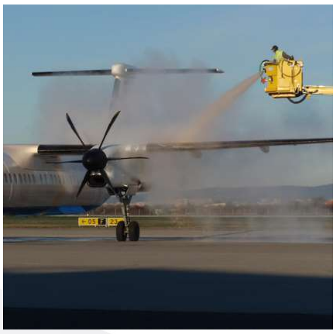
MARCH 2022
AVINOR

AVINOR RISK ASSESSMENT:

Update of long-term climate change risk assessment of Avinor Airports



SUMMARY REPORT

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CONTENTS

LIST OF ABBREVIATIONS

ACFT	Aircraft
AFIS	Aerodrome Flight Information Service
HAT	Highest Astronomical Tide (HAT) is the highest level which can be predicted to occur under average meteorological conditions. It is not the most extreme level that can be reached by the tide, as storm surges may cause considerably higher levels to occur.
H – "High climate projection"	90-percentile of an ensemble of climate projections. It implies a climate change which only 1 of 10 climate projections exceeds.
L – "Low climate projection"	10-percentile of an ensemble of climate projections. It implies a climate change which 9 of 10 climate projections exceed.
M – "Mean climate projection"	Mean value of an ensemble of climate projections.
IPCC	UN International Panel for Climate Change
NAV	Navigation
NCCS	Norwegian Centre for Climate Services
NOU	Norsk Offentlig Utredning (English: Official Norwegian Reports). The government or a ministry may constitute a committee and work groups who report on different aspects of society. A report can either be published as a Norwegian Official Report, or as a regular report.
NRL	Divisjon Nasjonale og Regionale lufthavner (Avinor's Division for National, Regional and Local airports).
NTP	Nasjonal Transport Plan
NVE	Norges Vassdrags- og Energidirektorat (Norwegian Water Resources and Energy Directorate).
RWY	Runway
SWH	Significant Wave Height
TWR	Tower
WMO	World Meteorological Organisation

ABSTRACT

GOAL

This report is an extended summary of the main report on updating of climate risk assessment for the 42 airports operated by Avinor. The summary report is intended to provide decision-makers and the wider public an overview of,

- the assessment steps, i.e. the underlying methods used
- main implications of climate change on airport operations
- guidance for reporting on sustainability and financial implications set forth by EU's taxonomy and Task Force for Climate-related Disclosures (TCDF).[1]

BACKGROUND

The climate risk assessment focuses on physical risks and is based on the report by the consultancy firm Atkins in 2014.

The study follows the context of the National Transport Plan and other governmental initiatives like the green paper (NOU) and white paper on climate adaptation in 2009-11 to internalize the risks imposed by climate change in the operation and maintenance of critical socio-economic infrastructure. The report builds on updated climate data from the Norwegian Climate Service Centre (NCCS) made available on (www.kartverket.no) for sea level rise and (www.senorge.no) temperature and precipitation.

UPDATING OF CLIMATE DATA

Updating of the climate projections from the IPCC 5th Assessment Report in (NCCS, 2015) predicts higher temperatures and more extreme precipitation than (Atkins, 2014) with the increase being highest in the northernmost regions.

There was no updated data available for wind or fog. Expectation of increasing temperatures translate into on average a reduction in depth of snow and number of days with snow throughout Norway. NCCS 2/2015 comments the changes in relation to NOU 2010 to be larger amounts of snow accumulations in the mountains and smaller in the lowlands trending toward a general shortening of the snow season.

With respect to sea level, updated data is referenced to NN2000 and not NN1954. This results in a small to moderate increase in expected sea level rise.

RISK ASSESSMENT

The risk assessment uses a structured approach in the form of an excel spreadsheet whereby a set of climate variables leads to identification of hazards that in turn are evaluated in terms of their probability of occurrence and consequence for airport closure time. Of primary importance to updating of the risk assessment is whether changes in climate data will lead to higher or lower risk for certain hazards.

[1] TCDF – Task Force for Climate-Related Financial Disclosure, https://www.unepfi.org/climate-change/tcfd/

FINDINGS AND RECOMMENDED MITIGATION

This identifies the following hazards that should be prioritized for further mitigation planning:

- More extreme precipitation leading to flooding of runways and general airport infrastructure. Depending on drainage conditions extreme run-off may lead to erosion of embankments.
- More variable snow conditions and temperature fluctuations around freezing leading to more challenging winter maintenance of which deicing operations is a key element.
- Rising sea levels and storm surges leading to flooding and washing out of ground of runways and surrounding safety areas.
- More variable wind and fog conditions
- Thawing of permafrost may comprise integrity of runways, buildings and other infrastructure that is sensitive to subsidence at Svalbard airport.

According recommendations emphasises the conducting of hydraulic modelling studies, environmental impacts assessments and contingency planning for designing respective improvements to drainage and flood protection works, minimize pollution and back-up plans for re-rerouting of traffic during times of extreme wind and prolonged fog.

SUSTAINABILITY AND FINANCIAL REPORTING

The EU-taxonomy and Task Force on Climate Related Financial Disclosures (TCFD) are two sets of guidelines that have emerged from the 2015 Paris Agreement that companies (public and private will have to comply with.

For the taxonomy this concerns the degree to which the company's activities contribute to reaching defined targets mitigating and adapting to climate change in an economically efficient and environmentally friendly manner. Since current aircrafts do not support emissions free flying and measures to introduce alternative fuels still are at an early stage of development, climate adaption emerges as the more relevant objective for Avinor to report on for meeting the obligations imposed by the EU-taxonomy. For undertaking of adaption measures, e.g. such as building of flood protection and improvement of drainage and deicing operations, the taxonomy emphasises the EU-Water and Environmental Impact Assessment Frameworks as the relevant guidelines to follow.

TCDF is an international organisation whose goal is develop recommendations for more effective climate-related disclosures to promote more informed decision-making on the nature on carbon related assets, their concentration and the financial system's exposure to climate-related risks.

Whereas EU-taxonomy defines criteria for climate related activities and methods to be used to assess the impact of these activities on the environmental goals, TCDF provides a tool for communication on resulting costs impact financing and climate resilience of the organisation.

1 INTRODUCTION

Background: In 2014 the consulting company Atkins undertook a study to prepare a comprehensive climate change risk assessment of Avinor operated airports.

To this end it uses a risk assessment methodology that was prepared for Heathrow Airport in 2011. Incorporating recent projections on climate change as published in the Intergovernmental Panel on Climate Change (IPPC) 4th Assessment Report in 2007, likelihood and consequence in closure time of a series of hazards are assessed to generate an overview of the risk picture at the location in question. This was intended to equip airport managers and operating personnel with strategic advice on where to prioritize adaption measures.

In the seven years that have elapsed since the 2014-analyses was conducted, there has occurred several extreme weather events of which some have affected airport operations. Combined with the availability of updated climate data, this have prompted interest in updating the climate risk assessment.

Purpose and objectives: Bearing the above in mind, the purpose of the assignment is to facilitate practical application of the climate risk assessment methodology for airport managers and other relevant staff. This is envisaged to make Avinor more climate resilient in terms of its ability to (i) apply adequate measures to maintain safety and minimize delays and to (ii) internalize climate adaptation in planning for future investments.

To help accomplish this the objectives of the assignment are:

- To update climate data and projections on likely changes in the years ahead for the 42 airports operated by Avinor throughout Norway.
- To assess implications of the risk assessments on EU and international standards for reporting on sustainability and financial viability.

This summary is shortened from 7 to 5 chapters as updated climate risk assessments for each airport are not included (e.g. see Chapter 4 of main report for 11 high criticality airports and Appendix A for remaining 31 low criticality airports).

Chapter 2 presents updated climate data and methodology for risk assessment

Chapter 3 – summarizes the results for the location specific assessments (each airport) in the form of an action plan for the most important climate related impacts

Chapter 4 – describes the implications of adopting EU's taxonomy and TCDF for sustainability and financial reporting

Chapter 5– presents concluding remarks and next steps.

2 UPDATING OF CLIMATE DATA AND RISK ASSESSMENTS

2.1 Climate Projections

Recognized as the physical and scientific basis for projections on climate change, the Intergovernmental Panel on Climate Change (IPCC) has since the original climate risk assessment by Atkins in 2014, published the 5th Assessment Reports in 2014 and is scheduled to publish the 6th set of reports in this series in early 2022. Compared to the earlier versions there is now emerging consensus that the 1,5 degree C warming target will be increasingly difficult to meet, and that the world should prepare for a 2 or even 3 degree C warming scenario (Economist, 2021). The implications of exceeding the 1,5 C warming target have not been assessed in a revised version of the national report NOU 2010:10 "Tilpasning til eit klima i endring – Samfunnet si sårbarhet og behov for tilpassning til konsekvenser av klimaendringer", on which the projections in the original climate risk assessment were based.

Apart from smaller adjustments, the original projections are therefore valid. Compared to the earlier assessment report (AR4), IPCC has introduced more scenarios for global warming based on calculated atmospheric concentrations of greenhouse gases in AR5, and are in the process of updating these for AR6. Termed Representative Concentration Pathways (RCP), the business as usual scenario (RCP8.5) where future emissions continue to grow at the same rate as today forecasts global temperatures to exceed 3 degrees C from 2080 and beyond. The estimated effect on sea level rise is noted in the updated climate data in this report. Expected sea level rise from RCP8.5 is also used to set required building heights for securing against 20-, 200- and 1000-year flood events for new buildings and infrastructures in national regulations [2]

Similarly, the Norwegian Meteorological Institute announced at the end of 2020 that the normal period on which current and projected future weather is gauged would be changed from 1961-90 to 1991-2020. When examining available climate data on www.senorge.no, reference is made to the 1961-1990 and 1971-2000 normal periods, but not to 1991-2020. The updated data is therefore largely based on the 1971-2000 normal period. Table 1 and 2 outlines the projected changes and data sources and changes for this updated assessment compared to the original climate risk assessment of 2014. No climate data was available for fog, lightening and groundwater level, but these parameters have still been used for identification of hazards.

More detail on the methodological background for forecasts in NOU2010:10 and their relationship to the acquired climate data is provided overleaf (Atkins, 2014). The descriptions follow the sequence in Table 1.

[2] Byggeteknisk forskrift (TEK 17) med veiledning (https://dibk.no/regelverk/byggteknisk-forskrift-tek17/)

Table 1. Overview of projected changes/ data sources for updating of the climate risk assessment

Variable	**Projected changes/ Data sources**	**Atkins**	**Updated**
Temperature	Change in annual temp. (LOW, MEDIUM, HIGH) [°C]	NOU 2010	Temperature (NCCS report no. 2/2015)
	Average temperature	Se Norge 1961-90	Se Norge 1971-2000
Precipitation	Change in annual precipitation (LOW), MEDIUM, HIGH [%]	NOU 2010	Precipitation (NCCS report no. 2/2015)
	Change in annual number of days with excessive precipitation (LOW) MEDIUM HIGH	NOU 2010	Precipitation (NCCS report no. 2/2015)
	Change in annual precipitation on days with excessive precipitation (LOW) MEDIUM HIGH	NOU 2010	Precipitation (NCCS report no. 2/2015)
	Annual precipitation	Se Norge 1961-90	Se Norge 1971-2000
Wind		NTP 2010-2019 Nasjonal transportplan 2010–2019	N/A
Snow	Annual number of days with snowcover	Se Norge 1961-1990	Se Norge 1971-2000
Snow	Change in annual number of days with snowcover from 1961-1990 to 2071-2100 [days]	Se Norge 1961-1990	Se Norge 1971-2000
Snow	Annual number of days with snowfall >10 cm/day 1961-1990 to 2071-2100 [days]	NOU 2010	Precipitation (NCCS report no. 2/2015)
Thaw/ freeze		NTP 2010-2019 NASJONAL TRANSPORTPLAN 2010–2019	N/A
Landslide		NTP 2010-2019 NASJONAL TRANSPORTPLAN 2010–2019	N/A
Sea level and 100-year floods	Sea level rise in cm (confidence interval -20 to +35 cm) from year 2020 to 2100.	"Havnivåstigning, Estimater av framtidig havnivåstigning i norske kystkommuner 2009 (Vasskog, Drange, & Nesje, 2009)	https://www.kartverket.no/til-sjos/se-havniva NCSS Report 1/2015
Significant wave height	Increase in SWH from 1961-1990 to 2071-2100 [%]	NOU2010:10.	N/A
Permafrost	Change in permafrost thaw depth	N/A	N/A

Models for climate change: Norwegian government's National Transport Plan (NTP) "NTP 2010-2019: Virkninger av klimaendringer for transportsektoren", report on the effects of climate changes on the transport sector. The report is based on regional climate scenarios prepared by the Norwegian Meteorological Institute in 2007. These correspond to the global climate models used by IPCC in the Fourth Assessment Report (AR4) from 2007.

In NOU2010:10, the climate projections from the global climate models are supplemented by down-scaled results using regional climate models from Norwegian and other European institutes to better account for varying shapes of the landscape such as mountain and coastal lines. Based on three scenarios (Low, Medium and High) for the evolution in atmospheric CO_2 concentrations, the report presents corresponding projections for expected changes in temperature and precipitation.

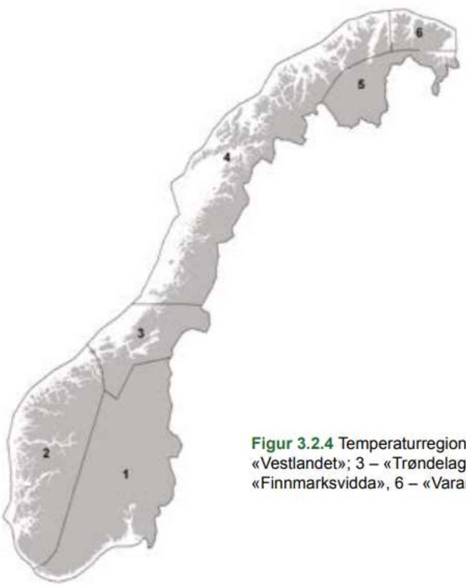
In this report, both Low, Medium and High projections are reported and used to estimate the change in climate variables from 1961-90.   The projections are updated based on the report titled Climate in Norway (NCCS, 2015).

Climate data: Normal climate values are obtained from www.seNorge.no; an open portal on the Internet that shows daily updated maps of snow, weather and water conditions and climate in Norway. The changes are extracted by clicking on the relevant airport locations and reading from the colour legend for the variable in question.

The changes for the parameters used in the climate risk assessment (i.e. compared to the original assessment) are briefly commented below.

2.2 Updated Data

Temperature: For identification and assessment of temperature related hazards reference is made to the NOU 2010 report, which divides the country into six regions where long-term projections within the region are roughly the same (e.g. see the below figure).



Figur 3.2.4 Temperaturregioner [70]: 1 - «Østlandet»; 2 - «Vestlandet»; 3 – «Trøndelag»; 4 – «Nordland/Troms»; 5 – «Finnmarksvidda», 6 – «Varanger».

Figure 1. Temperature regions.

The annual temperature has increased by ca. 1 °C from 1900 to 2014, with largest increase in spring and winter. For RCP8.5, the median projection indicates an increase in annual mean temperature for Norway of 4.5 °C (span: 3,3 to 6,4 °C) compared to 3.1 °C (span: 2.3 to 5.4 °C) from the 1961-90 normal period. The below table shows the projected changes. Subtracting the current from the previous forecast (values in parentheses), temperature is projected to increase in all regions and most in the in the northernmost regions illustrated with the increasing red hue.

Table 2. Change in Temperature 2014-2021 (from NCCS Report 2/2015)

Region	Change in annual temp. (LOW) [°C]	Change in annual temp. (MEDIUM) [°C]	Change in annual temp. (HIGH) [°C]
1	0,7	0,8	0,8
2	1	0,8	1
3	0,9	1	1,1
4	1,5	1,6	2
5	1,3	1,8	2,7
6	1,5	1,9	2,5
Svalbard	Data not available	Data not available	Data not available

The risk assessment uses the range in forecasted average temperature. Values for this parameter is updated for the reference period 1971-2000 by clicking on the relevant location in the interactive map on www.senorge.no.

Precipitation: Similar to temperature reference is made to the NOU 2010, which divides the country into 13 regions where long-term projections within the region is approximately identical (e.g. see below map).

Figur 3.2.13 Nedbørregioner [78]: 1 – «Østfold»; 2- «Østlandet»; 3 - «Sørlandet»; 4 – «Sørvestlandet»; 5 – «Sunnhordland/ Ryfylke»; 6 – «Sogn og Fjordane/ Nordhordland»; 7 – «Dovre/ Nord-Østerdal»; 8 – «Møre og Romsdal»; 9 – «Inntrøndelag»; 10 – «Trøndelag/ Helgeland»; 11- «Hålogaland»; 12 – «Finnmarksvidda»; 13 – «Varanger»

Figure 2. Precipitation regions (NCCS 2/2015)

The updated data show that precipitation is expected to increase more in the years ahead than the forecasted based on 1961-90 reference period. The below table shows differences in forecasted changes for the RCP8.5 high emission (business as usual) scenario for 1971-2000 to 2071-2100 compared to the 1961-1990 to 1961-2090 reference periods for Low, Medium and High projections for a range of precipitation events. Increasing blue denote change toward negative values, i.e. less expected increase) and red denote positive changes, i.e. precipitation is expected to increase more.

Table 3. Overview of regional changes from 1961-90 to 1971-2000 reference periods

	Change in annual precipitation (%)			Change in annual number of days with excessive precipitation (%)			Change in annual precipitation on days with excessive precipitation (%)		
Region	LOW	MEDIUM	HIGH	LOW	MEDIUM	HIGH	LOW	MEDIUM	(HIGH)
1	4	-1	2	21	4	50	5	1	6
2	2	3	10	28	16	53	6	3	11
3	9	2	1	28	20	7	6	3	4
4	0	-8	-13	15	-6	-20	3	-2	-1
5	-4	-7	-13	28	1	-66	5	0	-5
6	1	-5	-16	46	10	-65	11	1	-6
7	1	4	10	25	-1	49	6	0	10
8	3	-8	-25	19	16	-95	3	4	-10
9	4	-2	-15	30	-1	-41	5	2	-1
10	4	-2	-27	45	28	-62	9	7	-9
11	2	-2	-18	14	28	27	1	6	7
12	-2	5	11	32	30	50	12	6	11
13	-9	2	11	25	7	25	10	3	13
Svalbard									

Overall, the comparison shows that updated forecasts of future changes in precipitation varies. In terms of annual amounts, the forecasts based on the 1971-2000 reference period have been turned down compared to forecasts made based on 1961-90 reference period. Annual precipitation is expected to increase more inland and the northernmost regions and less along the coast. Extreme events indicated by number of days with excess precipitation is expected to increase more for the low and medium projections. The high projection shows that the number of days with extreme precipitation is expected to increase more inland and the far north of Norway than along the coast where the opposite trend is expected. Moving to the last three columns, a similar trend is expected for precipitation on those days.

To summarize NCCS 2/2015 states that precipitation has increased by 18% since 1900. The RCP8.5 median projection forecasts that this trend will continue towards 2100 leading to a doubling of the number of days with heavy precipitation. Preliminary analyses suggest that rainfall intensity of for duration of a few hours may increase by more than 30%.

The risk assessment uses the forecasted range in annual precipitation in mm. Values for this parameter is updated for the reference period 1971-2000 by clicking on the relevant location in the interactive map on www.senorge.no.

Wind: The original climate risk assessment (Atkins, 2014) draws on information in NOU 2010 and National Transport Plan 2010-19. Climate models in NOU 2010 show little or no change in average wind conditions leading up to year 2100. NCCS 2/2015 states that there has been a slight increase in wind velocity that is exceeded 1% of the time and that projections indicate only very small changes in average values and large wind speeds in the future. However, there is no update in the region-specific data on number of days with high winds.

The updated climate risk assessment herein therefore uses the same data as the previous. This is annual number of days with wind speed more than 20 m/s from the 1961-90 reference period and change in the number of days with wind speed more than 20 m/s from 1961-90 to 1971-2000. The changes are slight, one day with less wind region 3 (southern Norway) and one day with more wind in region 6, 7 and 8 (ref. Figure 2 above).

Table 4. Reference values and predicted change in annual number of days with wind speed >20 m/s from NTP 2010-2019 (Atkins, 2014)

Region	Annual number of days with wind speed >20 m/s for 1961-1990 [days]	Change in annual number of days with wind speed >20 m/s from 1961-1990 to 2071-2100 [days]
1	2	0
2	3	0
3	6	-1
4	4	0
5	5	0
6	7	+1
7	4	+1
8	1	+1
9	0	0
10	0	0
11	0	0
12	0	0

Snow: The effect of changing reference period from 1961-90 to 1971-2000 is on average a reduction in depth of snow and number of days with snow throughout Norway. NCCS 2/2015 comments the changes in relation to NOU 2010 to be larger amounts of snow accumulations in the mountains and smaller in the lowlands trending toward a general shortening of the snow season. These changes are expected to continue in the future. The snow season could become 1 to 5 months shorter under the low (optimistic projection) and 1-7 months shorter under the medium (business as usual scenario). At low altitudes where the Winter temperature today is only slightly below zero, the snow will be negligible in most years towards the end of the century under the high emission scenario.

Identification and assessment of snow related hazards uses the expected change in annual number of days with snowcover and number of days with snowfall >10 cm/day from NTP2010-2019 (e.g. same as the original climate risk assessment). Values for the number of days with snowcover for each airport is updated for the reference period 1971-20 00 by clicking on the relevant location in the interactive map on www.senorge.no.

Table 5. Reference values and predicted change in annual number of days with snowfall >10 cm/day from NTP 2010-2019 (Atkins, 2014).

Region	Annual number of days with snowfall >10 cm/day 1961-1990 [days]	Change in annual number of days with snowfall >10 cm/day from 1961-1990 to 2071-2100 [days]
1	1	1
2	4	-1
3	4	-2
4	4	-1
5	3	-1
6	4	-2
7	1	-1
8	3	-1
9	8	0
10	5	0
11	5	0
12	4	0

Thaw/ Freeze: There is no updated data on thaw/freezing cycles in NCCS 2/2015. This parameter is also not included in the climate data on www.senorge.no. The updated risk assessment therefore uses the same data as the previous. They are number and expected change in days with Tmax>0 and Tmin<0 from NTP2010-2019. The values are listed with respect to the 12 precipitation regions.

Table 6. Reference values and predicted change in annual number of days with Tmax>0 and Tmin<0 from NTP 2010-2019 (Atkins, 2014).

Region	Annual number of days with $T_{max}>0$ and $T_{min}<0$ for 1961-1990 [days]	Change in annual number of days with $T_{max}>0$ and $T_{min}<0$ from 1961-1990 to 2071-2100 [days]	Change in annual number of days with $T_{max}>0$ and $T_{min}<0$ from 1961-1990 to 2071-2100 [%]
1	55	-16	-29%
2	52	-20	-38%
3	36	-18	-50%
4	37	-15	-41%
5	38	-15	-39%
6	25	-12	-48%
7	25	-13	-52%
8	38	-18	-47%
9	69	0	0%
10	68	-3	-4%
11	71	-6	-8%
12	73	-16	-22%

Slides: Similar as for wind, snow and thaw/freeze cycles there are no updated forecasts on the frequency of slides in NCCS 2/2015. The latter, however, emphasises that climate change may lead to increased frequency of landslides, debris flows and slush avalanches associated with heavy rainfall. Increased erosion could trigger more clay slides. The risk of dry snow avalanches will decrease, while the risk of slush slides will increase, and may occur in areas where they have not occurred previously. The below table taken from the original assessment lists the values used in the updated risk assessment.

Table 7. Qualitative predictions (and prediction confidence) on the future frequency of landslides and avalanches from NOU2010:10 (Atkins, 2014)

Region	Future (~50 years) change in frequency of landslides	Confidence	Future (~50 years) change in frequency of avalanches	Confidence
1	A low, but noticeable increase in frequency of landslides is expected.	High confidence	No change	High confidence
2	No change	Low confidence	A low, but noticeable increase in frequency of avalanches is expected.	Low confidence
3	A low, but noticeable decrease in frequency of landslides is expected.	Low confidence	No change	High confidence
4	A low, but noticeable increase in frequency of landslides is expected.	High confidence	No change	High confidence
5	No change	High confidence	No change	High confidence
6	No change	High confidence	No change	Low confidence
7	A significant increase in frequency of landslides is expected.	High confidence	A significant increase in frequency of avalanches is expected.	High confidence
8	No change	High confidence	A low, but noticeable increase in frequency of avalanches is expected.	Low confidence
9	A significant increase in frequency of landslides is expected.	High confidence	A low, but noticeable increase in frequency of avalanches is expected.	Low confidence
10	A significant increase in frequency of landslides is expected.	High confidence	A significant increase in frequency of avalanches is expected.	High confidence
11	A significant increase in frequency of landslides is expected.	High confidence	A low, but noticeable increase in frequency of avalanches is expected.	High confidence
12	A significant increase in frequency of landslides is expected.	High confidence	A low, but noticeable increase in frequency of avalanches is expected.	High confidence
13	A significant increase in frequency of landslides is expected.	High confidence	A low, but noticeable increase in frequency of avalanches is expected.	High confidence

Sea level rise and waves: Since the original assessment in 2014, projections on sea level rise and flooding due to storm surge have been updated based on the IPCC AR 5 and the Coupled Model Intercomparison Project phase 5 (CMIP5) output. Previous and updated projects are both based on the RCP8.5 business as usual (high emissions) scenario. Values are obtained by typing in the location name for the airport in question in on the web page of the national mapping authority www.kartverket.no/til-sjos/se-havniva. Compared to the original climate risk assessment report (Atkins, 2014), the general behaviour is still valid. That is an expectation of rising sea level at all locations.

The updated values are shown in the below table together with absolute changes relative to (Atkins, 2014). Percent increase in significant wave height is included to facilitate comparison with mean airport elevation for identification of flood risk.

Predicted sea level rise with 200/100-year storm surge is shown with respect to NN2000 datum for the updated data and the NN1954 datum for the original data. Deviations between NN2000 to NN1954 depend on location. NN2000 is generally lower than NN1954 along the coast increasing to positive values inland[3]. Combined with higher recurrence interval (200-yea) for updated data as opposed to (100-year) for the original data can among other aspects help explain the dereferences in the predictions.

Comparing the two data sets, updated projections predict that sea levels will rise by approximately 10 to 20 cm more than originally estimated. Bold print denote locations closest to the sea and hence are at higher risk of flooding. An important consequence of sea level rise is that the recurrence intervals of storm surges will decrease. Alas a storm surge with 200-year recurrence interval today might be the norm at the end of the century.

Table 8. Predicted values for sea level rise and floods

Primary Airport ID	Sea level rise in cm (confidence interval -20 to +35 cm) from year 2020 to 2100.	Change in cm relative to (Atkins, 2014)	200-year flood in cm relative to NN2000 (confidence interval -20 to +35 cm) from year 2020 to 2100.	100-year flood in cm relative to NN1954 (confidence interval -20 to +35 cm) from year 2000 to 2100.	Increase in SWH from 1961-1990 to 2071-2100 (%)	Mean airport elevation (Atkins, 2014) NN1954
Alta	77	17	285	**287**	**0-2**	**305**
Bergen	80	7	213	241	0-2	5060
Berlevåg	86	19	279	279	2-4	1311
Brønnøysund	66	22	299	290	0	762
Båtsfjord	82	15	283	284	2-4	14395
Fagernes				Inland/ mountain airport		
Florø	83	13	238	247	0-2	1128
Førde	77	11	228	242	0-2	31852
Hammerfest	86	21	286	287	0-2	7986
Harstad/Narvik	53	-10	333	267	0-2	2591
Hasvik	85	21	285	286	0-2	701
Haugesund	90	10	195	214	2-4	2652
Honningsvåg	86	17	287	301	0-2	1402
Kirkenes	69	9	295	296	2-4	8595
Kristiansand	89	15	191	208	4-6	1737
Kristiansund	84	20	272	270	0-2	6248
Lakselv	75	16	295	305	0-2	762
Leknes	89	23	350	339	0	2469
Mehamn	89	18	288	296	2-4	1189
Mo i Rana	58	21	296	284	0	6980
Molde	84	17	270	274	0-2	305

[3] Ta i bruk NN2000 | Kartverket.no

Mosjøen	61	17	300	293	0	7315
Namsos	60	17	286	**276**	**0-2**	**244**
Oslo				Inland/ mountain airport		
Røros				Inland/ mountain airport		
Rørvik	68	20	292	288	0-2	457
Røst	69	0	303	**300**	**0**	**305**
Sandane	81	12	243	260	0-2	5974
Sandnessjøen	68	22	301	291	0	1737
Sogndal	68	3	212	246	0-2	49774
Stavanger	90	12	201	209	2-4	884
Stokmarknes	85	20	285	265	0	396
Svalbard				Data not available		
Svolvær	81	17	347	339	0	884
Sørkjosen	76	20	292	292	0-2	488
Tromsø	80	17	**295**	**287**	**0-2**	**975**
Trondheim	56	14	292	294	0-2	1707
Vadsø	74	10	299	302	2-4	3871
Vardø	79	11	292	293	2-4	1280
Værøy*	90	24	**304**	**295**	**0**	**457**
Ørsta-Volda	82	10	266	272	0-2	7407
Ålesund	86	15	269	274	0-2	2134

Flooding: Other forms of flooding is caused by snowmelt, excessive precipitation or a combination of these factors.

Flood projections are uncertain, as local variations are large. In general, floods caused by heavy rainfall can be expected to increase, whereas the probability of large floods caused by melting snow will be reduced. Higher temperatures will cause an earlier onset of spring floods, whereas there will be more floods in late autumn and winter. More intense local precipitation will create problems in small, steep rivers and streams and in densely populated areas.

Future changes in flood magnitudes (the mean, 200- and 1000-year flood) have been analysed for 115 unregulated catchments (NCCS, 2017). Changes in the 200-year flood between the reference period, 1971-2000 and future period, 2071-2100 show that:

- The changes observed will intensify in the future.
- The magnitude of change strongly depends on the emission scenario.
- Rain flood magnitudes are expected to increase while those of snowmelt are expected to decrease. In many areas, this is also associated with a change in seasonality.
- The flood generating process is of major importance for the direction of change, but local effects such as altitude and catchment area are also important.

Using these observed and projected changes it is recommended to multiply flood forecast calculations by 20-40% in all rivers dominated by rain floods and small rivers that respond quickly to heavy rain.

The below figure shows the median change in the magnitude of a 200-year flood (i.e. a flood that has an annual probability of 0.005 for RCP4.5 (reduced) and RCP8.5 (business as usual) emission scenario. Median means that half of the projections showed larger changes and the other half smaller changes.

Green indicates that the expected size of a 200-year flood will be smaller than today while blue indicates that the expected size of a 200-year flood will be smaller than today. Along most of the coastal line, flood size will increase from 20% to 60% by the end of the century. Furthermore, more extreme rainfalls with a lot of rain in a short time are expected to occur which will lead to more frequent local, excessive floods.

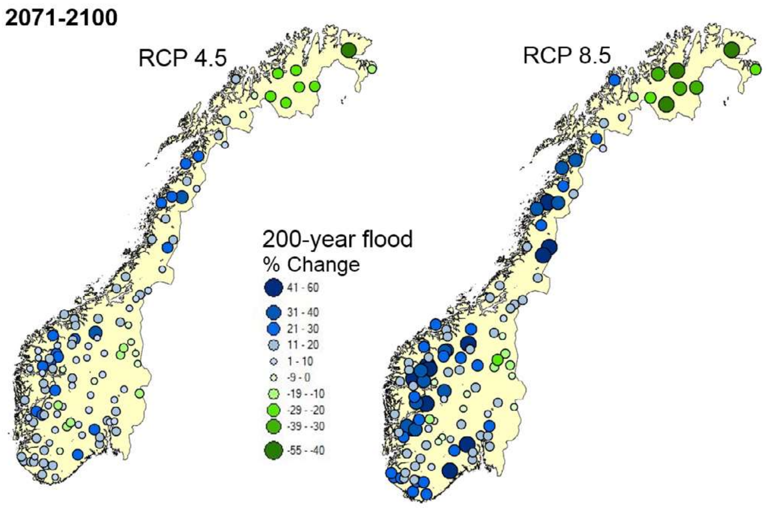


Figure 3. Expected increase (in %) in magnitude of a 200-year flood from 1971-2000 to 2071-2100

Waves and permafrost: There are no updated information on significant wave height and permafrost on www.kartverket.no nor in the latest NCCS report following the ICCP's 5th Assessment Report (NCCS, 2015). The updated climate risk assessment herein therefore uses the same information as in the original report (Atkins, 2014), which is based on NOU 2010:10. SWH is defined as the mean height of the highest 1/3 of the waves in period of 20 minutes. Expected increases are mostly in the range from 0-2 percent.

Temperature measurements performed since 1999 show that the permafrost in the Norwegian alpine areas is now rapidly warming up, at a rate of around 0.3° C per decade at a depth of 25 metres (NOU, 2010).

Besides creating uncertainty on the strength of underground, permafrost often creates ice when rain falls on the runways even though the rain is not subcooled. Svalbard Airport, Longyearbyen, is affected by this. Elsewhere in Norway, particularly access roads are affected by the melting permafrost and the increased risk of major landslides. This is particularly relevant in North Troms where the Nordnes Mountain with 22 million m3 soil is migrating towards Lyngen Fjord. E6 will be blocked for a very long time in case of a major landslide [10].

The updated climate risk assessment uses the same method as the previous (Atkins, 2014). For detailed descriptions reference is made to the latter. The main steps and implications for the updated climate risk assessment herein are outlined as follows.

2.3 Risk Assessment Method

Structure and step-wise approach: The risk assessment uses a structured approach in the form of an excel spreadsheet whereby a set of climate variables leads to identification of hazards that in turn are evaluated in terms of their probability of occurrence and consequence for airport closure time. Of primary importance to updating of the risk assessment is whether changes in climate data will lead to higher or lower risk for certain hazards.

The excel spreadsheet contains 8 worksheets:

- **Generic Hazard List** – identifies a set of 31 hazards from climate variables and asks the user to assess likelihood of occurrence and severity for closure for each hazard at an overall level and specifically for each airport. The worksheet also contains a column titled "All P/C" which can be selected as yes or no depending on if the probability "P" and consequence "C" of occurrence is common to all airports or not. The set of 31 generic hazards were identified in a workshop with Avinor staff on 21 and 22 November 2013. The listing is discussed after the section on the findings from updating of the Airport Data below. The Generic Hazard List incorporates climate data from several sources as outlined in Chapter 2 and thereby forms a comprehensive database that can added to and used for future climate risk assessments.
- **Risk Grading** – links probability of occurrence (low, medium, high) to duration of closure time with the assessed consequence (low, medium and high). The 42 airports fall into either of the two airport criticality categories: 'low' or 'high', the difference being the 'airport closure severity' scale. This means that the risk index in case of closure of a highly critical airport is substantially higher than that of the low criticality airport for the same period of time. 11 selected airports fall into the 'high' airport criticality category. Compared to the original climate risk assessment (Atkins, 2014), the risk grading has been refined from three to four levels of occurrence to better match Avinor's grading for operational risk grading. This is explained below.
- **Airport Data** – lists for each airport relevant climate data, number of passengers and movements per day and main technical characteristics for orientation and elevation of runways, technical rooms, proximity to water and access roads.
- **Variable List** – is used for defining the list of possible values that can be selected in the drop-down menus in the columns titled "Primary Climate Variable", "Potential Consequence", "Affected Infrastructure" and "Generic Control Measures" in the "Generic Hazard List" worksheet. The worksheet "Variable List" also contain a column for "Risk Dimensioning Variables", which is currently not used in the "Generic Hazard List", but may be used in a future risk assessment for identifying parameters that are risk dimensioning, e.g. such as an access road or capacity to deice aircrafts and runways.
- **Regional climate data** – lists the projected changes in each region based on the classification in NOU 2010:10 and update in NCCS 2/2015.

- **Pax and Fly-bev-Jan Des 2012** – these two worksheets list statistics for passengers and air traffic for year 2012[4]

  Airport Risk Assessment – links the information in the above worksheets for the airport in question. The risk assessment compiles and overview of the number of identified hazards and their assessed risk for each climate variable. It also contains a table that draws from the Generic Hazard List, and overview control measures for the hazard in question and allows the user to insert additional site-specific information on their adequacy the assessed adaptation response needed. Based on the overview the user can deduce the climate variables that are likely to pose the greatest risk that should be analysed in more detail.

It is important to bear in mind that there is no link between the magnitude of the climate variable and its impact on a given hazard and consequent risk. The risk assessment is based on the user's judgment. The main value of the assessment tool is that it provides structure and overview which facilitates this process in a transparent and traceable manner.

Updating of the climate risk assessment can therefore be understood as intimately linked to (i) the user's perception and ability to use the structured approach and (ii) the impact changes in climate variables have on identified hazards and overall risk picture.

Note on risk grading: Compared to the original climate risk assessment of 2014 the risk grading was refined from 3 to 4 levels by splitting the category for medium occurrence into two probability levels, one from 50%-75% and the other from 25%-50%. The result is to reduce the number of hazards classified as high enabling the user to focus attention on these.

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[4] Population and economic growth are expected to contribute to a steady increase in demand for air travel in the years to come. From 2014 to 2050 the number of air passengers is expected to increase by 84%, which equates to 1.7% per year (Avinor, 2015).

Revised: COWI 2021				
Airport Criticality = LOW	**Airport Closure Severity (no traffic)**	Low	Medium	High
Probability of at least 1 incident in 2071-2100		*< 12h*	*< 24h*	*> 96h*
Very Likely (High) the event occurs in most cases	> 75%	Medium	High	High
Likely (Medium) the event usually occurs	50% - 75%	Low	Medium	High
Unlikely (Medium) the event occurs sometimes	25% - 50%	Low	Low	Medium
Very unlikely (Low) the event occurs rarely occurs	< 25%	Low	Low	Low
Airport Criticality = HIGH	**Airport Closure Severity (no traffic)**	Low	Medium	High
Probability of at least 1 incident in 2071-2100		*< 6h*	*< 12h*	*> 48h*
Very Likely (High) the event occurs in most cases	> 75%	Medium	High	High
Likely (Medium) the event usually occurs	50% - 75%	Low	Medium	High
Unlikely (Medium) the event occurs sometimes	25% - 50%	Low	Low	Medium
Very unlikely (Low) the event occurs rarely occurs	< 25%	Low	Low	Low

2.4 Findings and Suggested Changes to Generic Risk Assessment Results

Table 9 overleaf compares climate data and identifies the changes in increasing red colour depending on the magnitude of the change compared to the original climate risk assessment in 2014. The findings are then used to prepare suggestions on modifications and amendments to the generic risk assessment results in **Feil! Fant ikke referansekilden.**

2.4.1 Findings from comparison of climate data

The results show an increase in expected sea level rise for most locations. Due to conversion from NN1954 to NN2000 maximum levels are largely the same as before in absolute terms.

For precipitation there are no changes except for Trondheim where the annual amount is expected to decrease by 250 mm. Average annual temperature displays similar behaviour with only a slight decrease of 2 degrees C^0 at Bergen. The expected fluctuations at the specific airport locations are larger and hence mask the expected increase at the regional level as shown in Table 2.

As for days with snowcover, the updated values show an increase of 50 days for Alta. For the remaining 10 high criticality airports days with snowcover is expected to decrease with 25 days at Bergen, 150 days at Hammerfest and Tromsø and 50 days at Oslo.

The implication of rising sea levels is more serious for Alta airport where the mean elevation of the runways is within the expected increase. Similarly changes in days with snowcover is likely to impact need for clearing of runways and consumption of deicing chemicals.

However, the latter will also be impacted by temperature fluctuations around zero, wind and humidity conditions, and is therefore why it is important to critically go through the risk assessment steps.

2.4.2 Suggested changes to generic risk assessment

The results of the generic risk assessment are presented in Table 14. The table also provides an illustrative summary of the potential consequences, affected infrastructure and the control measures either already in place or suggested measures to be considered for implementation. For information on the values for "Probability of at least 1 incident in 2071-2100" and "Airport Closure Severity (no traffic)", please refer to Appendix B. Orange print denotes additional remarks and measures from updating of the climate risk assessment herein.

Table 9. Comparison of climate data for high criticality airports

					senorge.no			
Primary Airport ID	**Sea level rise in cm (confidence interval -20 to +35 cm) from year 2020 to 2100.**	**200-year flood in cm relative to NN2000 (confidence interval -20 to +35 cm) from year 2020 to 2100.**	**Increase in SWH from 1961-1990 to 2071-2100 [%]**	**Change in permafrost thaw depth**	**Annual precipitation 1971-2000 [mm]**	**Average temperature 1971-2000 [°C]**	**Annual number of days with snowcover 1971-2000 [days]**	**Change in annual number of days with snowcover from 1961-1990 to 2071-2100 [days]**
	Atkins 2014: "Havnivåstigning, Estimater av framtidig havnivåstigning i norske kystkommuner 2009" COWI 2021 https://www.kartverket.no/til-sjos/se-havniva	Atkins 2014: "Havnivåstigning, Estimater av framtidig havnivåstigning i norske kystkommuner 2009" COWI 2021 https://www.kartverket.no/til-sjos/se-havniva	Atkins 2014: "NOU2010:10." COWI 2021 N/A	N/A	Atkins 2014: Se Norge 1961-1990, COWI 2021: Se Norge 1971-2000	Atkins 2014: Se Norge 1961-1990, COWI 2021: Se Norge 1971-2000	Atkins 2014: Se Norge 1961-1990, COWI 2021: Se Norge 1971-2000	Atkins 2014: Se Norge 1961-1990, COWI 2021: N/A
Alta (updated)	77	285	0-2	N/A	500-750	0 to +2	100-200	-65 to -50
Alta (original)	60	287	0-2	N/A	500-750	0 to +2	100-150	-65 to -50
Alta (change)	17	-2	0-2	N/A	500-750	0 to +2	50	-65 to -50
Bergen (updated)	80	213	0-2	N/A	2000-3000	+6 to +8	25	-35 to -20
Bergen (original)	73	241	0-2	N/A	2000-3000	+4 to +6	50-100	-35 to -20
Bergen (change	7	-28	0-2	N/A	2000-3000	2	-25	-35 to -20
Brønnøysund (updated)	66	299	0	N/A	2000-3000	+4 to +6	50-100	-65 to -50
Brønnøysund (original)	44	290	0	N/A	2000-3000	+4 to +6	50-100	-65 to -50
Brønnøysund (change)	22	9	0	N/A	2000-3000	+4 to +6	50-100	-65 to -50
Florø (updated)	83	238	0-2	N/A	3000-4000	+6 to +8	20-50	-20 to -10
Florø (original)	70	247	0-2	N/A	3000-4000	+6 to +8	20-50	-20 to -10
Florø (change)	13	-9	0-2	N/A	3000-4000	+6 to +8	20-50	-20 to -10
Hammerfest (updated)	86	286	0-2	N/A	1000-1500	+2 to +4	50-100	-100 to -80
Hammerfest (original)	65	287	0-2	N/A	1000-1500	0 to +2	200-250	-100 to -80
Hammerfest (change)	21	-1	0-2	N/A	1000-1500	-2	-150	-100 to -80
Kristiansund (updated)	84	272	0-2	N/A	2000-3000	+6 to +8	50-100	-50 to -35
Kristiansund (original)	64	270	0-2	N/A	1500-2000	+6 to +8	50-100	-50 to -35
Kristiansund (change)	20	2	0-2	N/A	-1000	+6 to +8	50-100	-50 to -35
Oslo (Gardermoen) (updated)	0	325	Data not available	N/A	750-1000	+4 to +6	50-100	-65 to -50
Oslo (Gardermoen) (original)	41	236	Data not available	N/A	750-1000	+2 to +4	100-150	-65 to -50
Oslo (Gardermoen) (change)	-41	89	Data not available	N/A	750-1000	+4 to +6	-50	-65 to -50
Svalbard (updated)	Data not available	Data not available	Data not available	3°C per decade at 25m below surface	Data not available	Data not available	Data not available	Data not available
Svalbard (original)	Data not available	Data not available	Data not available	3°C per decade at 25m below surface	Data not available	Data not available	Data not available	Data not available
Svalbard (change)	Data not available	Data not available	Data not available	3°C per decade at 25m below surface	Data not available	Data not available	Data not available	Data not available
Tromsø (updated)	80	295	0-2	N/A	1000-1500	+2 to +4	25-50	-100 to -80
Tromsø (original)	63	287	0-2	N/A	1000-1500	+2 to +4	150-200	-100 to -80
Tromsø (change)	17	8	0-2	N/A	1000-1500	+2 to +4	-150	-100 to -80
Trondheim (updated)	56	292	0-2	N/A	750-1000	+4 to +6	25-50	-50 to -35
Trondheim (original)	42	294	0-2	N/A	500-750	+4 to +6	20-50	-50 to -35
Trondheim (change)	14	-2	0-2	N/A	250	+4 to +6	25-50	-50 to -35

3 ACTION PLAN FOR MOST IMPORTANT CLIMATE RELATED IMPACTS

3.1 Overall

Based on updated climate data for temperature, precipitation and sea level rise using the reference period 1971-2000 and recent climate projections (IPPC, 2021) that are assessed as likely to unfold in Norway and the North areas (NCCS, 2015), the climate risk assessments for the 42 airports operated by Avinor have been updated.

The summary of the climate projections in the previous assessment is still relevant. It is presented below along with updated hazard distributions.

Current climate projections for Norway can be summarized as (Atkins, 2014):

- An increase in the annual average temperature
- A larger increase in winter temperatures compared to summer temperatures
- An increase in the total annual precipitation
- An increased frequency of extreme precipitation
- A larger increase in winter precipitation compared to summer precipitation
- An increased sea level
- An increase in the size of 100-year floods
- A decreased in the number of days with snow cover
- A decreased in the number of days with thaw/freeze periods
- An increase in the frequency of landslides
- A decrease in the frequency of avalanches
- A small increase in the maximum wave height
- A decrease in permafrost
- A small increase in maximum wind strength

A total of 30 hazards related to future climate changes have been identified. The distribution of hazards according to the primary climate variable (the climate parameter assessed as the major cause of the hazard) was as follows:

Table 10. Hazard distribution

Hazard	Freq.	Hazard	Freq.
Precipitation	6	Sea level rise	2
Temperature	6	Permafrost	2
Snow	5	Fog	1
Wind	2	Lightning	1
Thaw/freeze	2	Ground water level	1
Landslide/avalanche	2		

3.2 Focus Areas

Focusing on the 11 airports that with respect to among other aspects such as national security, emergency preparedness and connectivity have been identified as high criticality, the hazards that emerge as being more critical are:

- More extreme precipitation leading to flooding of runways and general airport infrastructure. Depending on drainage conditions extreme run-off may lead to erosion of embankments.
- More variable snow conditions and temperature fluctuations around freezing leading to more challenging winter maintenance of which deicing operations is a key element.
- Rising sea levels and storm surges leading to flooding and washing out of ground of runways and surrounding safety areas.
- More variable wind and fog conditions
- Thawing of permafrost may comprise integrity of runways at Svalbard airport.

Comparing the distribution of high-risk hazards in the previous and updated assessment in table below, the results shows that the number of high risk hazards has decreased. The airports that remain with the most high risk hazards are Alta, Hammerfest, Brønnøysund, Svalbard and Trondheim. Svalbard has an additional hazard from thawing of permafrost, which is not illustrated in the tables below. Measures to mitigate the above-mentioned more critical hazards should be prioritized for these airports.

Table 11. Comparison of distribution of high risk hazards according to primary climate variable for 11 critical airports

Atkins 2014									
Airport	**Total**	**Temp.**	**Prec.**	**Snow**	**Fog**	**Wind**	**SLR**	**Thaw/ freeze**	**GW**
Alta	8	2	3	1			2		
Bergen	6	1	1	2	1	1			
Brønnøysund	6	1	3	1	1				
Florø	6	1	3	1	1				
Hammerfest	5	1	2	1		1			
Kristiansund	3	1	1	1					
Oslo	4	1	1	1	1				
Stavanger	6	1	2	1			2		
Svalbard	5	1	2	1				1	
Tromsø	7	1	2	1		1	2		
Trondheim	4	1	1	1		1			

Updated									
Airport	**Total**	**Temp.**	**Prec.**	**Snow**	**Fog**	**Wind**	**SLR**	**Thaw/ freeze**	**GW**
Alta	5	1	1	1			2		
Bergen	2	1		1					
Brønnøysund	3		1	1	1				
Florø	2			1	1				
Hammerfest	3		1	1		1			
Kristiansund	1			1					
Oslo	2		1		1				
Stavanger	2		1	1					
Svalbard	3		1	1				1	
Tromsø	2		1	1					
Trondheim	3			1		1			1

In addition to generic control measures in the hazard log the following additional measures are recommended.

Flooding and erosion of embankments/ safety areas from extreme precipitation (hazards Gen07 and Gen08) – examine drainage conditions of surfaces and underground piped networks by hydraulic modeling to identify capacity constraints and areas with fast-flowing run-off and that may lead to accumulation of water and erosion.

To achieve the necessary level of accuracy and precision high resolution terrain will be needed. Relevant sources such as www.hoydedata.no and InSar[5] for also monitoring potential subsidence including possible effects of frost heaving induced by water accumulation should be acquired.

Increased use of deicing chemicals and pollution risk from more variable snow (Gen17) - Milder weather with more variable snow conditions, thaw-freezing cycles is likely to call for more deicing of runways and planes. Apart from OSL-Gardermoen, which has a very advanced collection and treatment system, used deicing chemicals in snow are largely allowed to percolate to the ground. Spent-glycol from deicing of planes is pumped to the nearby sea where they may pollute if the circulation is not sufficiently high for dilution.

To minimize ground pollution from the melting of snow with chemicals, snow should be stored on an impermeable surface and the resultant pumped to the nearby recipient or treatment works. The same measure applies to deicing of planes.

With anticipated increase in chemical usage the ability of the recipient ground or water body to cope with the pollutant load should be investigated and monitored. To have a baseline from which to gauge potential impacts, it is important that such investigations be done prior to effects of pollution are noticed.

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[5] https://insar.space/

Flooding from sea level rise, storm and tidal surges (Gen13 and Gen14): Of the high criticality airports it is only Alta that is very vulnerable to rising sea level. Flooding of safety areas and parts of the runway has already been experienced at Alta. Aside from costly measures to raise surfaces, building of embanks and temporary flood protection are relevant measures that combined with contingency plans should form the basis for managing flood risk from sea level rise.

Hydraulic modeling should be applied to examine flooding scenarios and to tailor choice of protection works.

More variable wind (Gen15) and fog (Gen24): Contingency plans including protocols for weather monitoring, re-routing and landing assistance should be reviewed and updated. Such update should also consider all incidences where wind and fog have complicated landing to extract lessons-learned and improve systems accordingly.

Damage to runway and ground pollution from thawing of permafrost (Gen28 and Gen29): Only relevant for Svalbard airport the hazard is currently being monitored with already some measures applied to avoid accumulation of water beneath tarmacked surfaces.

It is recommended that the next time the runway is rehabilitated that removal of the permafrost layer be considered as opposed to insulating of the runway. By removal of material down to bedrock or assumed melting depth of permafrost over the forecasted economic life of the runway, and replacing of these deposits by gravel/ crushed rock, will substantially reduce/ prevent subsidence and cracking of the runway.

To minimize potential for ground pollution spent deicing chemicals should be collected (from snow deposits and planes and released to sea). Recipient investigations should be carried out to find more appropriate discharge points.

4 IMPLICATIONS FOR REPORTING ON SUSTAINABILITY AND FINANCIAL VIABILITY

The EU-taxonomy and Task Force on Climate Related Financial Disclosures are two sets guidelines that amongst other initiatives, have emerged from the 2018 Paris Agreement to limit future global warming to not more than 1,5°C increase in global average temperature compared to today.

Considering the respective goals of promoting investments and financial flows toward reducing of greenhouse gas emissions while at the same time satisfying the information needs of owners and investors about the associated risks of adapting to climate change, this chapter seeks to provide further information on key features and relationship with the climate risk assessment herein.

4.1 EU-taxonomy

DEFINITION AND SCOPE

The EU taxonomy is a classification system for environmentally sustainable economic activities. By providing the necessary guidance on which economic activities can be considered environmentally sustainable, the taxonomy intends to help investors, companies, issuers and project promoters navigate the transition to a low-carbon, resilient and resource-efficient economy.

The Taxonomy sets performance thresholds (referred to as 'technical screening criteria') through delegated acts for economic activities which:

- make a substantive contribution to one of six environmental objectives (see insert)
- do no significant harm (DNSH) to the other five, where relevant
- meet minimum safeguards (e.g., OECD Guidelines on Multinational Enterprises and the UN Guiding Principles on Business and Human Rights)

1 Climate change mitigation
2 Climate change adaptation
3 The sustainable use and protection of water and marine resources
4 The transition to a circular economy
5 Pollution prevention and control
6 The protection and restoration of biodiversity and ecosystems

To date as of June 2021 the first delegated act on sustainable activities for climate change mitigation and adaptation and objectives is approved. A second delegated act for the remaining objectives will be published in 2022.

GUIDANCE ON APPLICATION

The EU-Commission has prepared guidance material on the methodology for application and reporting on the criteria.[6] Useful tools in this respect is the taxonomy compass, the external

[6] Communication on 'EU taxonomy, corporate sustainability reporting, sustainability preferences and fiduciary duties. Supplement to Article 8 of the Taxonomy Regulation on content, methodology and presentation of information to be disclosed by financial and non-financial undertakings concerning the proportion of environmentally sustainable economic activities in their business, investments or lending activities.

advisory group provided through the platform on sustainable finance[7] and report on the recommendations for screening criteria by the Technical Expert Group (TEG) published in March 2020.[8] Apart from the taxonomy compass, which includes a line for low carbon airport infrastructure, aviation related activities are not included in the TEG report. It does, however, acknowledge the need for inclusion of such activities and the role of the external advisory group to provide input on further details.

A study on Sustainable Finance Taxonomy for the aviation sector[9] identified more sustainable manufacturing including fuel production, storage and distribution, air traffic and airport management as relevant for inclusion in the taxonomy provided that they make a substantial contribution to one of the six objectives of the Taxonomy Regulation.

It further emphasised climate change mitigation as the most relevant goal for the aviation sector, followed by pollution prevention and control.

The above-mentioned activities can qualify as contributing substantially to climate change mitigation if they meet the criteria set out under Articles 10 and 16 relating to contribution to and enabling activity for climate change mitigation. In effect this means they are considered either a low-carbon activity, a transition activity, or an enabling activity.

Starting with the activities related to aircraft and fuel, the report emphasises that these are largely transitory since current aircrafts due not support zero or low-emission flying. Such investments or activities which are consistent with pathways toward major emissions reductions can be included in the EU Taxonomy as transition activities, so long as the principle of following the 'leading edge' (the best technology available at any given point in time) of available improvements is applied.

This leads to air traffic management and airport operation as the activities that in terms of the taxonomy are most relevant for Avinor. Specifically this concerns the following environmental objectives:

Sustainable use and protection of water and marine resources:

- Activities to reduce the adverse environmental impact of de-icing fluids, which contain chemicals which can mix with and contaminate the surface and groundwater in the vicinity of airports should be included in the taxonomy.
- Criteria: reduction of volatile organic compounds (VOCs).

Transition to a circular economy:

- Activities to improve aircraft decommissioning practices.

Pollution prevention and control:

- Aircraft: activities that can reduce particulate matter (PM) and NOx air pollution as well as aircraft noise.

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[7] https://ec.europa.eu/info/business-economy-euro/banking-and-finance/sustainable-finance/overview-sustainable-finance/platform-sustainable-finance_en

[8] https://ec.europa.eu/info/publications/sustainable-finance-technical-expert-group_en

[9] https://transport.ec.europa.eu/news/sustainable-finance-taxonomy-aviation-sector-2021-03-15_en

- Airport operations: activities which can reduce airport noise.

RELEVANCE TO CLIMATE RISK ASSESSMENT

Based on the above, deicing operations emerge as an obvious area where the climate risk assessment has a direct connection to the EU-taxonomy. However, in the context of the Steer report, this appears to relate more to protection of water resources than pollution prevention.

The taxonomy compass provides useful guidance on associated reporting activities for low carbon airport infrastructure. To date these are defined for the environmental objectives climate mitigation and climate adaption. The framework is illustrated below for the case of climate adaption and will apply to the other environmental objectives pending definition of criteria. For each of the objectives reference is made to Appendices A, B, C, D, that contain further explanation on according methodological requirements. [10] Flood protection works and improvement of drainage would fall within the adaption category as among the measures that are relevant for updating of the climate risk assessment herein.

The taxonomy tool developed by the technical expert group on sustainable finance (TEG) provides further information as well as a summary of the above steps to assess and report on the degree of compliance with an climate adaption activity with the taxonomy. This is shown in the figure overleaf.[11]

It is worth mentioning the distinction made with regards to adapted activities and those enabling adaptation. The building of flood protection is in this context considered to be an adapted activity for airport infrastructure and not an enabler. The reason for this is the reference to other economic activities such promoting of technological innovations and removal of information, technological and financial barriers.

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[10] https://ec.europa.eu/sustainable-finance-taxonomy/

[11] Technical expert group on sustainable finance (TEG) - Taxonomy tools | European Commission (europa.eu)

Figure 4. Adaption screening criteria

Explanation:
The technical screening criteria for substantial contribution to climate change adaptation are re-stated here for convenience. They differentiate between 'adapted activities' and 'activities enabling adaptation'. For further discussion of these concepts, please see the summary report and technical annex.

Screening criteria for adapted activities

Criterion	Description
A1: Reducing material physical climate risks	The economic activity must reduce all material physical climate risks to that activity to the extent possible and on a best effort basis.
A1.1	The economic activity integrates physical and non-physical measures aimed at reducing - to the extent possible and on a best effort basis - all material physical climate risks to that activity, which have been identified through a risk assessment.
A1.2	The above-mentioned assessment has the following characteristics: • considers both current weather variability and future climate change, including uncertainty; • is based on robust analysis of available climate data and projections across a range of future scenarios; • is consistent with the expected lifetime of the activity.
A2: Supporting system adaptation	The economic activity and its adaptation measures do not adversely affect the adaptation efforts of other people, nature and assets.
A2.1	The economic activity and its adaptation measures do not increase the risks of an adverse climate impact on other people, nature and assets, or hamper adaptation elsewhere. Consideration should be given to the viability of 'green' or 'nature-based-solutions' over 'grey' measures to address adaptation.
A2.3	The economic activity and its adaptation measures are consistent with sectoral, regional, and/or national adaptation efforts.
A3: Monitoring adaptation results	The reduction of physical climate risks can be measured.
A3.1	Adaptation results can be monitored and measured against defined indicators. Recognising that risk evolves over time, updated assessments of physical climate risks should be undertaken at the appropriate frequency where possible.

Screening criteria for an activity enabling adaptation

Criterion	Description
B1. Supporting adaptation of other economic activities	The economic activity reduces material physical climate risk in other economic activities and/or addresses systemic barriers to adaptation. Activities enabling adaptation include, but are not limited to, activities that: • Promote a technology, product, practice, governance process or innovative uses of existing technologies, products or practices (including those related to natural infrastructure); or, • Remove information, financial, technological and capacity barriers to adaptation by others.
B1.1	The economic activity reduces or facilitates adaptation to physical climate risks beyond the boundaries of the activity itself. The activity will need to demonstrate how it supports adaption of others through: • an assessment of the risks resulting from both current weather variability and future climate change, including uncertainty, that the economic activity will contribute to address based on robust climate data; • an assessment of the effectiveness of the contribution of the economic activity to reducing those risks, taking into account the scale of exposure and the vulnerability to them.
B1.2	In the case of infrastructure linked to an activity enabling adaptation, that infrastructure must also meet the screening criteria A1, A2 and A3.

EU-TAXONOMY IN PRACTICE

The taxonomy regulation sets out three types of users. These are (i) financial market participants offering financial products including pension fund providers in the EU, (ii) large enterprises (more than 500 employees) that are already required to provide a non-financial statement under the Non-Financial Reporting Directive and (iii) the EU and Member States, when setting public measures, standards or labels for green financial products or green (corporate) bonds.

Financial market participants will be required to complete their first set of disclosures against the Taxonomy, covering activities that substantially contribute to climate change mitigation and/or adaptation, by the 31st of December 2021. Companies will be required to disclose in the course of 2022. All companies subject to this requirement will include a description of how, and to what extent, their activities are associated with Taxonomy-aligned activities. For non-financial companies, the disclosure must include the proportion of turnover aligned with the Taxonomy and capex and, if relevant, opex aligned with the Taxonomy. This disclosure should be made as part of the non-financial statement, which may be in annual reporting or in a dedicated sustainability report.

Turnover gives a clear picture of where a company currently is relative to the Taxonomy. It allows investors to report the % of their fund invested in Taxonomy-aligned activities. Capex, in contrast, gives investors a very good sense of a company's direction of travel. It is a key variable for assessing the credibility of a company's strategy, and it helps investors decide whether they agree with their strategic approach.

Companies that disclose their capex investments in economic activities as part of a plan to be Taxonomy-aligned provide invaluable information for constructing green portfolios, and for analysing companies' transition plans and/or environmental sustainability performance and strategies.

The TEG recommends that companies complete the Taxonomy calculation separately for each of the environmental objectives for which substantial contribution technical screening criteria have been developed (EU Technical Expert Group on Sustainable Finance, 2020).

Since aircrafts do not yet cater for zero-emissions flying, the mitigation objective of providing according to airport infrastructure is not yet considered relevant. For Avinor this implies that climate adaption is the main reporting criteria for the taxonomy.

The calculation methodology for Taxonomy-aligned turnover, capex and opex, if relevant, varies depending on the financial vehicle (equity or debt) and the purpose of the investment regarding the environmental objective being pursued. Here the TEG states that only costs incurred can be counted (capex and if relevant, opex). Because of the distinction between the mitigation and adaption objectives and fact that adaptation is an ongoing process, TEG recommends that turnover generated from the activity should not be counted.

Keeping with the taxonomy Avinor can then claim that the percentage of its expenditures relating to adaption (e.g. flood protecton, improving of drainage works and ventilation of buildings) is taxonomy aligned.

4.2 Task Force on Climate Related Financial Disclosures

The TCDF[12] is an organisation established by the Financial Stability Board and is comprised of 32 countries from across the G20, representing both preparers and users of financial disclosures. The TCFD is chaired by Michael R. Bloomberg, founder of Bloomberg L.P.

12 https://www.fsb-tcfd.org/

The goal of TCDF is to develop recommendations for more effective climate-related disclosures that could promote more informed investment, credit, and insurance underwriting decisions and, in turn, enable stakeholders to understand better the concentrations of carbon-related assets in the financial sector and the financial system's exposures to climate-related risks.

Climate risks and opportunities can be understood as main drivers of strategic planning. Recommended measures whether they are revised communication strategies to handle political and reputation risk, investments in new technology or improvement/ changes to infrastructure to manage the other associated risk elements, will in turn imply changes the organisation's profit and loss and balance accounts.

TCDF disclosure recommendations are structured around four thematic areas that represent core elements of how organizations operate: governance, strategy, risk management, and metrics and targets. These thematic areas are intended to interlink and inform each other(e.g. see below Figure 5). The recommended disclosures within each of these areas is a set of indicators for gauging an organisations performance in relation to the TCDF-framework.

Governance	Strategy	Risk Management	Metrics and Targets
Disclose the organization's governance around climate-related risks and opportunities	Disclose the actual and potential impacts of climate-related risks and opportunities on the organization's business, strategy, and financial planning where such information is material.	Disclose how the organization identifies, assesses, and manages climate-related risks.	Disclose the metrics and targets used to assess and manage relevant climate-related risks and opportunities where such information is material
Recommended Disclosures	**Recommended Disclosures**	**Recommended Disclosures**	**Recommended Disclosures**
a)Describe the board's oversight of climate-related risks and opportunities b)Describe management's role in assessing and managing climate-related risks and opportunities	a)Describe the climate-related risks and opportunities the organization has identified over the short, medium and long term. b)Describe the impact of climate-related risks and opportunities on the organization's businesses, strategy and financial planning. c)Describe the resilience of the organization's strategy, taking into consideration different climate-related scenarios, including a 2° C or lower scenario.	a)Describe the organization's processes for identifying and assessing climate-related risks. b)Describe the organization's processes for managing climate-related risks c)Describe how processes for identifying, assessing and managing climate-related risks are integrated into the organization's overall risk management.	a)Disclose the metrics used by the organization to assess climate-related risks and opportunities in line with its strategy and risk management process b)Disclose Scope 1, Scope 2, and if appropriate, Scope 3 greenhouse gas (GHG) emissions, and the related risks. c)Describe the targets used by the organization to manage climate-related risks and opportunities and performance against targets.

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Figure 5. Thematic areas and indications for TCDF-disclosures.

Updating of the climate risk assessment in this report can be seen as linked to the first bullet points (identification of climate related risks and opportunities, processes for risk identification and metrics) under the thematic areas Strategy, Risk Management and Metrics and Targets. The EU-taxonomy would then by the yardstick for defining criteria for climate related activities and methods to be used to assess the impact of these activities on the environmental goals. Recommendations that the organisation decides to implement would in turn carry cost components and impact the financing of the organisation. In this way TCDF can be understood as a tool for how an organisation can embed climate resilience in its operations and communications.

5 Concluding Remarks

The consultancy Atkins undertook a comprehensive climate risk assessment for all Avinor's airports 42 airports throughout Norway in 2014 based on an approach and methodology that previously had been applied to London Heathrow Airport. It focuses on the physical risks to the safety of aviation as impacted by landing/ take-off and operational conditions on the ground.

Not overlooking that the availability of updated climate data and projections on likely changes in weather patterns considering the time that has lapsed since 2014, is a main motivating factor for updating of the climate risk assessment herein, another is the desire to increase practical application of the assessment methodology and a third is the relationship with emerging requirements for reporting on sustainability and financial viability under the EU-taxonomy and TCDF (Task Force for Climate-related Disclosures).

Starting with the assessment methodology and how the excel spreadsheet calculates the risk grading based on the identified likelihood of the event occurring and its consequence on airport closure time, the original assessment uses three probability categories. Refining the risk grading to four levels enabled focus on the risks that were deemed more important in terms of changes in underlying climate data (temperature, precipitation, sea level rise etc). This identifies the following hazards that should be prioritized for further mitigation planning:

- More extreme precipitation leading to flooding of runways and general airport infrastructure. Depending on drainage conditions extreme run-off may lead to erosion of embankments.
- More variable snow conditions and temperature fluctuations around freezing leading to more challenging winter maintenance of which deicing operations is a key element.
- Rising sea levels and storm surges leading to flooding and washing out of ground of runways and surrounding safety areas.
- More variable wind and fog conditions
- Thawing of permafrost may comprise integrity of runways at Svalbard airport.

According to recommendations emphasises the conducting of hydraulic modelling studies, environmental impacts assessments and contingency planning for designing respective improvements to drainage and flood protection works, minimize pollution and back-up plans for re-rerouting of traffic during times of extreme wind and prolonged fog.

On the relationship and impact of the EU-taxonomy and TCDF reporting requirements on operations and measures to mitigate, adapt and minimize adverse impacts on the environment, improvements to infrastructure to avoid flooding and pollution from deicing chemicals, emerge as focus areas where progress reporting will have to adapt to the new requirements. The EU-Water Framework and Environmental Impact Assessment Directives are the relevant regulations to check against.

The TCDF-framework provides a useful overview of relevant types of disclosures for an organisation. Although targeted toward climate change the overview is also relevant for other types of risks. The EU-taxonomy is embedded within TCDF as the method for defining relevant activities and metrics for their measurement.

6 References

Atkins. (2014). *Avinor Risk Assessment - Long-term climate risk assessment of Avinor airports.* Avinor.

Economist. (2021, July 24). Three degrees of global warming is quite plausible and truly disastrous. Londo, United Kingdom. Retrieved from https://www.economist.com/briefing/2021/07/24/three-degrees-of-global-warming-is-quite-plausible-and-truly-disastrous?giftId=203d47e5-0052-49d3-920a-c35645f20660

EU Technical Expert Group on Sustainable Finance. (2020). *Taxonomy Final Report.* Brussels: EU. Retrieved from https://ec.europa.eu/info/files/200309-sustainable-finance-teg-final-report-taxonomy_en

Heathrow Airport Limited. (2011). *Heathrow Airport - Climate Change Adaptation Reporting Power Report.* London: Heathrow Airport.

IPPC. (2021, October 20). *IPCC*. Retrieved from www.ipcc.ch: https://www.ipcc.ch/report/ar5/syr/

NCCS. (2015, October). Retrieved from www.klimaservicesenter.no: https://klimaservicesenter.no/kss/rapporter/rapporter-og-publikasjoner_2

NCCS. (2015). *Sea level change for Norway.* Retrieved 10 27, 2021, from https://www.miljodirektoratet.no/globalassets/publikasjoner/M405/M405.pdf

NCCS. (2017). *Climate in Norway 2100 - a knowledge base for climate adaption.* Retrieved 10 17, 2021, from file:///C:/Users/jokd/AppData/Local/Temp/1/MicrosoftEdgeDownloads/50360985-4948-40a8-aa9d-87fda93f5a89/klimarapport-2100-engelsk-web-0160517.pdf

NOU. (2010). *Adapting to a changing climate.* Retrieved 10 29, 2021, from https://www.regjeringen.no/no/dokumenter/nou-2010-10-2/id668985/

Nyhus, J. (2013). *Vurdering av klimaendringers påvirkning på Avinors lufthavner (en forstudie).* Oslo: Avinor.

Nyhus, J. K. (2013). *Prosjekt Erkjent risikobilde - Stavanger lufthavn Sola.* Avinor (Internal document).

Schuur, T. (n.d.). *Arctic Report Card - Update for 2019*. Retrieved 2 2022, from Permafrost and the Global Carbon Cycle: https://arctic.noaa.gov/Report-Card/Report-Card-2019/ArtMID/7916/ArticleID/844/Permafrost-and-the-Global-Carbon-Cycle

Vasskog, K., Drange, H., & Nesje, A. (2009). *Havnivåstigning, estimater av framtidig havnivåstigning i norske kystkommuner.* Det nasjonale klimatilpasningssekreteriatet ved Direktoratet for samfunnsikkerhet og beredskap.