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Impact assessment and adaptability of a building within a SPEN in a changing climate

Robustness of BEP systems in terms of future climate , a study on impact of climate change using future climate model

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Sustainable Architecture
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Abstract

Climate change is an obvious challenge likely to arise and be distinctive in the coming years. Therefore, while planning for sustainable neighborhoods and focusing for growth of sustainability in the construction sector, it is also very much important to keep in mind the challenge of changing weather and the changing demand likely due to change of external conditions for a building. The current analysis and planning of buildings consider the present climate and underestimates the extremeness it can possess. Therefore, to quantify the situations of change that might arise with extreme conditions, this study was carried out for assessment of the rise of cooling demand and the demand for flexibility of the systems to support such a demand and keep at par in total the energy demands. This study is based on simulation of a residential building, as it has an almost 24/7 hours of functioning and located in a sustainable positive energy neighborhood at Fredrikstad, in the Viken country of Norway. It was used for analysis of Climate change effects on a residential building. Future climate data was synthesized using verified methods and use of verified models, also approved by IPCC. The model used is EC-EARTH, RCA, forcing them into further two of representative pathways and using reference years of 20-30 years of the selected years, and data was analyzed for 120 years in total. It was observed that there was almost a 13% decrease of heating degree days for the conditioned situation while an increase of about 22% of Cooling degree days, when compared to present climatic conditions. This difference of percentage is likely to increase more when considered an extreme condition. Moreover, Results urge that cooling demand rises by 60 percent from a medium considered representative pathway to an extreme pathway. It also suggests that it increases from the first reference year considered, in this case 2010 to the last reference year considered 2097. With the rise in the demand for cooling there are also periods of overheating for the building specially during the mid-day of a warm summer. And issues of overheating have been found mostly on the southwestern side of the building. Overheating scenarios also change with the floor heights. So, though the current situation does not have any requirement of cooling or a system for cooling, with such a rise over the years, the demand for installation of a system for cooling might arise especially considering years after 2060. Passive cooling techniques are likely of work but only until a certain point of the decades. These changes are again likely considering a lot of future factors like population growth, more urban development around the area. Therefore, it is a necessity to consider the future climate or else there might be situations of lack of adaptation and collapse of a system in terms of maintaining the primary goal of thermal comfort and in turn pressuring the Energy performance systems.

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List of abbreviations

ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers
BEP	Building energy performance
CDD	Cooling Degree-Day
HDD	Heating Degree-Day
RCM	Regional Climate Model
RCP	Representative Concentration Pathway
GCM	Global climate model
CDF	Cumulative distribution function
TMY	Typical Meteorological Year
NCCS	Norwegian Centre for Climate Services
EPW	Energy plus weather file (Standard)
ECY	Extreme cold year
EWY	Extreme warm year
XMY	Extreme meteorological year
TDY	Typically downscaled year
SMY	Synthesized Meteorological year
IAM	Integrated assessment models
CM	Climate model

1.Introduction

Today the world experiences climate change due to emissions of greenhouse Gases. [1] Climate change have had very distinct evidence all over the world and it seems to have been growing over the years. Some places have experienced very hot summers while others have experienced warm winters when compared to the usual winters experienced by these places. [2] Climate change include a lot of uncertain factors, consequences, and probabilities in factors like emissions, carbon cycle response and climate itself and its impact. A lot of factors tend to contribute to rise in these uncertainties which include rise in population, economic development, and technological developments. As suggested risk assessment using these factors is important and building up of probabilities to scenarios is also important [3]. It is predicted that due to a mix of factors the current emission rate is likely to increase and increase in average global temperatures [4]. There are possibilities of more frequent extreme conditions and occurrence of extreme events. In Europe there are predicted events of increase in heatwaves, droughts, wildfires, river and coastal floods and windstorms [5]. Weather related disasters are likely to increase, and these disasters are likely to affect the livelihood and lives of about 2/3 of Europe's population [6], [7].

However, with time there has been responses to climate change, and these are mitigation and adaption [8]. Mitigation ow involves efforts towards reducing the pace of global warming by reducing GHG emissions. Climate change adaption now denotes to preparation for adaption to these unexpected futuristic changes. This in turn is also very necessary as it is likely to have very long-term severe problems in specially populated cities if actions are not taken on time.

Buildings play a vital role, as they are supposedly inducing around 30% of the world's total GHG emissions and contribute to 32 percent of the world's total final energy use and these figures are expected to be double by the year 2050 [9].

It was observed that it is very important to reduce anthropogenic climate changes and limiting the global average temperature rise below 2 degrees Celsius above the preindustrial level. The effects of climate change likely to be posed by high temperature rise, heatwaves will be experienced and have been experienced since 2003(heatwave of western European countries) which was followed by extreme warm summers thereafter (Robin et al, 2008). These changes in climate have also affected Thermal energy demand of a building, which in turn depends mostly on different factors, including climate change, user behavior, regulations, population growth, building properties and the diffusion and availability of technologies. [10]

Also, it has always been a goal for humans to maintain comfort and therefore indoor thermal comfort has always been given a priority. With climate change and with a result of warming climate there are considerable possibilities for increase in cooling energy demand specially in regions with temperate climates, where cooling demands are currently low. There is a possibility that the number of days that require cooling to maintain comfortable indoor air temperatures could reach levels, where a growing fraction of people would want to install a cooling system. Which in turn might Result in increase of cooling energy demand and this might result in electrification of heating which will have various impacts on the energy system such as affecting peak electricity demand and thus, the need is, to be consider all aspects when designing and planning future energy system. [11] Also, it was noticed there has been an increase of Cooling degree days (CDD) with passing years, many evaluations showed that the impact of temperature increase was directly on summer cooling demand based on CDD values and the Eurostat thermal comfort threshold across Europe. According to many analysis and results there was an increase of a 115% CDD for 2035 and along with it an increase of 46% of electricity energy consumption (Aebischer et al.) [12] .Also various studies analyzed, cooling demand trends with outdoor temperature changes for different climate models and scenarios at the European level, showing a general CDD increase, with a higher incidence in Nordic regions. From results in relation to other studies using CDD values based on the Eurostat method, showed that there was a percentage increase on CDD values. (et al Larsen) [12].

It is important to also model and evaluate future energy performance of building stocks in cities and these can provide important information for adaption of buildings and energy systems to climate change. But doing so is bit of a challenge due to lack of detailed information. A building stock can be assessed in terms of an archetype or sample building [13].These models make it easy to describe and analyze building stocks, when data availability is limited [14]. Cooling and heating demand can be considered under a necessity for thermal comfort. Cooling in buildings account almost around 2.9 to 6.7% of the world's energy use. Global cooling demand is likely to increase by 34% by 2050 and 61% by 2100 in the residential sector alone [15] .

The Research put up here is on interest considering all the parameters and the necessity to study the building energy performance systems with changing climatic conditions. There has been advancement in climate models used for various purposes and creation of TMYs but these TMYs cannot be alone used for Analyzing extreme climatic conditions therefore it is important to synthesize the weather data and analyze the buildings considering all future climate conditions and making them adapt to it is also important. (Yang et al). nryana. Extreme climate events have effects on the performance of energy systems on both demand and supply. These events tend to put extra load on the energy systems and then compromising with the thermal comfort of people residing [16] [17]. Therefore, the need is to have a mostly accurate assessment of the energy performance of buildings to prepare well for climate change adaption. Though many such attempts have already been made and developed, yet the building sector is lacking with high resolution measured data of energy and indoor climate data as well as predicted climate data used for prediction of robustness of these BEP systems in terms of the future conditions, inclusive of extreme events., uncertainties are also a factor to be considered. [18]. Quality of weather data also plays a vital role in defining the accuracy of the outdoor conditions which is important for the model to be analyzed for robustness. Usually, a TMY can also be used, but it only serves the purpose of analyzing the most common monthly conditions rather than the extreme cases [19] [20]. But to be inclusive of climate change adaptation it is extremely important to consider extreme conditions. To be including climate change and considering extreme climatic conditions it is crucial to use Synthesized Meteorological year (SMY). Using SMY will help achieve accuracy and provide future data based on various scenarios and considering extreme conditions [21] [22].

1.1. Frederikstad in the region of Viken

Fredrikstad is a city in the municipality of Viken or called Viken country. It located south of Oslo. Viken is a Norwegian country recently established in the year of 2020, which was formed after merging of earlier countries Akerhus, Buskerud and Østfold. It borders till east of Sweden, onto the east and north towards the inland, in the west reclines towards Vestfold, also Telemark and with Vestland towards the south. The country has a total area of 24,595 square kilometers and is considered Norway's sixth largest region in terms of area. It is also one of the most populated regions. Most densely populated towns of this region are located in the lowland areas, along the lake Mjøsa. However, the largest population can be found in Oslo, also with more density, which extend to several areas of Viken. Fredrikstad is one of the city centers of Viken, alongside Sarpsborg, Drammen and Moss.

According to current dynamics, Viken has a total area of 22768 square kilometers. It has a population over 1.2 million as per 2019. However, the density has been different at different areas of the region. Fredrikstad is also known to have largest population concentration along with several other cities of Viken. It also has the fastest growing population in the recent years. Population growth in Viken has been observed around 12.9 percent in the duration of last 10 years [23]

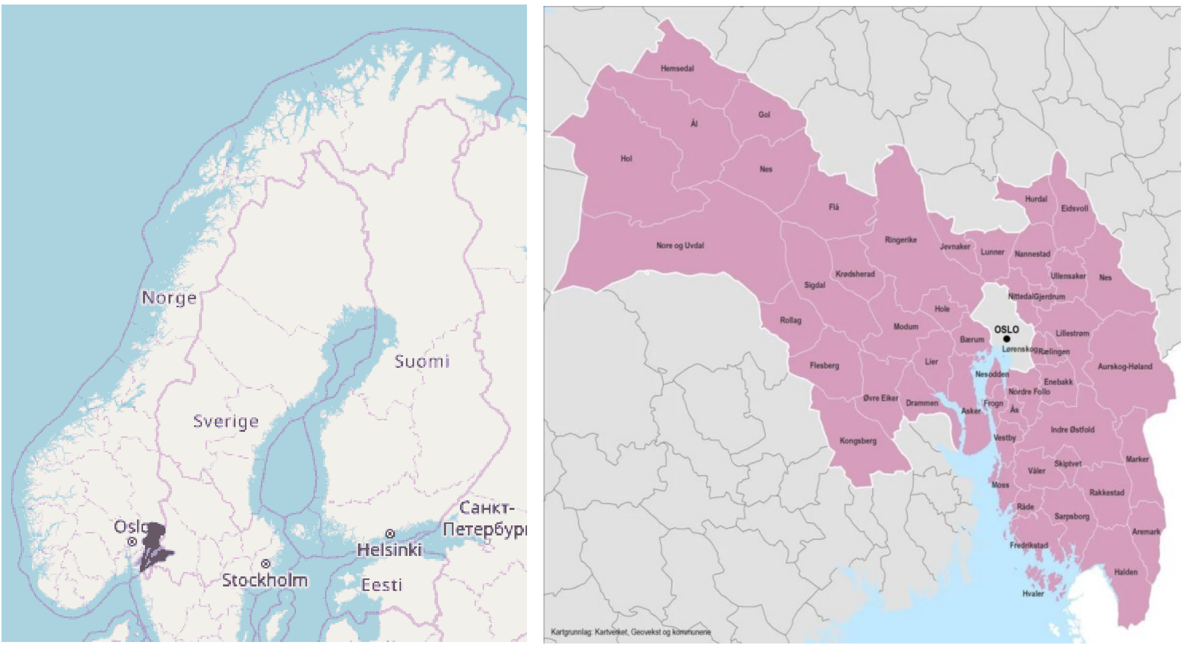


FIG 1:SHOWING FREDRIKSTAD IN NORWAY, SHOWING COUNTRY OF VIKEN (BY DAVID NIKEL , MAY 13, 2019)

1.2 Current climate around Viken and Frederiksted

Currently Viken is a newly introduced region, after the reforms happened in Norway as of 1 January 2020 reducing number of regions from nineteen to eleven. The area belongs to eastern Norway and is considered the most densely populated areas with around 1,241,165 inhabitants on an area of 24,595 Sqm as was of January 2020. It was observed that more than 87% of the inhabitants in Viken lived in densely populated areas. Also, within the region itself there is diversity in landforms and elevation in the area which results in great variations in weather and climate. There are considerable warmer winters along the coast and in the south, in contrary to the northern parts of Viken that experiences longer and colder winters as compared. Each region has had set goals of reduction of emissions to reduce effects of climate change and viken also have similar goals. As per the distribution of Co2 emissions in each sector in Viken, goals are to reduce around 70% of emissions from the building and construction sector. [24]

Climate around Viken have always been comfortable during summers for some years now, Fredrikstad an area in Viken also remains comfortable with around 24°F to 69°F. The average of temperatures has remained 62°F at max during summers. The warm season lasts for 3.3 months, from May 31 to around September 8th. The hottest month of the previous years in Fredrikstad has been July, with an average high of 68°F and low of 55°F.However, the cold seasons lasted for 3.9 months, from around November 21 to March 17, with an average daily high temperature below 40°F. The coldest month of the year in Fredrikstad has been January, with an average low of 25°F and high of 33°F [25].

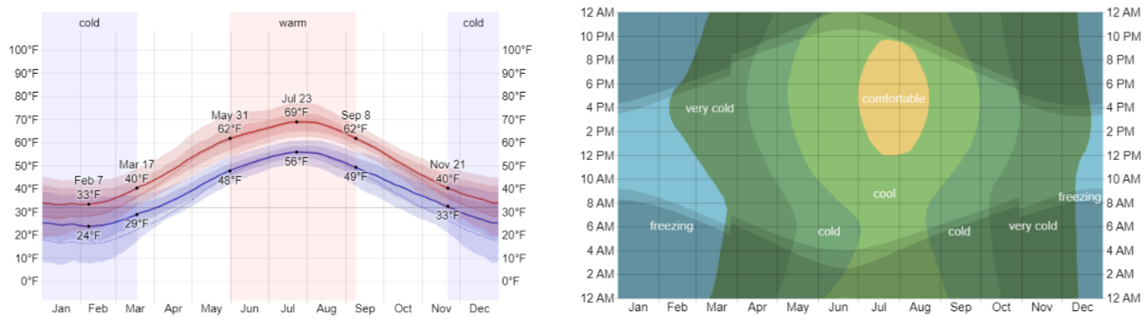


FIG 2:SHOWING TEMPERTURE IN FREDRIKSTAD AOUND THE YEAR (WEATHER SPARK)

1.3 Research Background

As mentioned earlier climate change can be overwhelming. And according to past trend of emissions, it is predicted that there will be some degrees of warming regardless of any mitigation processes undertaken or considered. And it is very likely that it might surpass the threshold of 2 degrees. With such harsh changes, adaptation is a must factor and cannot be avoided under any condition.

This study focuses on the possibilities of robustness of a system and making them flexible with time and climate change to adapt, which is a great possibility and a feasibility, which can lead to mainstreaming it into the standards, policies, and construction sector in overall.

It has been seen that though there are numerous amounts of studies done on sustainability and climate change mitigation in buildings, but at the same time it has been noticed that there is a lack of research available for impact assessments of climate change and adaptation of buildings to it. There is also a lack of study with consideration of good, synthesized data used for extreme climate conditions in studying buildings for future. Also, to knowledge there is a very slow sharing of climate modelling to the energy engineering sector or the construction sector, alongside there has been less application of the generated knowledge in the sectors. [26]

It is now immensely important to critically consider the future climate while taking notable decisions be it in policy making or decision making for any sector implementation.

Therefore, the need is to perform a detailed analysis impact assessment of climate change along with adaptation of advanced climate models to maintain the accuracy and be aware of the challenges to arrive due to climate change in future [16], [26] .

This study focuses on impact assessment of a residential building in Fredrikstad , Norway under a SPEN(considering that climate change will not only impact ordinary buildings but also buildings with high and sustainable performance) and how likely these buildings will be able to tolerate climate change impacts and how important will it be to keep note of the robustness to maintain its sustainable performance.

1.4 Aim and Objective

The main aim of this study is to analyze and assess the impact of future climatic conditions on building demands, particularly focusing on the change of cooling demands based on Building energy performance system. Aim is to compare the cooling demands to present day climate to the change of demands in future keeping in mind the extreme possibilities of climate change, also looking into possibilities of mitigation and adaptation since most buildings in the current times are built assuming a static condition of climate and are built considering little to no requirement of cooling. Looking into the possibilities of reducing pressure on the systems when such likeability of events increase was also considered for strategies.

The objectives that were taken into consideration to achieve the desired aim and keeping account of all necessary points to be evaluated are:

- To examine the possible factors leading to climate change and analyzing the current conditions and awareness of adaptation among the construction sector and policy makers in it.
- To examine the different types of climatic data available for research into the subject and analyzing them.
- To study and filter relative climate data and files and synthesize them using verified processes to do so as stated in much of research done.
- To compose the relevant data set for a climate file after screening through the all-climate data collected after synthesizing, to know the almost accurate possible condition changes in parameters of climate and prepare for mitigation.
- To quantify the nearly best ways for adaptation of the structure during times of crises and making the system aware for flexibility and changes that would require attention in the future.
- This work is also about quantifying the benefits of knowing the future probabilities of climate change and creating awareness beforehand to maintain the same pace of performance of the systems and keeping the energy demands at par, most specifically the demand of cooling which is likely to change. This is related to many other factors inside the building like one such important factor is maintenance of thermal comfort.

1.5 Methodology

This Part shows the methods and processes of approach used to achieve the Research goal.

scrutinization and erudition of Literatures has shaped in definement of the issue to be handled and constructing the research goals, aims and objectives. The study was performed on a residential building from the SPEN (sustainable positive energy neighborhood) at Frederikstad.

This study shows the relationship between climate change, building and its Energy systems adaptation to it. Therefore, simultaneous studies and analysis was also carried out for weather data, its collection using climate models and scenarios.

Alongside, the residential building was identified and picked up from the site after study and energy modelled with detailed geometry and simulated to assess the impact of changing climate and future extreme conditions using energy performance simulation tool (IDA ICE).

For climate data, Historical and future climate data files were studied, data were collected from the nearest weather station called Sarpsborg almost 13.3 km away. Future climate files were modelled and collected using verified methods and climate models and sorted for extreme months of heat, categorizing into Extreme warm months and hours for input into IDA ICE and analyzing the requirement and possible increase of cooling demand in the future and adaptability of BEP systems to it.

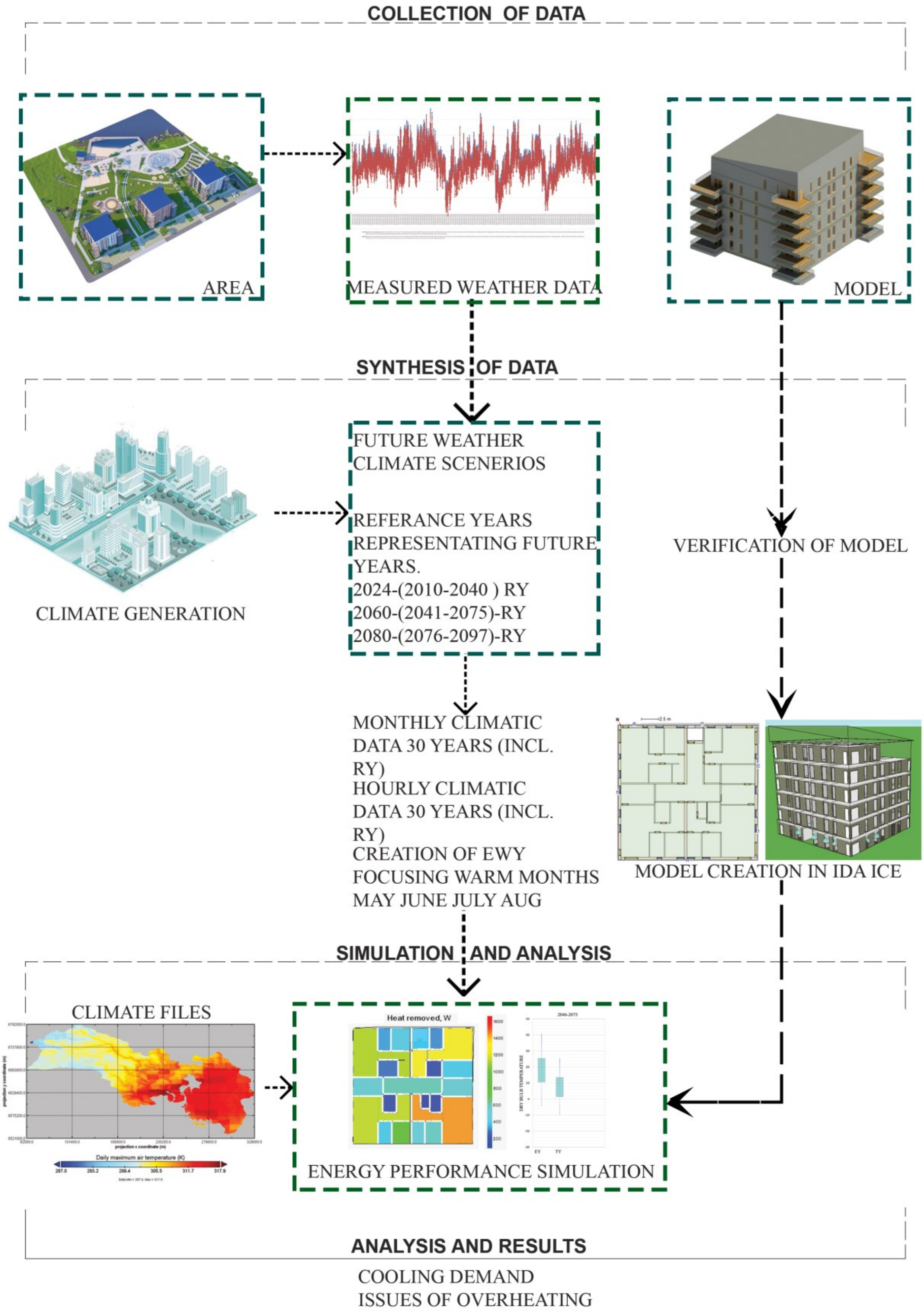


Fig 3: Methodology flow chart

2.Theory

2.1 Introduction to Climate

Earth's climate has always been very variant. And the cause has been both internal and external. The changes can be marked from the interannual era to the geological era. It has been known since ages that life forms on earth are according to the adaptable capabilities to tolerate changes and ranges of temperature. The climate of our planet has known to have been remarkably consistent in the last billion years. But when viewed closely it has also been inconsistent in many ways. The known cause of inconsistency since ages has been the history of climate change. And much changed after the expansion of coal production which began almost 250 years ago, previously the balance was mostly towards human consequences and climate cause [27], [28].

With the world's climate undergoing dramatic changes. Earth is supposedly becoming warmer, and its weather has become remarkably unpredictable. Therefore, it is very important for human beings to adapt to these changes in climate. And understanding of the magnitude of the challenge of adaptation is also important to understand how it could take place. However, there has been limited understanding of the vulnerabilities and development of the adaptation that could take place, therefore more and more research integration is required to know better [29], [30].

2.2. Building and Climate change

The building sector is known to contribute up to 30% of the annual global greenhouse gas emissions and at the same time consumes 40% of all energy. With the growth of new construction technologies and demand of more constructions with the growing population, greenhouse gas emissions from the sector might double in another 20 years or so.

Urban Infrastructure and the sector involved plays a vital role in shaping the current and future scenario of GHG emissions, which in turn contribute to the change of climate. And the change of climate in turn effect the future urban infrastructure and its adaptability. At the very level, the main contributors of GHG emissions are likely to be provision of water, HVAC systems, sanitation, and waste services, and the release of methane from landfill sites. [31].Climate changes and uncertainties can have a major impact on the building performance and hygro-thermal performance of the building facades (et.al Vahid. Nik) [32].

2.3 Climate change in Norway and change of microclimate

Climate Change in Norway will also be inevitable, predicted climate change for Norway will be affecting all life. Climate change is likely to have Significant changes in Temperature, precipitation, and wind velocities. There are likely to be lesser colder months and summers are likely to be hotter. The most changes will be in the annual mean temperature which are expected to be in the northern Norway for both emission scenarios and future periods. [33].The temperatures are shown an increase of around 3.5℃ to 6℃. Figure 1 mostly indicated the gradual rise of temperatures and effect on regional climates using regional climate models. In the last 40 years the increase in temperature was significantly seen rising in Norway. It was observed that the warming in Norway started in two periods, the first was in the start of the 20th century, with maximum temperature recordings in the 1930s. A linear trend of about +0,32 °C/ decade was observed in rise from 1900 until 1938, but from 1976 to 2014 the rise changed to +0,50 °C/decade. A period of cooling with -0,04 °C/decade was also noticed between 1938 to 1976. (IPCC, 2013). The most temperature change was observed for Trøndelag and Nordland/Troms. The temperature increase for Norway was greatest in spring while for the winter season it was found the least [5],[6].

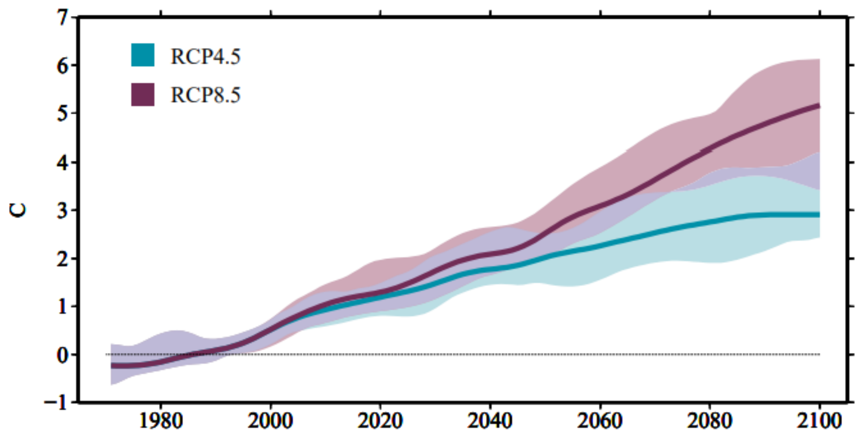


FIG 4:CHANGE IN ANNUAL MEAN TEMPERATURE FOR NORWAY RELATIVE TO THE REFERENCE PERIOD (1971-2000). THE BLUE AND RED LINES SHOW THE MEDIAN VALUES FOR THE ENSEMBLE OF 10 RCM RUNS FOR RCP4.5 AND RCP8.5(MODULES USED BY NVE REPORT).

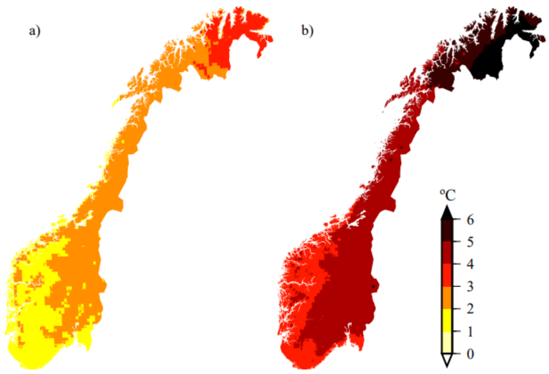


Fig 5:Change of annual temperature based on RCM modelling, showing the projection periods a) 2031-2060 and b) 2071-2100.

Precipitation also shows significant changes over the years. The present and historical precipitation from 1971 to 2000s shows a rise of 10-20% and while comparing it to the future precipitation conditions from 2071-2100, shows a rise of 16-28%. **[34].**

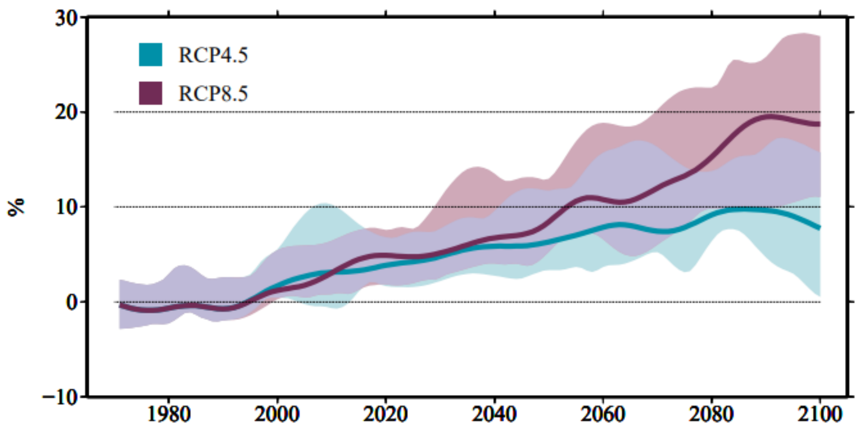


Fig 6: showing percentage of annual rainfall as per RCP 4.5 and RCP 8.5(Wai Kwok Wong).

The precipitation for the Norwegian mainland changed to a mean of 1600 mm annually. It was found highest around more than 3500mm in the central parts of western Norway and was observed lowest in the valley of Gudbrandsdalen. However positive trends of precipitation were also observed in some regions. The observation of increase of precipitation Seasonally, for the Norwegian mainland, was recorded highest during spring with a rise of +27 % since 1900, and the least was 12 % in summer. The northern and western regions of Norway are likely to experience relatively more annual precipitation. According to the projections there will be an annual increase in number of days of heavy rainfall between 49% to 89% by end of the century. Most changes were recorded for the winter season. [35] [33] In future, infrastructure and buildings in Norway are likely to experience damages due to High intensity of rainfall. Western Norway supposedly showed the highest values of change for daily, monthly, and annual rainfall, the areas around the Oslo fjord also received much more rainfall than expected and along the south coast the highest intensities of rainfall during a few hours or shorter were recorded. The change of Both intensity and frequency along with an increase of short-term heavy rainfall has been documented in recent years (Førland et al., 2015). The projections for 2031-2060 and between 2071-2100 show that in Østlandet, Vestlandet and Nordland regions there is a likeability of a slight increase in runoff. However, a slight decrease is projected for Trøndelag. And for Sørlandet, Troms and Finnmark regions, only minor changes in annual runoff are expected. [33] [35]

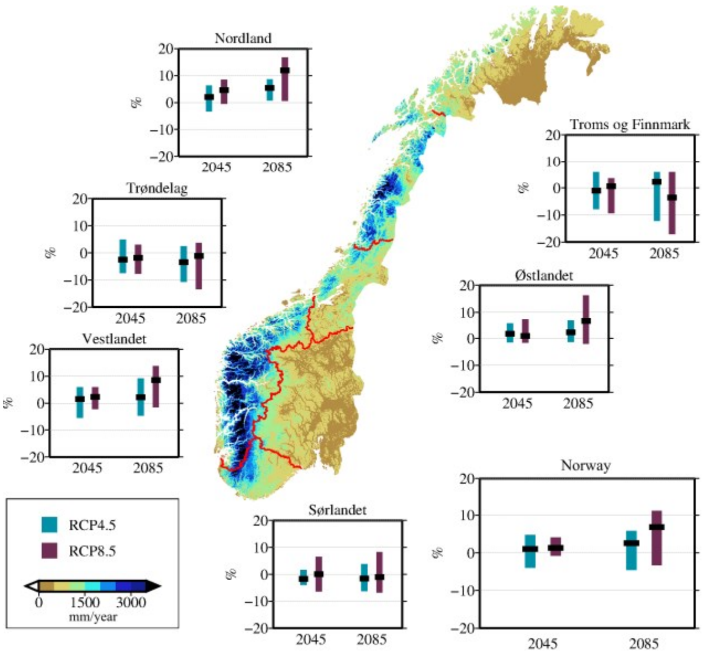


FIG 7:SHOWING RELATIVE CHANGES IN RUNOFF IN NORWAY USING RCP 4.5 AND RCP 8.5 FOR A WIDE RANGE OF YEARS (WAI KWOK WONG)

It was observed that there were relative percentage changes in annual runoff for different regions of Norway from 1971-2000 to 2031-2060 (2045) and 2071-2100 (2085) after reviewing them using different scenarios like RCP4.5 (blue) and RCP8.5 (red). Median projections are marked as a black solid line, while low (10th percentile) and high (90th percentile) projections are marked by the lower and upper ends of the boxes. The map in the middle shows the annual runoff (1971-2000) and the red lines indicate the regional boundaries.

The maximum amount of snow is likely for reduction by the end of the century; however, it is to increase in some high lying areas. The expected number of days for snow cover seems 1-7 months shorter than usual. In flat lands, at low altitudes where winter is very slight, is likely to not experience snow cover in future. [35]It was observed that the wind velocity increased over the years from 1961 to 2010 above the threshold. [36]

2.4 Factors Responsible for Climate change

Most life on earth depend on the influence of gases and surfaces on the planet, the surrounding spheres help and protect life on earth. All vegetation and life on earth depend mostly on the capacities of the surroundings and the gases which is commonly known as Greenhouse effect [37]

Urbanization

Urban Centers are seen to be some degrees warmer than the surrounding countryside. Even when compared with vegetated surfaces and building materials, it was noticed that it retains more solar energy during the day and have lower rates of radiant cooling during the night. Urban areas were also likely to have lower wind speeds, less convective heat losses, and less evapotranspiration, yielding more energy for surface warming. It was also studied that the use of artificial space heating, air conditioning, transportation, cooking, and industrial processes have introduced additional sources of heat into the urban canopy layer. [38]

Emissions

Emissions from the first decade of the millennium showed that there was an uncontrollable increase in use of energy for heating purposes, electricity, and transport mainly, which resulted in increase of Emissions. The reason of hiking up of emissions was also due to rapid industrialization particularly in some nations. This further escalated when around worlds half of the population was still dependent on fossil fuel economy and to some degrees still are dependent [39]. Along with the changing and growing of emissions emission scenarios were developed, which is inclusive of both national and global, emission scales. This was to identify and quantify the understanding of scale and rate of mitigation, impacts, and means of adaptation with the levels of climate change.

Emissions from most gases like methane and N2O and CO2 hold significance for Climate change and Co2 mostly contributes to about 75 percent of climate gas emissions while the other three gases together cover about 96 percent of the total emissions in Norway. And it has also been found that it includes the effect of changes in intermediate intensities in the decomposition. This is mostly dependent on, typically process-related emissions, such as methane and N2O, but also considering the changes in CO2 emissions related to industrial processes. Keeping in mind the two situations, regulations were made effective and ways to regulate the process emissions, like methane treatment and making agreements with the energy intensive industry and the authorities on processing emission reductions. [40]

Emission Scenarios: Emission Scenarios and Socio-economic scenarios are usually used for climate research, to get details and information about the future evolution in terms of parameters like socio- economic possible changes, technological changes, emissions of greenhouse gases, air pollutants and many such factors. These factors are considered as input for assessing possibilities of climate change impacts. Earlier many different scenarios have been already created for such type of assessments. One such example is the IS92 Scenario, and the other recent example is the SRES type called the Special Report on Emission Scenarios which also include scenarios for evaluation. But with time there was an increased need of new scenarios for running the developed generation of climate models. Therefore, IPCC had to finally request the scientific communities for development of some new sets of scenarios to meet the need for future assessment of climate change [41], [42]. And therefore, Development of RCPs came into existence. The main aim of this kind of a pathway was to dissipate information on changing and development of trajectories responsible as main factors to climate change and inclusive usage of climate models (CMs) and Integrated assessment models (IAMs). The naming itself suggests, the word representative in RCP, signifies that each of the RCPs represents a larger set of scenarios. And Concentration pathway means emphasizing that these are not the final new, fully integrated scenarios. There might be more modifications in the future and internally consisting of sets of projections of the components of radiative forcing that are used in subsequent phases. Concentration was used as word inclusive instead of emissions because concentrations are used as the primary product of the RCPs, designed as input to climate models. RCP models were created keeping in mind the development of CM (Climate models) and four pathways were created that lead to radiative forcing levels of 8.5, 6, 4.5 and 2.6 W/m2. And each RCP covered time duration from 1850s to 2100s, keeping the flexibility of extending to 2300. The RCPs were named according to radiative forcing of target level for 2100. The radiative forcing estimates are based on the forcing of greenhouse gases and other forcing agents. Possible future emissions were reduced to four pathways. And each of the pathways covered years from 1850-2100. It includes a single mitigation scenario which lead to a very low forcing level called the RCP 2.6, and other were, two medium stabilization scenarios namely RCP 4.5 and RCP 6 and the last one was a very high baseline emission scenario called RCP 8.5 [43].

RCP 2.6: It is considered the most ambitious pathway of all as it sees emission peak early and then considers fall due to active removal of atmospheric CO2. This pathway is also sometimes referred to as RCP3PD, it means representing the midcentury peak radiative forcing of almost 3W/ sqm followed by a decline in it. RCP 2.6 needs early inclusion from all main emitters, including those in developing countries.

RCP 4.5: This pathway is similar to the lowest emission scenario assessed in the IPCC AR4 and also to the other medium stabilization scenario RCP 6, the pathways stabilize total radiative forcing shortly after 2100 by the application of a range of technologies and strategies for reducing greenhouse gas emissions.

RCP 8.5: The 8.5 pathway was formed from the conception of little to no efforts to reduce emissions and represents a failure to curb warming by 2100. It is like the highest-emission scenario (A1FI) in the IPCC Fourth Assessment Report (AR4) [43] , [44].

Albedo

Albedo effect is dependent on the sun, as it is the measure of reflectivity of sun's energy back into space by the earth's surface. This is also an important effect to cool the earth's surface [45] .Any changes In the land surface can be affected by human activities and thus can affect the climate Land plays a vital role in it and so thus the atmosphere , it a phenomenon of heat exchange between the two , this can occur through vegetation or evapotranspiration from exposed surfaces , which in turn help to determine the state of the local atmosphere . Any change in vegetation or the earth can change the heat, moisture, and momentum, therefore will inversely affect the atmosphere and circulation [46]. Albedo effect can be different for different surfaces.

2.5 Buildings in Norway and their adaptability to the climate in current scenarios

The importance with climate change is that is to prepare buildings and infrastructure, and prepare society for the coming climate challenges, and for that many guides were suggested and developed. It will be very obvious that with climate changes there will be an increased climate stress on buildings and infrastructure. Climate adaptation is not only dependent on structures but also processes on technical concepts and solutions. It has been found that it is important to dissipate knowledge to stakeholders concerning decisions related to climate adaptation. There have been many services developed to help stakeholders in decision making and processes for adaptation that could be considered. These services have been providing products like data, maps, scenarios, documents, consultations, networking and much more to support in decision making for the changes to be experienced by the built environment in Norway in the future. However, there has been lack of proper coordination and cooperation between stakeholders, scientists, and users for these strategies to be adapted. [47]

Moreover, with climate change there will not only be increase of temperature but also other factors like precipitation and in future this might increase the cost and frequency of annual maintenance of buildings and is estimated to be from Nok 4.5 to 10 billion from 2070 to 2100.Analysis of empirical data has shown that the process itself have had defects that clearly illustrate the vulnerability of building envelopes under varying climatic exposure. From a Study in 2007, Norwegian municipalities expressed that Norway requires more knowledge on climate adaptation. There has been an active need for guides dealing with climate adaptation of buildings and infrastructure to avoid damages and frequent maintenance, which might increase cost [47] [48].

2.6 Issues of overheating in buildings

There is growing evidence of an increased incidence of overheating during warm weather in buildings without air-conditioning, especially homes in temperate climates where the retention of winter heat has been the principal focus of thermal design. But in future to be likely for even cold climates. Overheating has been particularly notable in new homes and in existing stocks. Excess heat affects the health and wellbeing of occupants, especially if sleep is degraded. In extremis, the heat stress caused can lead to premature mortality, especially amongst more vulnerable members of society. The problem came vividly to the fore during the devastating 2003 pan-European heat wave which caused 15,000 premature deaths. Overheating has been observed across Europe and in North America, but this issue is illustrative of the rising level of concern about overheating in many places with a comfortable climate in cold areas during summers currently. Domestic air-conditioning is very uncommon. But rather counterintuitively, the climate, together with the prevailing economic, political, and cultural context, do lay the foundation for the overheating problems. The traditional un-refurbished homes do not therefore retain heat well and so overheating has not historically been a concern. The construction industry is always concerned about reducing cost, increasing the speed of construction, and minimizing risk. Increasingly, therefore, dwellings are composed of standardized, performance-guaranteed components, delivered to site by road. Transport costs, site-handling considerations and resource efficiency mean that construction materials are becoming increasingly lightweight. Such usage led to compact dwellings, and walls made of thermally lightweight materials like, thin metal, wood, plastic, and plasterboard. Thus, they lack the thermal mass necessary to ameliorate the large temperature swings that could be caused by summertime internal and solar gains. In concern with good insulation standards, due to this lack of thermal mass renders, such buildings get more susceptible to summertime overheating. The tendency of urban apartments to overheat is further exacerbated by the inherently higher ambient temperatures in summer, and particularly summer nights, caused by the urban heat island, and the high internal heat gains.

It is extremely important to keep in mind the issues of overheating that might arise, alongside making the building perform better thermally. [49]

2.7 Thermal performance of buildings

Since more than 40% of the end-use energy and as much as 70% to 80% of electric energy consumption are caused by the building sector in different countries worldwide, energy-efficient buildings play an important role not only in local economies, but they also impact the global climate protection. Although buildings are the key driver of electricity demand, they can also be a part of the solution to peak demand issues, through special designs implementing high thermal performance envelopes, optimizing dynamic thermal response, as well as an application of thermal storage, new controls, and renewable power generation. Static and dynamic thermal processes in buildings and building components, together with associated thermal mass effects and thermal storage, play an equally important role in overall building energy efficiency, utilization of renewable energy sources and in energy demand management. Building enclosures, which include both fenestration and the opaque portions of the envelope, effectively control the influence of outdoor conditions on the interior environment, reducing the heating, cooling, and lighting requirements to maintain the desired indoor conditions. The above factors directly impact the corresponding energy use and its dynamics. It is becoming well-understood now that the current world population must significantly reduce the energy demand for operating buildings and then meet it with renewable energy sources to the greatest extent possible. According to the experts, to reduce energy consumption in buildings, two main actions can be implemented: 1) to manage the systems to assure an optimal operation during critical periods and 2) to improve the thermal performance of the building envelopes. Over the last decades, there have been abundant studies where the incorporation of different strategies for energy savings in buildings has been investigated. Solutions for different climates, urban layouts, type and use of buildings, envelope configurations and many more accounted, have been addressed and presented. In a comprehensive review, the main influencing factors for an efficient energy design of buildings were explored. Vital factors, such as occupant behaviour, equipment, and building characteristics, are identified as key features to attend. It was found that the energy-saving ranges vary from 10% to 28%, and they can be increased up to 71% with the use of smart control. Furthermore, a comprehensive comparison of the performance of insulation materials was carried out for building envelopes. As per studies, it was found that Low thermal resistance walls are presented as the more economically viable option for a region where the cooling demands are prevalent. On the other hand, for heating, it is highly encouraged that the buildings have a high thermal resistance. [50]

2.8 Thermal comfort

Human beings have always sleeked comfort and always modified their surroundings and adapted as per their comfort levels. Human have always had a high adaptability to changes. But however, at times this adaption has led to creation of artificial conditions. These artificial conditions have in turn led to reduction of a human being's adaptability and narrowed the limits of survival. [51]

Thermal comfort again depends on various factors, Air temperature being one of them and accounted the most important. Air temperature is calculated by DBT (Dry bulb temperature). It plays a role in determining the convective heat dissipation along with air movement, which results in reduction or increase of clothing of a person. Thermal comfort also depends on the age and gender of the people residing in a particular space. As per studies older people tend to have a narrow comfort range while women prefer a higher temperature than men for a space.

A building in general serves the purpose of providing an environment that is comfortable. A large amount of research has already been done into the subject of thermal comfort, and thermal comfort judgment mainly follows two very distinctive concepts of thermal comfort standard, one is laboratory-based methods and the other is deterministic stimulus-response standards famously known as the Fanger's PMV-PPD model (Fanger, 1970) [52] [53].

Thermal Discomfort can be caused by factors like unwanted heating or cooling of the body, radiant temperatures asymmetry, cold or warm surfaces, draught, vertical air temperature difference, cold and warm floors. However, with the changing climate changes in thermal comfort is also going to be a vulnerability. Thermal comfort in a space is also defined greatly by the insulations used in that space, the effect of insulation measures in a space has a lot of influence in decreasing or increasing of discomfort.

It was noticed that thermal comfort vulnerabilities are mostly relative to the ventilation system and functioning, also considering night ventilation measures mostly in bedrooms and the measures adopted and considered for insulation installations can have serious impacts on thermal comfort for future years as suggested by researchers. (Et al Ricardo Barbosa) [54].

2.9 Weather data

From age old times it has always been believed that a building or a shelter should fulfill three basic needs for a human being namely shelter from the external environment, comfort, and luxury. Most buildings have seen to have met the requirement of shelter and delight, but it should also fulfill the need for comfort. It has been observed that a normal human being spends most of his life inside buildings, almost around 80- 90%. So, having a comfortable and good internal condition is considered very much necessary. And these conditions are likely to effect health and productivity of the occupants. Local weather and climate have great effects on defining the construction typology and performance of a building. It has always been necessary to utilize good quality weather data for the analysis. Weather data should serve as an advantage to the designers for testing out stress onto building performance for atypical conditions which might be cold snaps or heat waves since these conditions really test out the building's performance and, on such occasions, mostly, they are exposed to performance failures.

European heat wave of 2003 was one such example, which resulted in many deaths. These occurrences of such conditions in future are not well predicted and it might be within 1 to another 250 years, which is very unknown [55] , [56]

Weather data is used by the building industry mostly to assess design and performance of the structure or the built environment during the planning stage. Using climate data has become more and more important over the years because climate change is going to increase the frequency of extreme weather events. Lately, dynamic building energy simulations were studied and built from the 1950s, but it did not develop well until the 1970s, only from the 1970s the scientific society realized the use of it for improvement of energy performance of a building or a space. Earlier weather data was an input that was applied to the software differently and in a very different format unlike today. But was always used in a standardized manner, using them as weather files. They were mostly used by the 3rd generation of dynamic building simulators. They were in forms of composed typical weather years, created usually by using hourly data from historical data recorded after observations.

But with time, the need for adaption of buildings and need for mitigation has created a necessity for incorporation of climate change projections into the weather files. This can be done by two ways, one by morphing and the other could be synthetical generation.

It has been observed that a typical building has a lifetime of around 60 years or more, therefore it has been very significant to observe the patterns of climate change. And necessary to include weather data with information of the future changes in the climatic conditions. (et al. Manuel Herrera) [56].

Considering the future climatic conditions and setting up the data in order to be used for the assessments, it is necessary to synthesize the data into categories of typical and extreme weather data sets. A typical weather data set is a composition of a typical year developed using a multiyear series, by selection of actual months for assembling to a single reference year, which is supposedly representative of the long-term typical weather conditions. However, this data can be further developed to nearly match the true frequencies by some statistical techniques. An example is the development of a reference year by the European technical standard EN ISO 15927-4:2005, termed as TRY_{EN} , the method that was used for composition of such a year of weather data was the Finkelstein-Schafer statistics [57] , [56]. This method can be used for composing a TRY or a TMY, a TRY is a test reference year developed and also considered the Danish method, but however international Organization for Standardization (ISO) established and considers a TMY for calculations. [58]

The Finkelstein-Schafer statistics is a statistical method that can applied for analyzing a year period data, generally around 20-30 years (eg:1975-2008) hourly measured data which might generally include global solar radiation, dry bulb temperature, precipitation, Relative humidity, and wind speed data for generation of a TMY file. This method is based on Comparing cumulative distribution function (CDF) of a single and reference data set and collecting data from the one closest to the long-term distribution [59], [26].

However, there has been different types years composed, according to the preference of one's objective and aim for the desired evaluation. Example of different composed years can be a TMY, a TRY, a TDY, ECY and EWY and many such more. However, composition of these different types of years are done differently. A TDY is a Typically downscaled year and different from a TMY, as a TDY is preferred to be prioritizing hourly values of the outdoor air temperature for its composition. Unlike, a TMY which also considers other climate parameters.

TRY: A Test reference year is a set of weather data assimilated and modified and was first developed and tested for 60 locations in the USA during 1976. But for 1976 the years considered for reference then were 1948 to 1975. When weather data sorting was done for those years, monthly extreme values were selected out until a single year remained with the least severe (or most average) weather conditions. TRY when was first developed contained parameters like dry bulb, wet bulb, and dew point temperatures, wind direction and speed, barometric pressure, relative humidity, cloud cover and type. However later, the methodology of creating a TRY was modified and was adapted worldwide. But again, it also depended on the creating institution responsible for the creation of the files.

TMY: A TMY is the Typical Meteorological Year and is another type of weather data set sorted and assimilated using the same method called the FS statistic method as the TRY, however a TMY files uses more input variables than the TRY files, extra variables considered for a TMY file could be minimum, maximum, and mean values of dry bulb temperature, dew point temperature and minimum and maximum of wind speed. TMY also includes an additional parameter of direct normal radiation [60], [56].

XMY: XMY is called the Extreme meteorological year dataset, which is an extension of the TMY type for a whole year. For its composition it uses the same type of variables and similar conditions as the composition of a TMY. It is created by choosing from the years that are considered for study, the extreme values are accounted instead of the averages. Months with the highest and lowest hourly average values are combined to form a year with the hottest summer and the coldest winter.

EWY and ECY: EWY is a year composed, called the Extreme warm year and ECY is called Extreme cold year, the composition of such a year is like that of a TDY (Typically downscaled year). However, instead of looking for the least absolute difference like in a TDY, for composition of a EWY or ECY. For an ECY the year with the maximum difference is considered and for an EWY the years with minimum difference are selected as the years representing the extreme temperatures for each month. While going through the values before selection of the years a real number considering temperature as a parameter is considered for the months and not necessarily a positive real number as in case of a TDY. [26]

There are also many other modelled data sets that can be considered apart from a TMY, TRY, ECY, EWY or XMY like TMY2, TMY 3, WYEC2 and many such more.

Along with composition of these files, the compositions might face challenges and limitations and are likely as stations are widely scattered and not exactly located on the site itself so there might be slight difference of observed data if not huge. Also, for extreme set data, the limitations might be of approximately predicting these extreme conditions, as these conditions might have a different frequency of occurrence then predicted and the time series considered for it might not fall into the timeframe of its frequency, if the frequency of the extreme event is from 50 to 100 years.

The Limitations are likely to arise from different factors when the subject comes to future data, which is a probable data synthesis done. Factors might include limits of human knowledge, limitations in the models used itself but being aware of them and utilizing them at utmost to produce accuracy is the subject.

Climate models are considered important for deeper understating of current and future climate, they can produce quantitative and qualitative data of the future climate, though they are highly capable, they tend to remain mere models and they might face challenges in portraying the climate and accurately collecting and portraying each important process that might affect climate. There might be several uncertainty factors. The magnitude of these variations depends on the uncertainty factor, which for GCMs climate uncertainties can cause variations up to 13% in the calculated 30-year average of water content and 28% in its standard deviation [33], [65].

There might be also uncertainties based on the amount of human knowledge, many scientists are known to also possess incomplete knowledge of the exact variations likely of the different atmospheric, land surfaces, oceanic and ice components, and its interactions. If not any but there is always a possibility of the great challenge that comes with the study of the vast and complex relationship between the atmosphere and the elements of it [65].

3.Sustainable positive energy neighborhood at Frederikstad

The sustainable plus energy neighborhood is called Verksbyen and comprises of many different clusters of structures and one of them is Panorama. All the apartments of the neighborhood are 5 to 6 floor high. Panorama comprises of a total area of 1775 sqm, while Atrium has an area of 2779 sqm. Its construction started in fall of 2021 and have targets of finishing by 2023. According to synikia the ambition levels are targeted for plus energy.

3.1 Site Analysis

The case study chosen for analysis is an apartment building in the SPEN neighborhood, situated in Fredrikstad, Norway. It is one among the multiple neighborhoods under Synikia. It is a town located almost about 90 km south of Oslo. Fredrikstad is under the municipality of Viken currently. Fredrikstad has always been known for Initiation in environmental policies and its active participation from the early 1990s. It has continued actively to take action for climate change. The municipality of Fredrikstad also plays a vital role for finding ways for assessing impacts of climate change, focusing on implementation and adaption of measures to mitigate with it. Fredrikstad also previously carried out extensive vulnerability assessments for knowing ways of adaptation and measures that will be a necessity [61].

Verksbyen in Fredrikstad comprises of more than 1500 dwellings, a kindergarten, a school, and some commercial buildings. There are different clusters of these structures which have been under construction with phases. Namely Panorama, Atrium and Verksbakken. The cluster chosen for study was Panorama, which comprises of 60 apartments alone. And amongst those apartments a residential building comprising of 6 floors, named as the K type was chosen for the intensive analysis.

FIG 8: IMAGE OF NEW DEVELOPEMENT AT FREDRIKSTAD (ARCA NOVA)

3.2 Plan and material Analysis

The building studied for this was amongst the K types named by the company dealing with the constructions. It is a residential unit from the cluster type called Panorama. The building is of 6 storeys with a basement connected to the adjacent building, which is also a similar type.

The orientation of the building is in the northeast-southwest direction The building is accessible through an entrance on the ground floor from the northeastern direction. Also, it is accessible from the basement through a flight of stairs and an elevator connecting the basement to the floors above. Each floor of the building consists of different sizes of apartments. Each floor comprises of 4 apartments, along with a balcony. The first floor above the basement also has 4 apartments tagged as H0104 K, H0101 K, H0102 K and H0103K each with sizes 74.6 sqm, 45.7 sqm, 106.2 sqm and 87.4 sqm respectively. The names of the apartments above have been given accordingly as per the floor goes. For the second floor the sizes and plans of the apartments were different then the first floor but were typical until the 5th floor. The apartment above H0104 in the first-floor changes in size to 64.7 sqm on the second floor, while rest remains the same. The 6th floor only comprises of two studio apartments on the northeastern side, while rest of the floor is open to the roof. Each studio apartment tagged as H0502 and H0501 is of 76.4sqm and 81.2 sqm respectively in sizes.

FIG 9:SHOWING FIRST FLOOR PLAN (ARCA NOVA)

FIG 10: SHOWING 6TH FLOOR PLAN (ARCA NOVA)

Materials for the structure was carefully chosen before implementation into actual construction. Materials were used in the envelope to provide good insulation and good thermal environment inside the structure, along with taking care of control of emissions during implementation and construction. It was done focusing on achievement of the ambition levels. The whole structure was mostly wooden based construction. The floors were mostly prefabricated Elements, assembled on site. There was also use of several recycled materials. A SPEN is usually developed targeting optimal usage of advanced materials, using local renewable energy sources, local storage, smart energy grids, demand response, energy management, user interaction involvement, and ICT.

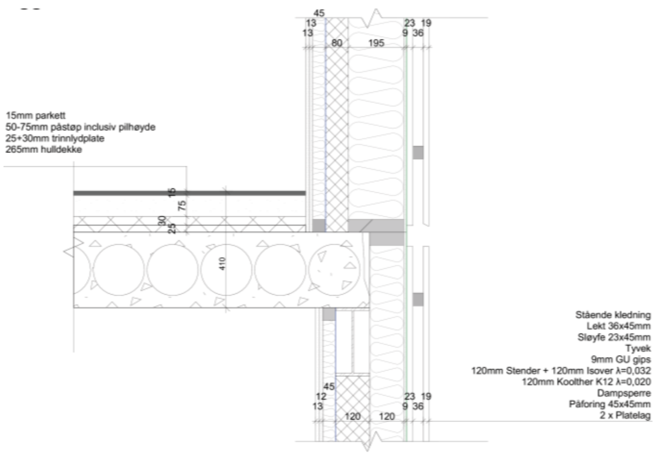


FIG 11: SHOWING WALL AND FLOOR DETAILS (ARCA NOVA)

3.3 Theoretical Modelling and consideration of thresholds

Calculation of degree days is considered extremely important as higher levels of insulation are used in buildings and building s are becoming more and more airtight which can at some point lead to imbalance of temperature. There are several methods to however find out the degree days both cooling and heating, but most evidently used one is the Thom's method.

It is considered a very important tool for assessing the energy demand and consumption likely for building. Therefore, the heating degree days and the cooling degree days were calculated using the following formulas. And the degree days were calculated for all scenarios and all years. After the calculation, they were compared to check the range of deviation.

$$\text{HDD} = (1DAY)\sum_{DAYS}(\text{Tb} - \text{Tm}) \longrightarrow 1$$

$$\text{CDD} = (1DAY)\sum_{DAYS}(\text{Tb} - \text{Tm}) \longrightarrow 2$$

Here , HDD is heating degree days and CDD is the cooling degree days , T_b is the base temperature and T_m is the outdoor air temperature at a particular day.

Overheating is a case that was selected for study along with cooling demand analysis, but for overheating analysis there are different methods to go forth. One such method is by using the overheating indicator. But after looking into the usage of the indicator, it was noted that as overheating is to be assessed based on thermal zones, which are again based upon factors like zoning and a zone might also include varied thermal properties therefore it is likely that the indicator might misjudge all the factors of overheating necessary to be assessed. The threshold for an overheated scenario was considered above the temperatures of 26 degrees as per the standards. [62]

4.Climate Data

Future climate scenarios are usually generated using GCMs, they are usually the most complex and fundamental method of climate change models which were developed by meteorologists. This method developed considers all parameters including transfer mechanisms between a three dimensional turbulent and radiation-active atmosphere and spatially heterogeneous land, ocean, and cryosphere surfaces, based on the different models of it. Running and analyzing GCMs also requires numerical iteration so sometimes they are only limited to metrological specialist [63]. Climate projections have shown changes in frequency and magnitude of extreme events. RCMs (Regional Climate models) are usually also used, which are derived from the GCMs by dynamic downscaling and these data sets can be preferred as they have an advantage of generation of physically consistent data sets across different variables. RCMs can be directly preferred for building and energy simulations as they provide weather data with suitable temporal (15 minutes) and spatial resolutions almost closer to 2.5 sq.km of a region.

For weather simulation and consideration of a Year, be it a EWY, ECY or a TMY it has been extremely important and recommended to consider time span of at least 20 to 30 years, since relying on short time spans can cause errors specially when dealing with future climate Scenarios.

However, these Synthesizing might face different Uncertainties which might affect the simulated climate data, these uncertainties might occur while selecting GCMs, RCMs, Emission Scenarios, and spatial resolution. Dealing with large data sets has not always been easy and might produce uncertainties, however, to get a proper impact assessment it is important to consider several scenarios but at the same time it creates a challenge.

There have been different ways of building up these climate data sets known as EWY, ECY and TMY, which are also referred as synthesized data sets, but sorting data for a TMY is different from a ECY or a EWY. But all these types require selection of each month to assemble in a single year, representing the long-term year. [26]

A TMY is composition of typical months which are derived using comparing the cumulative

distribution function (CDF) of the single and reference (or long-term) data sets and finding the one closest to the long-term distribution. The method is based on the Finkelstein-Schafer statistics, but to compose a EWY or a ECY statistically non-representative months warmer in the summer and colder in the winter (with daily dry bulb temperature and global irritation

higher in summer or lower in winter than the long-term averages respectively [26] [57].

4.1 Climate Model and Scenarios used (Data collected)

For this Study, weather data used was of two types, one was a future climate data set and the other one was a past climate dataset. The past dataset consisted of historical data and in place measurements taken from a weather station located nearby the area to be examined, namely Fredrikstad and the weather station was located at Sarpsborg, which is around 13.3 Km from the real site of study. This collection of data from the station nearby led to the built up of a standard TMY file, which was later used, compared, and modified for future climate references.

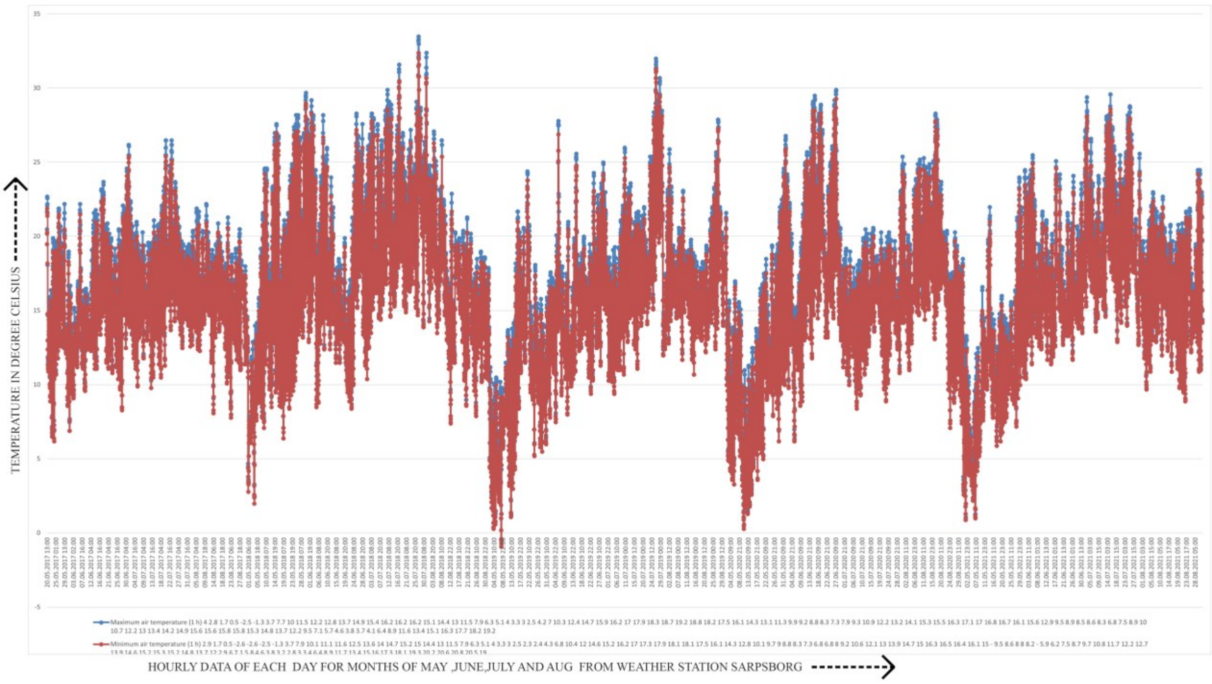


FIG 12: SHOWING HISTORICAL HOURLY DATA OF EACH DAY FOR FOUR YEARS, 2017 TO 2020

Future data for this study was generated using climate data from RCA a regional climate model (RCM) by means of dynamic downscaling from GCMs, which were again based upon two representative concentration pathways (RCPs), namely RCP 4.5 and RCP 8.5.

In this case many GCMs were considered, models like CNRM-CCLM, CNRM-RCA, EC-EARTH-CCLM, EC-EARTH-HIRHAM, EC-EARTH-RACMO, EC-EARTH-RCA and HADGEM-RCA were considered for study, however it was only focused on EC-EARTH models called EC-EARTH-RCA, which were again based on RCP 4.5 and RCP 8.5.

The EC- EARTH model used here, was originally developed by several European national weather services. An EC-EARTH model has a prime advantage of usage over other models as the operational infrastructure allows an enormous number of observations to be assimilated into the model and its behavior can be verified against observations from the daily and seasonal to decadal timescales (et al V. Nik, [26]), [64].

In total of 2 Scenarios were studied, with consideration of years 2024, 2060 and 2080. 2024 was taken into account as the starting of the operational year of the accounted building in the neighborhood, 2060 as the Mid-year of operation and 2080 as the end year or end of the life cycle of the building, to check on the functioning of the building into the future climatic situations as the building will still be operational in those years. However, for accounting those years, minimum of 20 – 30 years had to be considered as reference years therefore, for 2024, reference years studied were 2010-2040, for 2060, the reference years were 2041-2075 and for 2080, the years were 2076-2097.

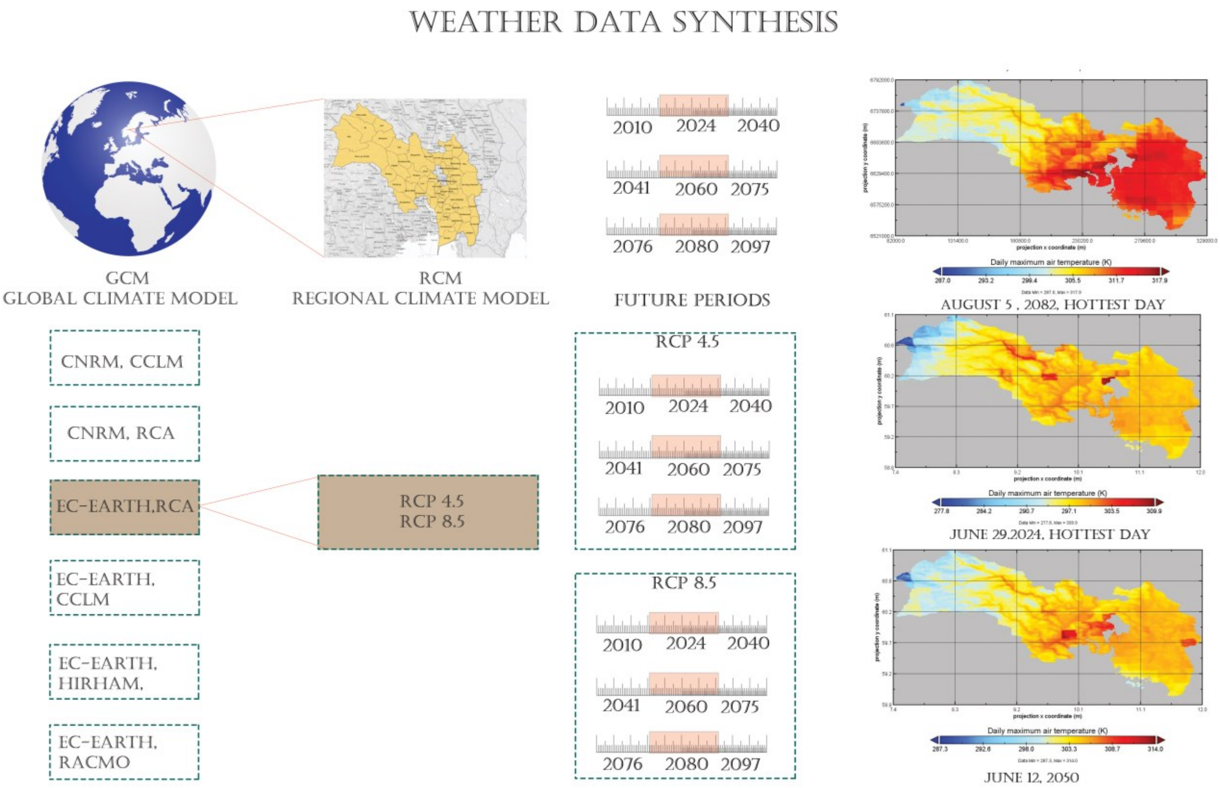


FIG 13:SHOWING FLOW DIAGRAM OF COLLECTION OF WEATHER DATA AND SORTING OUT OF THE WEATHER DATA

This analysis results in collection of data for 90 years, with two different scenarios for each set of years. The RCM data sets collected and analyzed are synthesized and was derived from a database software created by NCCS (Norwegian Centre for Climate Services), designed specifically for collection of future data using different models and difference scenarios, which later can be used to compute the weather indices of interest.

4.2 Climate data synthesis (Data sorted)

The collection of data of the years was done and these datasets of future years were dynamically downscaled to the regional scale using the Coordinated Regional Climate Downscaling Experiment (CORDEX).

After the collection of data from a downscaled dataset and collecting it with years in reference almost 20-30 years forced into Scenarios of RCP 4.5 and RCP 8.5 respectively, Extreme candidate months were chosen into an EY (Extreme year) for analysis with extreme scenarios that could be possible, specifically concentrating on cooling demand rise and overheating issues. These were again chosen based upon a main weather parameter that is air temperature.

However, it has always been recommended to use air temperature as a parameter to select as not all climate parameters get effected by climate change equally and these parameters do not show as much of as of the same strength for all the climatic parameters. Climate change indications have always been higher through parameters like temperature and rain precipitation, but indication of change has been lesser through wind and solar radiation. This in a way effect the process of selecting a month and weighting the climatic parameters for it. There has always been difficulty of considering all climatic parameters when considering more climate scenarios as it increases the size of evaluation of these datasets and at times be tedious. But it is clearly known that uncertainties of future climate has effects on each parameter separately , as stated as example if taken two scenarios ,one may be showing 30% difference of 30-year mean value temperatures but for the same two scenarios, the difference for wind data can only be 10% , therefore it has been almost to impossible to exactly know the correct weighting factors for each parameter and know the differences specially while using RCMs(et al Nik) [26].

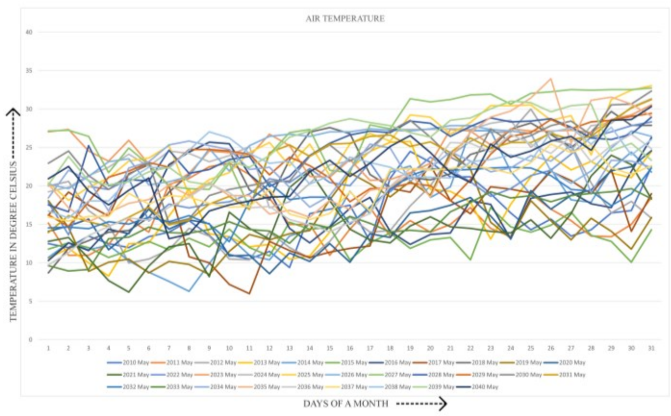


FIG 14:COMPARISON OF AIR TEMPERATURE DATA FOR THE MONTH OF MAY FOR 2010 TO 2040

5.Building Modelling and Simulation

The building body was created using Revit, a software that is based upon Building information modelling (BIM) and it makes evaluation, representation, and documentation much easier, Basically, it helps in the whole process of its life cycle. After, creation of the detailed model in Revit inserting all desired materials for all the elements used. The file was converted to an IFC model which can later be loaded into IDA ICE for simulations, but before loading of the IFC model, the model was reverified, validated and made almost precise by using Simple BIM, which is a software not generally used for model authorization but to validate, it is a software to enrich and standardize IFC models [65] [66]. After careful speculation of the model and re-adjusting for precision the IFC model was finally loaded into IDA ICE for further Build up and finally using it for the desired simulations.

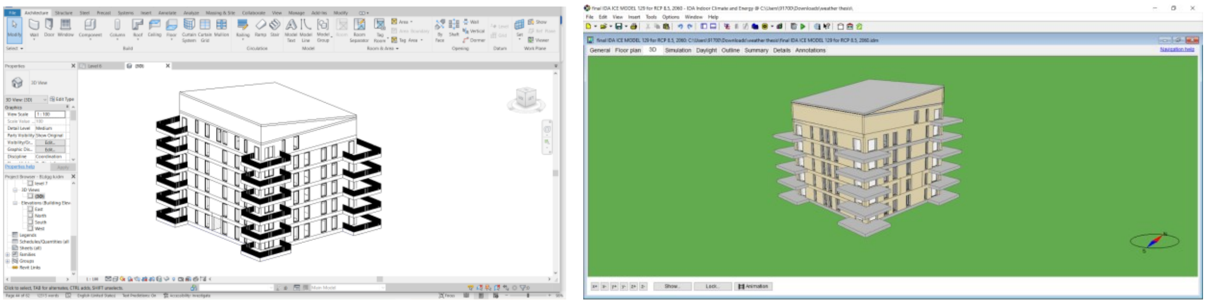


FIG 15:SHOWING MODELLING OF THE RESIDENTIAL BUILDING IN REVIT AND THEN AFTER VERIFICATION IMPORTING TO IDA ICE

5.1 IDA ICE

The IFC model after uploading into IDA ICE was further worked upon and developed into multiple zones which were created for all the spaces, desired for inspection and results in terms of indoor climate analysis and Climate change adaption of the spaces and BEP systems within the building.

IDA Indoor Climate and energy (IDA ICE) is a software which a dynamic multi zone simulation program, which can be used for examination of the thermal indoor climate and energy consumption by the building. It is a software built up by EQUA simulations AB (Equa Simulation AB, 2014). IDA ICE mostly functions with enormous number of values which goes into the model. But, at the same time it also provides ample amount of information and overview of the model, through spreadsheets and visualization.

5.1 Input parameters

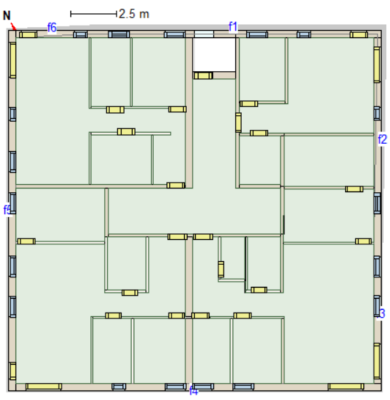
5.1.1Climate data

Climate data is one of the most important inputs for the analysis carried out. It plays a key role in generation of impact assessment of future climate on the energy systems of the building in the SPEN. Both historical and future climate datasets were collected, Historical ones were collected from the most nearby weather station while the future datasets were collected from a database created by NCCS, from where data can be derived using preferred Future model of GCM and RCM through RCPs. The main climate data was focused upon was Air temperature, but also relative humidity, wind speed, wind direction and solar radiation were considered. The future datasets were further Synthesized and sorted according to requirement of the aim to analyze the cooling demands and overheating issues likely to be in the future.

The datasets were then converted into EPW files, which are Weather data files saved in the standard Energy Plus format. These types of files are also supported for weather input into IDA ICE. Therefore, the above format was used for analysis of the residential Building at Fredrikstad with future climate data.

5.2.3 Zoning

Zones were created using each of the spaces of the residential building and was kept simplified for optimization of the simulation time, but at the same time, there was a necessity felt for simulation of all the different rooms of a single apartment as the different rooms were variedly occupied during certain times of the day and a residential building can be considered a space in use at almost all times of a day. The apartments were facing different directions and located differently at different floors, therefore for overheating analysis of each of the space and for observation of the changes in pattern of overheating with location of these spaces, each space was considered a different zone.



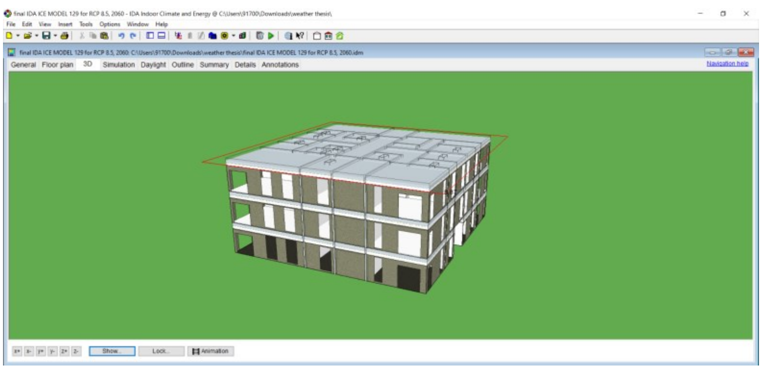


FIG 16:SHOWING ZONES CONSIDERED FOR SIMULATION IN IDA ICE

5.2.4 Building Geometry

For the accurate fulfillment of analyzing results, building geometry plays an important role as an input parameter and moreover, IDA ICE is also a geometric based simulation therefore, the building geometry requires to be as accurate as possible.

The Residential structure at Fredrikstad was modelled into IDA ICE with details received from actual planned construction under Arca Nova Group. It was modelled as a building with 6 floors. The dimensions used were as per the details received, each floor was 19.26 m x 19.9 m. Floor to floor height was kept 3 m. The model had window sizes of 2.19 m x 1.09 m, 2.19m x 0.69 m, 2.19m x 2.29m and 2.19m x 2.69m considering all facades.

5.2.5 Technical Data Input

Technical data input is very crucial, especially inclusion of the thermal transmittance coefficient (U -value), as it is regarded as a very important parameter for energy performance simulations. However, constructions will have different performances after a long period of exposure to climate. (et. al Mohammad Hosseini) [67]. Measurements are also likely to be sensitive for U values and its input into the model, as they tend to define the indoor thermal comfort.

U values were considered as per the standards and as per the information shared from real site by Arca Nova Group. U values are very important for the calculations and analysis of the issue targeted. They are dependent on the material properties of the installations decided for the building.

Type of Element	Material Used	U value
Exterior Walls	Lekt 36 x 45mm Sløyfe 23 x 45mm GU gips 9mm Stender 120mm Isover 120 mm , λ=0,032 Koolther K12, λ=0.020 Dampsperre-påforing 45x45mm	<0.12(Passive-house standard)

	Platelag x 2	
Floor Slabs	Parkett 15mm Parkett underlag 5mm Påstøp 100mm EPS 200mm Lettklinker-Hulldekke 450mm	<0.08(Passive-House standard)
Roof		0.09
Windows		0.8
Infiltration Rate		0.5-0.6

Table 1: Showing details of materials used for the structure and their U values

The technical installations consisted of the plant model and the ventilation system involved, as per the information provided by the company involved with construction of the neighborhood, the systems included a separate ventilation system aggregate for each of the apartments, Hydronic floor heating, Ground source heat pump for thermal energy inclusive into the plant and PVs on the roof. The building is supported by Bore hole system for energy supply and store, the bore hole system is connected to the GSHP, which makes it already very energy efficient. The bore holes are considered to a depth of 60 meters. Currently there are no cooling devices involved into the model and on site as the cooling demand has been negligible to none. The model has been built flexible in terms of user behavior considering operable windows when temperatures were beyond the current set point temperatures of 25 degree Celsius, to provide natural cooling into the zones when required and number of occupants were considered almost precociously considering size of the apartment with 4 persons residing in a single one. These considerations were made to give a more realistic approach while running simulations and analyzing the demands in future, changes that might come into existence and adaptation of these changes by the building and its systems.

Parameter	Residential Building (K type)
Conditioned floor (Sqm)	1874.6
Ventilation per Person (l/s)	5
Ventilation Per area (l/s)	2
People per area (p/sqm)	0.02
ACH	0.5
Heating set point temperature (present conditions)	21
Cooling set point temperature (present conditions)	25
Heating set point temperature (future conditions)	21
Cooling set point temperature (future conditions)	27

Table 2: Showing details of input data used in the model for running of simulations

5.2.6 Building Properties

The balance of energy and demands are mostly factors dependent on the components of the building. They are greatly affected by the indoor and outdoor conditions and mostly temperature. As difference in condition from outside to inside may result in condensation issues. Conditions are mostly controlled by theories of conduction, convection, infiltration, evaporation, and radiations. The Envelope, the HVAC, the plant, basically the systems installed are to control the indoor environment that serves the purpose to make the indoors comfortable.

5.2.7 Simulations

Simulations are very much necessary to measure the impact of climate change and future climate on the building systems in order to maintain thermal Comfort. After the assimilation of data and inputs into the model as per described, the building was simulated with building configurations as a constant parameter and the climate files as variable inputs to test the different timeframes and scenarios considered.

The following type of climate data was placed as an input variable for the comparison of changes in demand with future climatic conditions:

Typical sets of data from the nearest station called Sarpsborg (13.3 km in distance) was collected from NCCS database service (Norsk Klimaservicesenter (met.no)), which was then formed to a TMY file, and then used as an EPW for input, accepted for usage by IDA ICE.

Data was also collected for future climate years for the area, using GCMs and RCMs as standard models. The data was collected from the database service set up by NCCS and NVE collectively(Norwegian Climate Service Centre - Download (nve.no))which allowed collection of data using verified Climate models that has been synthesized using CORDEX and had the flexibility of choice of the models to be chosen, which can be categorized further using RCPs (Scenarios) according to the desired analysis to be looked at.

Further the data collected was sorted and analyzed for making the relevant years, which could be considered a EY, after looking into the data of the respective years to be evaluated and composing them by analyzing 20-30 years of reference and each month of those reference years, evaluating the extreme months that could be considered for analyzing an extreme case condition for studying the building with future climate data and possible extreme situations.

The building modelled was then simulated with each of the weather years composed separately for the scenarios considered, the sorted weather data was assimilated into EPW files for the purpose of simulations. Finally, the simulations were looked for mostly change of cooling demands and issues of possible overheating for future, keeping in mind the change of temperature trends.

6.Results and Discussion

This section describes the likeability of performance of a building in critical situations that might arise in future due to extreme conditions that might occur. The structure being tested with downscaled data sorted into extreme months to produce an extreme conditioned year. Since the focus was mainly kept around the change of cooling loads and probability of occurrences of overheating scenarios, it discusses the changes and quantifies the effects in terms of the climatic changes.

6.1 Future weather conditions

Future climate was built on using the database provided by NVE for future climate using verified climate models of GCMs downscaled using CORDEX into RCMs that could be observed using the scenarios namely RCP4.5 and RCP8.5, here the climate model chosen for observations was EC-EARTH , RCA and forced into Both scenarios of RCP 4.5 and RCP8.5 , RCP 4.5 was chosen to see the medium range of change and RCP8.5 was chosen believing in the extreme case scenario and the possibilities it could possess for new adaptation of techniques that could be a necessity in such a condition. After the data was collected it was further sorted for extreme months to build a year with likeability of extreme condition. The temperature distribution can be as shown in Fig.

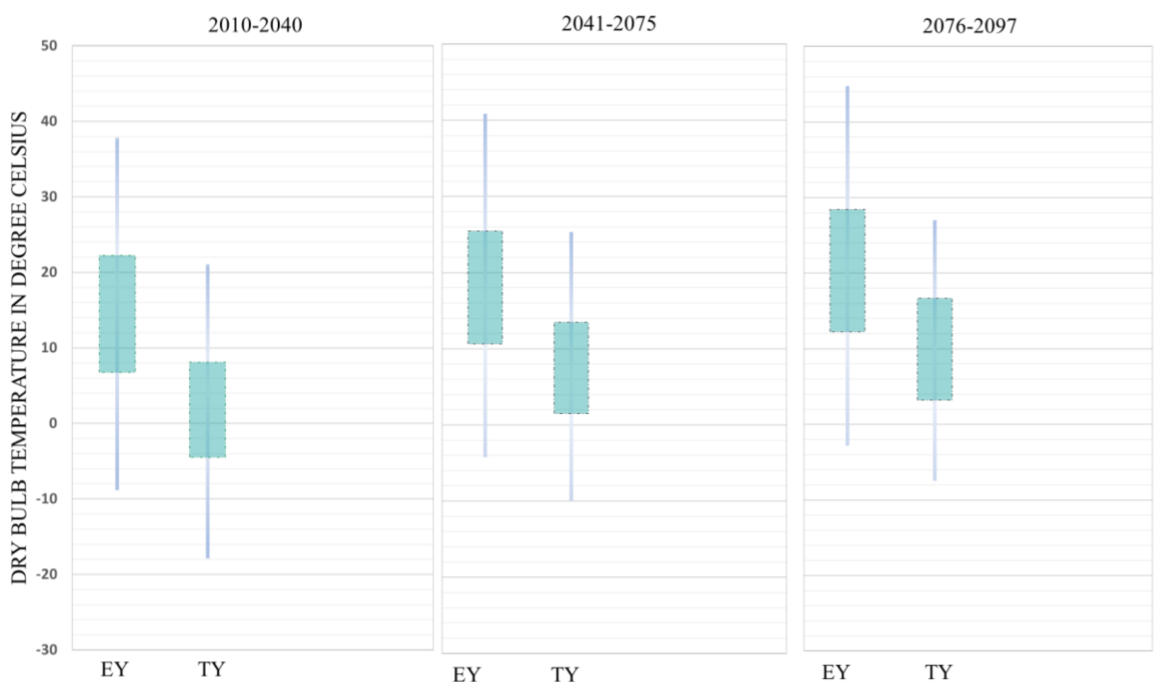


FIG 17;SHWOING TRENDS OF CHANGE IN DRY BULB TEMPERATURE WITH CONSIDERATION OF AN EXTREME YEAR TO A TYPICAL YEAR

6.2 Changes in CDD and HDD

Simultaneously Cooling and heating degree days were also studied to know the number of days of cooling and heating for 120 years and compare the deviations it possesses with change of scenarios and progression of years.

Theoretical modelling was used for calculation of HDD and CDD and the calculations were based upon Equation 1 and Equation 2 mentioned previously.

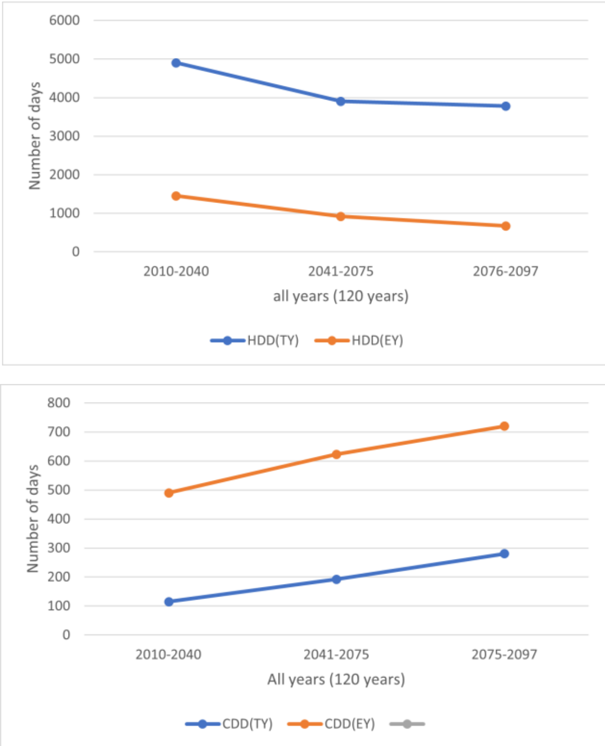


FIG 18:SHWOING PERCENTAGE TRENDS IN VARIATION OF HEATING DEGREE DAYS AND COOLING DEGREE DAYS WITH YEARS 2010 TO 2040, 2041 TO 2075 AND 2076 TO 2097

It was observed that there was a 30% deviation from an extreme year to a typical year. For Heating degree days, it almost remained constant or slight decrease was observed over the period of 120 years. This likely says that there will be decrease of demand for heating by almost 40%. Similarly, CDD analysis interprets that there will be increase of cooling degree days in another 120 years by around 25-31 %.

6.3Cooling demand analysis

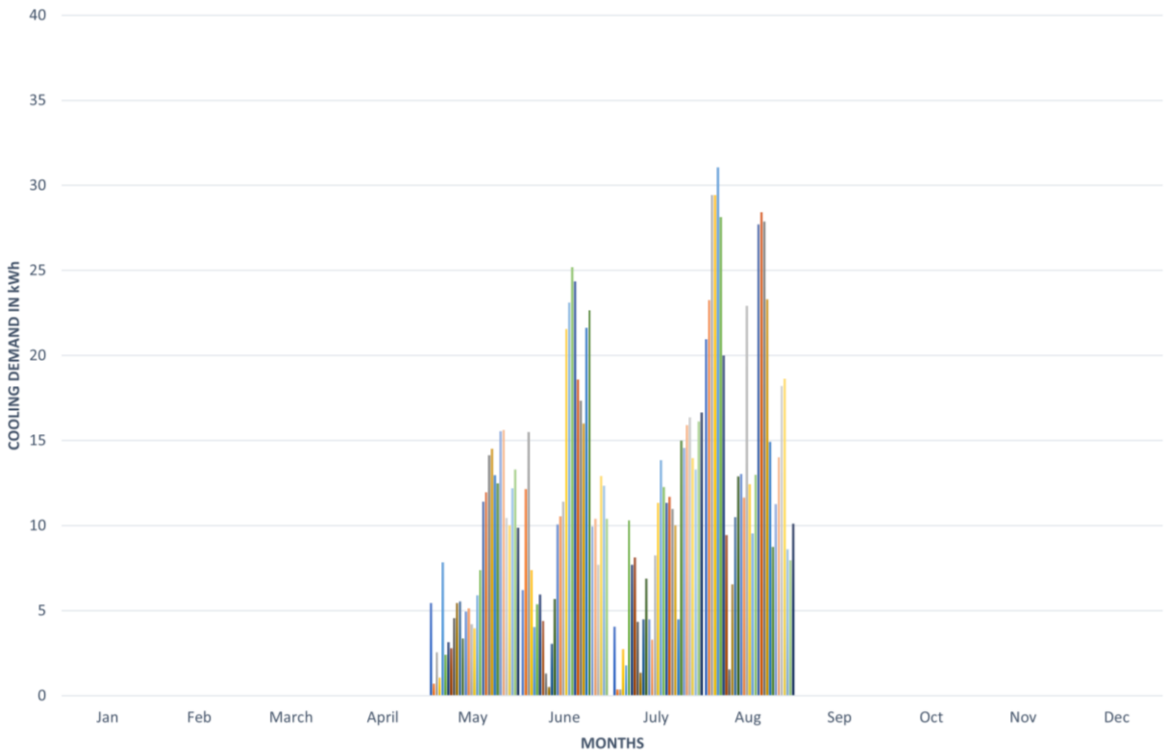


FIG 19:SHOWING HOURLY AVERAGE COOLING DEMAND OF EACH DAY FOR THE SUMMER PERIOD USING RCP 4.5 FOR THE YEARS WITHIN 2010 TO 2040 IN KWH

The graph above explains the cooling demand likely to be for the year 2024, considering years of reference 2010-2040.The cooling demand is indicating a rise from the current years or previous years showing that with increase of change in climatic conditions there is a possibility of change of cooling demands. By the beginning of the month of August there is a rise in peak cooling demand but however towards the mid of August it starts to decline again. However, when compared with the graph below it shows the scenario of cooling demand rise with possible extreme situation arousal, in that case all months are likely of having higher cooling demand then the previous scenario listed in the above graph. And the cooling demand is likely to hit peaks during mid of July.

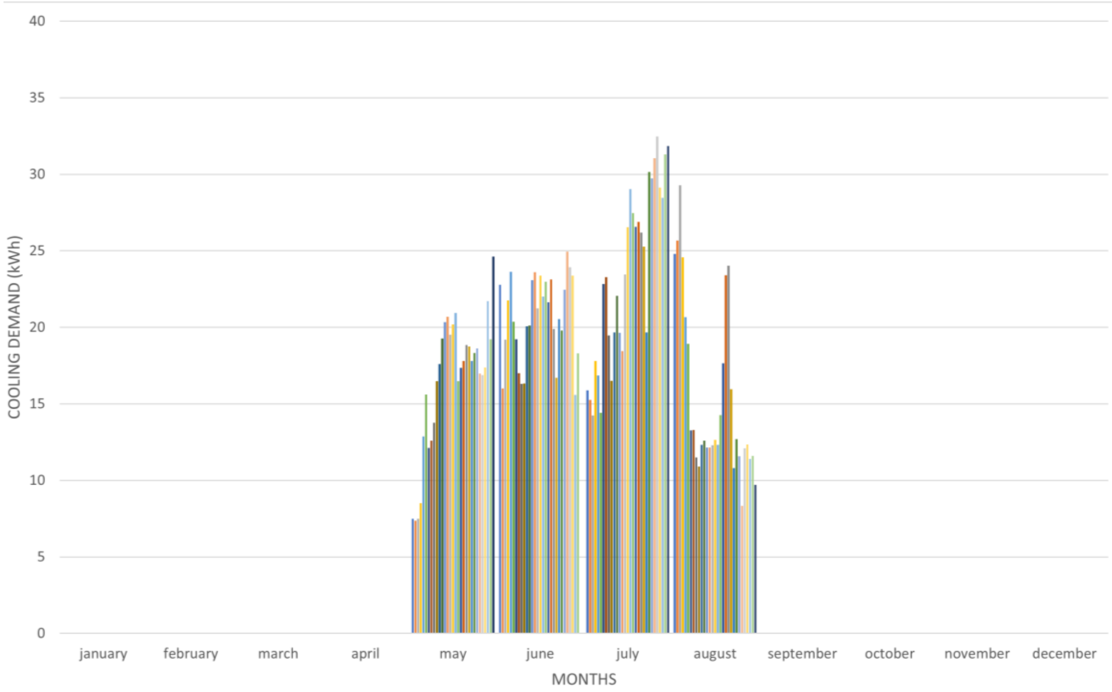


FIG 20:SHOWING HOURLY AVERAGE COOLING DEMAND FOR EACH DAY OF THE SUMMER PERIOD FOR THE YEARS 2010 TO 2040 USING RCP 8.5 IN KWH

Graph indicating medium range scenarios likely for 2060, considering reference years of 2041 to 2075 has shown that Cooling demand will be on rise and will increase within 10-15 % for the entire period of summer, when compared to the years of 2010-2040. The case scenario expresses that the peak load for cooling demand will be likely during mid of June and would be a consistent peak and gradually decrease towards the end of the month.

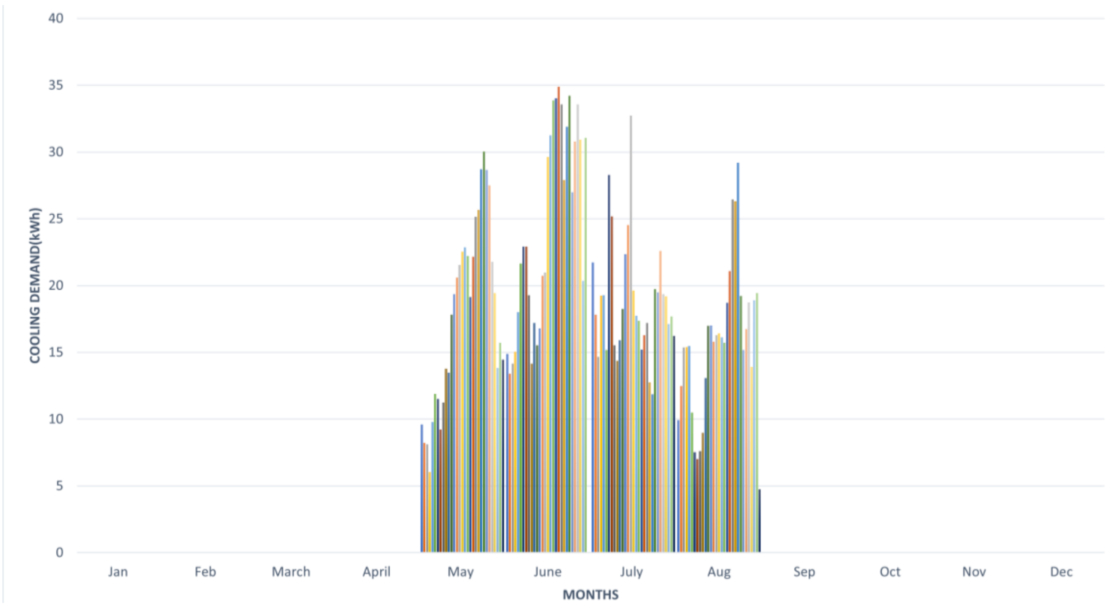


FIG 21:SHOWING HOURLY AVERAGE COOLING DEMAND FOR EACH DAY OF THE SUMMER PERIOD IN 2041-2075 USING RCP 4.5 IN KWH.

The graph of 2060 with the highest possibility case scenario of change, indicates a rise of the cooling demand of 9-10% for all months compared to the intermediate scenario of 2060. It portrays a possibility of hitting peak demands at the least for an accounted day or two for almost in all months of the summer period.

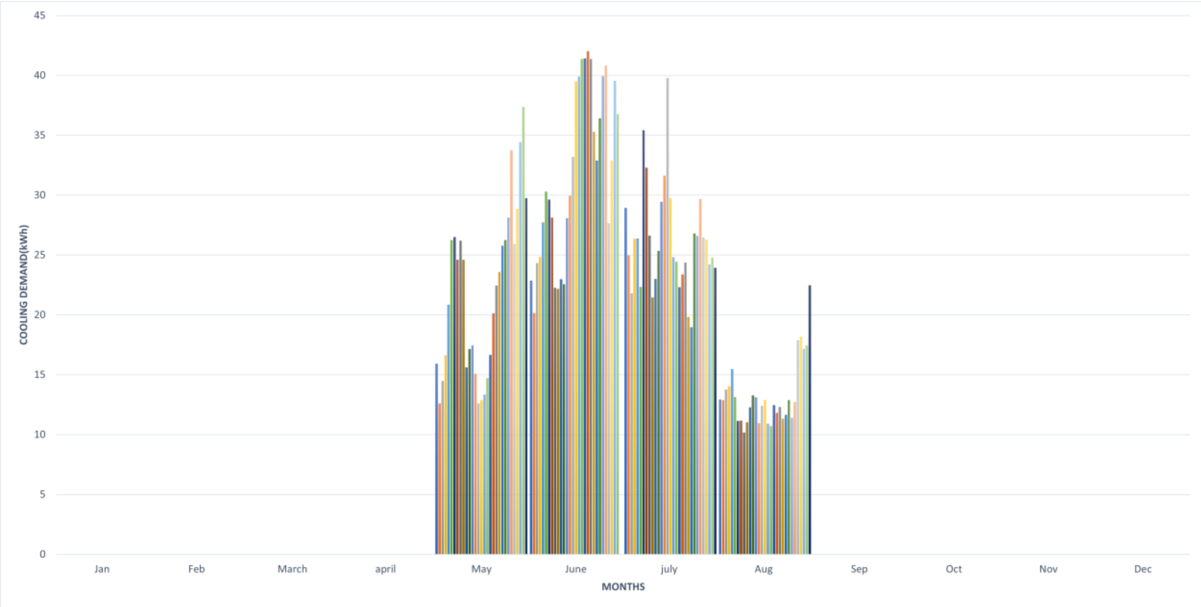


FIG 22:SHOWING HOURLY AVERAGE COOLING DEMAND IN KWH FOR EACH DAY OF THE SUMMER PERIOD OF 2041-2075, USING RCP 8.5

The results in graph are an extension of the results of the above graphs, indicating the peak hours of a day of the month specifically with the possibility of having the highest cooling demand in the whole period of summer.

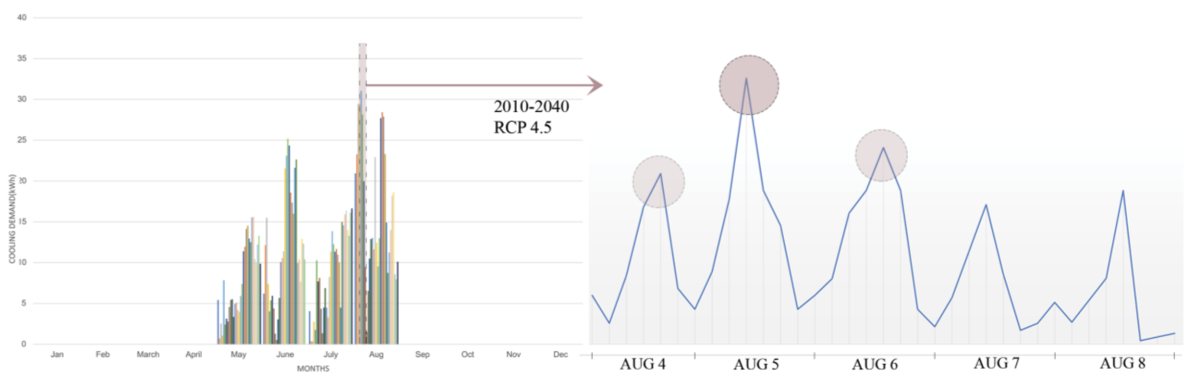


FIG 23:SHOWING TREND OF HOURLY DATA FOR THE DAY WITH THE HIGHEST COOLING LOAD IN THE ENTIRE SUMMER PERIOD OF 2010 TO 2040 USING RCP 4.5 , TO SHOW PEAK LOAD HOURS

The graph shows assessment of the hours of peak demand in the whole year, which occurs during the month of Aug for the estimated years within 2010-2040. It catches a peak after rising gradually to around 14% from the other months demands and reducing again from that to 2% and then below. However, when compared to the graph, it signifies peak hourly demands in the end of June and increasing to about 5% when compared to the peak demand days of the previous years in Fig considering intermediate pathway for the years within 2041 to 2075. Also, the pattern of both graphs suggests that with the passing of years, it is likely that the peak demand periods will advance to the earlier months. In this case it has advanced from August to June. The peak demand conditions are likely to remain in repetition until the end of the summer period when compared to the earlier years before 2040.

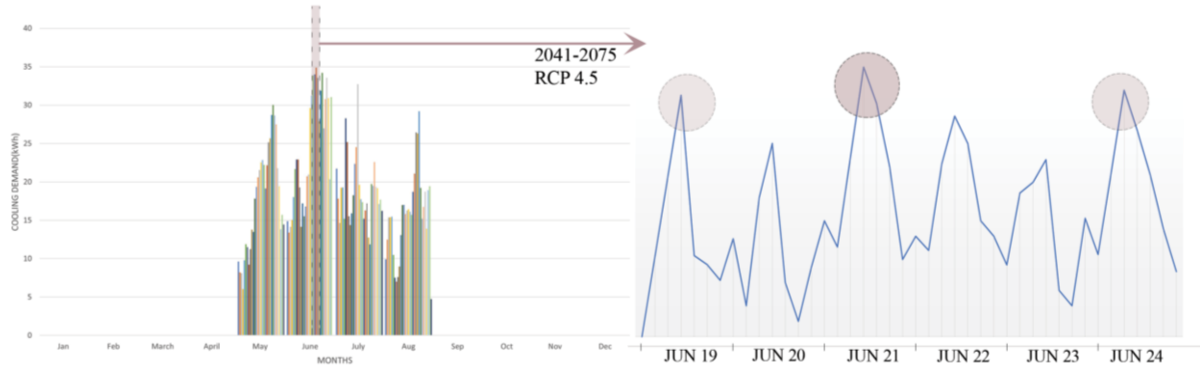


FIG 24:SHOWING TREND OF PEAK LOAD HOURS BY ANALYSIS OF A SINGLE WEEK WITH THE HEIGHEST PEAKS IN THE ENTIRE SUMMER PERIOD OF 2041 TO 2075, USING RCP 4.5

Again, the demands change with change of scenarios and with consideration of a much intensive scenario, the demands in all months rise for whole of the summer period. Overlooking the intensive period for 2010 to 2040 and 2041 to 2075, it speaks about the cooling demands crossing 10 to 20 kwh on an average for all months, compared to the previous scenario where that range was average for peak demands only for the months considered.

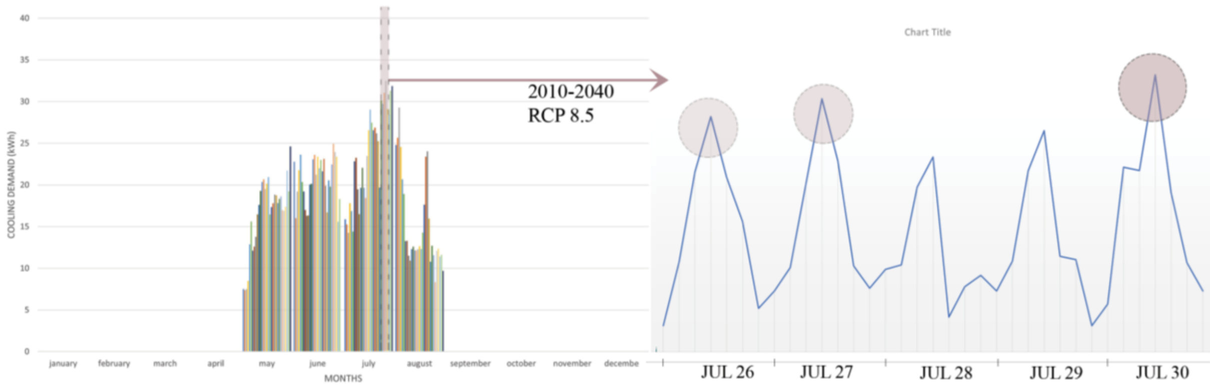


FIG 25:SHOWING HOURLY DATA OF COOLING DEMAND FOR A WEEK WITH HEIGHEST PEAKS IN THE MONTH OF JULY, IN THE SUMMER PERIOD OF 2010 TO 2040, USING RCP 8.5

Analysis of the graph has shown that there are possibilities of a peak cooling demand during the end of July indicating increase of outside temperature. For an intensive period of RCP 8.5, during the years between 2010 to 2040. The peak demand will reach to around 5 to 30 kWh, which is a 5% increase for another less intensive scenario accounting the same tenure. This will again increase to 6 to 8% considering the highest hit peaks for the next set of years of 2041 to 2075. And the cooling demand is likely to shift from a much later date in summer to early in summer indicating summer timeframe expanding and advancing.

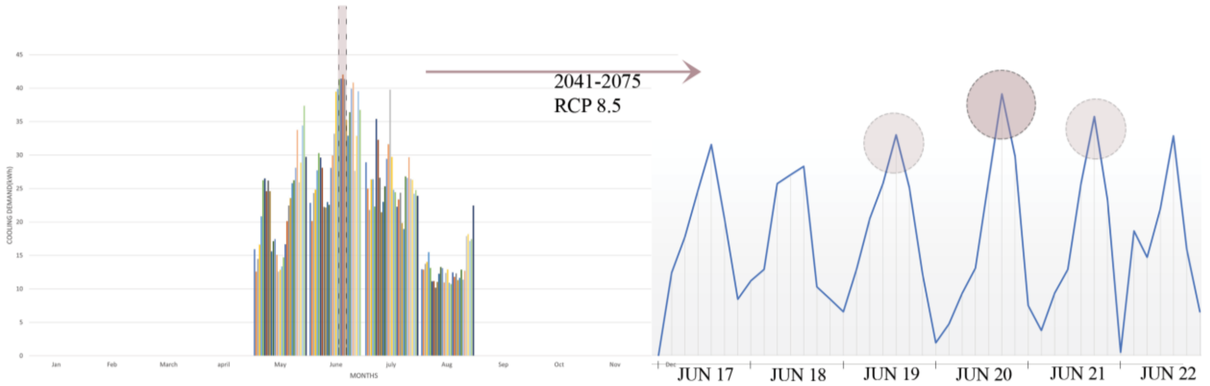


FIG 26:SHOWING HOURLY DATA OF A WEEK IN THE YEARS OF 2041 TO 2075 WITH THE HIGHEST PEAK TRENDS IN THE SUMMER PERIOD, USING RCP 8.5

6.4 Overheating Analysis

Overheating as an issue was also seen and considered , which is also inter-related to the demand for cooling and thermal comfort. The following graphs were generated to compare the variation of issues of overheating with the change of floor height and also loaction of a zone and orientation of it for a building.

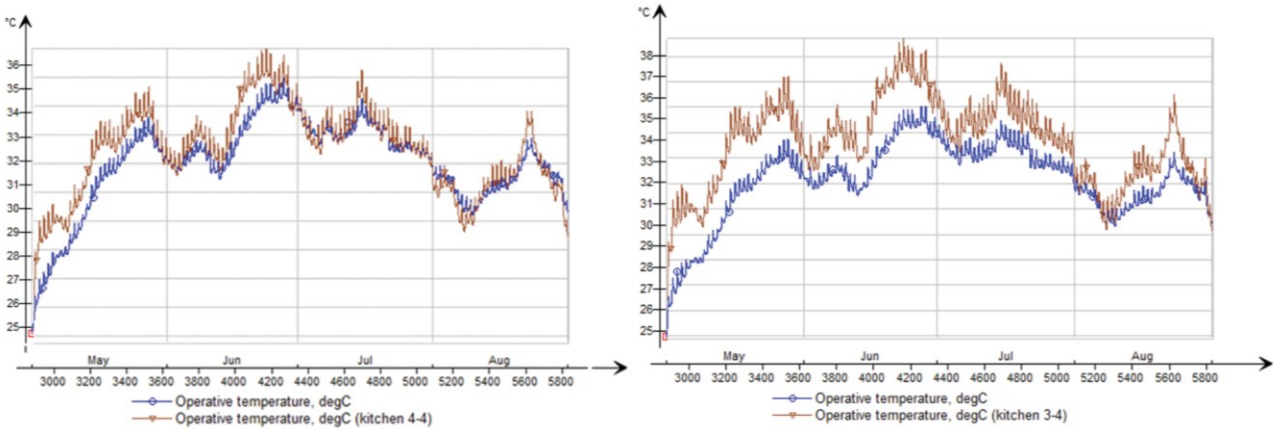


FIG 27:SHOWING OPERATIVE TEMPERATURE DATA INDICATING OVERHEATING IN THE SUMMER PERIOD COMPARING THE GROUND FLOOR ZONES TO THE LAST FLOOR ZONES OF KITCHEN 4 AND KITCHEN 3, USING RCP 8.5 FOR THE YEARS 2041 TO 2075.

Issues of overheating were mostly analysed for the whole building and all the rooms as zones but the zones facing the southwest façade received issues the most in terms of maintaining thermal comfort and tackling overheating.

It was done for all scenerios but the graphs here are expressive for a single scenerio of the highest intensity and the years of 2041 to 2075, and all had the same pattern of difference of temperatures in the indoors from the ground floor to the first floor. Graphs demarcated that temperatures in the ground floor zones were slightly lower than the floors above. The Ground floors showed slightly less of a trouble then the last floor facing the southwest façade.Also the rooms facing extreme south were more effected then the rooms inclined slightly towards the west.

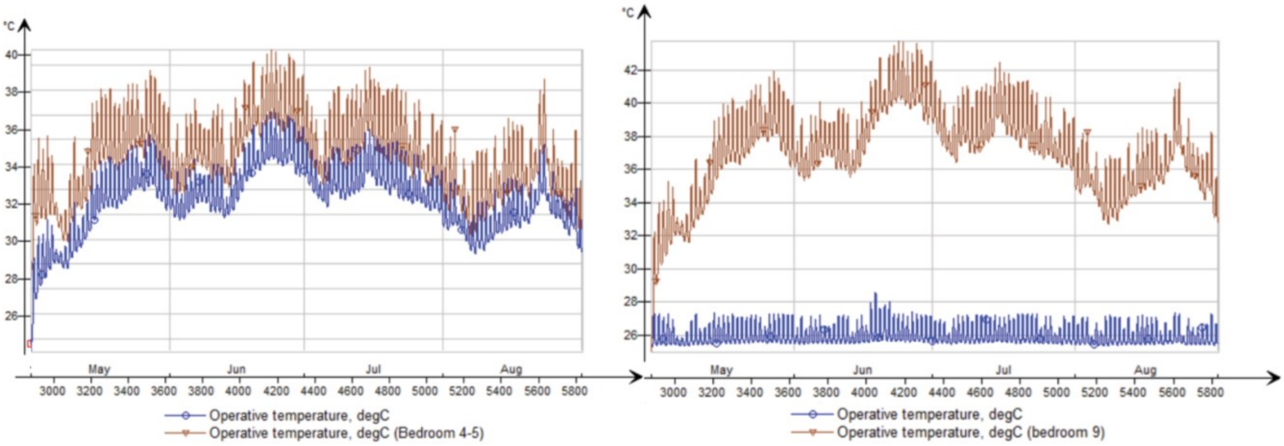


FIG 28:SHOWING OPERATIVE TEMPERATURES FOR THE BEDROOMS LOCATED IN THE SOUTHWESTERN SIDE OF THE BUILDING INDICATING OVERHEATING, USING RCP 8.5 FOR THE YEARS 2041 TO 2075

Careful analysis was done of the results from simulation, which indicated the overheating issue faced by each of the zone. The results showed that the zones along the southwest façade faced challenges of overheating the most, and according to also the previous analysis of overheating by change of floor height suggested that the topmost floor, that is the zones facing southwest on the 5th floor will be intensively affected by overheating.

The key plan in fig. demarcates the zones selected for the analysis on the 5th floor

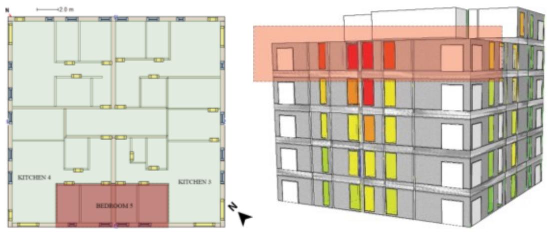


FIG 29:SHOWING KEY PLAN OF THE 5TH FLOOR AREA USED FOR ANALYSIS OF OVERHEATING ISSUE

The 5th floor analysis was done comparing both scenarios of intermediate and extreme conditions. For the Living room and kitchen area covering parts of northwest zone like the kitchen and living space named 4 likely showed more overheating thank the same kind of room, same larger space on the other side covering southeastern area. Again, the scenarios were covered for assessment which showed that with increase of extremeness the overheating continues even during the nigh hours as the heat is likely to be still trapped inside the structural elements and cooling down of it will be longer then of scenario RCP 4.5, where nighttime cooling shows of been taking place.

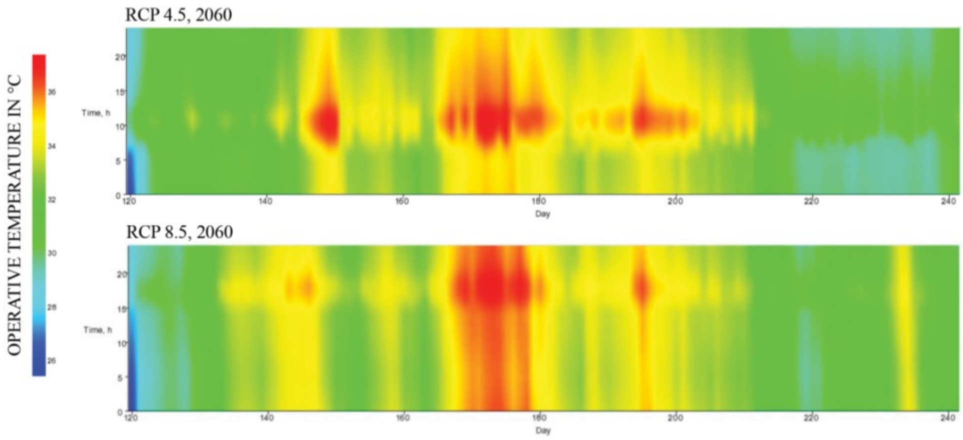


Fig 30:Showing operative temperature for kitchen 4, for the year 2060(2041-2075),using RCP 4.5 and 8.5 , indicating overheating

Similarly for the other living room of same size as Kitchen 4, Kitchen 3 shows cooling down at nighttime in a much easier way, as the overheating was also not much as compared to the Fig above of kitchen 4.

But that is only a case considering RCP 4.5, for the other case of RCP 8.5 the cooling shows bit of a struggle and tend to remain stagnant at a temperature.

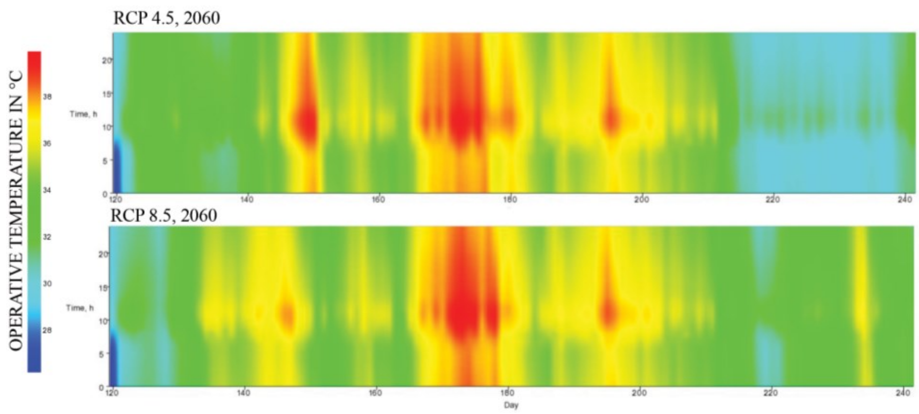


Fig 31:showing operative temeprature of kitchen 3 ON the 5th floor for the summer MONTHS, using RCP 4.5 and RCP 8.5 for the year 2060(2041 to 2075)

For the Zone of bedrooms in that area, all bedrooms were merged to one zone depicting that overheating chance was higher at that zone more than the living spaces because the other rooms were considerably larger in size to the area of occupancy all together in the bedroom. The peak of overheating temperatures rose to more than 2% then the other larger rooms. And was seen rising to nearly 38 degrees for 2041 to 2075.

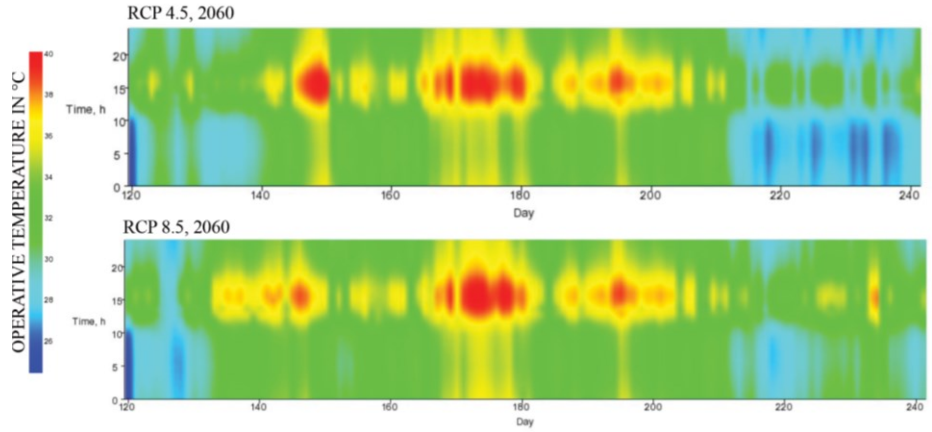


FIG 32:SHOWING OPERATIVE TEMPERATURE OF BEDROOM ZONE ON THE SOUTHWESTERN FACADE FOR THE SUMMER PERIOD OF 2060(2041-2075), USING RCP 4.5 AND RCP8.5

Similarly, for the years considering 2060 the overheating issues were recorded a 20% higher than the overheating scenario of the years considering 2024. Specially in consideration of the intermediate pathway it was recorded not much higher, it exceeded two degrees of the threshold temperature of 26 degrees.

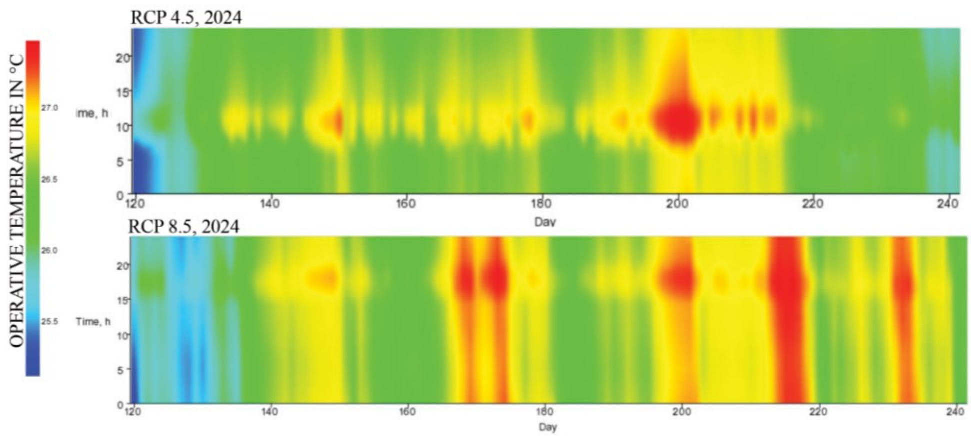


FIG 33:OPERATIVE TEMPERATURES OF KITCHEN 4, FOR THE SUMMER PERIOD OF 2024(2010-2040), INDICATING OVERHEATING, USING RCP 4.5 AND RCP 8.5

Considering 2024, with the lower scenario pointed out that the overheating is not going to be extreme, however similarly as for 2060, in 2024 the living room and Kitchen number 4 is going to encounter issues more then the other similar sized Kitchen 3.

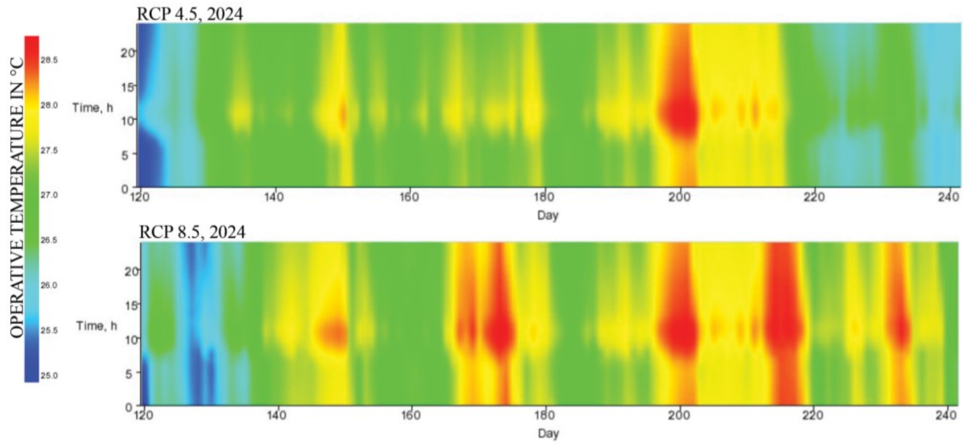


FIG 34:SHOWING OPERATIVE TEMPERATURES FOR KITCHEN 3, FOR THE SUMMER PERIOD OF 2024(2010-2040), USING RCP 4.5 AND RCP 8.5

But for the bedroom zone it was perceived that due to smaller volume of the room unlike the living rooms, it was experiencing overheating to almost 36 degrees. But overheating was observed a 5% higher for the scenario 8.5 then RCP 4.5.

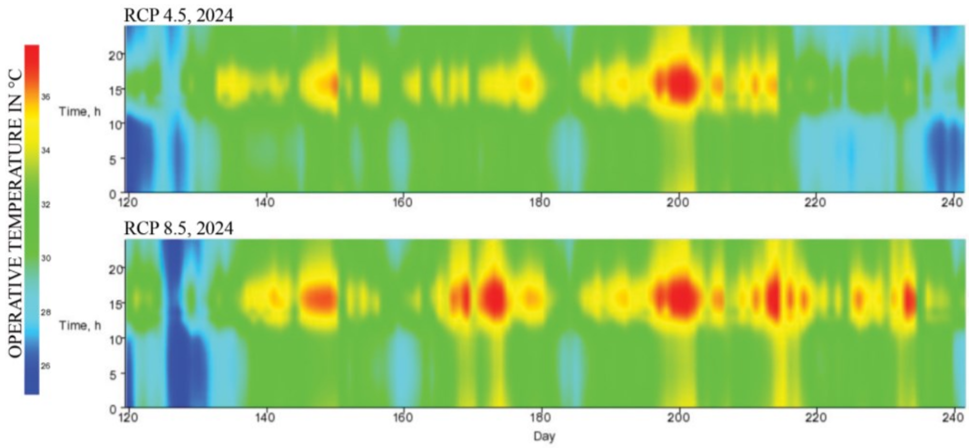


FIG 35:SHOWING OPERATIVE TEMPERATURE OF THE BEDROOM ZONE, FOR THE SUMMER PERIOD OF YEARS 2010-2040, USING RCP 4.5 AND RCP8.5

7.Limitation and challenges

Previously the general limitations were mentioned and considered, and the analysis was carried out after the considerations.

Being aware of the challenges and limitations is very important during the process of assessment as it helps to create a more realistic study of the situations that might arise in the future and tackle them being realistic. Though most of the scenarios used in the study and the models, are verified, and approved by IPCC, there are certain limitations.

Apart from that in this study challenges were faced as data collected from NVE through their database with selection of verified models had many missing data of Hourly data of a day but had daily data of a month for the years. Therefore, several hourly data had to be generated using methods of interpolation, which were later verified and readjusted according to previous data patterns of the hourly data of a day generated from historical weather data from the Sarpsborg weather station.

Challenges were also faced for collection of data for the modelling of the building and accurate input of data for the systems installed, as it is a new upcoming building and the neighborhood is also very new, so most phases were under modification and the site is still under construction and the building has not been under usage. Most apartments occupancy behavior and number are also unknown. Also, the current load on the installations is unrevealed as it is unused.

8.Conclusion and Future Scope

This research was carried out to investigate the impact of climate change on building performance under stressful conditions, considering maintenance of thermal comfort. The research was performed for a residential building which usually have much more timings of operation when compared to other building types, located in the region of Viken, in an urban area called Fredrikstad which is a fast-growing city. The building is under a SPEN, which already considers a lot of control on emissions from the beginning of planning stage and decision making. Analysis have been performed mainly focusing on the probability of rise of cooling demand and change of it over the years to know and come up with solutions of mitigational strategies and making the structures resilient for future.

After collecting futuristic data of climate by usage of verified models, it was sorted for years to be considered and mostly focusing on the summer period, since the focus was to analyze the cooling demand, the model used was EC-EARTH, RCA, with two scenarios forced into, to know the performance of the building in attaining thermal comfort in intermediate change scenario to extreme scenario. Three future periods were kept into account, 2024(2010-2040), 2060(2041-2075) and 2080(2076-2097), considering the building age line, that it will be functional fully from 2024 onwards, and undergo changes or refurbishment during mid-year of its lifetime around 2060 and final years of the structure. However, it was mostly focused for the years of start of operation and to mid lifetime, as likely that is the time of the structure's peak performance.

First the analysis of weather data comes into the forefront and when compared to historical data suggested that there was a rise of 10% on average for the intermediate scenario of RCP 4.5, while for extreme considerations of RCP 8.5 it was 25 to 30% more. And when a typical year was compared to an extreme year the results suggested a minimum of 2 degree rise and rise of temperatures in winters with future years and rise of also hot summers. It also suggested from analysis of hourly data of all years that during nighttime the temperatures are likely to experience a fall. This was important to investigate and keep in mind to study the interrelated subject of nighttime cooling and compare the overheating cases with change of outdoor temperature.

After analysis of the datasets and composition of weather data into epws for simulation , the structure was modelled first in Revit and after verification using Simple Bim , it was put up into IDA ICE along with all the necessary input data and systems installed in the structure.

According to the results it suggested that with rise of outdoor temperatures there was an increase in demand for cooling, but it was gradual. The cooling demands for 2024(2010-2040) with an intermediate scenario of RCP 4.5 claimed a little rise of cooling demand and that can be however tackled by use of passive cooling techniques and proves no requirement of system to cool the spaces. The frequency of peaks is low. However, for the years of 2060 and beyond considering 2041 to 2075 the cooling requirement was seen higher, and it seemed unlikely that could be solved by usage of passive cooling alone, with cooling demand peaks being frequent and almost to a percentage of 25.

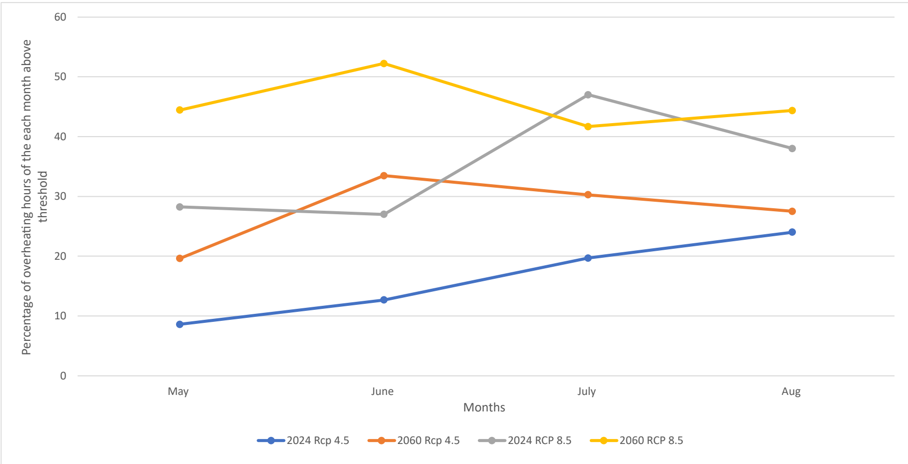


FIG 36:SHOWING VARIATION IN PERCENTAGE TREND OF OVERHEATING HOURS OF EACH MONTH FOR ALL SCENARIOS OF RCP 4.5 AND RCP 8.5 IN ALL YEARS OF 2010-2040 AND 2041-2075

This is also relatable to the results of overheating cases that might be experienced in conditions of high rise of temperatures. As explained by the hours of overheating, for 2024, it was noticed the hours of overheating period for the entire summer was lesser than 20% accounted for 2952 days, which indicated the summer period considering RCP 4.5 for the years of the decade starting from 2024 is likely to be comfortable.

But years down the line and considering extreme situations the hours of overheating period for an entire summer accounting each day will rise to a 50 percent. But for the intermediate case the overheating will be for a lesser period. This is where nigh time cooling can play a role, as for climate change conditions, the nighttime temperatures experience drops. This can be used as an advantage when such conditions come into scene, for preparation of the building to the next day’s heat built up.

It was also seen that with extreme case and with increase of hours of exposure to overheating, the heat is likely to be trapped inside the boundaries of the building for more hours then as for an intermediate case. And the building might experience heat inside even when the outdoor temperatures will drop.

This all conclusions suggest a need for adaptation and making it flexible to suit future conditions as most structures are not equipped with cooling systems, it also helps to prepare and make everyone aware of the future and extreme event that might occur.

Future scope therefore can be exploration of the subject more and trying the systems and envelopes out with lighter and with option of interchangeable flexibility adapting to change right from the planning stage. These climate changes will not only affect a general building but also a building in the sustainable positive energy neighborhood, therefore it can be a future scope for building up on ideas of beyond Sustainable positive energy neighborhood, which will keep the energy marking intact at the same pace despite harsh changes. And in turn built more flexibility of the buildings contributing to the sustainable positive energy neighborhood.

Also, future scope can be with testing of the various factors contributing to the assessed results and testing out with the solutions planned for each of the contributing factor, to what extent the solutions could make a difference to keep the structure robust.

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Annexures

Norsk klimaservicesenter

Maximum temperature projections for Norway, 1 km2 spatial resolution, 2024-2025

Topic category:	ClimatologyMeteorologyAtmosphere
Keywords:	Climate, Meteorology, Maximum temperature projections, RCP4.5, Gridded data, Bias-adjustment, Empirical quantile delta mapping, Norway
Scenario / GCM / RCM:	/ RCA / RCP4.5
Title:	Maximum air temperature projection
Standard name:	air_temperature
Units:	K

ABOUT THE DATA

Created date:	2019-12-13
Created by:	Wai Kwok Wong
Institution:	Norwegian Water Resources and Energy Directorate (NVE)
Contact:	climatedata@nve.no
Summary:	Due to the systematic biases of the GCM/RCM outputs and their mismatch in scale with impact models data requirement, a post-processing of those outputs is necessary to obtain plausible time series for use in local impact studies. An empirical quantile delta mapping method (EQDM) was used to bias-adjust maximum temperature in Norway for a Euro-CORDEX simulation (EC-EARTH/RCA) representing emission pathway RCP4.5. The original output was first re-gridded to 1 x 1 km using nearest neighbour method. EQDM which can preserve changes in maximum temperature quantiles was applied to adjust daily values from the climate projection on monthly and grid-cell basis. Climate and hydrological projections are uncertain for several reasons. Uncertainties are related to future anthropogenic emissions, natural climate variations, climate models, bias correction methods and hydrological models. This is important to bear in mind in the interpretation of results from any study where the downloaded projections have been used.
Acknowledgement:	We acknowledge the World Climate Research Programme's Working Group on Regional Climate, and the Working Group on Coupled Modelling, former coordinating body of CORDEX and responsible panel for CMIP5. We also thank the climate modelling groups (listed in the reference report) for producing and making available their model output. We also acknowledge the Earth System Grid Federation infrastructure an international effort led by the U.S. Department of Energy's Program for Climate Model Diagnosis and Intercomparison, the European Network for Earth System Modelling and other partners in the Global Organisation for Earth System Science Portals (GO-ESSP).
References:	Wong, W.K. and I.B. Nilsen (2019): Bias-adjustment of maximum and minimum temperatures for Norway, NVE Report, http://data.nve.no/report/BiasAdjustment_TmaxTmin_Norway.pdf

ABOUT THE EXPORTED DATASET

Format:	Network Common Data Form - NetCDF (.nc) - CF-1.6, ACDD-1.3
Temporal coverage:	from 2024-01-01 to 2025-12-31 - Resolution: Daily
Spatial reference:	EPSG:32633 - WGS84 UTM 33N
Spatial coverage:	X min: 82000 X max: 329000 Y min: 6521000 Y max: 6792000
Cell size (X,Y):	1000, 1000
Scale factor:	0.01
Processing history:	Data originally created: 2019-12-13. Exported using the Norwegian Climate Centre's data download services: 2022-03-28. During export, the original dataset was clipped to a user-specified area.

DISTRIBUTION

Distribution statement:	Free
Licence:	Norwegian Licence for Open Government Data (NLOD), https://data.norge.no/nlod/en/1.0

Fact sheet created 28 March 2022

Data collection through KSS, produced by NVE for data sorting and final usage in building simulation and turning them to climate files and then into EPWs.

Norsk klimaservicesenter

Minimum temperature projections for Norway, 1 km2 spatial resolution, 2024-2025

Topic category:	ClimatologyMeteorologyAtmosphere
Keywords:	Climate, Meteorology, Minimum temperature projections, RCP4.5, Gridded data, Bias-adjustment, Norway
Scenario / GCM / RCM:	/ RCA / RCP4.5
Title:	Minimum air temperature projection
Standard name:	air_temperature
Units:	K

ABOUT THE DATA

Created date:	2019-12-14
Created by:	Wai Kwok Wong
Institution:	Norwegian Water Resources and Energy Directorate (NVE)
Contact:	climatedata@nve.no
Summary:	Due to the systematic biases of the GCM/RCM outputs and their mismatch in scale with impact models data requirement, a post-processing of those outputs is necessary to obtain plausible time series for use in local impact studies. To bias-adjust minimum temperature in Norway for a Euro-CORDEX simulation (EC-EARTH/RCA) representing emission pathway RCP4.5, an empirical quantile delta mapping method (EQDM) was first used to bias-adjust maximum temperature and the diurnal temperature range (difference between maximum and minimum temperature) individually. EQDM which can preserve changes in temperature quantiles was applied to adjust daily values from the climate projection on monthly and grid-cell basis. After the bias-adjustment procedures, the minimum temperature was derived by subtracting adjusted diurnal temperature range from adjusted maximum temperature. Climate and hydrological projections are uncertain for several reasons. Uncertainties are related to future anthropogenic emissions, natural climate variations, climate models, bias correction methods and hydrological models. This is important to bear in mind in the interpretation of results from any study where the downloaded projections have been used.
Acknowledgement:	We acknowledge the World Climate Research Programme's Working Group on Regional Climate, and the Working Group on Coupled Modelling, former coordinating body of CORDEX and responsible panel for CMIP5. We also thank the climate modelling groups (listed in the reference report) for producing and making available their model output. We also acknowledge the Earth System Grid Federation infrastructure an international effort led by the U.S. Department of Energy's Program for Climate Model Diagnosis and Intercomparison, the European Network for Earth System Modelling and other partners in the Global Organisation for Earth System Science Portals (GO-ESSP).
References:	Wong, W.K. and I.B. Nilsen (2019): Bias-adjustment of maximum and minimum temperatures for Norway, NVE Report, http://data.nve.no/report/BiasAdjustment_TmaxTmin_Norway.pdf

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Temporal coverage:	from 2024-01-01 to 2025-12-31 - Resolution: Daily
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DISTRIBUTION

Distribution statement:	Free
Licence:	Norwegian Licence for Open Government Data (NLOD), https://data.norge.no/nlod/en/1.0

Fact sheet created 28 March 2022

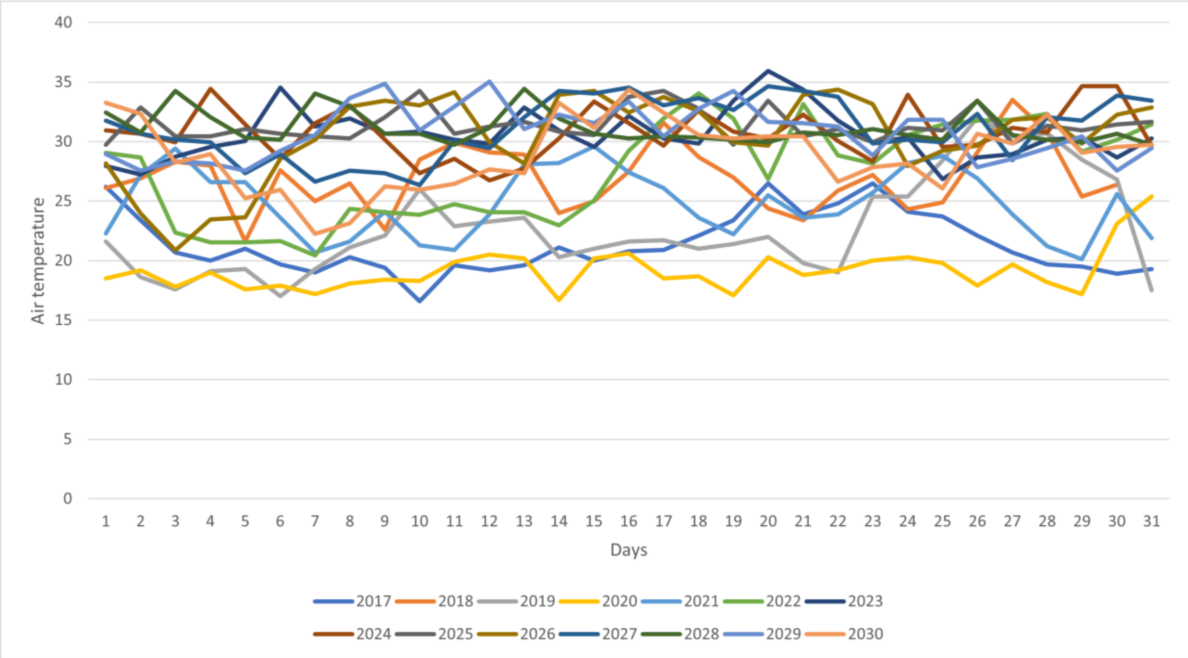
This way all data were collected for 120 years which were already synthesized data collected from database.

										2024		
	January	February	March	April	May	June	July	August	September	October	November	December
1	283.7	277	283.6	282.5	300.4	301.8	299.5	305.4	292.2	290	280.6	282.9
2	281.9	273	281.8	283.6	301.4	303	300.4	300	293.1	287.7	282.6	282.8
3	282	276	284.7	283.3	299	301	297.3	304.4	294.3	286.1	286.1	282
4	278.7	276	284.9	285.5	296.6	304.8	300.6	306	297.2	285.7	283.4	279.4
5	277.1	278	283.1	286.7	295.5	305	300.6	302.8	291.5	284.2	286.1	275.6
6	277.9	276	282.2	288.5	295.5	304	301.4	298.4	288.6	284.1	282.5	281.1
7	277.5	275	281.8	287.9	295	300	301.6	297.1	292	284.2	280	277
8	275	278	283	287.6	293	302.5	304.3	302.2	291.2	283	280.7	275
9	276.5	277.7	282	287	294	304	304	301.6	289.6	284.1	281.6	278.6
10	273	280	280	286.3	291.6	303	301.6	296.4	291.3	283.8	281.4	276.5
11	278.3	280	281	286	295.7	304.5	303.3	297.3	290.1	283	279.9	278
12	281.5	281	282	283	295	302	305.1	297.7	290.5	283	280.6	273.2
13	282	280.6	282	286.3	300	297	302.5	300.6	290.3	283.2	278.8	274.8
14	280	281	282.3	286.3	296.5	299	302	297.7	290.1	283	280.1	268.8
15	278.3	280.3	286.5	288	295.2	303.5	302	299	288.4	286.3	281.7	268.2
16	273	279.3	283.6	290	293.2	300.7	306.7	296.9	289.1	286.3	273.8	274
17	279	279.5	284.2	291	295.7	300	308	296.5	288.7	286.2	277.3	275.8
18	282	282	289.4	299	298	297.4	308	297.1	287.9	287.6	281.4	273.1
19	275	281.7	288.4	301.2	298.9	298	308.7	296.7	287.9	289	281.5	273.1
20	272	282.4	284.5	299.6	301.4	302	308.3	296	287.6	286.3	283	270.5
21	269.5	279.8	284.5	301.8	301.4	303	308.6	295.6	289.1	284.7	281	272.3
22	273.6	280	281.2	299.6	298.1	303.5	308.3	295.1	288.8	285.5	281.7	272.3
23	275	281.4	279.8	297	298.5	305.4	300	296.6	287.2	283.4	283.9	272.3
24	273	283.3	280.2	299	301	304.8	306.5	297.2	288.2	283.7	286.8	273.6
25	278	281.4	280.3	298	301.4	302.8	306.7	294.6	287.1	285.9	282.8	273.3
26	279	283.3	280.3	296	303	305.5	305.8	296.6	287.2	287.9	279.7	275.7
27	277	283	281	293	300.4	305.3	307.2	296.3	288.3	285.3	277.9	277.4
28	271.5	286	281	295.5	301	308	306.5	296.8	290.3	284.7	277.8	278.5
29	270	280.4	280	295	299.6	310	306.5	296.3	288.6	283.1	280.2	280
30	269		281	297	302.5	302	304.1	296.7	289.5	286.8	281.4	278.7
31	272		280		302.8		308.5	296		285.9		279.7

Data collected and sorted from NVE data base, actual files are . nc files.

		RCP 4.5																	
may	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2056	2057	2058	2059	2060	2061	2062	2063	2064
1	302.9	301.3	304.9	305.6	302.1	306.4					307.2	298.3	294.7	307	307.8	304	303.4	304.4	304.4
2	306	297.1	303.8	303.9	300.7	305.5					304.8	294.1	294.8	300	305.8	302.7	302.6	305.7	304.3
3	303.6	294	303.3	307.4	301.5	301.4					307.4	300.9	302.4	303.2	304.3	307.4	303.4	306.6	304.2
4	303.6	296.6	303.1	305.2	301.3	302.1					303.2	300	300.2	302.2	304.5	305.5	305.5	306.7	303.9
5	304.2	296.8	300.5	303.5	300.7	298.4					303.4	300.1	302.9	304.4	305.8	302.8	302.7	307.1	306.3
6	303.8	301.7	302.1	303.3	302.4	299.1					304.7	301.5	303	303.1	302.9	303	306.2	307.3	305.8
7	303.6	303.3	299.8	307.2	303.7	295.4					306.7	301.8	303.9	304.8	308.4	304.3	305.4	304.6	303.8
8	303.4	306.1	300.7	306.1	306.8	296.3					303.1	301.9	304	304.8	308.1	302.9	304.7	306.1	303.1
9	305.2	306.6	300.5	303.8	308	299.4					305.1	303.5	303.9	305.4	303.9	306.2	301.8	301.6	304.2
10	307.4	306.2	299.5	303.8	304.1	299.1					306.2	305.9	304.1	301.8	305.1	307.3	305	301.7	305.6
11	303.8	307.3	303.2	302.9	306.1	299.6					303.9	307.8	303.6	301.8	306.1	303.6	303.1	301.3	303.7
12	304.4	303.1	302.6	304.3	308.2	300.8					303.1	307.6	301.5	303.3	306.5	305	299.2	301.1	306.3
13	304.8	301.3	305.2	307.6	304.2	300.5					307.7	307.5	303.2	299.9	306.9	304.5	304.7	304.8	303.1
14	304	307.1	307.4	305.1	305.4	306.4					306.8	303.8	302.2	306	308.3	307.4	301.2	306.7	303.8
15	303.7	307.4	307.2	303.8	304.7	304.3					303.5	302.9	300	306.3	314	303.7	305	307.4	304.3
16	306.9	305.6	307.7	303.4	306.5	307.5					301.9	306.9	301.4	303.8	308.9	303.7	305.5	304.8	306.1
17	307.4	306.9	306.2	303.6	303.6	305.6					303.3	306.5	302.3	307.4	305.5	305.3	304.2	304.5	304.8
18	305.9	305.7	306.8	303.5	305.9	303.7					302.7	305.3	296.7	301.6	306.4	307	305.9	304.8	304.4
19	302.9	303.1	305.8	303.3	307.4	303.4					306.8	303.6	298.6	302.7	306.2	300.9	303.3	301.7	303
20	306.6	302.8	307.8	303.1	304.8	303.6					306.5	302.6	300.4	302.8	303.9	304.1	305.2	302.8	303.2
21	303.6	307.1	307.4	303.9	304.7	303.6					304.9	306.7	298.6	301.7	307.8	304.3	305.5	307.5	303.3
22	304.2	307.5	306.9	303.7	304.4	299.8					300.8	307	300.4	307.2	304.8	304.9	306.9	305.5	304.8
23	303.1	306.3	303	304.2	302	301					304	307.6	299.6	307.6	304.4	302.2	307.4	304	306.2
24	304.3	301.1	303.3	303.7	305	301.3					305	306.1	298.8	306.1	305	306.9	306.6	302.8	305
25	304.1	302.4	303.1	303.3	305	299.2					307	306.5	297	305	305.3	305.5	304.9	303.4	305.1
26	306.6	302.8	305.5	306.6	301	303.8					307.6	302.6	296.4	306	306.4	305.9	303.9	304	306.2
27	303	305	301.6	303.7	301.7	303					305.6	302.3	296.1	302.3	304.7	307.3	305.7	305.4	305.5
28	304.5	305.2	305.2	303.3	302.6	305.4					303.2	303.9	299.2	303.1	305.4	304.6	307	307.8	305.8
29	304.1	303	304.9	303.1	303.6	302.2					304.1	306.1	302.7	303.8	304.5	303.4	303.2	304.3	305
30	304.6	305.4	307	303.8	300.7	302.7					302.8	305.1	298.9	306.5	304.7	304.4	306.6	307.2	305.5
31	304.8	306	306.6	302.9	302.6	302.9					306.6	300.1	303	306.3	304.2	306.3	305.8	306.6	302.1

Future years sorted for composing of the years and each year month air temperatures



Air temperature trends for month of may used in epw after composing of the year

								2060				
	January	February	March	April	May	June	July	August	September	October	November	December
1	287	277.5	280.6	283.6	298.4	303.4	307.8	304.9	293.4	290.6	280	280.3
2	286.1	277.4	280.7	285.8	295.3	301.8	305.8	304.6	296.1	290.3	278.9	278
3	282.9	284.4	280.1	289	293.5	303.7	304.3	303.9	296.1	292.7	279.6	279.3
4	280.2	279.3	282.4	288.9	294.7	305.1	304.5	301	293.1	288.6	279.4	275.6
5	282.8	281.9	286.1	290.1	295.9	306	305.8	305.5	294	287.3	279.4	276.9
6	280.7	283.8	286.2	286.8	296.4	307.3	302.9	298.5	293.4	289.2	279.7	281.6
7	282.8	280.6	287.1	288.2	298.3	307.2	308.4	299.5	292	296.4	283.4	281.4
8	282.3	283.5	285.3	291.3	296.9	306.6	308.1	304.6	291.1	291.8	284.8	280.8
9	280.9	279.1	288.1	291.4	298.6	302.7	303.9	302.1	290.7	289	286.3	281
10	284.2	281.3	288.3	292.4	296.9	304.6	305.1	302.4	292.2	290.4	288.7	280.6
11	287.4	280.5	288.5	288.7	294.6	304.1	306.1	304.6	294.1	290.6	284.2	280
12	287	277.9	289.3	292	294.5	301.6	306.5	306.9	294.7	293.3	283	281.4
13	281.7	282.6	288.3	288.9	295	305.8	306.9	305.3	295	293.6	285	283.2
14	281.6	283.4	286.9	289.8	294.1	306	308.3	303.8	295.5	296	283.4	280.5
15	281.9	282.7	285.3	289.8	296.3	308	314	304.6	294.3	293.6	283.2	275.8
16	280.9	282.6	285	291	295.1	311.5	308.9	304.2	293.2	292.2	284.7	275.4
17	278.5	283.2	285.4	292.3	297.6	312	305.5	304.4	291.3	291	281.6	274.4
18	275.6	283.6	288.4	290.3	298	312	306.4	304.9	293.3	289.5	282	271.9
19	277	279.2	285.8	290.4	299.8	312.1	306.2	304.3	293.5	289.4	281.4	269
20	279.8	281.6	286.9	292.8	296.7	311.8	303.9	301.6	290.9	288.7	279.8	271.8
21	280.4	279	288	293.8	301.9	312.2	307.8	299.5	290.2	285.9	279.1	271.8
22	279.3	280	288.7	296	305.1	312.2	304.8	299.6	290.4	284.1	280.6	268.9
23	278.4	285.6	289	296.8	307.1	309.5	304.4	296.3	291	284.1	282.6	269.5
24	277.1	283.2	289.8	298.3	307.9	309.5	305	296.5	289.5	284.5	283.8	270.6
25	277.6	279.7	289.7	298.3	309.6	311.5	305.3	297.5	293.6	283.5	286	272.3
26	281.9	279.4	284.8	299.2	312.1	312	306.4	297.1	294.3	286	283.3	273.7
27	280.6	280.1	282.6	300.6	303.7	305.8	304.7	296.5	290.6	288.1	282.4	271.8
28	282.8	279	284.8	299.4	309.3	306	305.4	298.2	292.1	285.7	281.9	273
29	282.6	278.8	282.3	299.4	309.7	311.4	304.5	296.5	291.3	285.2	281.5	273.2
30	279.6		281.6	299	308.8		304.7	296.2	291.7	285.9	280.3	272.1
31	276.8		282.6		307.2		304.2	293.8		283.4		271.4

Air temperatures for 2060 used for sorting of climate files

2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
May	May	May	May	May	May	May	May	May	May	May	May	May	May	May	May	May	May	May	May	May	May	May	May	May	May	May	May	May	May	May
12.5	15.2	20	10.6	10.7	11.8	10.3	16.2	8.7	18.1	14.1	12.8	17.85	27.05	19.25	20.45	20.25	27.15	17.55	16.25	22.95	13.95	14.55	9.65	18.45	20.25	9.75	15.95	16.75	20.15	20.95
12	11	20.6	11.9	12.6	12.6	12.6	19.2	11.9	14.6	14.8	13.3	13.65	27.35	19.85	18.15	19.65	27.25	16.65	14.75	24.55	16.15	14.65	8.95	22.05	17.15	11.35	15.45	15.85	23.85	22.55
13.5	11	16.8	10	11.7	12	11.6	17.5	12.9	8.9	15.7	10.6	19.95	24.55	21.35	19.85	21.25	26.45	25.25	17.95	21.35	15.35	14.45	9.15	20.75	15.35	13.55	16.05	18.05	20.65	19.35
12.5	12.4	15	8.3	12.3	10.7	14.4	16.1	14	10.1	11.7	7.7	19.55	23.25	22.45	21.05	23.15	21.75	20.05	21.15	19.55	14.75	15.35	13.15	16.75	16.55	14.75	16.05	18.05	20.15	17.55
12	15.7	10	12.5	10.3	11.6	13.8	21.6	14.2	10.5	13.9	6.2	20.95	25.95	24.15	23.25	23.55	24.95	20.85	21.95	21.45	15.95	15.05	13.35	22.35	17.75	15.85	19.05	20.85	20.55	19.45
13.4	14	10.5	12.6	8.8	12.8	17.5	22.8	15.9	8.7	17	9.6	15.45	22.85	22.55	23.65	20.15	22.75	20.65	23.05	23.05	17.25	15.95	14.65	23.15	18.25	15.55	17.65	22.45	21.85	21.05
14	20.2	11.7	16.1	7.6	11.7	22.8	20	19.2	10.2	14.4	12.1	17.65	20.05	24.55	25.25	20.55	19.95	24.65	22.45	15.15	14.95	15.35	13.95	25.35	20.15	17.25	18.75	22.35	22.45	13.15
15.5	21	14.5	19.6	6.3	13.2	24.4	10.8	21.5	9.8	15.6	12.5	17.15	21.65	24.25	18.85	21.25	19.65	21.65	24.75	15.75	15.55	16.15	13.85	25.85	18.75	18.55	18.55	24.65	20.55	13.75
13.6	22.5	13.5	13.8	9.9	12.1	25.7	10	24.6	8.5	15.1	8.2	17.65	24.55	23.15	20.85	24.85	19.55	22.15	24.75	18.75	17.65	15.05	14.35	25.25	20.45	20.25	17.75	27.05	20.15	16.75
11.1	23	10.5	13.4	13.4	14.4	25.5	7.2	24.6	11.5	10.9	16.6	17.95	24.35	23.95	21.75	21.95	22.95	23.45	24.55	19.55	18.65	12.75	15.35	24.75	18.75	19.15	17.25	26.25	23.25	17.55
10.5	21.5	10.4	12.1	11	12	21.5	6	19.5	13.7	11	14.5	18.95	23.85	25.15	24.35	25.25	17.15	23.85	24.15	20.05	16.95	18.05	14.35	22.15	18.75	17.15	17.35	24.25	22.45	18.05
11.5	18.4	14	12.4	10.4	10.9	19.3	12.8	18.2	13	8.6	13.1	20.95	26.75	17.15	25.65	26.45	24.15	19.95	21.45	20.55	24.35	20.35	14.15	22.45	16.35	17.35	19.55	22.95	23.95	18.55
9.4	15	12	10.5	13.5	15.3	14.5	11.6	23.4	13.8	11.3	19.8	20.45	25.25	17.95	22.65	26.75	26.95	21.25	23.75	20.65	25.35	18.25	12.55	19.85	16.85	15.65	16.35	23.25	26.35	18.65
16.4	15	10.6	10.9	14.4	14.4	12.6	10.7	27	14.2	10.2	22	22.25	21.25	20.35	25.45	26.45	27.35	23.95	22.65	23.85	23.85	18.55	15.15	17.25	15.95	14.95	15.65	20.25	27.15	21.85
17	11	12.8	14	14.7	14.6	14.7	11.4	27.6	18.2	12.5	18.1	20.45	21.15	22.75	21.35	27.05	22.05	25.55	21.05	25.35	25.45	18.55	14.55	18.75	18.15	14.05	16.45	21.35	28.15	23.35
17.5	14.4	16	22.2	19.3	10.4	17.1	11.9	26.8	21.7	10.1	14.4	20.05	23.45	23.25	25.45	27.05	21.75	26.65	17.95	23.25	25.55	15.05	16.05	22.15	16.95	15.25	19.25	23.75	28.75	21.25
12.8	17.2	14	24.5	16.4	12.6	18.5	12.2	21.5	20.3	13.8	13	23.05	20.75	24.45	26.85	27.45	27.95	27.15	19.65	24.95	26.45	17.25	15.15	25.45	19.45	16.45	16.75	23.05	28.25	22.95
21	13.5	14.2	25.7	21.8	13.9	14.1	19.7	19.9	18.6	13.3	12.6	19.25	20.85	27.35	25.85	27.25	27.45	26.95	19.75	27.15	26.65	19.55	14.05	24.95	19.85	19.95	22.15	22.45	27.85	25.15
24.5	15.5	17.4	25.8	22.6	11.9	12.4	19.2	21.1	20.6	16.5	14.8	21.55	21.75	27.35	29.25	27.15	31.35	28.45	20.35	28.55	25.15	21.35	14.25	20.65	21.65	22.25	22.25	21.15	26.95	26.55
23.1	14	20	19.6	18.5	13	13.7	22.7	20.8	18.8	16.8	16	23.75	22.95	27.35	28.95	27.45	30.95	28.15	20.05	26.35	25.75	22.25	14.05	22.35	18.55	22.25	22.05	21.15	26.35	24.35
21.2	15	24	19.3	19.9	13.3	13.9	18.1	21.6	24.4	17.5	14.7	22.05	27.35	27.45	26.75	27.85	31.25	26.45	18.05	23.75	24.35	22.05	16.65	24.45	23.75	25.65	22.25	21.05	28.55	21.75
21.2	17.2	25.8	17.9	27.2	10.4	18.1	16.4	24.1	22.2	18.5	14.5	20.55	27.15	27.35	28.25	27.85	31.85	27.75	20.85	22.45	26.25	22.15	17.85	23.25	26.95	25.55	22.65	23.15	28.85	20.45
19	14.5	27	13.1	27.2	17.2	17.6	19.9	24.9	15.3	16.1	14.1	18.65	25.35	28.15	30.45	27.35	31.95	28.85	24.15	27.45	24.85	22.35	19.25	21.85	28.95	24.45	22.25	23.45	30.05	25.45
16.5	13.4	27	17.6	21.9	14.7	13.1	19.6	27.4	13.2	13.2	13.9	19.65	27.45	28.55	30.45	27.15	30.65	28.35	26.45	25.75	25.65	22.45	18.45	22.35	29.75	26.75	21.65	24.05	31.05	23.75
14.3	19	30	21.2	18.9	14	18.4	19.1	28.2	18.1	19.4	15.6	21.35	27.15	25.05	30.55	26.85	32.05	28.45	26.95	26.55	25.65	22.35	18.75	23.95	31.45	25.45	23.05	23.25	30.85	24.55
15.7	17	26	23.9	22.2	14.9	18.9	21.9	26.7	15.5	17	13.2	22.05	27.15	27.15	28.55	21.95	32.25	28.75	28.65	27.85	26.85	21.35	17.95	23.25	33.95	24.25	25.45	27.05	29.65	25.85
13.5	15.5	25.4	22.1	18.2	16.6	19.2	20.7	25	13	18.8	16.4	24.15	27.25	24.55	29.15	20.35	32.55	27.65	27.45	28.45	26.05	19.55	18.75	25.35	25.55	26.45	24.35	27.55	30.45	26.45
14.3	13.5	20.4	23.2	17.9	13.6	17.7	19	27	15.8	19.5	21.3	26.35	26.95	27.85	24.05	21.95	32.45	26.25	28.35	26.65	26.45	19.35	19.05	19.15	31.15	23.15	25.35	25.45	30.65	24.65
16.5	13.4	16.5	21.7	22.2	12.8	17.2	22.1	29.7	14.1	22	24	27.05	28.65	28.15	31.25	24.95	32.55	26.05	28.55	30.55	28.45	17.45	19.25	23.35	31.55	25.25	22.35	27.65	24.55	28.55
16.8	15	18	21.1	24.4	10.1	21.9	14.1	27.9	11.8	22.5	22.8	27.85	29.25	30.25	32.45	27.15	32.55	26.75	29.05	30.65	30.15	18.95	19.65	23.25	30.65	26.75	21.55	24.05	25.55	28.65
22.5	18.5	15.8	24.5	21.8	14.3	26.3	19	27.9	15.9	24.6	18.3	28.35	30.55	31.35	33.05	26.45	32.75	28.95	29.45	32.35	31.25	22.35	18.35	22.45	29.05	24.85	22.65	26.05	23.35	30.35

Air temperatures until 2010- 2040