therefore cannot avoid collisions. Collisions can be very intense, seeing as the average collision speed is approximately 36,000 kilometres per hour.

OCCURRENCE

The frequency of solar storms (and thereby flares, CME, geomagnetic storms, and SPE) is closely related to the Sun's activity and is reflected in the number and scope of sun spots on the Sun's surface. From records dating back to the 1700s, we know that sun spot activity follows a cycle of higher and lower intensity. Average sun cycles span 11 years from one high or low intensity period to the next.

Statistically, in a low intensity period, solar storms occur every fifth day, and in high intensity periods, there are approximately three per day. Although solar storms occur with a high frequency, it is relatively seldom that any major consequences are felt on Earth. This is because there needs to be an overlap in adverse conditions (i.e., the type and strength of the storm, the direction in which the radiation and particles are dispersed, and the Earth's position in its path around the Sun at the time of the storm). In July 2012, the effects of an extraordinarily strong solar flare passed by Earth. Had the flare occurred just one week before, it would have hit Earth.

Isolated massive solar storms with damaging consequences on Earth are rare, but can occur in both periods with low and high solar activity. Statistically, medium-sized storms (e.g., those in 1972, 1989, and 2003) have hit Earth once every or every other 11 year cycle. Large storms (i.e., comparable to that of the storm in 1921) have hit Earth approximately every 100 years, while very large storms (experienced in 1859) have appeared as 100- to 500-year events.

Since existing knowledge about solar storms is based on just a few hundred years of observation, there is still a great degree of uncertainty regarding frequency assessments. It is also unknown how strong of a solar storm the sun is capable of generating. The understanding of the mechanisms behind solar storms and quality of prognoses as to when they occur are expected to improve in the coming years.

The duration of a solar storm's negative consequences on Earth are typically short (hours), but can be up to a couple of days. The indirect consequences can require a long time to repair and restore. The geographical scope is, as mentioned, large parts of the world at the same time, but the incident is experienced very differently at a local level. The northernmost and southernmost latitudes are especially vulnerable. Although Denmark is a northern country, we have not yet experienced damaging effects at a significant level, but it is likely that we will experience such effects in the future.

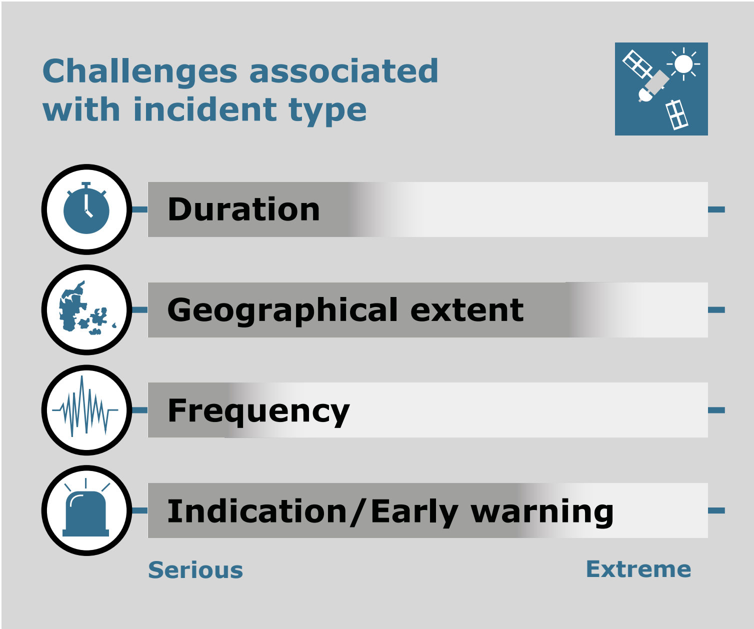
As with other natural incidents like extreme rain or hurricanes, it is not possible to redirect or deflect the effects of a solar storm. The solar storms that hit Earth can also not be predicted before they occur. It is, however, possible to give some level of warning before the effects are felt and to create prognoses while solar storms are occurring. CMEs and SPEs can take days to reach Earth. To make use of potential warnings, it is essential that mitigation measures are in place.

Unintentional collisions between manmade space objects are also rare occurrences. The problem is, however, that each time it happens, many new space junk fragments are created, thus further increasing the risk for subsequent collisions.

It is notable that as of now, four countries (USA, China, India, and Russia – most recently in November 2021) have shot missiles into their own satellites to destroy them, either to demonstrate military anti-satellite (ASAT) weapon capacity and/or to avert potential crashes. In these cases, the explosions have created millions of fragments still orbiting the Earth. Several other countries also possess ASAT weapon systems.

CONSEQUENCES

Over the last century, human activity has become more and more dependent on electricity, computers, and other technology for navigation, information, and communication. Space weather can therefore affect the technology that many vital societal functions and everyday services depend on. This is especially the case in Denmark, which is one of the most digitalised countries in the world. Denmark's vulnerability to space weather therefore depends on the degree to which we depend on specific individual systems.



It is challenging to determine the precise impact a strong solar storm would have on a given system or type of equipment since many of the previous incidents occurred before current technologies existed. Tightly compressed computer chips and advanced electrical apparatuses may prove more vulnerable than previous, more simple technology. In any case, electricity, computers, IT, and satellite technology is now omnipresent in everyday life. To the extent that modern day technology is indeed vulnerable to space weather, the phenomenon has the potential to cause wide-reaching consequences.

Geomagnetically induced currents (GIC) especially present problems. When a solar storm creates a geomagnetic storm in the Earth's magnetic field, disturbances can create electricity in elements with high conductivity. The most obvious are power lines in the energy supply net, where GIC can cause overvoltage of up to 20 volts per kilometre cable. Countries with sprawling supply nets and large distances between consumers and transformer stations are therefore especially vulnerable. This does not generally apply to the Danish power grid, although Denmark is connected to the Norwegian, German, and Swedish electricity networks. If overvoltage in these networks cause significant technical problems, under certain circumstances, the effects may spill over to the Danish grid. The extent of the consequences further depends on the conductivity of the ground, which can vary greatly based on local geological conditions.

In some cases, GIC has left transformer stations out of commission, causing long-term power outages. Power outages lasting more than a few hours can have significant cascading effects in many parts of society. In addition, strong geomagnetic storms can also affect undersea cables and other critical infrastructure.

Systems for radio communication and radar surveillance are also vulnerable to the effects of space weather. Geomagnetic storms can also render receiving radio devices out of order. When these systems are disrupted, it can be unsafe for planes to take off from or land at specific airports and certain flight routes may be cancelled or redirected.

Satellites in orbit outside of the Earth's protective atmosphere are especially vulnerable to the effects of space weather. Before being sent into space, satellites are equipped with a special material to protect them against radiation and particles from solar wind. Satellites can therefore resist the effects of a solar storm to a certain extent. There is, however, a limit on how robust of a protective layer can be applied without making the satellite too heavy to be launched. Additionally, satellites' solar panels and electronic wiring ages quicker when exposed to more intense space weather, making them vulnerable. Strong solar storms can therefore put satellites completely out of commission, whether it be temporarily or permanently. Finally, solar flares can also create disruptions to the upper parts of the Earth's atmosphere (the ionosphere) or create strong radio interference which can impact signals from navigation satellites.

As mentioned, as of January 2022, there were approximately 4,900 operational satellites orbiting the Earth. This satellite-based infrastructure serves various purposes including communication, transmission, navigation, precise determination of time, and observation of weather systems, climate developments, and other phenomena on the Earth as well as space research. For example, global satellite navigation systems (GNSS) are a widespread technology that is part of many people's everyday life in cars or mobile telephones. These systems are also a critical element in many industries and professions such as commercial maritime transport and land transport. The EU has estimated that to various extents, over 10 per cent of EUs aggregate GDP is dependent on GNSS. In a 2019 report, the consulting firm London Economics estimated that 23 per cent of Denmark's GDP is created by branches dependent on GNSS. Very precise determinations of time based on atomic clocks are also critical in many situations such as with regard to stock exchange and other financial transactions.

As an increasing number of everyday processes rely on satellite-based infrastructure, the difficulty of dealing with the consequences of potential loss of functionality of a given satellite or satellite system also increases. Many satellite systems consist of multiple satellites that have a certain degree of overlap in their functions while others perform a unique task. A strong solar storm could have serious consequences for many satellites simultaneously and/or satellites with especially vital societal functions.

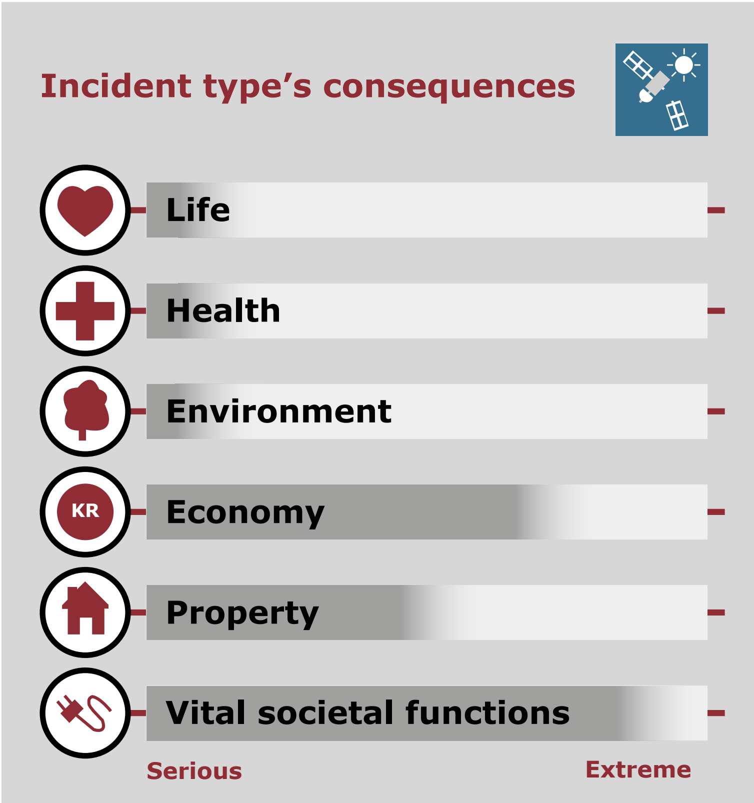
In addition to space weather, several of the aforementioned consequences can be caused by collisions between multiple satellites or a satellite and other manmade space objects. A single collision can generate enough space junk to destroy space infrastructure which, in turn, impacts navigation and communication on Earth. All satellites have a limited lifetime, and long-term plans are made for their replacement. Preparing and sending a satellite into orbit typically takes multiple years, however, and replacing one or more lost satellites is therefore a costly and protracted process.

On this backdrop – and despite the limited numbers of previous incidents – the potential consequences of a space incident in a 'realistic worst-case scenario' must be assessed as very serious for the maintenance of vital societal functions. Incidents can also lead to very large economic losses and damage to property. In a recent study from the ESA, it was estimated that the potential socioeconomic impact on Europe from an extreme space incident could cost around 15 billion EUR.

Conversely, the potential consequences for human life and health, the environment, and animal life are assessed to be very limited. Radiation from space weather can, however, pose a threat to astronauts and potential passengers and crew on very high-flying planes if the plane is in the air at the wrong time and place. There is also a risk of indirect consequences from disruption to navigation and communication systems. This can cause transport accidents, impact emergency call functions, or delay rescue responses. Finally, a satellite or other manmade space object crashing on Earth could cost lives and/or cause environmental contamination.

TRENDS

The Sun's activity reached its last minimum in December of 2019. In the current cycle, the activity will increase from now on, thereby increasing the number of solar storms until hitting a maximum in 2025. All else constant, a large number of solar storms means an increased risk for flares, CMEs, geomagnetic storms, and SPEs toward the Earth.



The maximum sun spot activity during this cycle is not expected to be especially strong, but this does not have any influence on the strength of the solar storms that can occur. From 2025, solar activity is expected to decrease again, but a trend has been observed whereby especially strong solar flares are seen in the years following maximum activity. This was the case in the fall of 2003 (described in this chapter's introductory text box).

Space is a domain that has large significance for the growth in society and can contribute to solving some of the largest challenges faced on Earth. It can be argued that a new space race has been initiated, not just civilly, but also militarily. Several countries have made defence strategies for space and established space commands, such as the USA's establishment of the U.S. Space Force in 2019. In December of the same year, NATO declared space an 'operational domain' on the same level as the pre-existing domains of land, water, air, and cyberspace.

In addition to the renewed focus from world powers and medium-to-large countries, smaller states have also expressed ambitions for space. For example, Denmark launched its first national space strategy in 2016, wherein space is identified as an area for strategic political research and innovation efforts with strong potential for growth. A revision of the strategy's goals in 2021 highlighted space-based technology and knowledge as foundational to the green transition, handling of climate challenges, and several vital societal functions.

In addition, Denmark sent its first military satellite (Ulloriaq) into orbit in 2018. The satellite is a test satellite tasked with looking into potential for monitoring ships and aircrafts in the Arctic from space. Based on experiences from the Ulloriaq mission, considerations are underway concerning the further development of Danish space-based infrastructure. Such infrastructure would primarily be used for monitoring and surveillance tasks, but could also potentially support other vital societal functions. With the agreement on the Arctic capacity package in 2021, Denmark's defence will be strengthened both militarily and civilly with regard to surveillance and presence in the Arctic through a satellite constellation within the framework of a multinational program. In addition, an Earth-based station will be established to receive satellite data and allocate resources to procurement of commercial satellite communications bandwidth to strengthen communications in the Arctic.

Though space has traditionally been a domain reserved for state actors, in recent years, more and more private actors have joined. Today, there are several commercial enterprises that send satellites into space. Some of these enterprises are planning to establish their own satellite network to offer services such as space-based internet. Technological advancements have enabled functional satellites to be built in sizes of 10 cm x 10 cm x 10 cm or even smaller. Because of this, single rockets can transport a large number of devices, which also decreases the cost of transporting each individual device (i.e., under 40,000 EUR). Such low costs enable even smaller companies and institutions to pay to launch their own satellite or constellation of satellites into orbit. It has never been cheaper to do so, and the price is continuing to fall.

All of these conditions point to an expectation that many thousands of new satellites will enter orbit within the next few years. As the number of manmade objects around the Earth increases, the risk for the most useful satellite tracks becoming obsolete for future generations does too. The ultimate consequence could be the so-called 'Kessler syndrome' presented by NASA researcher Donald J. Kessler in 1978: when the amount of space junk surpasses a critical threshold, collisions will cause a cascade of new collisions that will effectively prevent free and safe access to space. Because of the many new satellites in space, more and more researchers worry that this scenario could become a reality.

Even so, work is being done to limit the creation of new space junk and reduce the amount of the existing space junk. In 2019, NASA launched a satellite with the name Mission Extension Vehicle 1. In 2020, the satellite reactivated a dead communications satellite, and in 2022, NASA will send Restore-L to space to refuel and reactivate a dead Earth observation satellite. The ESA is planning to deploy its first test mission to remove space junk in 2025. The EU is also currently building a network of sensors that will monitor and trace objects in space in order to warn of specific collision risks.

In general, it is safe to conclude that society's dependency on satellite-based infrastructure will increase, since some Earth based-systems have either been replaced by satellites or are at least partially dependent on satellite-based infrastructure. Because satellite-based infrastructure is significantly more vulnerable to the effects of space weather and because the threat posed by space junk is growing, the aggregate threat for our society is also increasing.

EXAMPLES

On 2 September 1859, several unusually large flares were observed. 17½ hours later, the corresponding CME hit Earth and caused strong GIC in the telegraph network. Telegraphists were electrically shocked, and in some places, paper caught on fire in telegraph station buildings due to overvoltage created in the long cables. This event is known as the Carrington Event, named after the astronomer Richard Christopher Carrington who studied phenomena of the Sun. The event is often referred to as the strongest known geomagnetic storm on Earth. Despite the storm's intensity, the consequences were limited because at that time, little electrical infrastructure existed and dependency on electricity was therefore limited. Space-based infrastructure also did not yet exist at that time. It is unknown precisely how severe the consequences of the same event could be today.

In March 1989, a CME and subsequent GIC caused a breakdown of the energy supply in Québec, Canada. The strength of the CME was much less than that of the Carrington Event, but it left six million people without power for nine hours, causing large economic loss. At the same time, aircraft pilots reported static noise on the radio lines and several ships lost radio contact with land. Communications with several satellites were also disrupted for several hours and a large amount of weather data was lost. On Space Shuttle Discovery, gauges and instruments showed incorrect values. In August of the same year, a separate GIC incident caused a breakdown of Canadian PCs. The Toronto stock exchange was forced to suspend trading for three hours.

The next larger space weather events with serious consequences on Earth were the so-called 'Halloween storms' in October and November 2003, described in this chapter's introductory text box. Since then, there have been smaller events. On 4 November 2015, a solar flare disturbed radar systems in Sweden to such a degree that it was no longer admissible to fly and land planes in Swedish airports. Closures of airspace caused delays and cancellations of flight routes in and outside of Sweden. The fact that Denmark did not experience the same disruptions is likely because radar systems in Danish airports operate at a different frequency than those in Swedish airports.

Among the unintentional collisions between manmade space objects is one of the most well-known collisions which happened on 10 February 2009. Two satellites – Iridium 33 and Kosmos-2251 – accidentally collided. Iridium 33 was an active American-built commercial communication satellite owned by Iridium Communications. Kosmos-2251 was a Russian military communication satellite that was decommissioned in 1995 but remained in orbit as space junk without an active steering system. The two satellites flew with a speed of 24,480 kilometres per hour and had a combined weight of 1,500 kilograms. The colossal momentum completely destroyed both satellites and sent more than 2,000 fragments of approximately 10-15 cm into orbit around the Earth. Most of the fragments' orbits are now decaying and will ultimately burn up in the Earth's atmosphere.

This was the first time a high-speed collision occurred between two satellites, but there have been several close calls and many unintentional collisions between satellites and space junk since. One example of the latter occurred in January 2013 when a Russian nanosatellite collided with fragments from a destroyed Chinese weather satellite. The fragments were created in 2007 when China shot down the satellite.

What if...

... a violent solar storm with a strong flare and accompanying expulsion of electrically charged particles (SPE) hits the Earth in an unprecedented way. All four of the large global navigation systems (GNSS) – GPS (USA), Galileo (EU), GLONASS (Russia), and BeiDou (China) – report outages of the majority of their satellites. Determination of position with the help of satellite navigation is inaccessible and electronic financial transactions are also not possible. TV stations are out of commission and cannot transmit effectively because of the communication satellite outages. Europe's weather satellites that give DMI (among other actors) access to weather and climate data are also affected. Transatlantic and polar flight routes are rerouted or cancelled in order to avoid multiple plane crashes. As an indirect consequence of lacking signal precision, a serious maritime accident occurs in Danish waters. There are several deaths and many are injured.

About 12 hours after the SPE hits, an extraordinarily strong CME hits Earth, and GIC causes power outages in several of Denmark's neighbouring countries. This has consequences for the supply of electricity in Denmark. In addition, parts of Denmark experience periodical disruptions to mobile networks and the radio network used for emergency communication, SINE (Sikkerhedsnet). Communication lines are still inaccessible and the lacking stream of news on TV, unstable mobile network connections, and power outages make it difficult to get an overview of the situation. Worry builds amongst the population because of sparse information. At the same time, concern arises that criminal actors and foreign states will exploit the situation by waging cyber attacks against critical infrastructure.

ABOUT THE REPORT

National Risk Profile (NRP) is DEMAs periodical compilation of risk analyses at the national level. The report is published with intervals of 4-5 years.

NRP is published on behalf of the Ministry of Defence, on DEMAs own initiative, and to fulfil a requirement in the EU Civil Protection Mechanism which stipulates that member states must continuously develop risk assessments at the national or relevant subnational level. NRP is thus doubly anchored in both a national and an international need. It should be noted that NRP only deals with Denmark, not the other parts of the Kingdom of Denmark.

NRP is created in collaboration with a wide array of experts from sector-responsible national authorities and other actors (e.g., universities). It should be noted, however, that DEMA is solely responsible for the descriptions, assessments, and juxtapositions in NRP.

Method and terminology

With NRP, DEMA aims to offer an informative and accessible report. The method used is primarily qualitative, as reliable quantitative data is often limited or inaccessible for the selected extraordinary and rarely occurring incident types. Focus is therefore placed more on the incident types' characteristics and potential consequences than their statistical likelihood.

In NRP, 'risk' is not conceptualised as a product of likelihood (frequency or plausibility) multiplied by consequences, yielding a singular mathematical value, allowing a rank ordering of the risks. Instead, NRP understands the concept of risk(s) broadly as types of incidents or circumstances that result in unwanted consequences.

The term 'incident type' is used as an umbrella term in NRP, covering all incidents that share a sufficient number of characteristics in terms of how they occur and what is required to handle them, regardless of the fact that they can manifest very differently in concrete situations, times, and places.

The advantage of thinking of risks in the form of incident types is that it enables us to group the central challenging themes and increases our understanding of the components of the identified risks.

Risk identification, selection criteria, and selection process

NRP is not an exhaustive list of all incident types that could possibly affect Denmark. It is also not a guarantee that other completely new and unforeseen incident types will not occur. Some risks are relatively simple to identify, monitor, and analyse, either because associated events occur frequently or are given significant attention. In other cases, deeper analyses or a strong imagination is required to consider new risks or new ways in which well-known risks can develop.

The selection of the incident types in this NRP is firstly based on a list of a large number of plausible incident types. Since NRP is a national risk profile, this list is made up of incident types that could:

- Manifest as incidents, understood as limited events (in time and space).
- Create serious and immediate negative consequences within Denmark's borders.

- Trigger an acute need for coordination and crisis management at a level that is not merely local.

The incident types must also have an element of 'plausibility' based on experts' assessments of the possibility that incidents of each type could occur within the next five years. This does not mean, however, that similar incidents must have occurred or caused consequences for Denmark in the past.

The preliminary list of incident types is then split up into taxonomical levels. Phenomena with significant similarities are grouped together, e.g.:

- Various contagious disease outbreak is grouped under the title 'highly virulent diseases'.

- Accidents with passenger ships and contamination accidents at sea are grouped under the title 'maritime accidents'.

- Large accidents in air traffic, on motorways, bridges, and tunnels are grouped under the title 'transport accidents'.

Phenomena that can be considered as consequences in several instances are not addressed as incident types, but are instead placed under other incident types. For example, power outages are discussed as a consequence in the majority of NRP's chapters – regardless of the fact that power outages are initiated due to conditions internal to the electricity sector could be considered to be its own incident type. Wildfires are also considered as a consequence in the chapter 'heat waves and drought'.

The final selection of incident types included in the NRP is based on assessments of possible direct or residual consequences on six parameters: life, health, environment, economy, property, and vital societal functions.

The term 'vital societal functions' refers to the official Danish definition: *"The activities, goods, and services that make up the foundation of society's general ability to function."*

In accordance with the Danish definition, vital societal functions whose absence or severe scarcity would cause serious negative consequences are divided into the following 15 sectors/areas:

- Energy
- Information and communication technology (ICT)
- Transport
- Preparedness, police, and civil protection Health
- Social conditions
- Drinking water and food
- Waste water and waste treatment
- Finance and economy
- Education and research
- Meteorology
- Defence, including intelligence and security services
- Foreign service
- General exercise of public authority
- Cross-sectoral crisis management

Often, incident types will have the potential to affect several vital societal functions via an outage or disruption to supporting 'critical infrastructure'. In Denmark, critical infrastructure is defined as:

"Infrastructure – including facilities, systems, processes, networks, technologies, assets and services – that is necessary to maintain or restore vital societal functions."

Through this selection process, DEMA finally reached the final list with 14 incident types for NRP 2022. Some of the not-selected incident types may be included in future editions of the NRP. DEMA therefore invites readers to critically consider the selection in NRP 2022 based on their own organisational context. Not all incident types have the same relevance for all organisations.

It is further noted that the order of the incident types in NRP is structured thematically and is not an expression of a rank order. Each incident type can have potential to be 'the worst one' for different actors. DEMA invites readers to create their own ranking that takes the organisation's context into account, including exposure to various incident types.

The chapters' structure
NRP 2022 consists of one chapter for each of the 14 incident types. Each chapter begins with a short summary of a relevant serious incident that has recently occurred in or affected Denmark. The goal of these summaries is to give a concrete example of how the incident type can unfold.

The section 'characteristics' describes the phenomena that the incident type encompasses along with central knowledge about causal relationships. In addition, key terms and definitions are refined to fit the chapter's context.

The section 'occurrence' describes the available data and knowledge base and how it relates to where, when, how often, and for how long an incident type could occur. As with anything that deals with the future, this is riddled with various degrees of uncertainty. In addition, the knowledge level (i.e., what type of knowledge is available, how certain this knowledge is, and how this knowledge can be used) differs across incident types.

In the section 'consequences', the immediate damage, cascade effects, and later residual consequences of each incident type is described. Here, considerations are made for loss of human life, damage to human health (physical and psychological), negative effects on the environment, economic loss and expenses, damage to private and public property, and challenges for the maintenance of vital societal functions. These parameters are discussed to the extent relevant for the given incident type.

To discuss occurrence and consequences is not to attempt to predict the future or illustrate exactly how an incident type may manifest itself. Extraordinary incidents and their trajectory are per definition difficult to predict, and the concrete incident trajectory will almost always have elements that come as a surprise.

In the section 'trends', trends with potential to affect the risks associated with each incident type are analysed. As a general rule, the analysis considers a five year horizon, but in some cases (e.g., in relation to climate change), the time horizon extends further.

The 'examples' section describes selected past incidents. The examples are included based on an assessment of their relevance for the given incident type in a Danish context. Several of the examples have been the motivation behind preventive efforts and would therefore likely not be able to repeat themselves in the same way. Even so, the examples serve as an illustration of what has previously been surprising and resulted in serious consequences. The future cannot be predicted on the basis of the past, but experiences from previous incidents can give insight and teach important lessons that can help us to better speculate about future surprising elements or consequences of future incidents.

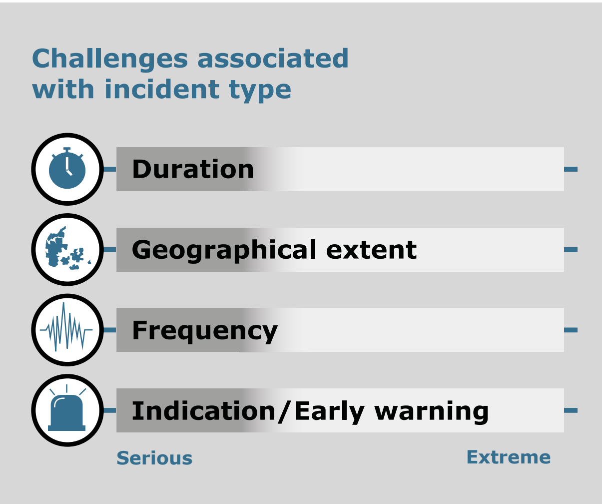
Finally, each chapter is concluded with a short fictive scenario under the heading 'What if…'. These scenarios should serve as encouragement for further reflection. The scenarios can also be used as inspiration for preparedness planning, planning exercises, etc. Several of the scenarios describe 'realistic worst case' incidents. The scenarios can also be scaled up or down to fit the organisational or geographic context.

Illustrations
The text in each chapter is accompanied by two figures. The figure titled 'challenges associated with incident type' illustrates the degree of the

challenges associated with each incident type on four parameters:

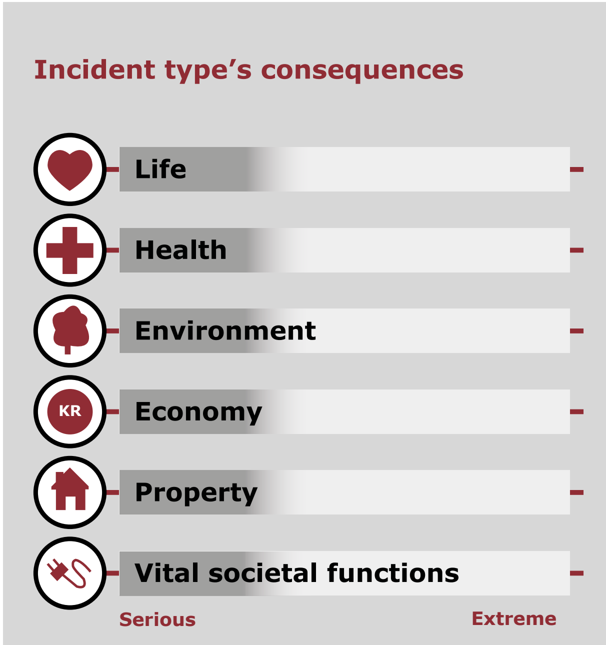
- Duration: how long might an incident of this type last?
- Geographical extent: how much of the country can this incident type affect simultaneously?
- Frequency: does this type of incident occur often?
- Indication/warning: to what extent is it possible to foresee that an incident will occur and warn authorities and the general population?

The figure entitled 'incident type's consequences' is a graphic representation of the consequences incidents of the given type can have, split up into six parameters:



- Life (deaths)
- Health (injury, illness, infection/contamination, anxiety, insecurity, etc.)
- Environment (contamination of land and water environments, damage to animal and plant life)
- Economy (monetary loss)
- Property (material destruction, loss of cultural heritage sites, loss of intellectual property rights, etc.)
- Vital societal functions (activities, goods, and services that form the foundation of society's general ability to function)

The figures should be seen as an expression of qualitative assessments. The figures are not based on mathematical calculations or exact science, but enable comparison across incident types. Since the incident types can manifest in innumerable ways, the assessments represented on the figures cover a wide variety of possible incident trajectories. Thus, the figures provide an interval rather than a specific value.



An example that illustrates how large an interval the parameters span is the incident type extreme rain. Extreme rain covers both very short-lived local cloudbursts as well as long-term and geographically diffuse precipitation events. The figure regarding the challenges associated with the incident type's characteristics thus represents a combination of the worst characteristics of the various possible incidents.

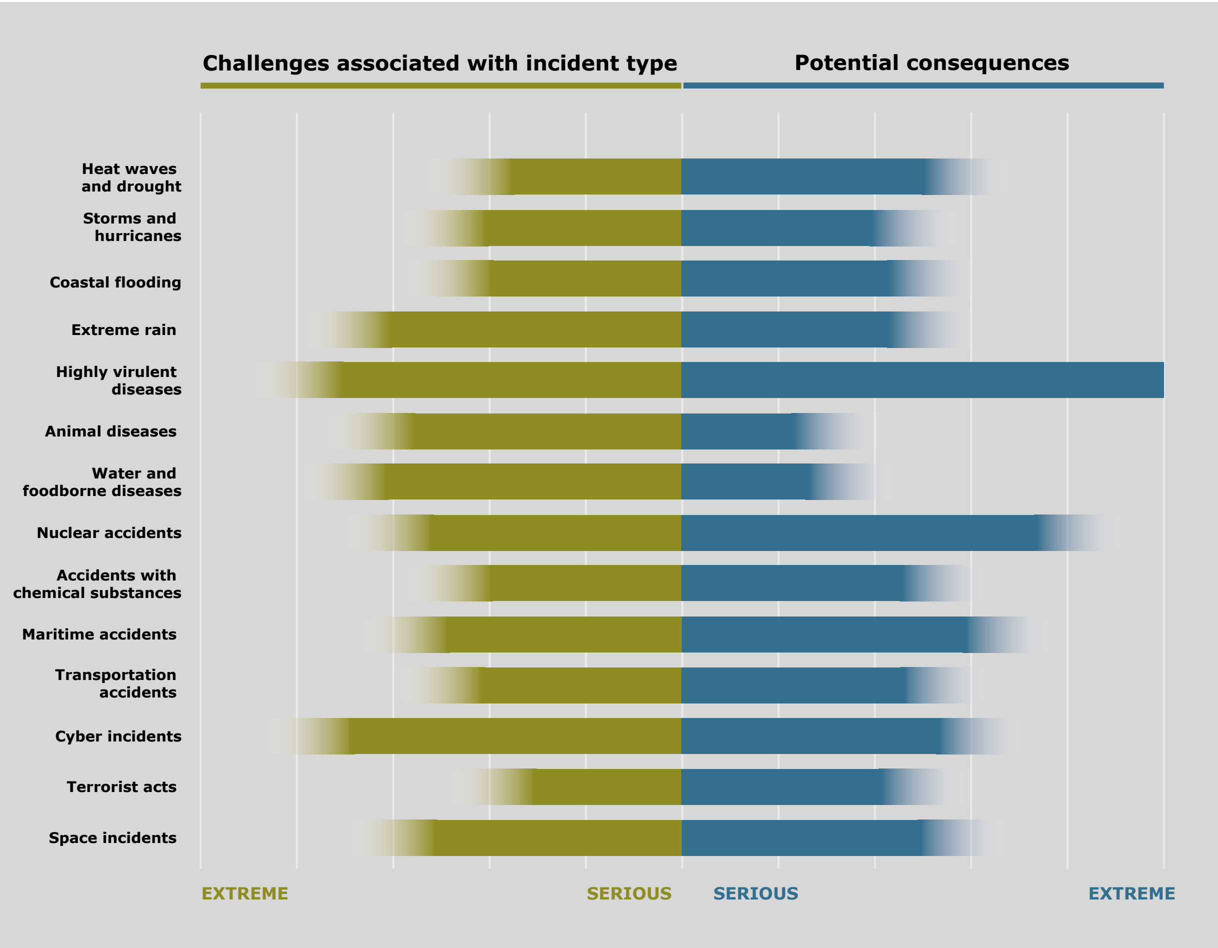
Based on the information presented in NRP 2022's chapters, DEMA has compiled all 14 incident types into a single overview figure. The figure lists the incident types in the order they appear in the report and should not be seen as a rank order.

The figure shows in part an assessment of the realistic worst-case scenario of a given incident type and in part a weighted average from the underlying analysis. The figures therefore offer intervals rather than specific values.

The green bar in the figure's left side illustrates the degree of challenges associated with the incident type's characteristics on the parameters duration, geographical extent, frequency, and indication/warning. The assessments span from serious challenges (in the middle) to extreme challenges (all the way to the left).

The blue bars on the right side depict the incident type's potential consequences on the six parameters life, health, environment, economy, property, and vital societal functions. The assessments span from serious consequences (in the middle) to extreme consequences (all the way to the right).

The incident types' combined bars in the figure (the green and the blue bars combined) should not be seen as absolute values since challenges and consequences can be weighted differently. Two bars (green and blue combined) being the same length does not necessarily mean that they are equal in the overall national risk profile.



ABOUT DEMA

DEMA is a national authority under the Danish Ministry of Defence and is a central part of Denmark's catastrophe preparedness. DEMA works to ensure a robust society by developing and strengthening emergency management so that accidents and catastrophes are prevented and mitigated. DEMA has two core tasks: operative emergency management and administrative tasks related to prevention, preparedness, and crisis management.

Operative emergency management
DEMA's operative emergency management covers national tasks regarding national and international preparedness, the training of conscripts, and specialised emergency management regarding nuclear and chemical preparedness. The national rescue services are 24/7 and placed in DEMA's six regional centres. DEMA is deployed for foreseen and unforeseen incidents that require special equipment and specially trained personnel as well as in long-term or personnel-intensive responses.

Tasks related to public administration
DEMA also performs several tasks related to the administration of the field of preparedness and ensures the development of national preparedness by focusing on opportunities, challenges, and general development trends. In addition, DEMA conducts oversight and consulting in relation to the municipal rescue services as well as managing several fire prevention activities.

DEMA further holds the responsibility for the development of the wider societal capacity for crisis management, crisis communication, preparedness planning, and operation of warning services.

Finally, DEMA performs tasks relating to the development, adaptation, and execution of the national rescue service's education branch for all actors within the preparedness sector. This includes the national rescue service, health preparedness, the police, municipal rescue services, and emergency management volunteers.

ACCREDATION

Cover illustration: Anders Moseholm, "Derfor bliver vi ved med at søge", 2018, oil on canvas, 41,5 x 183,5 cm. © Anders Moseholm.

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The image on the cover of this report was created by Anders Moseholm and depicts the catastrophe at Haderslev Dam. The catastrophe occurred when the boat 'Tourist' burst into flames, claiming 57 lives and leaving Haderslev in a state of shock. The event also sent waves of grief throughout the rest of Denmark in 1959.

Anders Moseholm said the following about the background story of the image:

> I was enthralled by the intense photos from the fire at Haderslev Dam – and at one point a figure resembling my father appeared in one of the photos. The similarity was uncanny. My father was a member of the civil defence in Haderslev in 1959. He was 23 years old at the time. In the photo, he is carrying a drowned person with two others. The catastrophe happened just a month before he was going to become a father, move into a house, and start his first job as a primary school teacher – all seminal events for entering into adult life. This was before the youth rebellion, when men were not supposed to cry […] Afterwards, there were no crisis psychologists or anything like that. He just went home to my mother and told her, "Today I experienced something awful and we will never talk about it."

In connection with Haderslev's Art Association's exhibition in 2019 about the catastrophe, Anders Moseholm wrote:

> My opening to being inspired by the pictures was that the pictures were also about something other than imbuing fear and expressing grief. In a more constructive way, pictures of catastrophes can remind us that human life is fragile. A memento mori. The unthinkably horrible does not just happen to your neighbor. It can also happen to you and your family. The catastrophe does not just affect a remote village in South America. The catastrophe can also happen in a safe little provincial city in a safe little country. Like Haderslev. It can happen on a beautiful summer day where elderly people and children take a boat ride together. In my experience, the memento mori that the pictures from Haderselv Dam reminds us of is also about responsibility and love. That we always have a responsibility to protect that which is uniquely human. Because it could just as well be us. It is a constructive responsibility and hope that these pictures also remind us of. We are people who show up when someone is in need, regardless of how much we otherwise disagree. It is part of us as humans and it is a fantastic strength.