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Increase in extreme weather events affects infrastructure, energy production and distribution

School of Business, Society and Engineering
Course: Climate change and energy: past, present and future
Course code: MTK347 23130 HT2024
Credits: 7.5 hp

Abstract

The climate is changing due to the global temperature increase. This climate change will alter weather patterns and events all over the world. During mid september of 2024 a heavy rainfall event, Storm Boris, occurred. Austria suffered from over 450mm of precipitation during the period, with damages accumulating between 600 to 1800 million Euros. To understand the consequences if a similar rain hit a city in Sweden a case study was done in Sigtuna. Analyzing the results of the case study by simulating a heavy downpour in SCALGO LIVE showed that this could heavily affect access to reliable and sustainable energy if no action to reduce climate change is taken immediately.

The Swedish government's National Strategy for Climate Adaptation strengthens flood resilience through preventive measures and local support. The National Expert Council promotes nature-based solutions, while the Climate Policy Council emphasizes better integration of climate risks and increased funding for flood mitigation.

1 Introduction

A concerning component of the ongoing climate change is the responding effects on precipitation that the increase of global temperature brings. The IPCC reports a projected increase by 1-3% in average global annual precipitation and the events of extreme precipitation to increase by 7-15% per 1°C (IPCC, 2021). This growing urgency to tackle climate change aligns with global initiatives like Agenda 2030, a United Nations framework aimed at fostering sustainable development across social, environmental, and economic dimensions (FN, n.d.). At its core are the 17 Sustainable Development Goals, each addressing key global challenges, from eradicating poverty to protecting the environment. For instance, Goal 7, "Affordable and Clean Energy," focuses on ensuring universal access to sustainable energy, a vital component for socioeconomic development. Similarly, Goal 13, "Climate Action," calls for immediate action to combat climate change, promoting resilience and adaptation to reduce the impacts of climate-induced events (FN, n.d.).

A natural disaster that occurred recently, during the period 12th to 16th of September 2024, is the heavy rainfall in Europe. This downpour event has gotten the name "Storm Boris". Multiple countries felt the effects of Storm Boris, including Austria, Czech Republic, Croatia, Germany, Hungary, Italy, Moldova, Poland, Romania and Slovakia. Not only does a downpour like this cause major flooding that destroys homes, infrastructure, agricultural harvestings and other sources of income for the countries. It also puts a big stress on the society, with at least a few hundred rescue operations, power outages, volunteer-work to start handling the consequences and a death toll of at least 24 people (Giuffrida & Henley, 2024).

For a long time, the average rainfall per year has increased in Sweden, although there are differences between different parts of the country. At the same time, there is a change towards a warmer climate, which depends on how the emissions of greenhouse gases develop. With expected climate change, rainfall will become more intense and downpours will become more common. This creates a higher risk of flooding. Changes in temperature are also expected to affect snowmelt and evaporation (SMHI, 2022a).

Already today, infrastructure is affected by extreme weather, which is expected to become increasingly common in rate as climate change progresses (Svenskt Näringsliv, 2024). High flows affect the dewatering systems: drums, wells, ditches and drainage lines. The risk of erosion, washing away, floods, landslides and landslides increases. So-called mudflows can clog road culverts and pipe bridges so that the road bank or embankment risks being washed away (Trafikverket, 2021). The transport infrastructure needs to be adapted to a changing climate to ensure its robustness and reliability in the future (Svenskt Näringsliv, 2024).

What would the amounts of rain that are now falling in Europe bring with them if they hit Sweden and what will the government's approach be to counteract damage from floods.

1.1 Research questions

- How did the heavy rainfall event in Europe arise and what consequences did it bring?
- What would be the consequences if a similar rain hit a city in Sweden?
- How does the Swedish government plan to mitigate flooding impact from heavy rainfall and what are the comments from the Swedish Climate Policy Council?

2 **Method**

The method for this project is a literature study, where data is obtained by using the databases Google Scholar and Google. The sources where relevant information is pertained includes peer- reviewed scientific articles, Sweden's Government, authorities and other relevant organizations websites. To acquire the sources various combinations of keywords is use as search terms, the keywords are presented below in English.

Keywords: *flooding, mitigate, climate, climate change, climate policies, Swedish Government, storm Boris, Boris, Central Europe, Europe, rainfall event, rain, precipitation, Vb, 5b, weather, maps, floodmaps*

This report utilizes governmental and expert sources to ensure the credibility and relevance of the information presented. Key documents include official publications from the Swedish Government, such as the *Nationell strategi och regeringens handlingsplan för klimatanpassning*, which provides insight into national climate adaptation strategies. Additionally, reports and directives from the Swedish Civil Contingencies Agency (MSB) highlight current national flood risk assessments and regulatory frameworks, reflecting Sweden's adherence to EU flood directives. Reports from expert bodies, such as the *National Expert Council for Climate Adaptation* and *Swedish Climate Policy Council*, offer valuable evaluations and policy recommendations on climate adaptation and resilience. These sources were selected to provide a comprehensive view of Sweden's climate adaptation efforts and are cited to support findings throughout the report.

Map studies from Sigtuna municipality and from the extreme weather event in Europe is being used to understand, pinpoint and verify data findings from the methods above. Data from storm Boris is utilized to carry out a SCALGO LIVE simulation of flood risks in a small area in Sigtuna municipality where information about terrain conditions and pipeline network is available.

To condense the findings, a section of comparisons, discussions and conclusions are made between the information from storm Boris and the present, but also contingent future situations, of Sweden which is being presented by the case study and the information provided from the Swedish government.

3 **Results**

3.1 Storm Boris in Europe

3.1.1 Rainfall event

The rainfall event in Europe was caused by a so-called Vb (5b) cyclone (Kimutai et al., 2024). Cyclones that emerge from southeastward air flowing over the Alps and the northern parts of Italy, deviates in a northeastward direction and flowing over central Europe is called a Vb cyclone. A characteristic of Vb events is that the precipitation tends to be minimal on the Southern slope of the Alps. Vb cyclones are rare, contributing to 2.4% of all cyclones in Western and Central Europe, with a mean duration of 3.1 days. Even though these cyclones are rare they have a great potential to trigger weather anomalies, being responsible for more than 14% of extreme precipitation days in Central Europe (Messmer et al., 2015).

In our present climate a rainfall event of this magnitude is expected once in 100 to 300 years. In a warmer global climate the characteristics of a Vb event could see a change in both frequency and intensity. Since pre-industrial time the likelihood of a heavy rainfall event lasting 4 days has increased by around 100%, with 20% more intense precipitation (Kimutai et al., 2024).This is based on a 1.3°C temperature increase since the pre-industrial era.

3.1.2 Precipitation data

Two of the countries with the heaviest rainfall during the event were Czech Republic and Austria, both of them with regions exceeding over 350mm of rainfall during the period of 12th to 16th of September 2024.

In the Czech Republic the weather station with the highest observed accumulated precipitation was around the city of Jesenik, exceeding 450mm, figure 1.

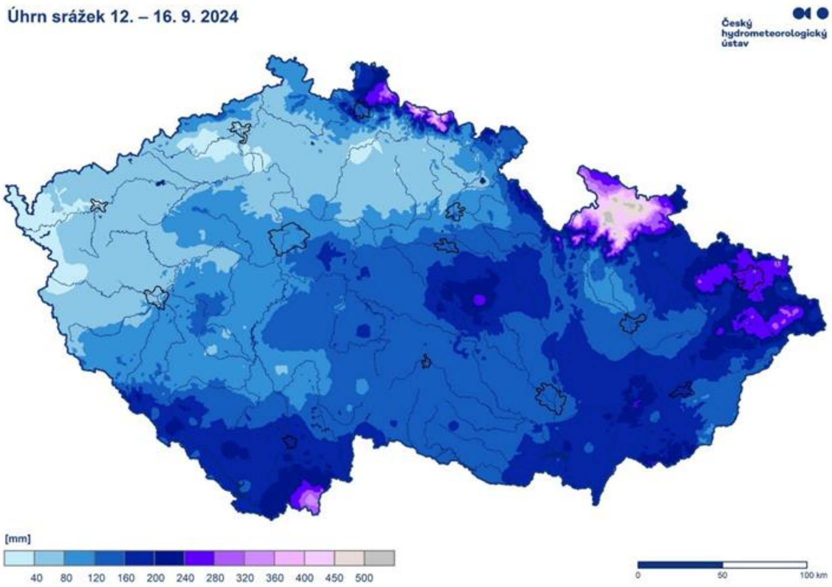

Figure 1: Accumulated rainfall data from Czech Republic (český hydrometeorologický ústav, 2024).

In Austria the situation is similar to the Czech Republic, with weather stations in regions Southwest of Vienna observing the most intense rainfall, illustrated in figure 2. From the map it's possible to observe that the rainfall is mostly in the Northeastern region of Austria and the Alps, which is typical for a Vb event.

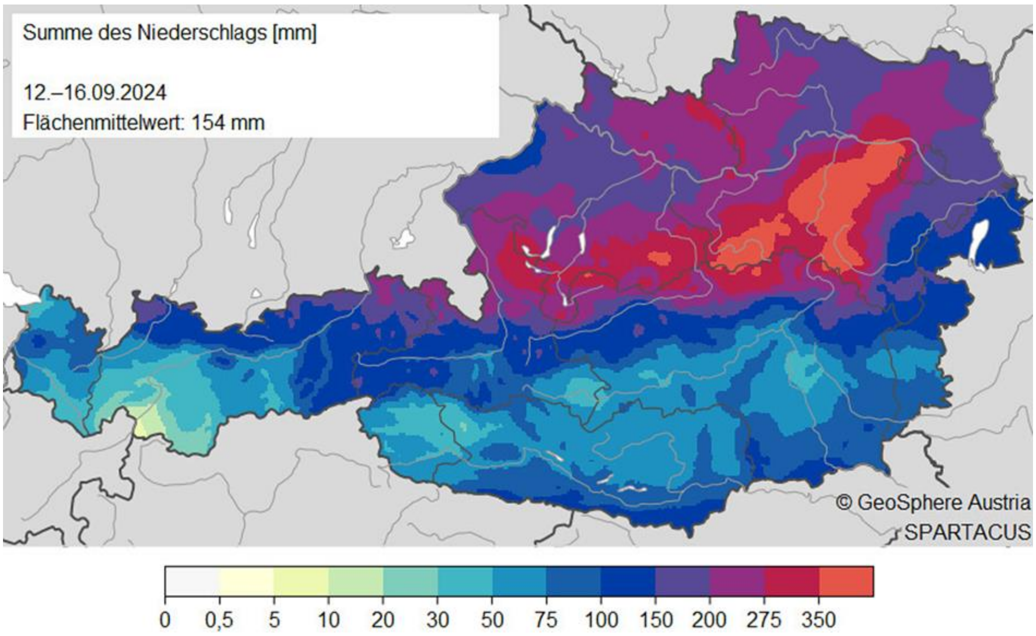

Figure 2: Accumulated rainfall data from Austria (Geosphere Austria, 2024).

3.1.3 Aftermaths

In Austria, the region Lower Austria was declared a catastrophe zone with almost 5 000 instances of people being trapped in their homes due to the flooding. Due to the flooding, great parts of the transportations systems in the eastern region were intermitted (Guy Carpenter, 2024). In terms of infrastructural damage cost in Austria, the damage to housing and transport is estimated to range between 300 to 900 million euros. Damage to agriculture is roughly 10 million euros. Estimated losses of production during the period are estimated to be 300 to 900 million euros (Friesenbichler et al., 2024).

3.2

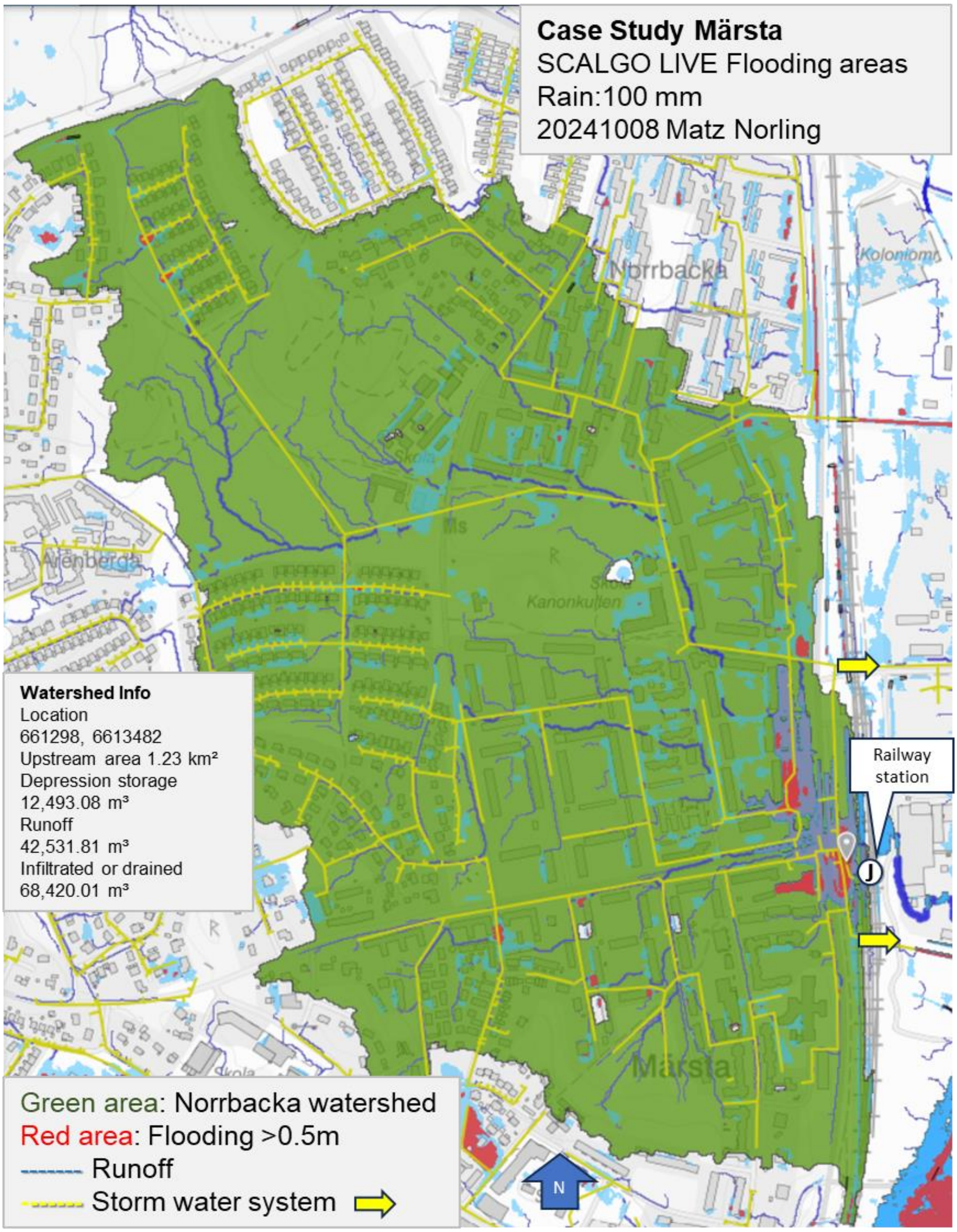

Figure 3: Flooding of Norrbacka watershed modeled by SCALGO LIVE

In order to understand the consequences of a major downpour in Sweden a case study was done in the Sigtuna region just north of Stockholm. Focus was on the Märsta railway station and the effect on the railway capacity. The railway passing through the area belongs to the Swedish main line with heavy traffic and there is a daily transport of aviation fuel to the Arlanda airport and fuel for Fortum's local power and heating plant.

Sweden's business life is heavily dependent on functioning state roads and the railways in the Mälardalen-Stockholm densely populated area is one of the nine identified areas of critical transport infrastructure (Svenskt näringsliv, 2024).

Sigtuna municipality has concerns that Märsta station will be flooded in places during heavy rains and is classified as a socially important function and must be protected in extreme rains (Trafikverket, 2021a). The management of extreme rainfall cannot be done in isolation within the railway area, but the problem needs to be seen in a larger context in collaboration with Sigtuna municipality (Trafikverket, 2021b).

Parts of the street Västra Bangatan that run parallel to the railway north of Märsta railway station are identified as a low point with some storage capacity. In connection with a 100-year rainfall, there is therefore a risk of flooding at this point, due to stormwater coming from the catchment. The storm water system covering the catchment traverses the railway at two points south and north of the railway station, see figure 3, and ends finally in the Märsta river and Lake Mälaren. The north outlet via the Odensala river and the south outlet to the main Märsta river culvert system.

The rain was modeled as a 100 mm rain and will be used as a baseline for this investigation (MSB, 2017). Similar results can be found in Trafikverket (2021) that used a 100-year rainfall with a duration of one hour and 25% climate factor (equivalent to 70 mm of rain) and Sigtuna (2020). In figure 4 there is an estimation of accumulated rain volume for a 100 year rain (Sigtuna, 2020).

According to new proposed regulations Sigtuna municipality must be able to store 20 millimeters of stormwater and the storage must take place for at least 12 hours. The minimum level for planning and elevation of land is that buildings should not be damaged in the event of a 100-year rain. Consideration must be given that future rains may be more intense (Sigtuna, 2024).

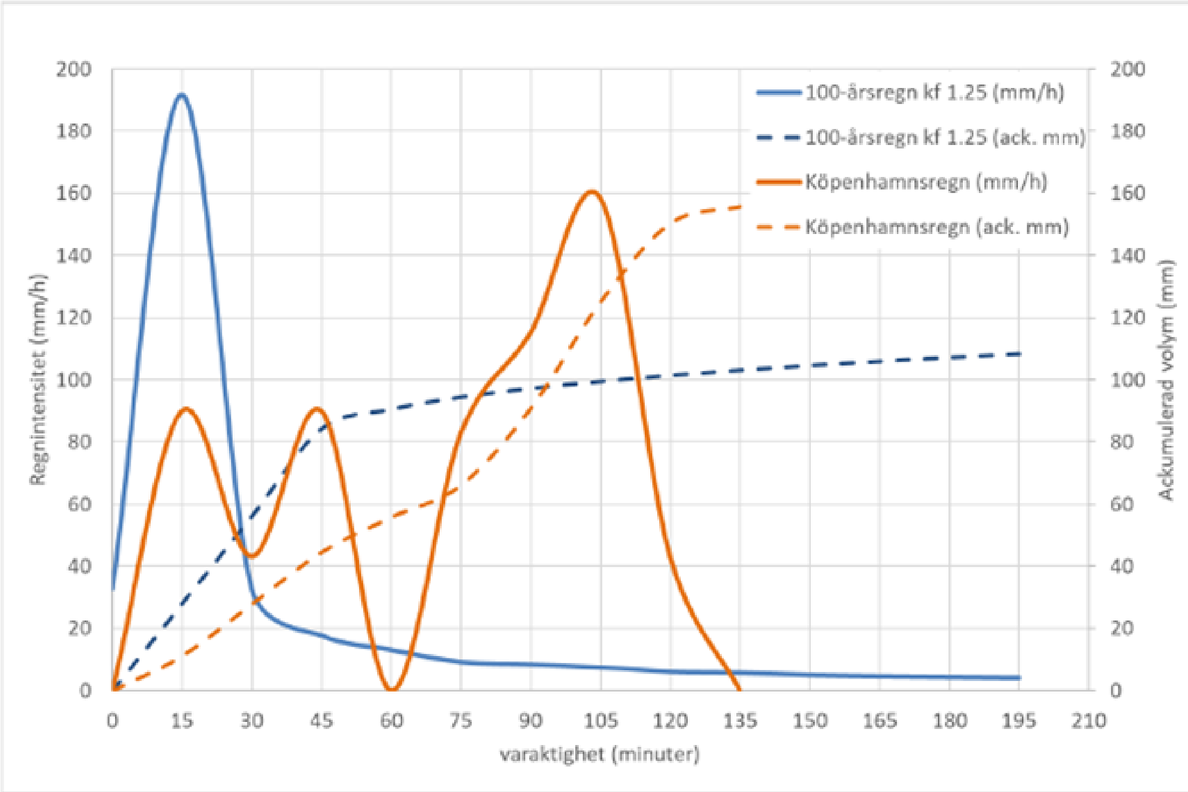

Figure 4: Rain intensity and accumulated rain volume as a function of duration for simulated rain events (Sigtuna 2022)

3.3 Mitigating flooding impact

The Swedish government has several strategies to mitigate the impact of flooding, with the aim to strengthen the resilience to climate change and prevent damages to infrastructure and communities, where one of the central policies is the National Strategy and Action Plan for Climate Adaptation (Government of (Regeringens skrivelse 2023/24:97), 2023). This action plan outlines a comprehensive approach to climate-related risks, such as flooding, and emphasizes the need for preventative measures to reduce vulnerabilities. Reducing vulnerability particularly includes strengthening flood defenses, modernizing water management systems, and improving land-use planning. Another important aspect of this plan is to designate resources to local municipalities, enabling them to better manage flood risks in their areas (Government of Sweden, 2023).

Furthermore Sweden has also implemented the EU Floods Directive through national legislation, such as the Flood Risk Ordinance (2009:956) and the updated version from 2024 (MSB, 2024a). These regulations require detailed risk assessments, mapping of flood-prone areas, and the development of flood risk management plans. The Swedish Civil Contingencies Agency (MSB) plays a central role in identifying areas most at risk of flooding, recently they have designated 26 high-risk areas for significant flooding (MSB, 2024b).

In addition, the Swedish government collaborates with the National Expert Council for Climate Adaptation, this council has been appointed by the government and decides every five years on a report that is the basis for the national climate adaptation strategy (National Expert Council for Climate Adaptation, 2022; SMHI, 2022b). This body serves as an advisory body, collaborating with the government, which focuses on evaluating and improving the country's climate adaptation efforts. In its report from 2022, the Council highlighted the importance of long-term planning and better coordination between different governmental levels (National Expert Council for Climate Adaptation, 2022). The National Expert Council for Climate Adaptation (2022) noted that while Sweden has made considerable progress in identifying flood risks, there is still a need for more, particularly in urban areas where the risks are compounded by increased construction and changing land use. They also recommended that the government increase investments in nature- based solutions, such as wetland restoration and the protection of natural floodplains, which can provide cost- effective ways to absorb excess water and reduce flood risks (National Expert Council for Climate Adaptation, 2022).

The Swedish Climate Policy Council has similarly commented on the government's efforts to address flooding as part of the broader climate adaptation agenda. In its report from 2021, the council acknowledged that Sweden has made significant strides in addressing climate risks but pointed out several shortcomings. One key concern was the limited incorporation of climate risk data into long- term urban planning and infrastructure development (Swedish Climate Policy Council, 2021). The council recommended that the government enhance its coordination between national, regional and local authorities to ensure that climate risks, including floods, are systematically considered in all levels of planning. Furthermore, they want increased financial resources to be directed toward flood mitigation projects and that current investments are insufficient to fully address the expected increase in extreme weather events (Swedish Climate Policy Council, 2021).

4 Conclusions & Discussions

Thanks to the well established technology of hydropower and the geography of Sweden, hydropower has been greatly implemented during the last few decades. In Sweden roughly 40% of the total energy production comes from hydropower plants (Energiföretagen, 2024). In our current state of climate the hydropower plants are performing efficiently, but that does not mean they will in the future. Due to the increase in temperature, the climate will change and this could impact the performance of the hydropower plants.

The increase in temperature and the alteration of precipitation patterns together with the increase of extreme weather events would produce changes in river flows and water availability throughout the year, increase the flood risks during heavy rainfall and reduce efficiency of the power plants.

With approximately 2000 hydropower plants (roughly 200 with capacity exceeding 10MW (Energiföretagen, 2024)) distributed all over Sweden, the probability of efficiency alterations or even instances of ceased production seems plausible.
Another instance where events of heavy precipitation, or natural disasters in general, could reduce the availability and production of energy from the grid are from infrastructural damage connected to the power grid. These scenarios can be connected back to the sustainable development goal 7 (FN, n.d.) where Sweden could deviate from the path of increasing the energy production from renewable sources as well as increasing the price of energy in Sweden due to the reduced energy availability.

When considering the impact of damages to the transportation infrastructure, this can be observed in the Märsta case study. Heavy rainfall similar to the Boris event would have a strong negative impact on our transportation infrastructure. The long duration of the rain will affect the stormwater systems capacity somewhat differently compared with the existing simulations with rather short rain durations. Runoff water and stormwater will have a combined effect on the railway track infrastructure. The long duration of the downpour could clog the stormwater system culverts in some areas which can result in severe runoff flooding which can undermine the railway embankment and possibly cause serious train incidents in the middle of Märsta municipality. In the worst case with the release of environmentally hazardous substances or human injury. As seen from the damages done to the transportation systems in Austria, where the damage costs exceed several hundred millions euros, similar or even lower numbers would be catastrophic for Sweden. A way to prevent these events would be to invest in means of adaptation towards climate change or flooding actions specifically, before an extreme event occurs.

Sweden's current efforts underline the importance of adaptation in addressing immediate climate vulnerabilities, particularly as extreme weather events increase. The National Strategy for Climate Adaptation takes a comprehensive approach by strengthening infrastructure and local resilience, showing how crucial it is to adapt urban planning and water management systems to anticipate climate risks. This approach would not only protect citizens but also aligns with sustainable development goal 13, which advocates for urgent action on climate challenges (FN, n.d.).

From a sustainable development perspective, combining flood risk mitigation with energy-efficient solutions connects sustainable development goal 7 (affordable, clean energy) to climate action. Integrating energy considerations into water management, for instance, could reduce reliance on fossil fuels and support resilient infrastructure. And could combine flood risk mitigation with energy- efficient solutions, which in turn connects to sustainable development goal 7, affordable and clean energy for all (FN, n.d.). For instance, by investing in nature-based solutions, such as wetlands that absorb excess water, as suggested by the National Expert Council for Climate Adaptation (2022) Sweden can meet both environmental and adaptation goals, achieving cost-effective and sustainable flood risk reduction.

The government's focus on flood risk mitigation, through both national strategies and compliance with EU directives, demonstrates a commitment to safeguarding communities and infrastructure against climate-induced risks. However, as emphasized by both the Climate Policy Council and the National Expert Council for Climate Adaptation, there is still a need for more integrated, forward-thinking strategies that better align climate adaptation with long-term planning and infrastructure development.

To conclude the above, the present energy infrastructure is already affected by extreme weather events, which is expected to become increasingly common as climate change progresses. The case study done in Sigtuna showed that there is a high risk of flooding of the railway system impacting on energy transportation. Similar problems are likely to exist along the entire Swedish energy production network. As seen from the recent events in Europe, the consequences could be catastrophic, with widespread effects throughout multiple sectors of the country. The overall cost of the damage done to an affected country which has invested less in actions of adaptations would be able to outweigh the investment costs of the climate actions itself. Sweden's current efforts underline the importance of adaptation in addressing immediate climate vulnerabilities, particularly as extreme weather events increase. The National Strategy for Climate Adaptation takes a comprehensive approach by strengthening infrastructure and local resilience, showing how crucial it is to adapt urban planning and water management systems to anticipate climate risks.

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