UiT THE ARCTIC UNIVERSITY OF NORWAY

Faculty of Engineering Science and Technology

Green Buildings in Cold Climate

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MASTER THESIS PROJECT

for

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(Student number 334162 and 530649)

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Green buildings in cold climate

Background

Global climatic and environmental challenges require change to a society where growth and development are driven forward in a way which nature is not harmed or damaged. A transition to products and services with significantly less impact on the environment is required. The release of CO2 to the atmosphere is likely our greatest challenge ever, as this incur global changes of climatic systems. And the fact that most human activities have a impact on the amount of CO2 released to the air, means that we should emphasize on minimizing emissions from the most dominant sources first. The building sector consumes about 40% of all stationary energy production, and hence it also stands for a major part of the CO2 emissions. In this respect, the main challenge lays within reducing the energy demands of existing buildings. In Norway, the focus on increasing energy efficiency of existing buildings are starting to show overall better performance of the building stock. It is however still long way to go. The situation is not better in other parts of the world. Energy efficiency is important, but not the only issue to be considered. Treatment of waste, recirculation, life cycle assessment, indoor environment, costs and more are also crucial to achieving a well functioning and environmentally low-impact building sector.

Green buildings is a term used for buildings confining to certain environmental and energy related criteria. This type of building implements green technologies and makes use of renewable energy sources. Under cold climate conditions, this may not be straight forward to implement, as cold climate often are associated with long and dark winters, extreme weather conditions and of course long periods of temperatures far below zero.

Objectives

The objectives of the Master's project is (1) to enlighten and analyze how differences in policies, regulations and other instrumental means affect the environmental footprint of buildings, (2) to assess whether cold climate conditions can be met by introducing concepts of green buildings and (3) to compare the performance of typical buildings of northern Norway and northern Japan.

Limitations of the master thesis project

Limitations of the thesis project work related to the numbered bullets below, must be agreed upon with the supervisor.

Tasks/topics:

1. Literature review on definitions and concepts of green buildings.
2. Comparative study on standards and regulations in Norway and Japan. This includes for instance energy efficiency of buildings in general, low energy and passive houses, life cycle assessments, use of renewable energy, other "green building" aspects.
3. Feasibility study of green buildings in cold climate.
4. Case study of a building in Japan and Norway. The case studies are not yet defined, but this is part of the work with the thesis. It could be real or virtual building (depends on the availability of data from real projects). The purpose is to make comparison of the building's energy and environmental footprint in Sapporo region and Norway. The candidates will use computer simulation software for the analysis.
5. Analyses of results, discussions, recommendations.
6. Scientific paper on the chosen topic (max. 6 pages).

Co-operating partner(s)

The thesis work is conducted in cooperation with Hokkaido University, Japan.

Generelt

Senest 14 dager etter at oppgaveteksten er utlevert skal resultatene fra det innledende arbeid være ferdigstilt og levert i form av en forstudierapport. Forstudierapporten skal godkjennes av veileder før kandidaten har anledning til å fortsette på resten av hovedoppgaven. Det innledende arbeid skal være en naturlig forberedelse og klargjøring av det videre arbeid i hovedoppgaven og skal inneholde:

- Generell analyse av oppgavens problemstillinger.
- Definisjon i forhold til begrensinger og omfang av oppgaven.
- Klargjøring/beskrivelse av de arbeidsoppgaver som må gjennomføres for løsning av oppgaven med definisjoner av arbeidsoppgavenes innhold og omfang.
- En tidsplan for framdriften av prosjektet.

Sluttrapporten skal være vitenskapelig oppbygget med tanke på litteraturstudie, arbeidsmetodikk, kildehenvisninger etc. Alle beregninger og valgte løsninger må dokumenteres og argumenteres for. Besvarelsen redigeres som en forskningsrapport med et sammendrag både på norsk og engelsk, konklusjon, litteraturliste, referanser, innholdsfortegnelse etc. Påstander skal begrunnes ved bevis, referanser eller logisk argumentasjonsrekker. I tillegg til norsk tittel skal det være en engelsk tittel på oppgaven. Oppgaveteksten skal være en del av besvarelsen (plasseres foran Forord).

Materiell som er utviklet i forbindelse med oppgaven, så som programvare/kildekoder eller fysisk utstyr, er å betrakte som en del av besvarelsen. Dokumentasjon for korrekt bruk av dette skal så langt som mulig også vedlegges besvarelsen.

Dersom oppgaven utføres i samarbeid med en ekstern aktør, skal kandidaten rette seg etter de retningslinjer som gjelder hos denne, samt etter eventuelle andre pålegg fra ledelsen i den aktuelle bedriften. Kandidaten har ikke anledning til å foreta inngrep i den eksterne aktørs informasjonssystemer, produksjonsutstyr o.l. Dersom dette skulle være aktuelt i forbindelse med gjennomføring av oppgaven, skal spesiell tillatelse innhentes fra ledelsen.

Eventuelle reiseutgifter, kopierings- og telefonutgifter må bæres av studenten selv med mindre andre avtaler foreligger.

Hvis kandidaten, mens arbeidet med oppgaven pågår, støter på vanskeligheter som ikke var forutsatt ved oppgavens utforming, og som eventuelt vil kunne kreve endringer i eller utelatelse av enkelte spørsmål fra oppgaven, skal dette umiddelbart tas opp med UiT ved veileder.

Besvarelsen leveres digitalt i WiseFLOW.

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UiT – Norges Arktiske Universitet
Institutt for bygg, energi og materialteknologi

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Faglig ansvarlig/veileder

Preface

This master thesis about Green Buildings in Cold Climate is result of almost 18 weeks of research, simulations and analysis to fulfill the formal requirements for the two-year education in Master of Technology in Integrated Building Technology (MSc), at the Department for Building, Energy and Material Technology, The Arctic University of Norway, UiT Narvik. The thesis constitutes 30 student credits and is executed in collaboration with the Hokkaido University in Sapporo, Japan.

A major part of the master thesis was written in Japan as exchange students at Hokkaido University where the main problem to be addressed were the enlightenment and analysis of the differences in policy, regulations and other means regarding energy efficiency and environmental impacts on buildings in Japan and Norway. Simulations were also implemented as a supplement in understanding and visualizing the difference in building policy regarding energy efficiency and energy related CO_2 emissions. This project has contributed to an increase in both academical means, regarding the understanding of potential and challenges of sustainable and existing buildings located in cold climate, and cultural means of living abroad in Japan, including and insight of the building and engineering sector in Japan.

We would like to express our gratitude to the academic responsible supervisor Professor Bjørn Reidar Sørensen at UiT Narvik and co-supervisor Associate Professor Koki Kikuta at Hokkaido University for supervision, guidance and the providing of necessary information. Furthermore, we would like to show great gratitude to Masahiko Fujii at Hokkaido University for guidance and taking care of practical and administrational doings, for us to have a great and memorable stay in Sapporo, Japan. Thank you.

UiT – The Arctic University of Norway

Narvik May 16th, 2018

Lasse Andersen and Nils Bernhard Alseth

Sammendrag

Byggesektoren i dag bidrar til over 35 % av det totale energiforbruket og generere 40 % av de energirelaterte klimagassutslippene verden over. Redusering av energiforbruket i bygninger er derfor kritisk for å redusere det totale energiforbruket og klimagassutslippet i bidragsytingen til fokuset for bærekraftighet og en sikrere energiforsyning, spesielt i kaldere områder av verden. Den største utfordringen ligger i energieffektivisering av eksisterende bygningsmasse.

Hensikten med denne masteroppgaven har vært å belyse og analysere hvordan forskjeller i politikk, reguleringer og andre instrumentelle aspekter som påvirker miljøfotavtrykket og energiforbruket i bygninger i kalde områder som nord Japan og Nord-Norge. Simuleringer har blitt utført som en case studie for å supplere og illustrere forskjellene i Japan og Norge. I tillegg har det blitt gjort en vurdering i form av en mulighetsstudie for å se på potensielle løsninger og tiltak for bærekraftighet i bygg i kaldt klima. Selve masteroppgaven har vært gjennomført som et samarbeidsprosjekt og utvekslings opphold om grønne/bærekraftige bygninger i kaldt klima mellom UIT – Norges Arktiske Universitet i Narvik og Hokkaido University i Sapporo Japan.

Høyt energiforbruk i bygninger preger både Norge og Japan i den forstand at tiltak må gjennomføres for å redusere disse, sammen med klimagassutslipp relatert til energiforbruk. Høyt energiforbruk i Norge preges av lave energipriser og høyt oppvarmingsbehov. Forbruket i Japan er høyt på grunn av lave termiske egenskaper for bygge komponenter og høyt varmebehov, samt kjøling. Energibehovet i Norge dekkes stort sett av fornybar elektrisitet basert på vannkraft. Japan baserte seg på atomkraft inntil et stort jordskjelv rammet øy nasjonen i 2011 og Japan ble tvunget til å importere fossilt brensel for å dekke energibehovet. Tiltak og strategier for redusering av energiforbruk stammer i hovedsak fra internasjonale miljøer som FN og Paris avtalen. Frem til ganske nylig har det vært lite fokus på eksisterende bygningers potensiale for energieffektivitet sammenlignet med nyere bygg som faller innenfor strengere energi krav. Økende fokus på renovering og rehabilitering er noe begge nasjoner vektlegger. Bygningers levetid i Norge varierer fra 60 – 80 år. I Japan har levetiden vært anslått til 30 – 50 år. Det viser tydelig at det er potensiale for bedring av energieffektiviteten i eksisterende bygninger både i Japan og Norge.

En meget omfattende litteraturstudie ligger til grunn for resultatene og sammenligningene som viser forskjeller mellom Japan og Norge, hvor det har vært avgjørende å finne de riktige aspektene med tanke på tiltak og strategier for politiske føringer og reguleringer innenfor bygninger. Resultatene viser store forskjeller mellom landene når det kommer til energieffektivitet i nye og eksisterende bygninger og de største virkemidlene for disse forskjellene med tanke på klimatiskefotavtrykket etter en bygning er: lokasjon, kulturell og historisk bakgrunn, politiske strategier og reguleringer basert på nødvendighet og tilgjengelige ressurser.

Abstract

The building and construction sector accounted for over 35 % of the total final energy consumption and generated 40 % of the energy related greenhouse gas emissions in the world. Reducing energy consumption in buildings is critical to reduce the overall energy demand and greenhouse gas emissions to contribute to the major focus of a more sustainable and safer energy supply especially in the colder regions of the world. Hence, the main challenge lays within reducing the energy demands of existing building.

The purpose of this master thesis project has been to enlighten and analyze how the differences in policies, regulations and other instrumental means affect the environmental footprint and energy consumptions of buildings in cold regions such as northern Japan and northern Norway. Simulations has been conducted as a part of a case study to further enlighten and visualize by figures the differences between Japan and Norway. In addition, an assessment of feasibility and potential measures that complies with cold climate aspects regarding energy efficiency is conducted. This has been executed as a collaboration project and exchange stay about green/sustainable buildings in colder regions of the world between UiT – The Arctic University of Norway in Narvik and Hokkaido University in Sapporo, Japan, including an exchange stay in Sapporo.

High energy consumption in buildings affect both Norway and Japan in the sense that measures must be taken to reduce the consumption and greenhouse gas emissions related to energy consumption. The energy consumption in Norway are mainly due to low energy prices and high heating demand. Energy consumption in Japan is mostly due to low thermal resistance of building components and a mixture of heating and cooling demand. The energy demand in Norway are largely covered by electricity based from renewable sources such as hydro power. Japan used to be based on electricity production from nuclear power, but after the earthquake in 2011 and the nuclear shutdown, forced Japan into using fossil fuel to cover the energy demand. Measures and strategies regarding the reduction of energy consumption in buildings derive from international societies such as the UN and the Paris Agreement. Until recently there has been little focus on existing buildings potential for energy efficiency compared to new buildings, which fall within the stricter energy requirement. Increased focus on renovation and rehabilitation is something both Japan and Norway emphasize. Buildings lifespan in Norway variates from 60 – 80 years. In Japan the life expectancy is estimated at 30 – 50 years. The potential of reducing energy efficiency in existing buildings is significant both in Japan and Norway

A comprehensive literature review forms the basis of the results and comparisons that shows the difference between Japan and Norway, and it has been crucial to find the right aspects in terms of measures and strategies. The result show great difference between the two countries regarding energy efficiency in existing and new buildings and the major means that affect the environmental footprint are: locations, cultural and historic background, policy and regulation strategies based on each nation prerequisites and available resources.

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1 Introduction

Natural causes have always changed the global climate, but in the past 150 years, human impact has affected and changed the climate more than ever before. In 2014, the Intergovernmental Panel on Climate Change (IPCC) stated with a 95 % certainty that human impact has contributed to global warming and the necessity to take measures to decrease the effects of climate changes are of significant importance [1]. Most of the human impact on global warming can be related to increased energy consumption and high greenhouse gas emissions. For the last three decades, energy consumption has increased by almost 50 % and around 40 % increase of greenhouse gas emissions.

The building and construction sector represent considerable social value of a country and a damage to this will cause major challenges in the terms of growth and development. The global building and construction sector accounted for over 35 % of total final energy consumption in 2016, an increase of 35 % since 1990, and generated approximately 40 % of the global energy-related greenhouse gas emissions [2]. Reducing energy consumption in buildings is critical to reduce the overall energy demand and greenhouse gas emissions to contribute to the major focus of a more sustainable and safer energy supply especially in the colder regions of the world. Hence, the main challenge lays within reducing the energy demands of existing building.

In cold-climate regions, like Norway and northern Japan, people spend considerably amounts of time indoor [3]and must rely on heating, electricity and ventilation to achieve reasonable living conditions. This results in high energy consummation, and considerable amounts of greenhouse gas emissions and waste in the environment. Cold climates are associated with long and dark winters, including extreme weather conditions and long periods of temperatures far below 0 °C, makes the people more dependent on heating, electricity and ventilation than in other climates of the world.

In the achievement of energy efficient buildings, various measures and strategies related to design, construction and operation of buildings are used to face the challenges regarding energy consumption and greenhouse gas emissions. Such measures and strategies include passive (ambient energy sources, natural light and ventilation, sufficient insulation and air tightness) and active (renewable energy, energy saving gadgets and controls) design strategies [4]. Energy efficiency is of great importance but not the only issue when it comes to the reduction of greenhouse gas emissions. Treatment of waste, recirculation, life cycle assessment, indoor environment, costs and more are also crucial to achieving a fell functioning end environmentally low-impact building sector. Green or sustainable buildings are a concept based on the understandings of the impact of buildings on the environment and the reduction of negative environmental aspects in the life cycle of a building: from production to design and construction, operation, maintenance, renovation, demolition and recycling.

Norway and Japan are two countries located on the opposite side of the world from each other, resulting in different approaches and promotion of the implementation of global goals of reducing the energy consumption and greenhouse gas emissions that are applied for buildings. This include building regulations and building energy codes, architectural style, material selection and availability, and more.

1.1 Background

The origin of the master thesis is a collaboration project about green/sustainable buildings in colder regions of the world between UiT – The Arctic University of Norway in Narvik and Hokkaido University in Sapporo, Japan. It was expressed a request of international exchange of knowledge related to buildings energy performance and CO_2 emissions, while creating international relations in the terms of an exchange stay in Sapporo. It was therefore determined that the thesis should enlighten and analyze differences between Japan and Norway, regarding energy-, climate-, and building policy and other instrumental means that affect a buildings environmental footprint where the common link for Japan and Norway was cold climate and building energy efficiency and energy related CO_2 emissions from buildings.

1.2 Objective and problem description

The main objective of this master thesis project has been to enlighten and analyze how the differences in policies, regulations and other instrumental means affect the environmental footprint and energy consumptions of buildings in cold regions such as northern Japan and northern Norway. Simulations has been conducted as a part of a case study to further enlighten and visualize by figures the differences in climate and energy policies, building regulations, architectural style and the potential of energy efficiency and energy related CO_2 emissions in cold climate. In addition, perform an assessment of potential measures that complies with cold climate aspects regarding energy efficiency. The master thesis involves the following:

- Literature review and definitions of the concept Green Building and Cold Climate
- Literature review of instrumental means that affect a buildings environmental footprint and enlighten and analyze the difference between Norway and Japan.
- Feasibility study for the achievement of the concept Green Buildings in cold climate.
- Use SIMIEN for simulations and modelling different cases where outputs are building energy performance and Energy related CO_2 emissions in buildings.
- Produce a scientific report of the subject: Green Buildings in Cold Climate.

1.3 Limitations

The limitation of the master thesis project is as following:

- Literature review on definitions and concepts of green buildings, where the basic elements of green buildings are described.
- Literature review on definitions and boundaries of cold climate. Short presentation of the climate in Norway and Japan to classify some areas of the country as a cold climate region.
- Comparative study on standards and regulations in Norway and Japan. This includes energy efficiency of buildings in general, low-energy and passive houses, life cycle assessment, use of renewable energy in buildings and CO_2 emissions from buildings. Along with energy and environmental measures and strategies for the development of building energy efficiency.
- Feasibility study of green buildings in cold climate. Determine the challenges regarding the five basic elements of green buildings in cold climate and address potential solutions by referring to existing examples.
- Case study of a typical building in Japan and Norway. To make comparison of the buildings' energy and environmental footprint in Sapporo region and Narvik. Where the building is virtual and comply

with the existing building codes in the respective countries. The computer simulation software that will be used for the analysis is SIMIEN.

1.4 Structure of the report

The Table 1 presents the structure of the master thesis project, where the purpose is to supplement the table of content regarding the purpose and content of each chapter.

Table 1: Overview of the structure of the master thesis project and its content and purpose

No.	Chapter	Content and Purpose
1	**Introduction**	**Content** Give a short overview of the background, objectives and limitation of the master thesis. **Purpose** The purpose is to give the reader the information of the importance of green buildings and the enlightenments of challenges regarding energy efficiency and CO_2 emissions in cold climate, which form the basis of measures countries need to implement.
2	**Method**	**Content** Gives a description of the what kind of approach is used to complete the master thesis. The methods are divided in: literature study, feasibility study and case study. **Purpose** The purpose is to give the reader an overview of what kind of approach is used to carry out the objectives.
3	**Green Building**	**Content** This chapter is set of by defining the concepts of green buildings and its fundamental features regarding improvement and maintenance. Thereafter comes the structure of the green building concepts and base elements, including the evaluation and approach for the elements of the concept. The chapter ends with an explanation of the measure LCA for sustainable production and eco-green strategies at a building level. **Purpose** The purpose of this chapter is to explain the foundation of the theory carried out by the master thesis regarding green buildings and give the reader information of the basic elements, strategies, and evaluation.
4	**Cold Climate**	**Content** This chapter concerns the climate aspects of the master thesis and defines the term “Cold climate” and presents its boundaries in the Norther hemisphere, including different climate types. There is also a section of building design challenges that are subjected to cold climate. An overview of the climate in Norway and Japan is presented, including some cities in these countries that are located within the boundaries of cold climate. **Purpose** The purpose is to present the reader information and definitions of cold climate, including examples (Japan and Norway). It is also the purpose to enlighten the reader of the challenges buildings face in cold climate.
5	**Building and energy market**	**Content** The chapter of building and energy market presents an overview of the current situation and development regarding building stock, architectural style, total energy consumption, energy consumption in buildings, total CO_2 emissions and CO_2 emissions related to the building sector for Japan and Norway. **Purpose**

		The purpose of this chapter is to give the reader an overview of the building stock and its concerning elements to see the potential of energy efficiency, climate adaption and CO_2 emissions.
6	**Policies and regulations**	**Content** This chapter is set of by describing the international guidelines and determinations regarding environment and energy use from the Paris Agreement. Then, the chapter describes policies regarding energy use in total and in the building sector. It also describes the measures and strategies the governments have set to reach the intended national determined contribution. **Purpose** The purpose of this chapter is to present the reader the measures and strategies for the increase of energy efficient buildings, including energy supply, building codes, regulations and CO_2 emissions, to determine the difference between Japan and Norway.
7	**Feasibility study**	**Content** The content of this chapter is an assessment of the challenges and potential of measures regarding the concept of green building in cold climate. Existing examples of possible solution to some of the challenges are described. **Purpose** The purpose is to inform the reader of the challenges of implementing the green concept of green building in cold climate. It will also present the reader of potential solutions, by reviewing existing examples.
8	**Case study**	**Content** The content of this chapter includes information about the simulation software program, input data and assumptions for the execution of the simulations, and a presentation of the result from the simulations. **Purpose** This chapter is to supplement and visualize the differences of building policy regarding energy demand and energy related CO_2 emissions. This will also illustrate the influence the climate as of a building.
9	**Discussion and analysis**	**Content** This chapter will be discussion of results from the case study and literature review and highlight the main differences between Japan and Norway. The simulations and its uncertainty will be discussed. In the end there will be a discussion about the feasibility study and its implementation into the case study. **Purpose** The purpose is to present thoughts for the reader in the terms of making a conclusion.
10	**Conclusion**	**Content** This chapter will present the overall objectives and conclude the objectives as executed. **Purpose** The purpose is to summarize the results based on the literature review, feasibility study, case study and the discussion.
11	**Further work**	**Content** This chapter contents suggestions and recommendation for further work. **Purpose** The purpose is to give the reader topics for further studies and research.

2 Method

Methodology description is an important part of the master thesis project to provide quality assurance of own work in the awareness of the methodological issues, to provide a scientific education, and for others to pursue the topics for further work. Initially, an overall method was presented to find a solution to the objectives described in the introductory pages of the master thesis. The planned methodology is based on a systematic collection of documentation, and are as follows:

- Literature review on definitions on concepts of green buildings
- Comparative study on standards and regulations in Norway and Japan
- Feasibility study of green buildings in cold climate.
- Case study of a building in Japan and Norway

2.1 Literature review

Initially, the master thesis project work started with a comprehensive literature study to localize relevant facts and theories about concepts of green building, definitions of cold climate, policies and regulatory systems in Japan and Norway, international and domestic strategy and measures regarding energy efficiency and CO_2 emissions, building codes, standards and statistical means in the term om building stock, energy consumption, CO_2 emissions, etc. These topics have been found by conduction and the reviewing of academic reports, including a comprehensive internet search and other relevant literature. The objective of the literature review is to create an overview and gather information about the topics of this master thesis. Vast amounts of information have been reviewed and examined during the literature review, resulting in an increase of knowledge about various topics the master thesis deals with among the authors. All the references used in this report have been critically assessed and are based on literature from Norwegian, Japanese and international academic societies.

2.2 Comparative study

The comparative study involves statistically collection of data from Japan and Norway and other strategically collection of data to make comparisons and enlighten the differences in energy and GHG reducing measures, strategy, regulations, policy and other topics regarding this master thesis project. This comparative study will be conducted as a literature review.

2.3 Feasibility study

The feasibility study is to assess whether concept of green buildings can be met by the introduction of cold climate. This is done by the base of the literature review of examining examples containing solutions to the building challenges that are addressed in cold climate regions. The feasibility study will contribute to the discussion of the potential of reducing the energy performance of the buildings in the case study.

2.4 Case study

The case study is conducted with energy performance simulations of a building in Japan and Norway. Instead of doing simulations on real existing buildings, it was more appropriate to create a reference model of the selected building category to get a more comparable objects and therefor a comparative case study was chosen. A small assessment of simulation software programs was executed, where SIMIEN was chosen for the simulations in the case study. This was based on the interface of the different simulations software programs (SIMIEN, Energy Plus, BEST) and previous knowledge, but the need of acquirement and knowledge was still needed. Due to narrow knowledge of SIMIEN, the developers were contacted to make a new climate data base of Sapporo, Japan, so statistically data were collected to do so. The input data for the simulations were identified through the literature review, the authors assumption from own experience and help from supervisors. The case study results will support the comparative study by the visualizing of figures of the differences in building energy performance and input-based standards and building codes.

3 Concepts of Green Building

This chapter form a theoretical basis of the feasibility study where the achievements of meeting the requirements of green building in cold climate. Concepts of Green Building is based on a literature study and review of the definitions of concepts regarding Green Buildings and its basic elements.

3.1 Definition of Green Building - World Green Building Council

The World Green Building Council defines *"Green building"* as a building that in its design, construction or operation, reduces or eliminates negative impacts, and can create positive impacts on our climate and natural environment [5]. It can be perceived as the theory, science and structure of how buildings can ensure environmentally sustainability throughout its whole life-cycle: from planning to design, construction, operation, maintenance, renovation and deconstruction [6].

Green building is interpreted in many ways. For instance, the concept is often referred to and known as "green architecture", "sustainable building" or a "high-performance building" [7]. Overall, it's a term used for a building confining to certain environmental and energy related criteria. The concept includes a structure of several elements depending on which certification tool is used and what is being emphasized depending on each country prerequisite and characteristics. A common view regardless of any country or type of structure is that the main objective is to find the right balance between high-quality construction and low environmental impact. The fundamental features of a Green Building, is a building that can maintain or improve [8], [9]:

- The quality of life and harmonize within the local climate, tradition and culture.
- An intelligent approach towards minimizing and efficiently using energy, water and other resources of matter.
- Protection of occupant health and wellbeing by delivering good indoor air quality and use of non-toxic materials.
- Maintain environment by pollution and waste reduction measures, and the enabling of re-use and recycling throughout the entire buildings life-cycle.

3.2 Structure of the concept Green Building - Basic elements

Green building brings together a vast array of evolving practices, techniques and certification systems that may differ from region to region. Common to them all, is that the process of designing a successful green building does not escape addressing key elements of that have to comply with the green criteria. USGBS LEED Green Building Rating System, one of the world's most developed rating system addresses five of the most *central* elements from which the concept is derived [10] (Figure 1). It ranges from sustainable site design to conservation of materials. The essential element of a green building concept in general, is the energy efficiency performance of a building. Throughout the years the world has seen several actions through new development and standards to advance energy efficiency in buildings. Passive house and Zero Emission Buildings are examples of such actions and has enhanced the key element of the possible criteria for the future Green Building. The following sections will give a brief explanation and address each element by principle related to its concept and structure.

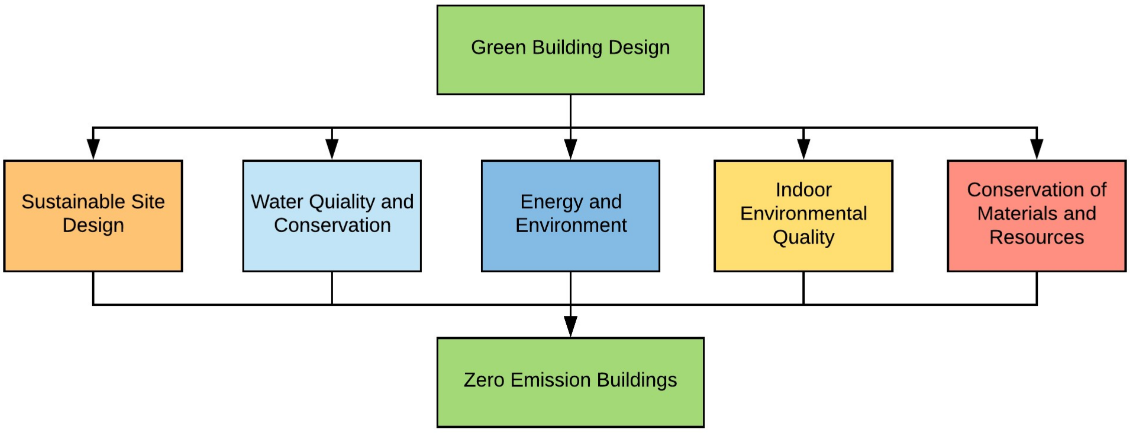


Figure 1: Structure of key elements of the concept Green Building

3.2.1 Sustainable Site Design

The foundation of any construction is to design a site that integrates itself sustainable with the built environment and its surroundings. The process begins with an intimate understanding of the site to preserve key environmental assets through careful examination. Key principles are that it should work with natural features by minimize urban sprawl and unnecessary disturbance of valuable land, habitat and wildlife, protecting trees, streams with an effective use of drainage and energy-saving shade [11]. Urban sprawl and disturbance of land is often the result of inefficient low-density development, so to promote higher density and pursue brownfield development to save valuable green space are therefore crucial [11]. Significant energy savings can be proclaimed by location and the orientation by taking advantage of the sun and wind to optimize the use of passive solar energy, natural lighting, and natural breezes and ventilation. In addition, the design and its location can both create shared public space and encourage the use of alternate transportation methods. If not, and if people have no choice but to travel long distances by cars to get the service they need, the overall sustainability, regardless of how green the building it is, will in some certainty be compromised.

3.2.2 Water Quality and Conservation

Water can be captured, stored, filtered and reused, and its often referred to the source of life. Reducing water consumption and protecting water quality are key objectives in sustainable building, and to ensure that its used efficiently, green design encourages on-site mechanisms such as rainwater harvesting, waste water treatment and recycling, green roofs and controlled storm water treatment, aside from water conserving appliances [12]. As a result, the infrastructure that supplies potable water, collects and discharge storm water, and disposes waste water, such as pipes and treatment facilities will take less damage over time [12]. Overall, green buildings should include water conserving landscapes as well as water saving fixtures and appliances. Buildings stands for a significantly impact on global water consumption. Showers, sinks, washing machines and toilets are all appliances people today depends on, and to streamline a whole building in terms of water conservation, it is important to plan buildings infrastructure and the choice of appliances carefully. By selecting appliances that are water-efficient and minimize the distance between the hot-water heater and kitchens or bathrooms, saves water and are cost-saving as well.

3.2.3 Energy and Environment

Energy is one of our most vital factors to our way of life. A green and sustainable design includes measurers to reduce energy consumption – both the embodied energy required to extract, process, transport, and install building materials, as well as the operating energy consumed by heating, cooling, lighting, and power for equipment's. A case study conducted as a life cycle energy analysis of buildings (residential and office), included 73 different cases across 13 countries, showed that operating energy were equal to 80-90% of the life-cycle energy consumption and are a significant contributor to a building's energy demand [13]. With the objective to reduce the thermal aspects of energy consumption in the operational stage, it would be necessary to specify how to heat, cool and light the building with the sun and wind and consider a computerized energy management system that can track loads to adjust maintain efficiency. Passive solar building design takes advantage of a building's site, climate and materials, and will dramatically reduce the heating and cooling costs of a building [14]. As simple as surrounding the building with trees can provide shade in summer (cooling) and block winds during the winter (heating). A high-performance building envelope includes high-efficiency windows and insulation in walls, ceilings and floors to increase the efficiency of the building, which can block, hold, and release energy to let mother nature work with its design. For example, effective window placement (daylighting) can provide more natural light and lessen the need for electric lightning during the day. Green building also incorporates low energy appliances, and renewable energy technologies such as solar power, wind power, hydro power and biomass conservation.

3.2.4 Indoor Environmental Quality

The essential goal for any building is an indoor air environment that enhances resident health and comfort. People spend a lot of time indoors and the indoor climate therefore has great importance to our health, comfort and well-being, which form an important factor when we measure sustainability from the social dimension. To achieve so, a high quality indoor environment requires careful design by the choice of products and materials that coexists with the air exchanges by a well-designed ventilation-system or high levels of natural ventilation. In addition, a well-designed building envelope that avoids mold and moisture by a clean construction and materials specifications, reduces dust and airborne toxins [12]. There are likely to be many sources of indoor air pollution in any home or building. Many modern building materials for instance contains dangerous chemicals that off-gasses into the atmosphere and are often contributors to a poor indoor environment and resulting of bad wellbeing. Green buildings shall incorporate materials with less chemical content and off-gassing potential [15].

3.2.5 Conservation of Materials and Resources

Another main aspect of sustainability and green buildings is the conservation of materials. Besides having a great effect on the indoor environmental quality, the environmental impacts of materials and products are considered across their entire life-cycle: extraction, production, operating and demolition. Responsible waste management is an essential part of building green and sustainable, especially in the construction phase. Green building encourages materials that are obtained from natural, renewable sources and harvested in a sustainable way. The materials are non-toxic, multi-functional, durable and easy to salvage and recycle at the end of a building's service life [12]. Moreover, they should be extracted and manufactured locally to the building site to minimize the embodied energy costs of transportation or salvaged from reclaimed materials at nearby sites.

3.3 The approach of Green Building

Any building can be a green, whether its house, a nursing home, a hospital or either the kinder garden or an office building. However, it’s not said that all green buildings are and need to be the same. Moreover, one of the Green Building features is to create a building that not just improve the quality of life, but also harmonize within the local climate, tradition and culture. Meaning, every country and regions is more than likely to have a variety of characteristics such as a distinctive climate conditions, unique cultures and traditions, diverse building types and ages, or polices which can be wide-ranging in terms of environmental, economic and social priorities – all of which shapes their approach to green building [5]. Regardless, the decision to take on a greener approach should be decided early in the design process to secure maximization of the green potential, minimize redesign, and assure the overall success and economic viability of the green elements of the green building project. After clear environmental and measurable goals has been set, and the evaluation of the buildings site characteristics have been considered, the science and the interrelationship between a buildings element is significantly important. Meaning, it’s not just a matter of assembling the latest collection of green technologies or materials, but it's rather the process in which every element of the design is first optimized and then the impact and the interrelationship of the numerous different elements and systems within the building and site, are re-evaluated, integrated, and optimized as a part of a whole building solution [6]. The interrelationship is important and the coexistence between the building site, site features, the path of the sun, and the location and orientation of the building and elements such as windows and external shading devices have a significant impact on the quality and effectiveness of natural day lightning. These elements also affect direct solar loads and the overall energy performance of the building. For the design to be fully optimized, these issues must be considered early in the design process. If not, the result is likely to be a very inefficient building [6].

3.4 Evaluation - Certification of Green Building

Rating and certification systems have been developed as a yardstick to measure the sustainability level and the environmental performance of a building. By now, there is a numerous of green building rating systems implemented worldwide, each addressing their selection of relevant elements, and having their categories and criteria under constant updates to follow the sustainable trends of building development. Among these are: BRE Environmental Assessment Method (BREEAM, United Kingdom, since 1990), LEED (United States, since 1998), Comprehensive Assessment System for Built Environment Efficiency (CASBEE, Japan, since 2001) and DGNB (Germany, since 2007) [16]. Other major Green Building Rating systems can be viewed in by Figure 2:

Figure 2: Major Green Building Rating Systems [17]

The purpose of rating systems is to certify the different aspects of sustainable development. To achieve a certain level of certification, a sustainable building in its design, construction and operation must attain several given benchmarks in their own respective categories. By using the criteria's compiled in guidelines and checklists, building owners and operators are given a comprehensive measurable impact on their buildings' performance and a quality assurance for building owners to secure convenience and usability for its users. The criteria could either only cover aspects of the building approach to sustainability, like energy efficiency, or they could cover the whole building approach by identifying performance in key areas like sustainable site design, water conservation, material conservation, indoor environmental quality, social aspects and economical quality [18].

Table 2: Comparison of different Rating Systems for Green Building [18]

System (country of origin)	BREEAM (Great Britain)	LEED (USA)	DGNB (Germany)	Green Star (Australia)	CASBEE (Japan)
Initiation	1990	1998	2007	2003	2001
Key aspects of assessment and version	- Management - Health & well-being - Energy - Water - Material - Site ecology - Pollution - Transport - Land consumption BREEAM for: - Courts - EcoHomes - Education - Industrial - Healthcare - Multi-residential - Offices - Prisons - Reatil	- Sustainable sites - Water efficiency - Energy and atmosphere - Material and resources LEED for: - New construction - Existing buildings - Commercial interiors - Core and shell - Neighborhood development	- Ecological quality - Economical quality - Social quality - Technical quality - Process quality - Site quality DGNB for: - Offices - Existing buildings - Retail - Industrial - Portfolios - Schools	- Management - Indoor comfort - Energy - Transport - Water - Material - Land consumption and energy - Emissions - Innovations Green star for: - Office - Existing buildings - Office interior design - Office design	Certification based on "building environment efficiency factor". BEE = Q/L Q: Quality Q1: space interior Q2: Operation Q3: Environment L: Loadings L1: Energy L2: Resources L3: Material Main criteria: - Energy efficiency - Resource consumption efficiency - Building interior
Level of certification	Pass Good Very Good Excellent Outstanding	LEED Certified LEED Silver LEED Gold LEED Platinum	Bronze Silver Gold	4 stars: Best Practice 5 stars: Australian excellence 6 stars: World leadership	C (Poor) B B+ A S (excellent)

As the user choses on tool to assess a building with, the assessment is forced to a certain model; definitions, weighting or scoring systems, and databases. The structure of rating systems is divided in different elements and aspects, like "Management" (BREEAM), Energy & Atmosphere (LEED) and

Site Quality (DGNB). For each element, several benchmarks exist and needs to be verified to meet requirements or obtain points. The result is the sum of individual or weighted points, depending on the method. The number of points is ranked in the rating scale, which is divided into different levels. The higher the number of points, the better the certification [18]. By now, many have elaborated on whether all the Green Building Rating systems achieve the same environmental performance; whether a certified project guided by one green building rating tool can attain the same green level under another green building rating system. The findings illustrate differences on assessment schemes, criteria and weights, resulting in the different achievement of the final scores.

The main difference is the weighting, and how the various national assessment systems choose to weight the different environmental categories. These naturally follow the main environmental and social issues for that country or region, which results in rating systems tailored to account for climate and local culture. In addition, some systems give credits for compliance with building regulations [19]. For instance, Japan's Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) is more concerned about land use, while Estidama (sustainability in Arabic), developed by the Abu Dhabi Urban Planning Counsel, is not surprisingly stressed on the importance of the country's water conservation [19].

3.4.1 BREEAM – BRE Environmental Assessment Method

BREEAM was developed by the Building Research Establishment (BRE) in 1988 and launched in 1990 in Great Britain, until introduced to the International market in 1998 [20]. It's the world's first and one of the leading sustainability assessment method for master planning projects, infrastructure and buildings, and a comprehensive and widely recognized measure of a buildings environmental performance. The system is currently present in 77 countries, including Norway as a country-specific scheme BREEAM-NOR. It is also widely accepted that almost all later major green rating systems such as LEED, Green Star and CASBEE are under the influence of BREEAM [21]. Aside from assessing local codes and conditions, BREEAM also allows application in international buildings and enables evaluation of a building's lifecycle in view to design, built, operation and renovation. Since it's market launch, BREEAM has issued more than 560 000 certifications, 2 272 801 buildings are registered for assessment, and accounts for 80 % if the European market share [22]. Different building versions have been created since its launch, to assess the various types of buildings, where the environmental factor is predominant with eight main categories including: Management, Energy, Transport, Water, Materials, Waste, Land Use & Ecology, and Pollution.

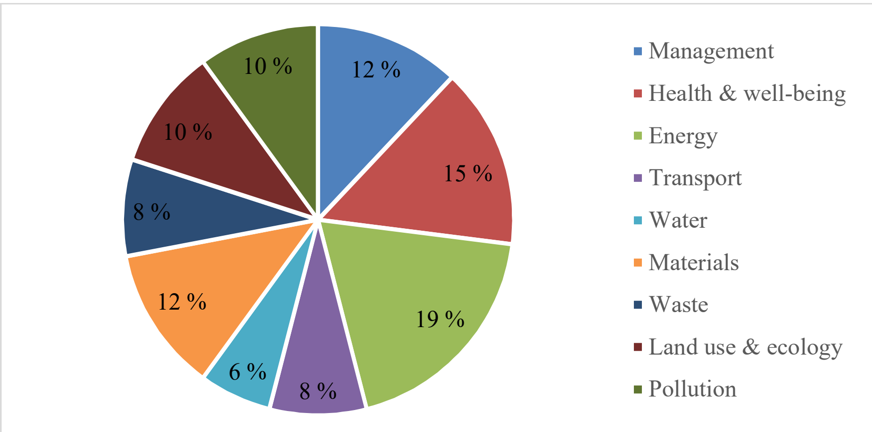


Figure 3: BREEAM weightings

Table 3: BREEAM ratings

BREEAM Rating	% score
Outstanding	85 %
Excellent	70 %
Very Good	55 %
Good	45 %
Pass	30 %
Unclassified	< 30 %

3.4.2 CASBEE – Comprehensive Assessment System for Built Environmental Efficiency

CASBEE was developed by a research committee established in 2001 through the collaboration of academia, industry and national and local governments to promote sustainable buildings, which established the Japan Building Consortium (JSBC) under the auspice of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) [23]. It's a voluntary, non-regulative program, and a method for evaluating and rate the environmental performance of buildings and the built environment. It's been designed to both improve the quality of people's well-being and to reduce the environmental loads associated with the built environment throughout its life-cycle, from a single home to a whole city [23].

Japan Building Consortium explains that the concept of eco-efficiency has been introduced for CASBEE to enable the integrated assessment of two factors: inside and outside the building site [24]. Normally, the definition of eco-efficiency is a "value of products and services per unit environmental load" and efficiency is commonly defined in terms of input and output quantities. CASBEE model is based on an expanded definition of eco-efficiency; "(beneficial output)/ (input + non-beneficial output)" which defines a buildings Built Environment Efficiency (BEE), that CASBEE uses as its assessment indicator.

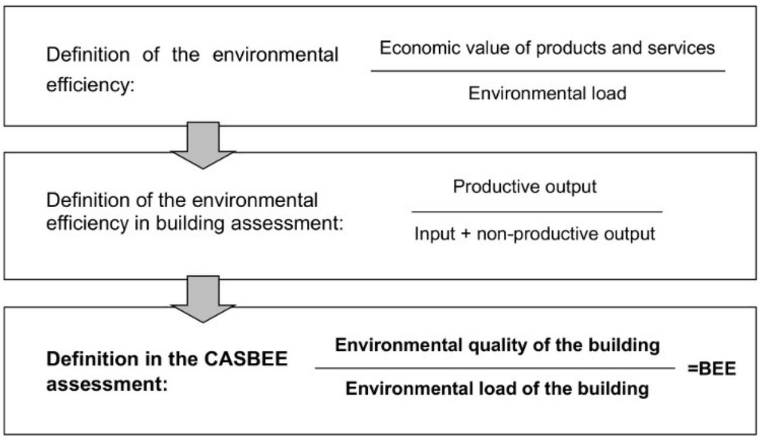


Figure 4: Development from the Eco-Efficient concept BEE [24]

CASBEE covers the following four assessment fields: 1) Energy efficiency, 2) Resource efficiency, 3) Local environment, 4) Indoor environment, and has been classified into BEE numerator Q (Built environment quality) and BEE denominator L (Built environment loads). Q is further divided into three items for assessment: Q1 Indoor environment, Q2 Quality of service and Q3 Outdoor environment. Similarly, L is divided into L1 Energy, L2 Resources and Materials and L3 Off-site Environment. This is the core concept of CASBEE, using Q and L as two assessment categories, where BBE is a calculation between them and enables a simpler and clearer presentation of a building's environmental performance assessment results. Figure 6 illustrates the assessment results that a building can be ranked on a diagram as rank C (poor), rank B-, rank B+, rank A, and rank S (excellent) in order of the increasing BEE numerator.

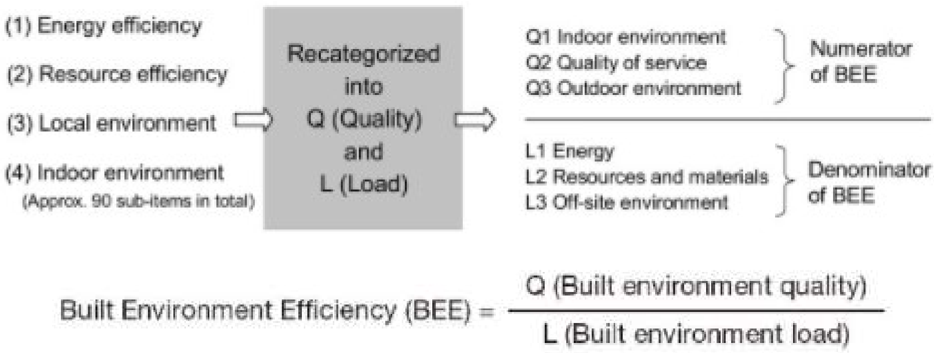


Figure 5: Classification and rearrangement of assessment items Q and L, and BEE numerator [24]

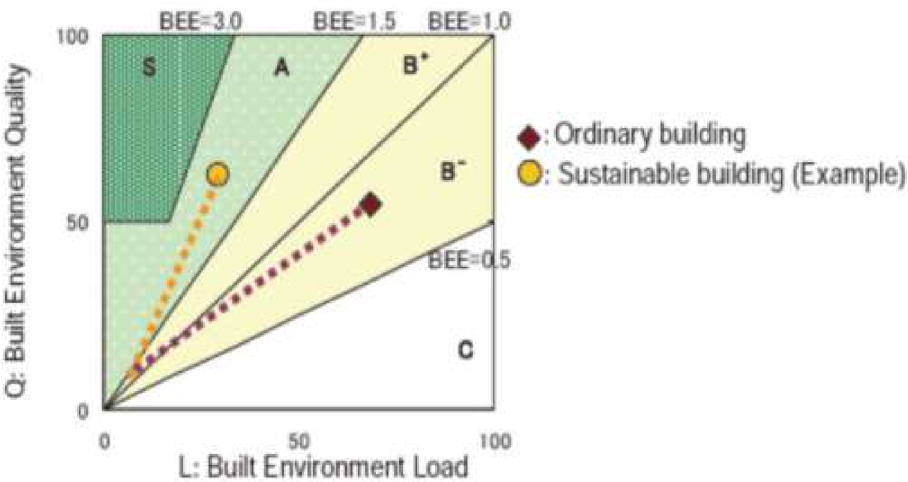


Figure 6: Environmental labeling based on BEE [24].

3.5 Life Cycle Assessment

Building green, makes it somehow complex to navigate the claims to meet present needs without compromising the future. Life Cycle Assessment (LCA) has emerged as a valuable decision-support tool and a technique to assess and evaluate the environmental impacts and resource consumptions associated with all the stages of a product's life-cycle.

The assessment is often referred to as a "life cycle analysis", "life cycle approach", "cradle to grave analysis" or "ecobalance", and represents an emerging family of tools and techniques to help in environmental management and sustainable development. The methodology dates to 1960s and early 1970s due to concerns over the limitations of raw materials and energy resources and focused on finding ways to cumulatively account for our consumption and to project future resources and further use [25]. Since then, the LCA-methodology has been exploited in varies types of industries. A great example is the original study commissioned by The Coca Cola Company in 1969 on comparisons between resource consumption and environmental release associated with beverage containers [25]. Meanwhile, in

Europe, a similar inventory approach was being developed, later known as the "Ecobalance". But it was not until the mid-eighties and early nineties that LCA really caught the eye to a much broader range of industries, design establishments and retailers, which later resulted in the ISO 14040 standard series by the International Organization for Standardization (ISO), first published in 1997 [26].

Figure 7: The LCA of a construction product [27]

3.5.1 Definition of LCA

The International Organization for Standardization (ISO) defines LCA as a "compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle" [26]. Meaning, LCAs are used to measure both material and energy inputs and outputs, evaluate the effects of those inputs and outputs and formulate the data into useful information for understanding the outcome of a product or process has on the air, land or water and the overall environmental effect. The general standards in the context of LCA, ISO 14040:2006 and ISO 14044:2006, provides a framework of principles, guidelines and requirements that concerns both the technical as well as the organizational aspects of an LCA project. The methodological framework for a life cycle assessment is defined by four main phases:

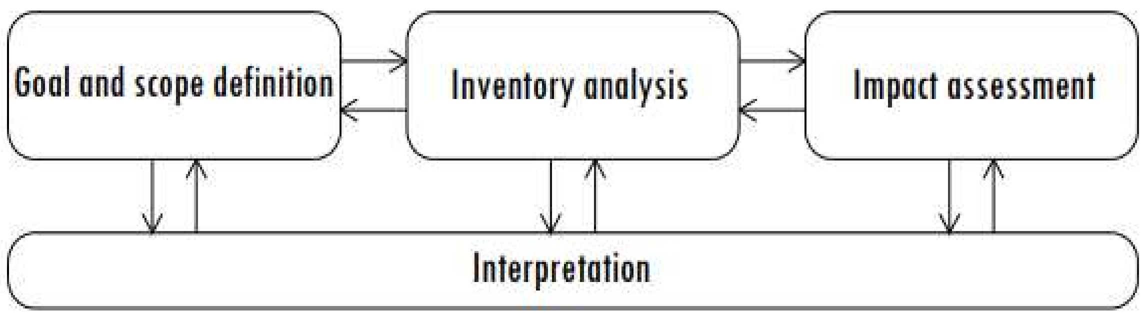


Figure 8: Methodological framework for a life-cycle assessment

- *Goal definition and scoping:* The goal includes the intended application, the reason for the study, the audience, and whether the results are disclosed to the public. The scope defines the product to be studied, the functional unit, system boundaries, impact categories and treatment of uncertainty.

- *Life-Cycle Inventory (LCI):* Involves compiling and quantifying inputs and outputs for a product through its life cycle, and collection of the data necessary to meet the goals of the defined study.
- *Impacts Analysis (LCIA):* Evaluate the significance of the potential environmental impacts for a product system throughout the life cycle of the product.
- *Interpretation and Improvement Analyses:* The phase in which the finding of either the inventory analysis or the impact assessment, or both, are evaluated in relation to the defined goal and scope on order to reach conclusions and recommendation.

3.5.2 LCA at the building level

The building industry, governments, designers and researchers of buildings are all affected by the trend of sustainable production and eco-green strategies. LCA has since 1990 been an important tool for evaluating buildings and the interest has been growing fast from the 21st century [28]. The value of integrating LCA in a building design process is somehow crucial for the professionals to evaluate the life cycle-impacts building materials, components and systems to choose the most sustainable combinations and reduce a building's overall environmental impacts. When LCA is applied to the building, the product studied is the building itself, and the assessment will be defined according to a certain level and contain all the materials processes [28].

Integrating LCAs in a building design process, do also come with some complexities. Aside from now having a product being a whole building itself with its components, the lifespan particularly plays a significant part. In a design stage it can be hard to predict the whole life-cycle from cradle-to-grave with a product estimated to a lifetime of 50 years, where it may also undergo many changes on its form and function, which can be as significant, or even more significant, than he original product, especially in terms of its use-phase. As mentioned, the operating energy consumption has been estimated to represent approximately 80 to 90 % of the life-cycle energy use, while 10 % to 20 % is consumed by the embodied energy and less than 1 % through end-of-life treatments [9]. It is therefore critical that LCAs should be used as a decision-making tool to predict, not guarantee what the overall outcome after, for instance 50 years would be. It is also worth mentioning is that by the development of energy-efficient buildings and the use of less-polluting energy sources, the contribution of the material production and end-of-life phases is expected to increase in the future [9]. In terms of building green and sustainable, LCA provides two primary benefits [29]:

- During the design and building processes, LCA helps building-code officials make more informed decisions
- Enhances innovation by revealing opportunities to improve a products quality

When equipped with an LCA's insights [29]:

- Contractors can get a better understanding to prevent environmental problems in their projects
- Home Builders can use LCAs as a tool to get a better understanding on how green building materials yields energy savings
- Building Owners can see the positive effect of choosing the right products through an environmental aspect

4 Cold climate

This chapter form the theoretical basis for the thesis that concerns the climate aspects and is based on a literature study of cold climate, its definitions, types and prevalence, climate in Japan and Norway, and challenges buildings face in cold climate and the factors affecting this.

4.1 Cold regions

Cold regions can be defined by three different parameters; air temperature, permafrost and ice on rivers, lakes and harbors. In general, a cold climate environment exists wherever frost affects engineering systems [30] and are characterized by long cold winters with low air temperatures, snow, ice, frozen ground, ice fog and whiteout [31]. Cold regions can be divided onto three temperature-defined climatic zones and was done by Gerdel in 1969 [31]:

- *Cold winter*, where the mean temperature during the coldest month of the year (θ_{30d}) is between -17.8°C and 0°C.
- *Very cold winter,* where -31.7°C < θ_{30d} < -17.8°C.
- *Extremely cold winter,* extending northward form the -31.7°C isotherm, where temperatures of -62.2°C or less might be expected.

In 1966, Bates and Bilello [32] defined cold climate and its boundaries by four parameters: air temperature, snow depths, days with ice cover and frozen grounds and concluded that the cold region boundaries lie within the 40th latitude with few exceptions [31]. The ice cover definition will not be further described.

4.1.1 Cold region boundaries determined by air temperature

For the definition of cold region by air temperature, the southern limit of the cold regions in the Northern hemisphere is defined as the isotherm for 0°C mean temperature during the coldest month of the year [32]. The Figure 9 shows the cold region boundaries of air temperature set by Bates and Bilello in 1966, at the 0°C isotherm and -17.8°C isotherm.

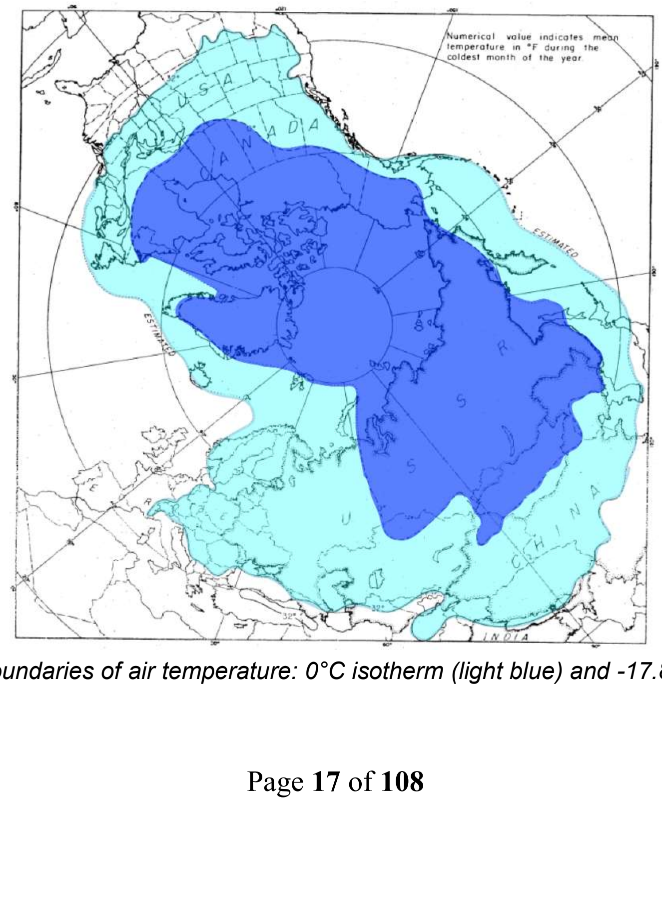


Figure 9: Cold regions boundaries of air temperature: 0°C isotherm (light blue) and -17.8°C isotherm (darker blue) [32]

4.1.2 Cold region boundaries determined by snow depth

Defined boundaries determined by snow depth, where the maximum observed depth of snow on the ground were recorded at the end on the month in the Northern hemisphere. This is shown in Figure 10 and isolines joining depths of 12 and 24 inches [32]. Due to global warming since 1966, might have affected the areas, and the cold region determined by snow depth is become smaller.

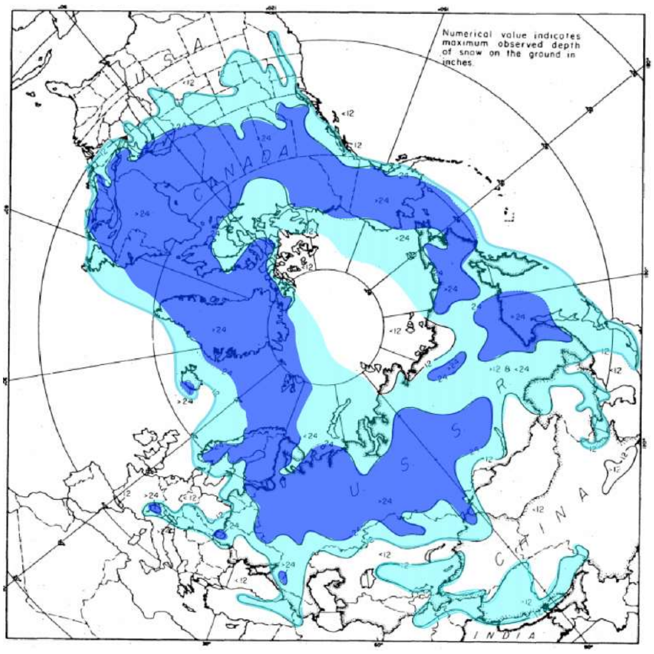


Figure 10: Cold region boundaries of snow depth: 12 in < light blue < 24 in, darker blue > 24 in [32]

4.1.3 Cold region boundaries determined by frozen grounds

The boundary lines for cold region determined by frozen grounds are based on three criteria: continuous permafrost, discontinuous permafrost. and frost penetration in the ground once in ten years. Where the latter one was obtained by using mean of 100 degree-days of freezing temperatures (base 32°F) as index [32].

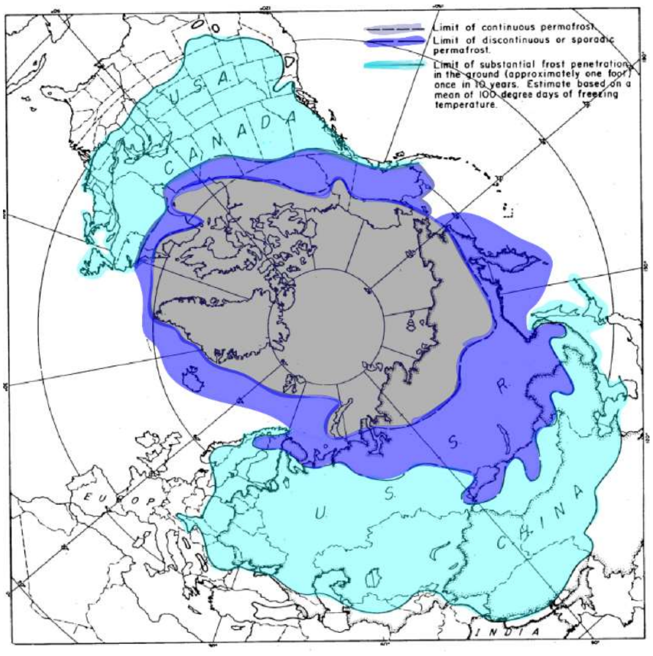


Figure 11: Cold region boundaries of frozen grounds [32]

4.1.4 Cold region boundaries determined by heating degree days

The boundary lines for cold climate determined by heating degree days have no common definition regarding building energy performance, but the heating degree days gives and indicator of the heating demand and referring to cold climate. It is defined by the amount of degrees the daily mean temperature is below 18°C [33]. An assumption of the definition of cold region by heating degree days could be from 3000 heating degree days and up.

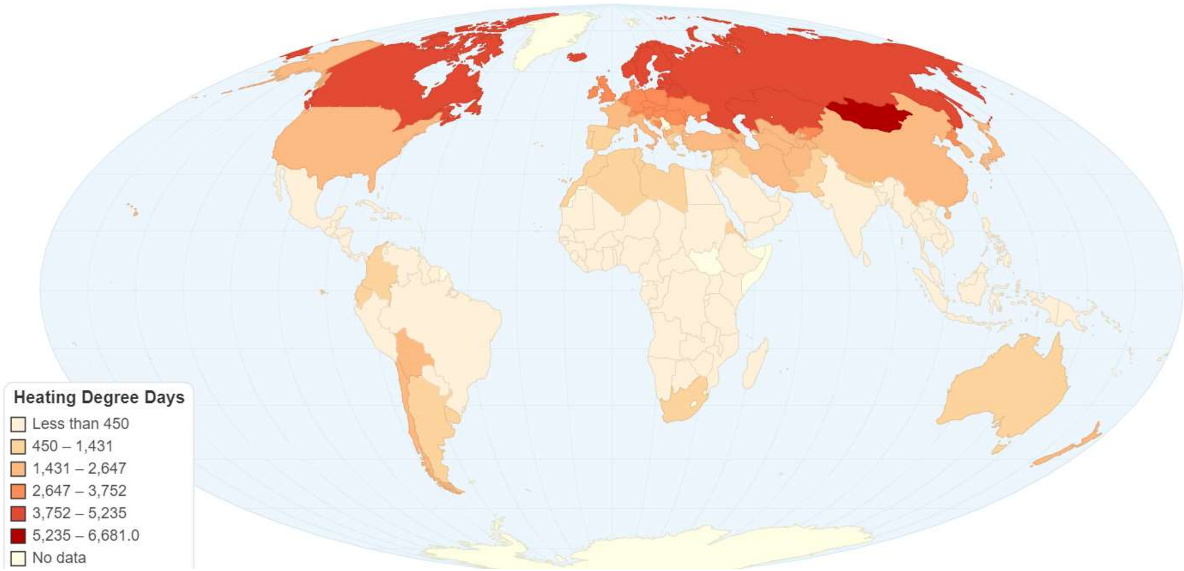


Figure 12: Heating Degree Days around the world [33]

4.2 Köppen climate types

Köppen climate classification system is a widely used system for classifying the world's climate designed by W.P. Köppen and are based on annual and monthly mean values of temperature and precipitation. The climate around the globe can be divided into five major climate types from the Köppen climate classification [34]:

Table 4: Köppen major climate types and its characteristics

	Climate zone	Characteristics
A	**Tropical climate**	- Cover approx. 20 % of world's landmasses. - Annual mean temperature; $\theta_{365d} > 18$°C.
B	**Dry climate**	- Cover approx. 26 % of world's landmasses. - Wide variances in seasonal and daily temperatures. - Low and unpredictable precipitation. Annual precipitation < 500mm.
C	**Temperate climate**	- Cover approx. 16 % of world's landmasses. - Mean temperature during coldest month of the year; $-3°C < \theta_{30d} < 18°C$.
D	**Continental climate**	- Cover approx. 21 % of world's landmasses. - Mean temperature during coldest month of the year; $\theta_{30d} < -3°C$. - Mean temperature during the warmest month of the year; $\theta_{30d} > 10°C$.
E	**Polar Climate**	- Mean temperature during the warmest month of the year; $\theta_{30d} < 10°C$.

The figure below shows the prevalence of the five main climate types from the Köppen climate classification. Within the cold region boundaries in Figure 9 are temperate climate, continental climate and polar climate whereas the latter two are the most dominant and temperate climate occurs in some minor cases.

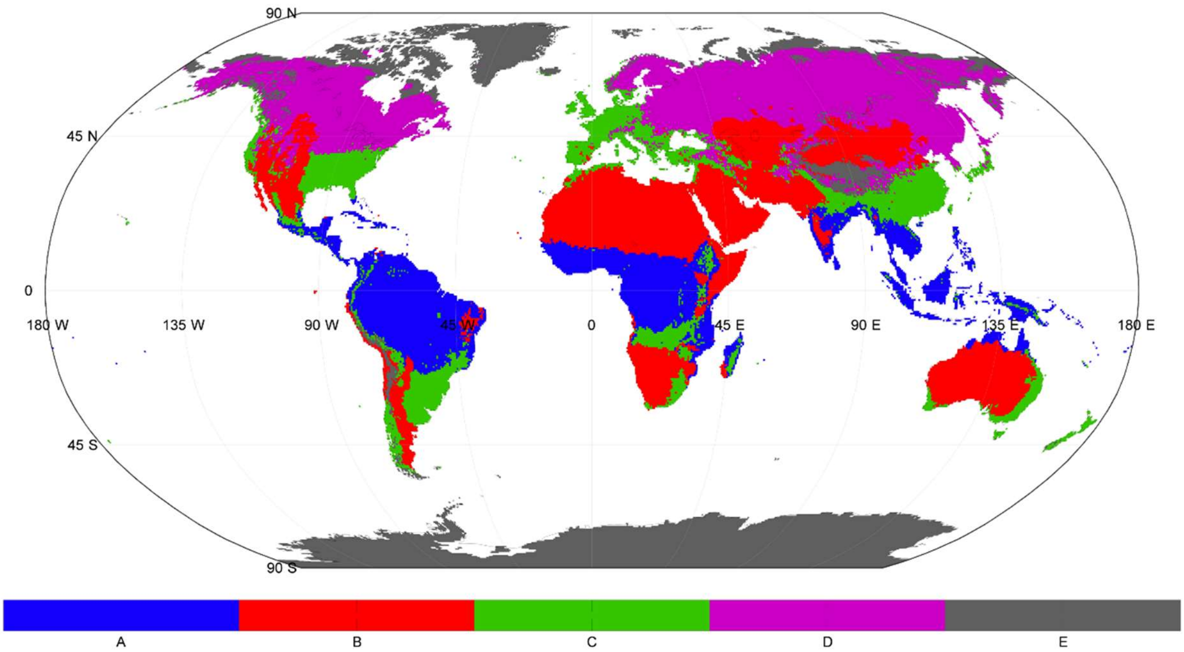


Figure 13: World map of Köppen climate classification

4.3 Building design challenges in cold climate

People face vast and various challenges by living under harsh winter conditions in cold-climate regions in the Northern hemisphere. Gerdel (1969) stated that strains due to cold climate environment influence engineering design, facilities maintenance and operations, transportation, and human performance. Adapting to the environment becomes a necessity under such circumstances and has become second nature to the people living in cold-climate regions [31]. Main challenges for buildings in cold climate include ensuring the buildings envelope is acceptable, structural aspects regarding foundation, mechanical and plumbing, electrical, controls, fire and safety, and site services. The challenges of building in cold-climate regions are generally like those in other climates, but the cruciality of an eventual failure of the solutions to the challenges are greater and more sever in cold climate due to higher air temperature differences, i.e. a hindrance in a temperate climate may threaten health and life safety in a cold climate. The following subsections are based on the ASHARE's *Cold-Climate Building Design guide* [35]:

4.3.1 Cold climate factors of building design challenges

Building in cold climate regions face not only challenges related to cold, but remoteness, limited utilities and materials, permafrost, and extreme temperature shifts. A cold-climate related challenges in buildings are defined by a combination of factors such as temperature, frozen precipitation, wind, humidity, thermal comfort, maintainability, and permafrost and frozen ground.

4.3.1.1 Air temperatures and humidity

Cold temperatures, below the freezing point of water, are one of the main characteristics for cold climate regions. Humidity and moisture cause extra complications due to cold climate and make materials susceptible to rising relative surface humidity and surface condensation. Robust and well-maintained construction materials, support systems, and equipment are there for necessary to function at low temperatures due to water content and the susceptible to freezing if not protected. There is also a significant difference in the indoor temperature and the outdoor temperature under a cold climate than for hot climate; for cold climate the temperature difference (ΔT) might exceed 60°C, from 20°C indoors to -40°C outdoor temperature (For hot climate 20°C indoor temperature, 45°C outdoor temperature, ΔT = 25°C) [35].

4.3.1.2 Wind and precipitation

Cold climate is characterized by frozen precipitation and buildings must be designed for snow, ice, vapor and freezing rain, if not it can cause serious complications. Extra support is needed to accommodate the accumulating amounts of snow received through the winter. Snow also create barriers regarded to access and fire safety in buildings due to roof avalanche, heavy snowfall and snow drifts. Pressure differentials caused by wind cause infiltration, create snow drifts, drive snow into louvers, and rip roofs and sidings off buildings. It is important take air velocities and pressure into account when building in Cold climate [35].

4.3.1.3 Thermal comfort and maintainability

Maintenance of buildings is necessary to keep a building operational. In cold climate, this can be complicated due to freezing temperatures, freezing precipitation and wind. Maintenance may occur more frequently due to harsh weather conditions. In the lack of necessary maintenance, the thermal comfort will decrease due to cold interior surface, lower inside temperature and drafts. The combination of passive and active systems is required to establish thermal comfort for occupants in a building in a cold-climate region [35].

4.3.1.4 Permafrost, frozen grounds and remote building location

Both frozen grounds and remote building location affects and limits the construction season in cold-climate regions, as well as construction materials and methods, i.e. building a foundation on permafrost may be challenging and frozen ground can cause damage to the foundations and other utilities in the ground. As the remote locations also experience more harsh winter conditions, the transportation to the building is limited resulting in less maintenance, and a high chance of power interruption [35].

4.3.1.5 Duration

The length of time the building is exposed to cold weather conditions is also a factor for the challenges regarding the building design in cold climate. Over a longer period in cold-climate weather, walls and other elements can experience ice build-up and condensation due to freeze and thaw cycles resulting in rot, the decrease of the thermal performance and poor indoor quality. The longer the exposure of extreme temperature, and temperature changes the more maintenance is required to maintain acceptable performance.

4.3.2 Building Envelope

The building envelop is the primary system for retaining heat, air, and moisture. There are several key points that are required for a buildings envelope regarding performance in cold climate. This passive heat loss resistance system prevent heat for leaking out and work in conjunction with active systems such as HVAC and lighting to provide thermal comfort. In cold climate the building envelope is optimized when integrated with other building systems and its performance should remain constant during its lifetime. Remain a constant performance in cold climate is challenging in a cold climate as the building envelope are very critical to air and moisture movement through components. This leads to ensure that the insulation is properly installed and that there is no direct conductive thermal bridge, but also ensure integrity of the insulation and the water barrier in the interface of structural, mechanical and electrical penetration. For the building envelope in a cold climate in the event of a failure, the challenges can grow severe and include a cost of failure; where the failure are beyond simple repair and may threat life and health of occupants in buildings because of overcapacity and eventual failure on the heating systems, construction challenges; lack of available materials to replace cause delay or might be impossible to repair due to remote location, and collateral effects on related systems; when thermal performance decreases, it places additional strain on other heating systems and cause negative effect on the serviceability and operating costs. The key element of buildings envelope in cold climate is the thermal control which is an effective control of limiting the transfer of thermal energy through the skin and limiting the usage of material that carries energy out of the building.

4.3.3 Structural

The challenges of the structural means regarding cold climate is the importance of the elimination or mitigation of thermal bridges between the superstructure and the foundation by keeping the thermal envelope continuous around structure elements, as the foundation supports the buildings superstructure. Another strain due to cold climate and its factors is the amount of accumulating of snow load received through the year and the supporting the structure to refrain it from collapsing. One of the characteristics of a cold climate is the length of periods with freezing temperature. This results in frozen grounds and the term frost depth penetration is highly relevant for the foundation of a building or other structure. To prevent damage from i.e. frost heaving, building foundations are required by code to be a defined distance below the frost penetration depth. The frost penetration depth is dependent on moisture and the length of the period of freezing, and it is important to ensure proper drainage around the foundation to prevent moisture and water to freeze and cause damage to the foundation. In more extreme conditions where buildings are built on permafrost it is important to maintain the integrity of the permafrost, because if it melts the building gets an uneven settlement and will damage the building and structure.

4.3.4 Mechanical and plumbing

Mechanical and plumbing regard the HVAC systems and are highly dependent on the thermal envelope and its performance. Mechanical and plumbing systems are generally dealing with the flow of liquids and heat. There is a high risk of these systems fail in a cold climate and the consequences are costly and sever. Because of the need of sufficient heat capacity is greater in cold climate, critical heat components should be protected against cold climate factors, i.e. redundant backups and manual control overrides of the heating components, proper insulations and/or antifreeze solutions to prevent and protect from freezing, corrosion and rupture in hydronic heating systems exposed to low air temperature, and all components should be placed inside the thermal envelope. As for the components placed outside the thermal envelope, it should be placed under the frost penetration depth to prevent from freezing and causing damage. It is also important to ensure that the controls and operators are suitable for low-air temperatures.

4.3.5 Electrical

Electric systems such as lighting systems are highly sensitive to light output reductions at low temperatures and cold climate. Most areas with a cold climate are located with a proximity to the poles and lack of natural daylight is characteristic for cold-climate regions. Lighting component need to be suitable for extreme temperatures. Electric heat is also used to supplement other heating systems in the building to maintain the thermal comfort. In remote locations, electric power might be unstable, and generators are required for electrical power and security of fuel supply is critically important.

4.3.6 Fire and safety

During a long period of cold weather and heavy snowfall constitute a risk regarding fire and safety. This includes clearing snow from emergency exist and provision to ensure safe evacuation in severely cold weather. Different systems are required for different areas in buildings in cold climate. In areas subjected to low-air temperature it is important to protect the fire safety systems not to fail during a fire, in this case using air sprinkling systems in cold areas and water sprinkling for areas that are warmed up to refrain from freezing. Unnecessary evacuation often occurs in the result of moist indoor air exposed to cold air create something that resembles smoke and trigger the smoke detectors to set off.

4.4 Norway

Norway is a rich and developed country with a high standard of living, located in the high north and compromises the western part of the Scandinavian Peninsula. It is known for its mountains, fjord coastline and a long history as a seafaring power. The geographical locations of Norway’s mainland extend over more than 13 latitudes, from Lindesnes at the latitude 57°N to Nordkapp at the 71°N latitude with an area of 324 000 square kilometers. Considering the high latitudes and the coastline facing the Arctic Ocean, Atlantic Ocean and the North Sea, Norway has relatively warm climate compared to other regions of the world at the same latitude. This is because of the Norwegian current, the northeast extension of the Gulf Stream, and the southerly air currents form the Atlantic Ocean. In the result of this, a subarctic climate dominates most of Norway, along with a temperate climate along the coast and an Arctic climate in the mountainous regions. The Figure 14 shows a map over Köppen climate types in Norway.

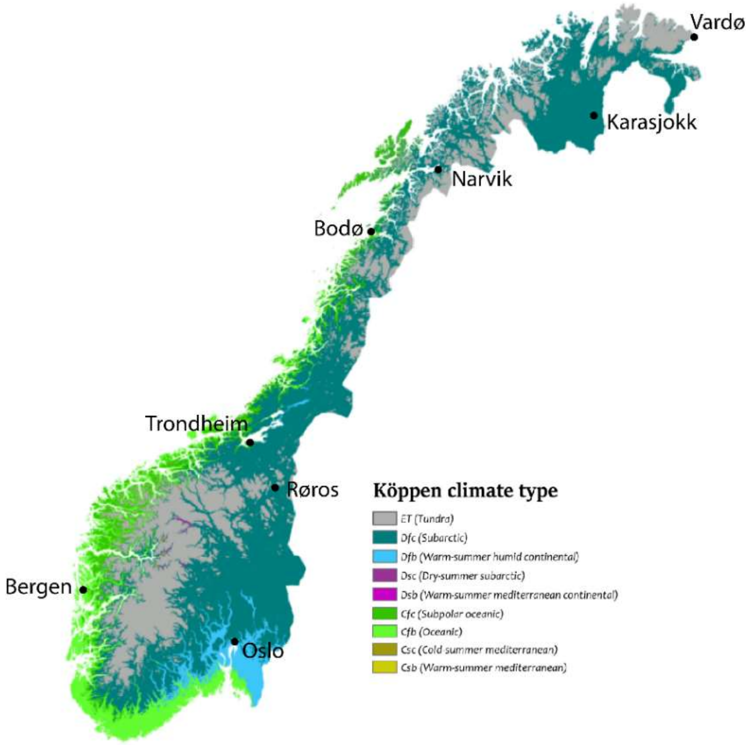


Figure 14: Norway map of Köppen climate classification

4.4.1 Weather data

The weather in Norway is highly dominated by the Westerlies and polar winds in the north, with alternating low- and high-pressure activity, resulting that the western coast experiences more rainfall and wind than further north. Great parts of the inlands both in the south and the north are in a rain shadow and are less exposed to wind and rain. The table below shows weather data from different locations in Norway as mean values:

Table 5: Norway weather data

Location	Latitude [°]	Temp. during coldest month [C°]	Annual Temp. [C°]	Annual Precipitation [mm]	Annual Wind speed [m/s]	Heating Degree Days Base 18°C
Oslo	59°55'N	-4.3	6.3	763	2.2	3969
Bergen	60°23'N	1.5	7.5	2250	3.6	3423
Røros	62°18'N	-11.2	1.0	504	3.3	6031
Trondheim	63°30'N	-3.2	5.1	850	4.6	4302
Bodø	67°16'N	-2.2	5.4	1020	6.3	4344
Narvik	68°16'N	-4.4	3.8	830	4.4	5161
Karasjok	69°13'N	-17.1	-2.5	380	2.7	6785
Vardø	70°13'N	-5,4	1.4	563	5.6	5415

Due to the extensions of high latitudes, there are big differences in solar energy received throughout the year. This difference is extremely significant in Northern Norway above the Arctic circle, with midnight sun during the summer and lack of sun during the winter. In addition, the topography, such as the mountainous terrain causes vast local and regional differences across the country in both solar energy and precipitation. The Figure 15 shows the distribution of daylight received through the year in the city of Narvik.

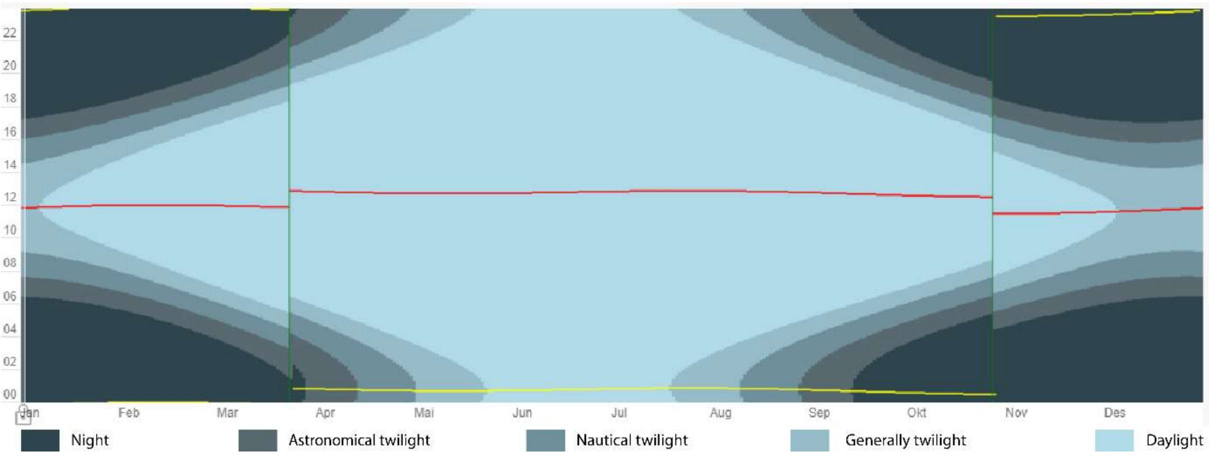


Figure 15: Annually daylight distribution in Narvik, Norway [36]

4.4.2 Climate changes in Norway

The Norwegian economy, environment and society are all vulnerable to climate change. The climate in Norway is expected to become even milder over time due to the climatic changes, the annual temperature is estimated to increase approximately 4.5 °C by 2100, which will increase the growing season all over the country and increase of annual precipitation with 18 % [37]. The expected temperature will also cause a major part of the glaciers to melt and parts of the winter season will be characterized as mild and vast amounts of rainfall. The expected increase of heavy rainfall results in an increased risk of floods and landslides as well as shorter and milder winters especially in the north. The power supply in Norway is primarily based on hydropower, and an expected increase in rainfall will probably serve to increase power generation. As the temperatures are increasing, required heating will decrease and be substituted by cooling [38].

4.5 Japan

Japan is among the most highly developed and educated countries in the world. Located in the Pacific Ocean with a total population of 127,307,280 inhabitants, the country is the 10th largest country in the world by population and the 62nd largest in the world with a total land area by nearly 380,000 square kilometers. It's a sovereign island nation and a stratovolcanic archipelago in the Pacific Ring of Fire, making Japan to be considered as one of the most seismically active areas in the world located at a point where three tectonic plates meet – the Eurasian plate, the Pacific plate and the Philippine plate. The main islands from north to south are Hokkaido, Honshu, Shikoku, Kyushu. Together with The Ryukyu Islands the islands are often knows as the Japanese archipelago and are surrounded by the Sea of Okhotsk in the north, the Pacific Ocean to the east and south, the East China Sea to the southwest, and the Sea of Japan and the Korea Strait are to the west. Being a country with hilly terrains and steep mountainous regions, Japan approximately having over 70% of the land in the mountains.

Because of being situated at the northeastern edge of the Asian monsoon climate belt, brings Japan a fair amount of rain and humidity throughout the year. Although having four distinct seasons, the country's wide range of longitude, seasonal winds and different types of ocean currents, causes a strongly variation in climate from subarctic in the north to subtropical in the south. The four major islands cover a broad zone of longitude. However, the climatic differences between northern and southern parts is greater than the difference in breath alone. The two primary factors which influences Japan's climate is the Siberian weather system and patterns of the southern Pacific, and the existence of two major oceanic currents; the warm Kuroshio (also known as the Japan Current) from southwest, producing a milder and more temperate climate than is found at comparable latitudes elsewhere, and the cold Oyashio (also known as the Okhotsk Current) from the Bering Sea, flowing along the eastern coasts of Hokkaido and northern Honshu.

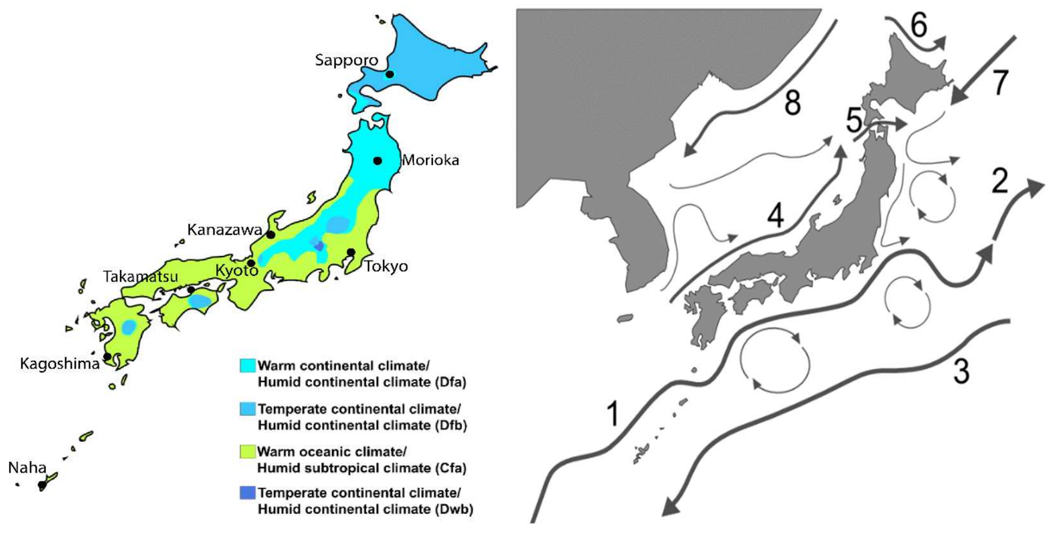


Figure 16: Japan map of Köppen climate classification and Japan map of ocean currents

4.5.1 Weather data

While the reminder of the country enjoys a far more milder weather down to the southern regions, northern Japan has warm summers but also very cold winters. The cold, winter monsoon winds from Siberia pick up moisture over the sea before they reach Japan; hence winter snowfall is more severe in the northern territories, like Hokkaido and the west coast of northern Honshu. Eastern Japan, buffered by the central mountain ranges, enjoys a finer weather during the winter with hot and humid summers, while the Western and Southern part has moderate cold to mild winters and very humid summers.

Table 6: Japan weather data

Location	Latitude [°]	Temp. during coldest month [C°]	Annual Temp. [C°]	Annual Precipitation [mm]	Annual Wind speed [m/s]	Heating Degree Days Base 18°C
Sapporo	43°03'N	-4.6	8.9	1108	2.8	3567
Morioka	39°42'N	-2.5	10.5	1270	2.9	3105
Tokyo	35°41'N	5.2	15.4	1530	3.4	1468
Kanazawa	36°35'N	2.9	14.7	2422	3.3	1954
Kyoto	35°00'N	4.0	15.9	1509	1,7	1704
Takamatsu	34°19'N	4.8	16.3	1092	2.4	1583
Kagoshima	31°33'N	8.1	18.6	2287	3.0	1063
Naha	26°12.N	16.0	23.1	2031	5,1	118

The Figure 17 shows the distribution of daylight received through the year in the city of Sapporo in Japan.

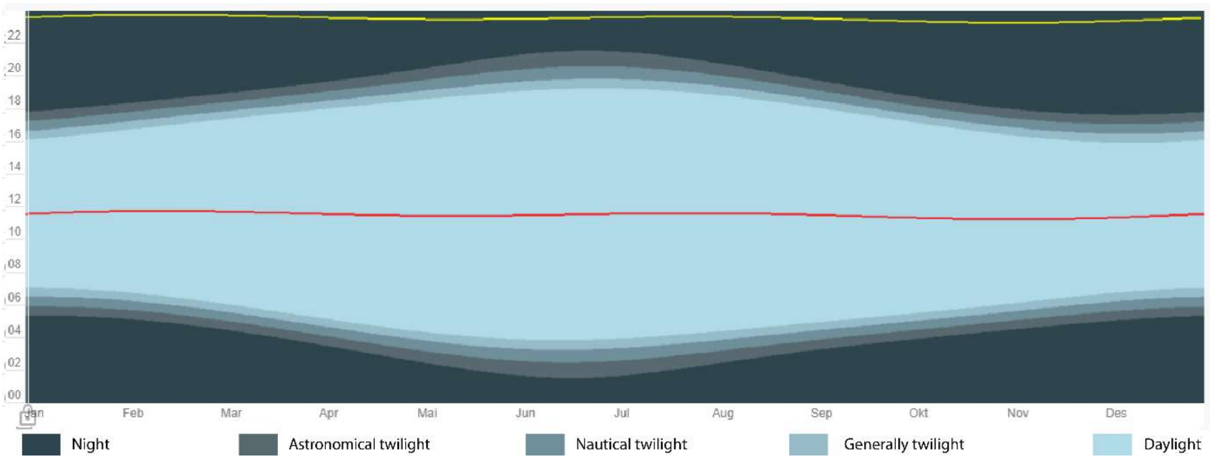


Figure 17: Annually daylight distribution in Sapporo, Japan [39]

4.5.2 Climate changes in Japan

The climate changes in Japan have affected a temperature increase rat of 1.15 °C per 100 years, where the global average is 0.68 °C per 100 years. Alongside the rise of temperatures, it is also expected an increase of heavy rainfall and less days with little rainfall causing and increase risk of drought, change in water quality and heavy rain induced disasters, such as flooding and landslides. Other projections are decrease of snow and winter season in the north. Typhoon strikes will decline but typhons with low central pressure will occur frequently, sea level rise and sea surface temperature rise causing changes in the ecological system in the sea surrounding Japan [40].

5 Building and energy market

This chapter form a theoretical basis of the comparative study by enlightening the current situation of the building and constructions market, including building stock and its architectural style and material, energy consumption and greenhouse gas emissions in Japan and Norway to emphasize the potential of sustainability in buildings located in cold-climate regions.

5.1 Global overview of building and energy market

Progress towards sustainable buildings and construction is advancing, through stricter energy codes, certification-systems and development of high-efficiency technologies, but it is well documented that the Building and Construction sector still accounts for over 35 % of global final energy consumption and now stands for approximately 40 % of energy-related carbon dioxide (CO_2) emissions when upstream power generation is included in 2015 [2]. This illustrates that improvements from 2010 are still not keeping up with a growing building sector and rising demand for energy.

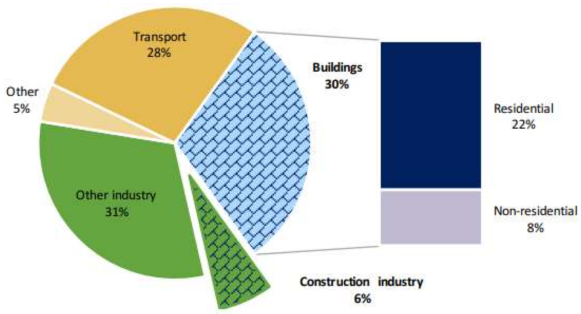


Figure 18: Share of global final energy consumption by sector, 2015 [2]

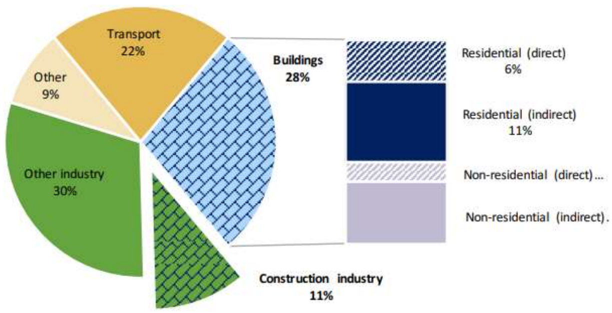


Figure 19: Share of global energy related CO_2 emission by sector, 2015 [2]

The global building sector continues to grow, with a floor area growth estimated to 2.3 % annually, generating a total floor area estimated to 235 billion m2 in 2016, but the energy intensity seems to improve at a rate of 1.5 % [2]. According to the UNEP in the *Global Status Report 2017*, 82 % of the final energy consumption in buildings was supplied by fossil fuels in 2015 including primary energy input for power generation and excluded traditional use of biomass such as fire wood, generating almost all the energy related CO_2 emissions. But it also appears as the global annual buildings-related carbon intensity emissions are decreasing and reached its peak in 2013 with 9.5 gigatons of CO_2 and decreasing to 9 Gt CO_2 in 2016.

5.2 Norway

Norway with 5.3 million inhabitants ranks as one of the richest countries in the world and is ranked four in gross domestic product (GDP) per capita at 62 075 USD purchasing power parity (PPP) in 2015 among the Organization for Economic Co-operation and Development countries (OECD). A great access of natural resources such as petroleum, hydropower, fish, forests and minerals has significantly contributed to the wealth and richness of Norway, especially the discovery of offshore oil and gas reserves in the late 1960s that made Norway one of the largest gas and oil exporters in the world, generated 40 % of all exports and 15% of the GDP in 2015 [38]. The service sector was accounted for 60 % of the GDP, while the industry, including oil and gas, generated approximately 40 %. 2 % were accounted by the fishing and agriculture industry, including forestry. The GDP has gradually been increasing since the discovery of offshore oil but plummeted in 2009 because of the financial crises. Norway quickly recovered but suffered again when the oil prices started to drop 2013 (Figure 20: GDP Norway (current US$)) [41].

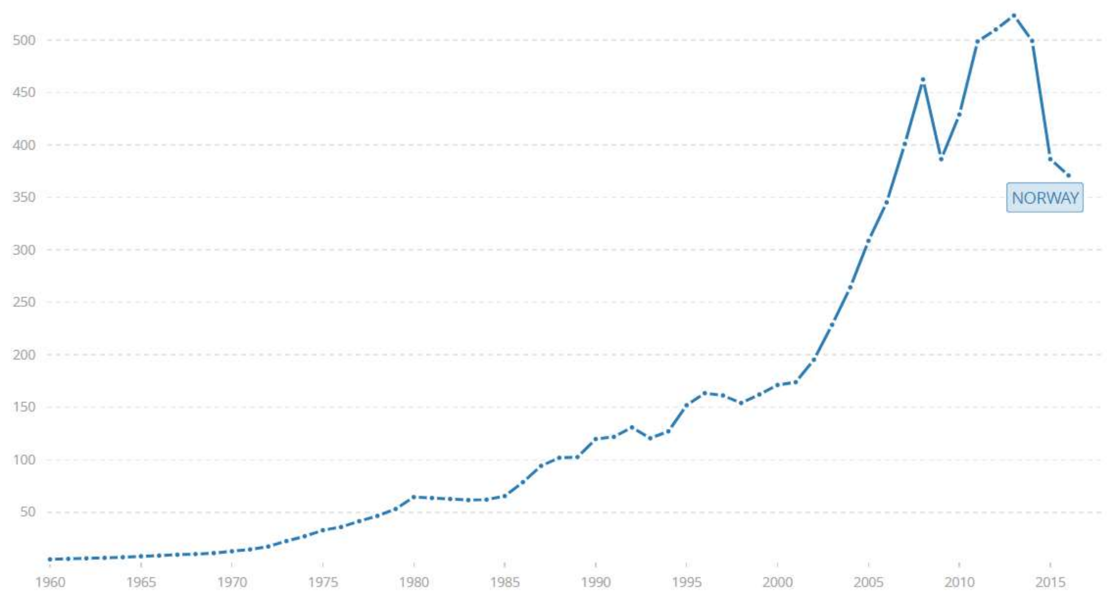


Figure 20: GDP Norway (current US$) [41]

5.2.1 Architectural style and materials

Buildings in Norway have for a long time been characterized by a practical and protective design in a rugged climate and building methods have developed drastically since the Viking ages and wooden long houses to protect from snow, wind and cold temperatures for people to survive in harsh climate. For many centuries, wood have been the main materials used for buildings due to the vast resource of timber all over the country. Buildings also had to rely on locally available materials, such as wood. As cities grew larger, great fire started to erupt and many wooden buildings got lost in the fire, this resulted in a law that required using brick as building material.

After the second world war a massive build-up of the has affected the architectural style to be functional, level-headed and economical in time and production, and many concrete/brick buildings started to emerge. Today most buildings are using both wood and concrete, as well as steel in a mixture to form great architectural building designs. Later years it has become more and more relevant to use sustainable materials to reduce the greenhouse gas emissions from the building sector. Most residential buildings such as single-family houses are normally constructed as a frame house of timber with concrete basement and wooden panel cladding while other buildings are constructed by mostly steel, concrete and wood. Concrete and steel are often substituted by massive wood or other sustainable materials in public buildings. To optimize the functionality of the building, the cost efficiency and sustainability, correct use of materials are highly prominent. The most important building materials for the Norwegian building and construction sectors are wood, concrete, brick, light expanded clay aggregate concrete (LECA), insulation material, steel etc.

Through good building practice and architectural design, the building and construction industry can contribute to more climate-friendly buildings when it comes to material selection and energy solutions. The building and construction industry is the largest consumer of material resources and therefor the environmental impact on materials used in construction will be crucial for the reduction of greenhouse gases and the performance of sustainable buildings.

5.2.1.1 Norwegian Building Stock

The building stock in 2018 consist of over 4.15 million units and approximately 1.5 million are residential while around 2.6 million are non-residential [42]. Holiday houses and garages linked to dwellings accounts for 45 % of all the building units in Norway.

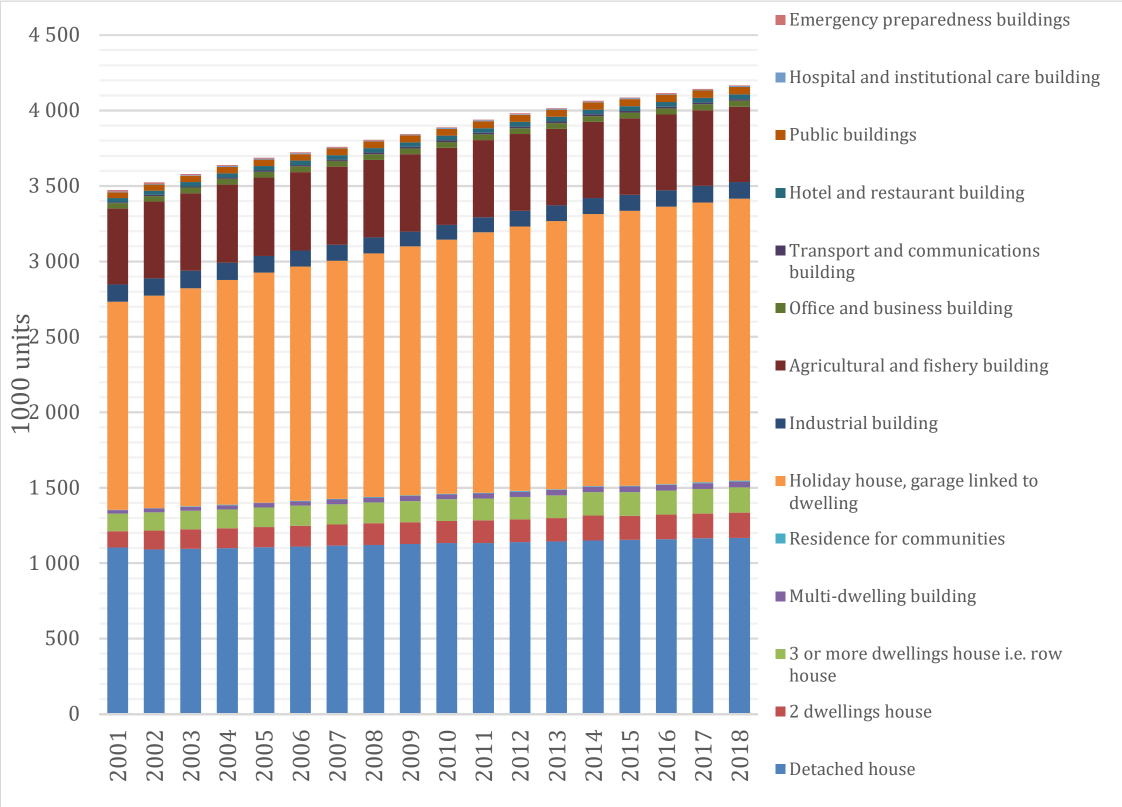


Figure 21: Development of the Norwegian building stock [42]

There has been a considerable increase in the building stock from 1997 and to this day. This change in building stock are explained by new construction, demolition, rebuilding and altered use of buildings. From 1997 to 2018 the total building stock increased by 909 705 buildings which is equivalent to a 28 % increase (Table 7)

Table 7: Change in the Norwegian building stock from 1997 to 2018 [42]

Building category	1997	2018	Change per cent
Residential buildings	1 288 403	1 545 899	19,99 %
Non-residential buildings	1 967 256	2 619 465	33,15 %
Total building stock	3 255 659	4 165 364	27,94 %

The net increase of the building stock in 2017 was 0.6 %, which is the lowest growth rate in 20 years, this development is a result of less single house dwellings built, and more multi-dwelling buildings. The biggest increase was in 2001 where the building stock increased by 1,9 %. According to data presented by statistics Norway there has been a slight decrease of the growth rate of the building stock after 2011 [42](Figure 22). New buildings contribute to approximately 1 – 2% of the building stock every year.

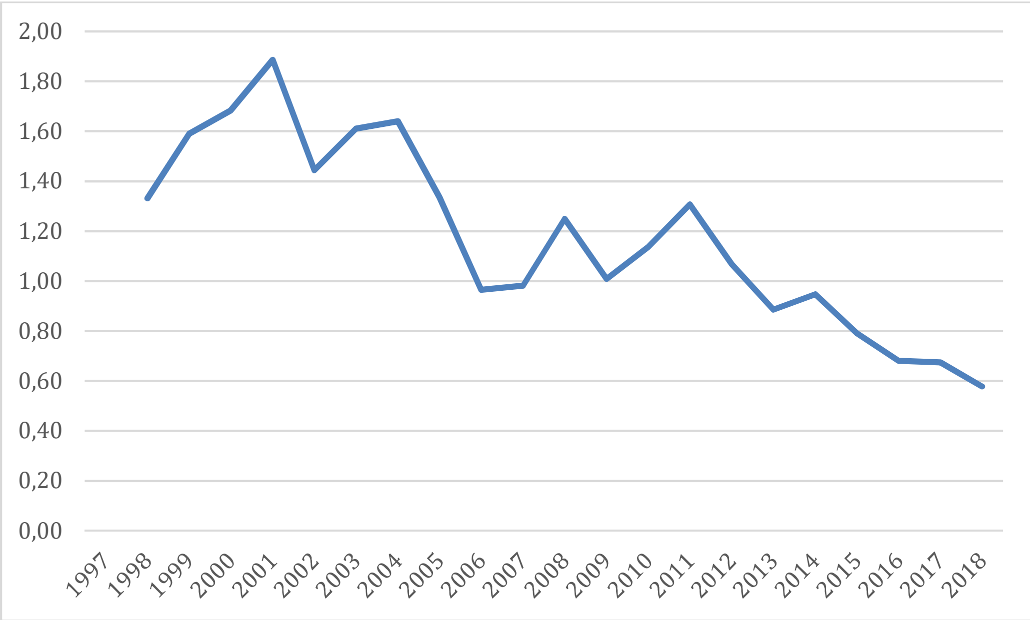


Figure 22: Annual increase of the Norwegian building stock, 1997-2018 [42]

5.2.1.2 Technical condition and life expectancy of the Norwegian building stock

Association of Consulting Engineers, Norway (RIF) [43] published that a major part of the building stock in Norway has had a decay over a longer period because of the lack of maintenance and the necessity of maintenance is great. This include all building categories public buildings (schools, kindergartens, cultural buildings, churches, and other public owned buildings) healthcare buildings and dwellings. Healthcare buildings and public owned buildings face vast challenges regarding the demographic development (capacity and area demand) [43]. Further in the report published by RIF, public buildings count for approximately 32 million square meters and the building stock condition is evaluated as:

- 1/3 appears as good/satisfying.
- 1/3 appears as partly unsatisfying and requires corrective measures.
- 1/3 appears as poor and requires considerably technical upgrade.

Challenges elaborated by RIF regarding the public building stock is area and energy efficiency of the buildings and stimulation of environmentally based management, operation and maintenance, due to the consideration that 80 % of the public building stock will be used in 2050 [43]. In the case of healthcare buildings, building and technical upgrading is required due to lack of maintenance and new regulatory and standard requirements:

- 50 % of the building stock appears satisfying.
- 40 % of the building stock appears as unsatisfying and requires corrective measures.
- 10 % of the building stock appears as poor and requires considerably technical measures.

The building stock of healthcare buildings consists of considerably large share of older buildings, where the building structure is not adapted nor adaptable for the required us today. Generally, the technical facilities are in poorer condition than the building structure and does not meet the requirements which result in poor indoor climate.

According to Risholt et al [44], there are little to no public statistics or documented data on the technical conditions nor the renovation status of existing buildings stock concerning dwellings. The report focused on detached dwellings built in the 1980s and constitutes 10 % of the total dwelling stock. The detached dwellings build in the 1980s are characterized as big with various architectural solutions, have a high demand of energy, and are in a stage where major renovations are expected, such as window and ventilation replacements. The technical condition of a dwelling after 30 years depends on factors like material and construction robustness, climate conditions, maintenance and renovation. The expected lifetime of materials and components typical to Norwegian single family dwellings are presented in Table 8, which also reflect the issues of dependent factors of replacements and maintenance [44]. There are many factors concerning the total life expectancy of a building but based on the lifetime of components in dwellings in Norway, the estimated life expectancy of a single house dwelling is approximately 60 years with regular maintenance and no comprehensive renovations, but minor necessary renovations.

Table 8: Expected lifetime for wooden house elements and components [44]

Component/element	Expected lifetime
Exhaust ventilation	15
Bathrooms	25-30
Drainage	20-60
Floors, concrete and wooden	40-80
Masonry basement walls	20-60
Exterior timber-framed walls and cladding	40-80
Wooden windows and doors	20-60
Roofing: Bitumen shingle	20-30
Roofing: Concrete tiles	30-60

In the period from 1960 to 1990, approximately 600 000 residential buildings were built. A 100mm insulation material was standardized in these buildings. Whereas the todays building codes requires energy efficiency that calls for 250 mm insulation, result in the buildings from 1960 – 1990 have considerably potential of energy efficiency. According to Thyholt et al. 2009 [45] in *Energy Analysis of the Norwegian Dwelling Stock*, the energy saving potential from the existing building stock before 1945 and to 2005 was totally 12 – 17 TWh (25 – 40 % reduction), depending on the extent of renovation.

5.2.2 Energy supply, consumption and intensity

Norway is one of few countries in Europe that does not depend on imports for its energy supply due large domestic oil and gas production which makes the country self-sufficient on energy supply among with renewable resources such as hydropower and wind [38]. Vast resources of hydropower enable Norway to have low levels of fossil fuel consumption, but great access of cheap and clean hydropower has also lead to high consumption of electricity, which is the largest primary energy source.

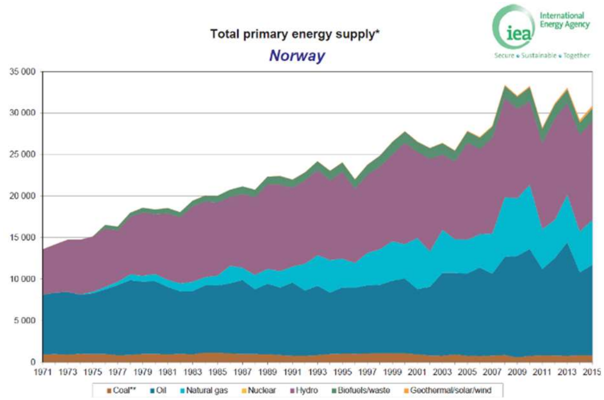


Figure 23: Total primary energy consumption in Ktoe Norway, 1971-2015 [46]

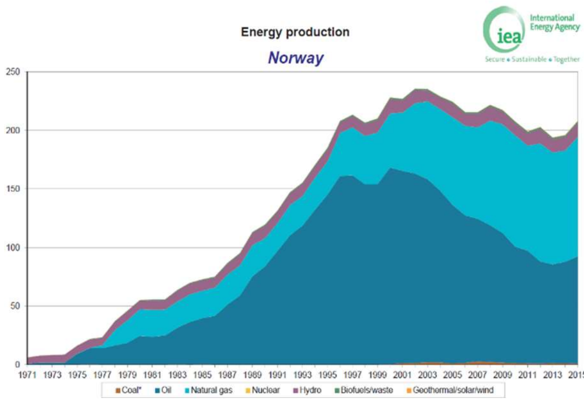


Figure 24: Energy production Norway in Mtoe, 1971-2015 [46]

In 2015, the total primary energy supply accounted for 344 TWh distributed mainly on hydro, oil and gas (hydro 40%, oil 36,8%, natural gas 18,2%, biofuels and waste 5,4%, coal 2,8%, wind 0,7%, heat 0,3%). This is an increase of 10 % since 2005 and overall there has been an increasing trend for several decades. The energy production was accounted for approx. 2420 TWh (natural gas 49.1%, oil 44%, hydro 5,7%) in 2015 where about 85% was exported to other countries [38]. Almost all of the electricity production is based on hydropower and accounted for approximately 96 % of the total electricity production in 2015 [47].

5.2.2.1 Total final energy consumption

The total final energy consumption (TFC) has been quite stable the last 15 years, reaching its maximum in 2010 and minimum in 2009. In 2010, the energy consumption reached its maximum as a result of a year with low temperatures, but overall the energy consumption has been rather constant in the later years [49]. The fall of energy consumption in 2009 was due to the financial crisis which lowered the energy consumption in the industry sector. The largest sector in energy consumption in 2015 was the industry sector and was accounted for 32 % of the TFC, followed by the transport sector (28%), households (21%) and other sectors (19%) which includes commercial and public services, agriculture, fishing and forestry.

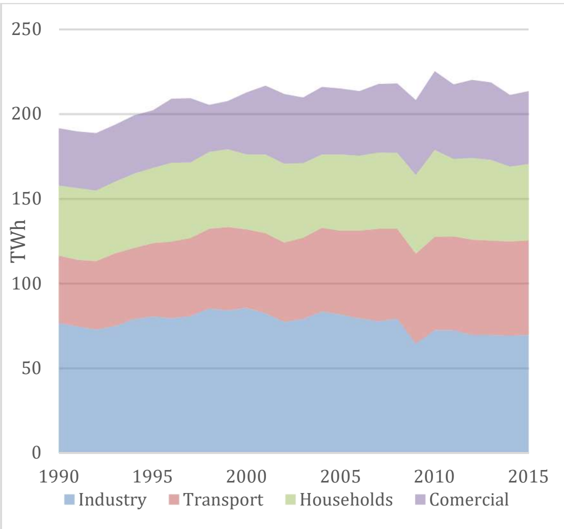


Figure 25: TFC by sector in Norway, 1990-2015 (TWh/year) [48]

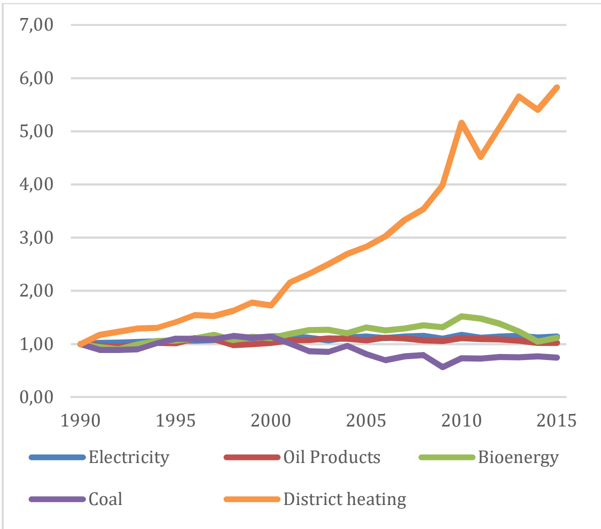


Figure 26: Trend in TFC by carrier in Norway, 1990-2015, 1990 = 1 [48]

The largest energy carrier for the TFC is electricity, accounting for approximately for 47% of the total in 2015. The only sector where electricity is not dominant is the transport sector where the share of oil products is 93 %. The transportation sector is the main contributor for oil products being the second largest energy source with approximately 32 % of the total TFC. District heating constitute only 2 % of the total TFC, but it is the largest growing carrier and have almost doubled the since 2005. District heating consumed in the residential sector (2 %) and the commercial sector (8 %).

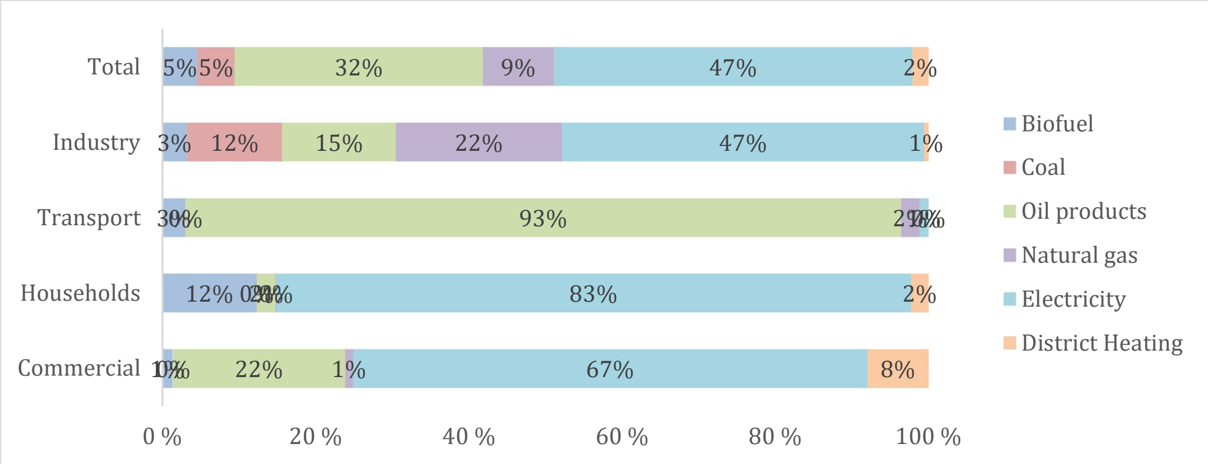


Figure 27: Fuel share of the TFC by sector in Norway, 2015 [48]

5.2.2.2 Energy intensity

The energy intensity have been decreasing from 2000 to 2009 because of more efficient use of energy, structural changes towards a less energy intensive industry, increase of production through technological development and workforce productivity, and general growth on the economy. Other explanaition of the decline in energy intensity are more energy effectice household appliences, better building envelope and higher outdoor temperature due to climate changes [50]. In 2009 to 2010 the energy intensity increased by 7 % due to less decline in GDP than energy consumption reasaulting in less energy efficiency. The increase of energy consumption in 2010 is also an resault of the increasing energy intensity. In 2011 the GDP grew and energy consumption declined resulting in decreasing of the energy intensity. From 2000 and to 2015, the total decrease of the energy intensity was 24 % (From 90 to 68 GWh/billion NOK production) [51].

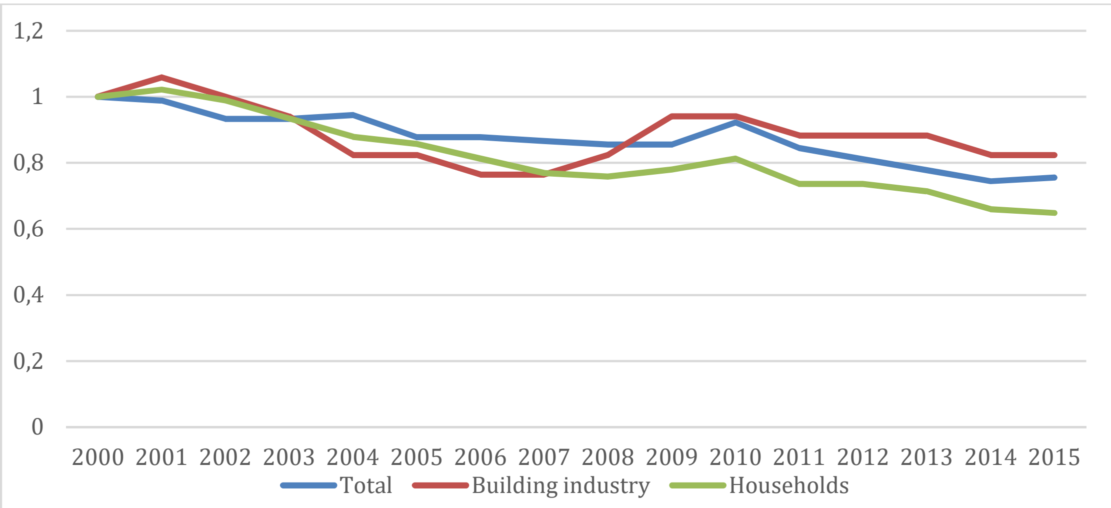


Figure 28: Trend in energy intensity development, 1990-2015 [51]

5.2.2.3 Energy consumption in Norwegian buildings

The energy consumptions in building are highly affected by factors like energy prices, building codes, energy taxes, requirement to energy effective appliances, population and economic growth which are affected by the increase of building stock area. The energy consumption in the Norwegian building stock is used primary for room heating (through ventilation and radiators), technical equipment, lighting and cooling. The energy consumption in the building stock was in 2015 about 77 TWh, where households contributed to 45 TWh and the tertiary industry used 32 TWh. This is almost 18 % increase since 1990. The biggest and most important energy carrier is electricity; 83 % in households and 80 % in tertiary sector in 2015. Compared to 1990 it has increased 23 in households and 32 % in tertiary. This change is attributed by the increase of electricity equipment in both residential and tertiary sector and has become more normal to use electricity for heating. In 2015, the use of oil products has drastically increased since 1990. In 1990 oil products constituted 14 % of the TFC in buildings while in 2015 this number is 4 %, a reduction of approximately 65 %. This is due to the prohibition of fossil fuel heating in newer buildings and an out phasing of the fossil fuels in existing buildings. In 1976 almost half of the energy consumption in the building stock came from oil products, and since then the building stock has been introduced to new energy carriers such as district hearing, bioenergy and gas. The use of bioenergy in households varies with the outdoor temperature and was at its highest in the cold year of 2010 with 8,5 TWh [49]. District heating is the carrier that has increased the most over the last few decades and contributed to approximately 4,5 TWh, while in 1990 it was 0,67 TWh.

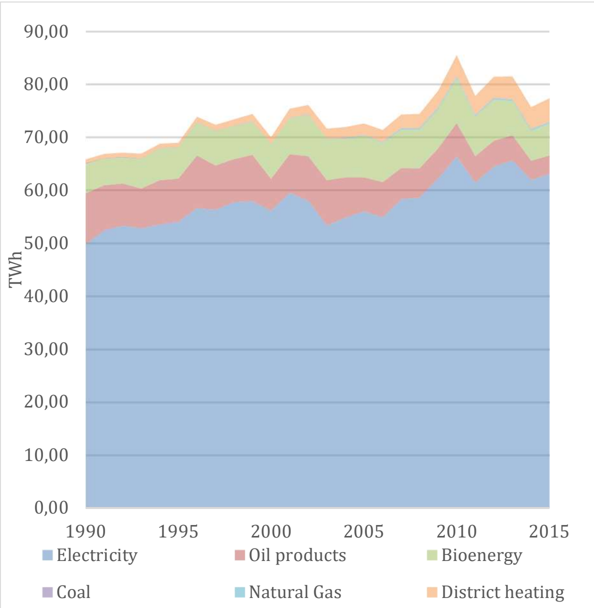


Figure 29: TFC in the building stock in Norway, 1990 – 2015 [48]

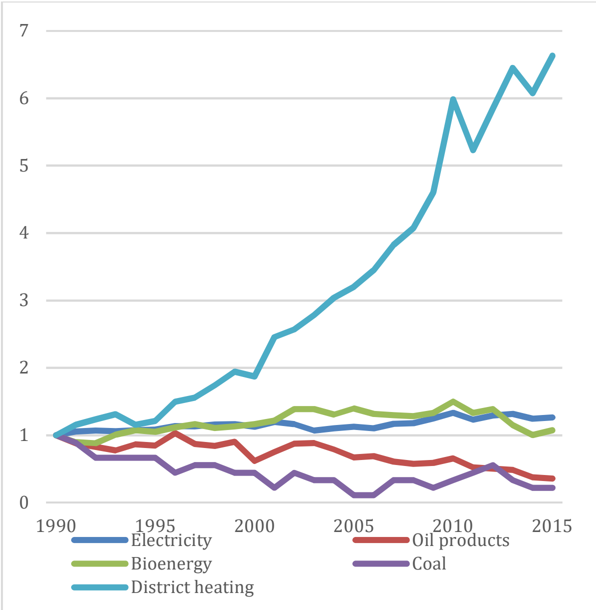


Figure 30: Trend in energy carrier based on the TFC, 1990-2015 [48]

The energy consumption for new buildings have requirements described in building and energy codes and the figure below shows the development of a stricter energy demand in existing buildings in Norway and illustrates an overview of the energy consumption in the current building stock (Figure 31:).

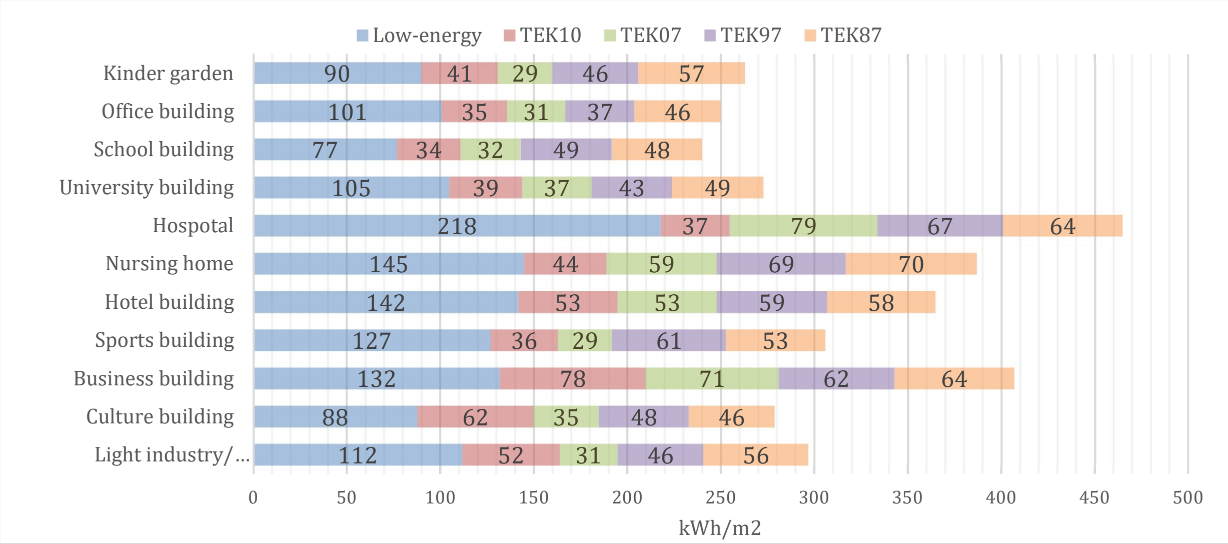


Figure 31: Development of energy consumption by building category in Norway [52]

5.2.3 Greenhouse gas emissions and intensities

Compared to other countries, Norway is a lower-carbon economy, because of the usage and dominance of renewable energy such as hydropower [38]. Energy used in buildings is already decarbonized due to the great use of electricity for heating. The focus area for reducing energy related GHG emissions are in the oil and gas activity, manufacturing, and the transport sector. The main factor that affect the GHG emissions is the economic growth and population growth and keeping the carbon intensity relative stable over the last decade. The air quality in Norway are characterized as relative good compared to other countries and are below European Union limit values, but several urban areas experience exceeding limit values for particulate matter (PM) and nitrogen oxides (NOx) mostly in the winter where as the main source is road transport (exhaust emission and asphalt dust) [38]. GHG emissions in Norway include carbon dioxide (CO_2), methane (CH4), nitrous oxide (N2O), perfluorocarbons (PFCs), Sulphur hexafluoride (SF6), and hydrofluorocarbons (HFCs) [38].

5.2.3.1 Total greenhouse gas emissions

The biggest sources to GHG emissions in Norway are the transport, oil and gas activity, and industry. The total Norwegian GHG emissions was 53,8 million tons CO_2 equivalents in 2015, representing a change of 4 % increase from 1990 where 83 % of the total GHG emissions was carbon dioxide (CO_2). Emissions from oil and gas extractions have increased with approximately 83 % since 1990 and is now the biggest contributor to the national GHG emissions. Industry used to be the biggest but has reduced its emissions by 40 % since 1990.

The trend in national GHG emissions displays a reduction in the building and industry sector, while there has been a stable increase in the oil and gas sector, and transport sector. The trend in energy supply are driven by temperature and climate conditions, e.g. the cold year of 2010 where the emissions from the energy supply leapt and over doubled in one year.

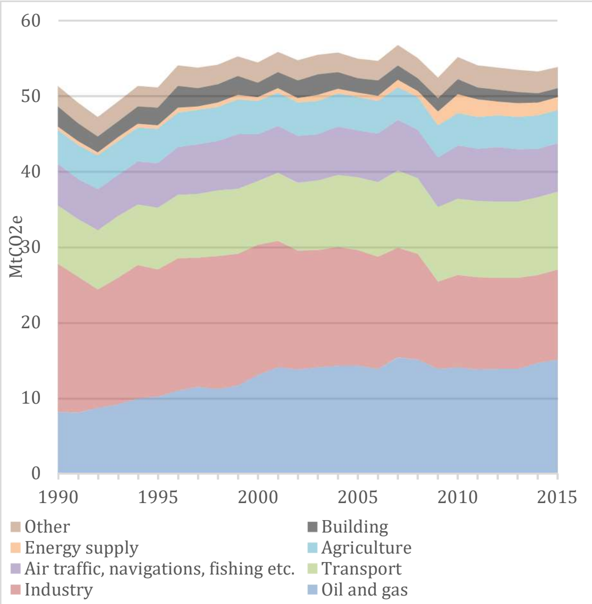


Figure 32: GHG emissions by sector in Norway, 1990-2015 [53]

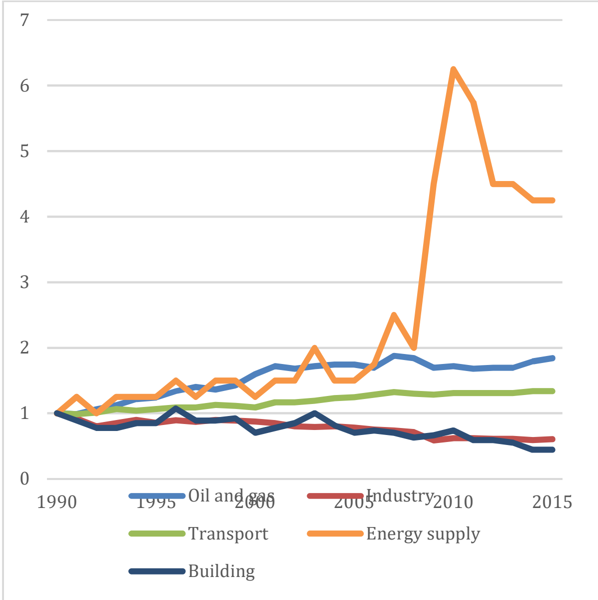


Figure 33: Trend in GHG emissions by sector, 1990-2015 [53]

5.2.3.2 Greenhouse gas emissions in the Norwegian building sector

Building stock related greenhouse gas emissions represented a share of 2 % of the total GHG emissions in Norway in 2015. These emissions are mostly due to the heating of buildings, and since the heating of buildings in Norway are mostly covered by electricity, the emissions are generally low compared to other countries and which are mainly from oil and bio fuels. In 1990 the total building stock related emissions amounted 2.7 million tons CO_2 equivalent, while in 2015 the emissions accounted for 1,2 $MtCO_2e$, equivalent to an approximately 50 % reduction. This reduction is caused by change in the energy prices, stricter energy requirements for new buildings, and an announced prohibition of using fossil fuel for heating coming into force by January 1st, 2020. Households, primary industry and the tertiary industry shows a significant reduction of GHG emissions, while the building and construction sector have increased the emissions, this is due to many buildings have change the energy carrier from fossil fuel to district heating. According to the Norwegian Environmental agency, fossil fuel constitutes 56 of the GHG emissions form heating buildings. As the figures below illustrate, the emissions variates from time to time, depending on temperature, energy prices between oil and electricity and therefor affect the emissions [54].

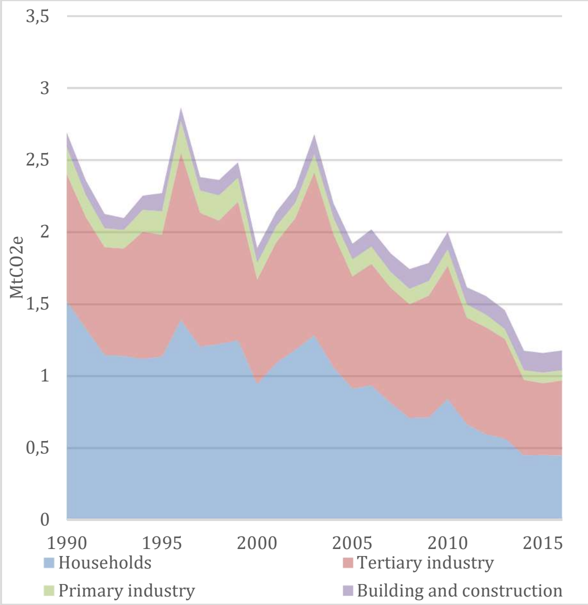


Figure 34: Building stock related GHG emissions, 1990-2015 [54]

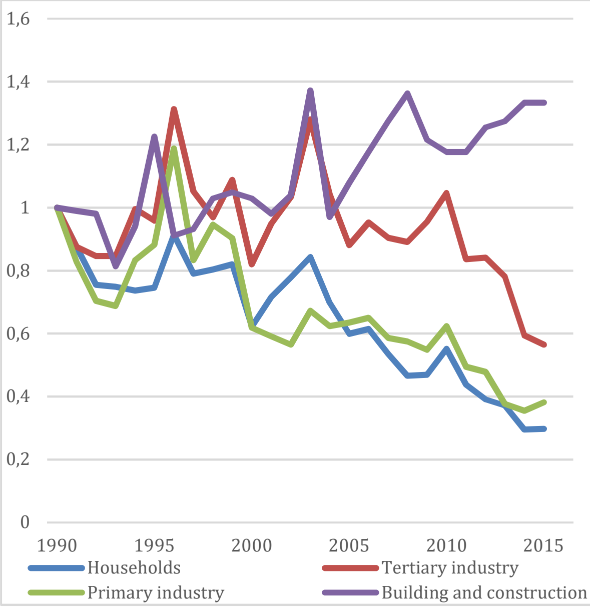


Figure 35: Trend in building stock related GHG emissions by sector, 1990-2015 [54]

5.3 Japan

After recovering from World War II, Japan became and economic power and a strong ally of the US. As of today, the country is ranked as the third largest national economy in the world after the United States and China by nominal GDP (Gross Domestic Product), and the fourth largest by the Purchasing power parity after United States, China and India [55]. A fundamental driving force behind Japan's economic growth has been the Japanese labor force, which is known to show strong enthusiasm and energy for its work. Along with the highly skilled workforce the Japanese economy benefits significantly from a large industrial capacity and is home to some of the most technologically advanced producers. As an island nation they generally run an annual trade surplus, heavily relied on imports for primary energy and industrial raw materials, and large exporters of vehicles, machines, engines, and electronic equipment. In 2016, Japan exported 605 billion USD and imported 583 billion USD, resulting in a positive trade balance of 21.6 billion USD [56].

Due to its location along the Pacific Ring of Fire, Japan accounts alone for about 10 % of all active volcanoes in the world and is considered as one of the most seismically active areas being affected by a junction of 4 tectonic plates – the Pacific, Philippine, Eurasian and the North American. Throughout the years due to earthquakes and subsequent fires, the loss of life and property in Japan has been enormous. The impact and the resulting effects of the Great East Japan Earthquake in 2011 (magnitude of 9.0 on the Moment of Magnitude Scale), made Japan not only to deal with humanitarian disasters, but it also hobbled the country's economy and energy infrastructure, and since the wake the energy policy have been dominated by efforts to overcome the fallout from the accident.

5.3.1 Architectural style and materials

Japanese architecture has evolved from the pre-historic to modernly times. Today, Japan has an interesting variety of building that exhibit different architectural forms, like temples, shrines, palaces and has in fact the world's tallest tower and second tallest structure in the world, Tokyo Skytree (643 meters) [57]. Considering the country's location, the development of earthquake resistance construction has always been a priority. Because of its relatively resistance and flexibility, wood has been the preferred choice in the art of building, especially residential housing. The climate has also had its influence. Summers in most of Japan are long, hot and humid, creating the ideal conditions for mold, especially with the onset of the rainy season. Japan's traditionally wooden construction fought mold by elevating the house slightly off the ground, leaving walls mostly exposed so that air can move freely under, around and through the entire interior space [58]. During winter, Japan a characteristic climate of dry air, seasonal strong winds and because of the mountainous land, foehn phenomena arises in certain areas. Japan having single-family detached house and multiple-unit building as two patterns of residence, poses a very high threat of fires – both small and large if they are densely built [59]. Covering roofs and exterior walls with noncombustible materials in central urban areas especially, has been main concern of action in building control to prevent conflagrations and has strengthen the fire safety after several incidents in larger buildings. A difference in perception between the EU and Japan for instance, is that the Japanese cultural in general values the harmony with the environment, even if it's cold. Japanese houses are traditionally hot during the summer and cold in the winter. Rooms are heated via air-conditioner or other portable space heaters, usually one by one when occupied. Outside of Hokkaido, central heating remains rare [60].

Before the introduction of brick and steel structure during the late 18th and early 19th centuries, wooden structure was the dominant type of structure, but from the of the 19th century other construction methods, like steel and reinforced concrete systems. Buildings were considerable vulnerable to fires and inferior in terms of durability, which prohibited for a long time to construct buildings with height more than 31 meters, due to be an earthquake-prone country. Now there are thousands of high-rise buildings in Japan, were the first "super high-rise" building already was constructed in 1968, ranging 156 meters tall [59].

5.3.1.1 Technical condition and life expectancy of the Japanese building stock

According to IEA [61], the commercial sector in Japan amounted to around 750 000 buildings in 2013 with a total floor area of 1,1 billion m^2. Between 1993 and 2013, the number of occupied dwellings (flats and houses) increased by 11.4 million from 40.8 million to 52,2 million. Along in the same period, increased the average floor area from 91,9 m2 to 94,4 m^2, resulting in a total floor area of 91,9 billion m^2. In addition, there were also 8.5 million dwellings which were empty and out of which 3,2 million had been vacant for a long period or were to be deconstructed. IEA also implies Japan has a high demolition rate. Considering that from 1993 – 2013, 11.4 billion new *occupied* dwellings were constructed. The same period but two years earlier (1991-2013), 24.1 million new dwellings were constructed. Meaning that for the time of 1991-2013, the construction sector had produced 13 million *non-occupied* new dwellings, out if which 8.5 million dwellings were empty, resulting in a demolishing amount of 4.5 million dwellings.

The EU-Japan center states that the construction industry is one of the core industries in Japan, comprising about 10 % of the national GDP in 2013 [60]. By 2013, construction investments amounted to 335.9 billion EUR, which represented an increase of 10. 2 % compared to numbers in 2012. The EU-Japan center numbers on occupied detached houses illustrates around 45 million in 2013, with high numbers of detached houses and apartments either as for sale or for rent.

The construction sector activity in Japan have over the last six decades been focusing on new construction and buildings and are now facing the accumulation of managing of existing buildings. Buildings in Japan experience the term of a "short buildings-life syndrome". The average lifespan of a steel structured building is less than 30 years, 40 years for reinforced concrete buildings and timber houses have an average of 50 years. The life expectancy of Japanese buildings is mostly due to socioeconomic reasons of an ever changing social and economic requirements, than the actually physical integrity [62].

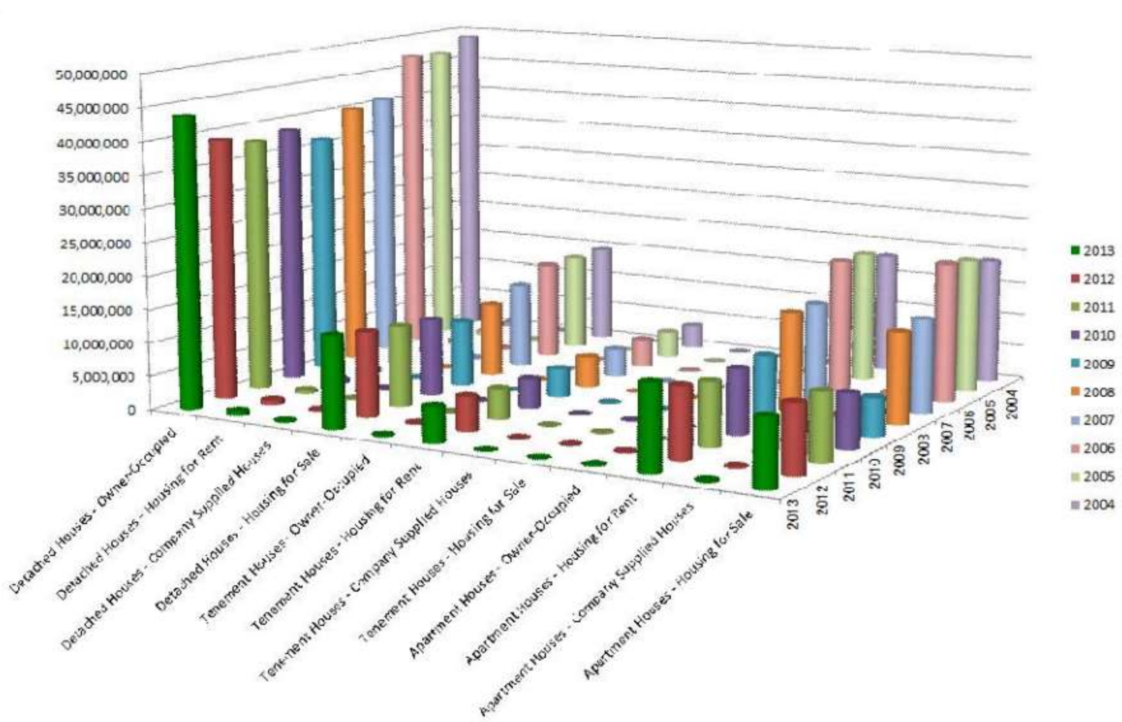


Figure 36: Number of homes per occupancy type [60]

5.3.2 Energy Supply, consumption and intensity

In the world of energy, Japan is a major player and one of the largest energy consumers and importers in the world today [61]. Even though being a leader in energy development, security of energy supply has traditionally been critical. Japan relies most of it fossil fuel supply from abroad, such as oil, coal and natural gas (LN). The Fukushima Nuclear Accident had a tremendous impact on Japan, and left a gap of around 30 % in electricity supply and the self-sufficiency rate equaled to 6 % 2014, which was a low level even compared to other OECD countries [63].

In 2015, the total primary energy supply (TPES) in Japan accounted for 436 Mtoe, or 5070 TWh distributed mainly on oil, coal and natural gas[63]. The numbers have been decreasing ever since it reached a peak of 521 Mtoe in 2004. In 2014, there was no nuclear power generation on Japan for the first time in 40 years. After the Fukushima Accident the electricity gap has mainly been replaced by fossil fuels which accounted for 93,7 % of the country's TPES in 2015 (23.3 % natural gas (LNG), 27,5 % coal, 42,9 % oil). Renewable energy production, however, has been more strongly promoted in the country and had a significantly growth over ten years by 2015.

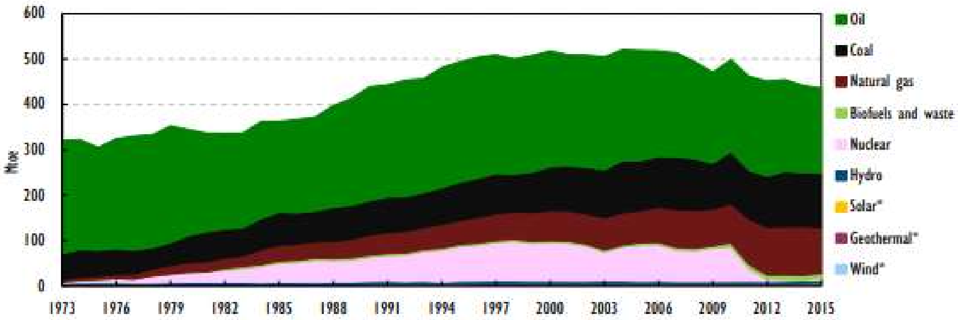


Figure 37: Total primary energy consumption, 1973 – 2015 [61].

Japan ranks as the fifth largest in electricity consumption and represented approximately 28 % of the total TFC in 2014. The amount of electricity has inclined since the great oil crisis in the 1970s where oil accounted almost 75 % of the total primary energy consumption and the government had to diversify the energy source to increase the energy supply security, but still oil counts as 40 % of the total primary energy consumption [61].

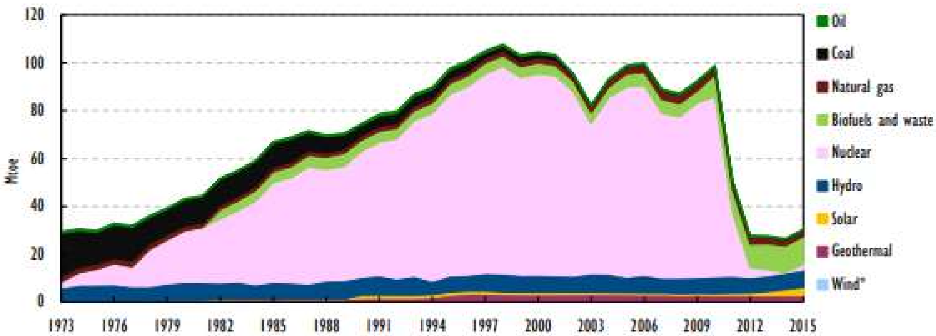


Figure 38: Energy production by source, 1973 – 2015 [61].

5.3.2.1 Total final energy consumption

The total final energy consumption (TFC) amounted to 296 Mtoe in 2014 and represented around 67 % of the country's TPES with the reminder used in power generation and other energy industries. TFC reached in maximum at 330 Mtoe in 2004 and has declined in the following ten years. Same as Norway in 2015, the largest sector in Japan by energy consumption in 2014 was the industry sector and accounted for 41.9 % of the TFC, followed by the transport sector (24.2 %), services and agriculture (18.8 %) and households (15.1 %) [63].

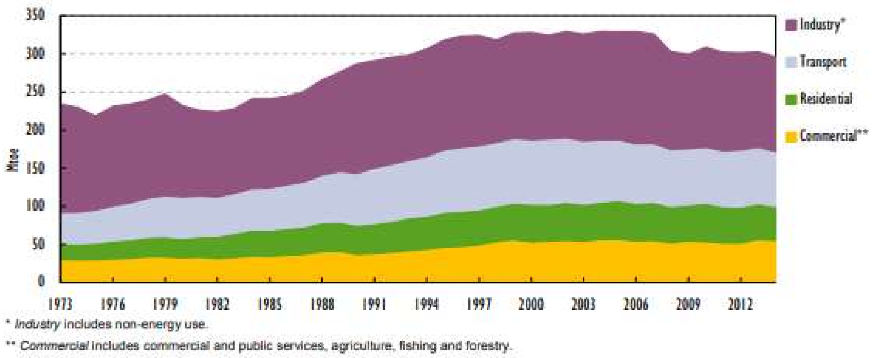


Figure 39: Total final energy consumption (TFC) by sector, 1973 – 2014 [61]

5.3.2.2 Energy Intensity

According to IEA, the energy intensity measured as the ratio of total primary energy supply (TPES) per unit of real gross domestic product (GDP) adjusted for purchasing power parity (PPP) for Japan, was 0.08 toe per USD 1 000 PPP (toe/USD 1 000) in 2015. The energy intensity in 2015 is ranked as the fifteenth-highest among IEA member countries, and was 19,7 % lower than in 2005 [63].

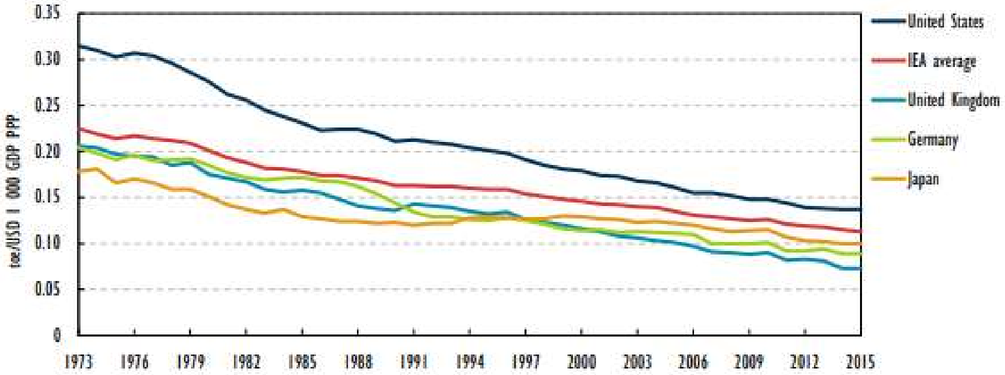
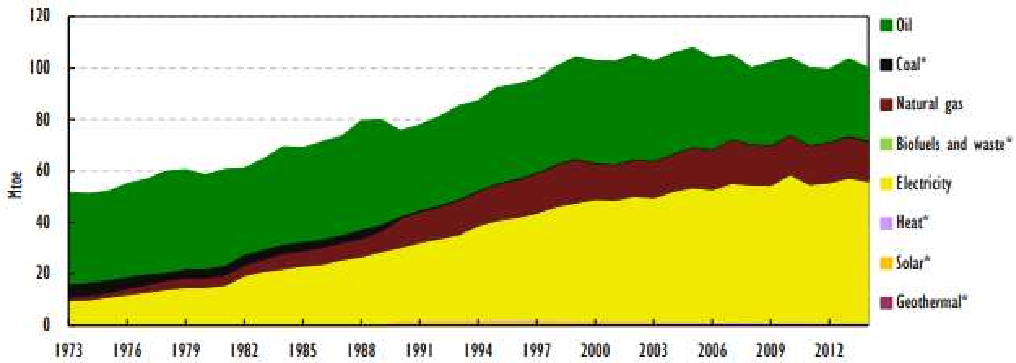


Figure 40: Energy intensity in Japan and selected IEA member countries, 1973 - 2015 [61]

In terms of international comparison, is it also a common indicator to use energy consumption per capital. In 2015, Japan had an energy intensity equal to 3.3 toe per capita per year as the thirteenth-lowest among IEA member countries [63].

5.3.2.3 Energy consumption in Japanese buildings

The energy consumption in the Japanese building stock consists primary of energy used for heating, hot water and electrical appliances. The energy consumption in the residential and commercial sector amounted approximately 1160 TWh in 2014 where electricity is the major energy supply (54.8 %) followed by oil (27.9 %) and gas (15.6 %). There is a clear trend of high increase in electricity over the past decades, just in 2004 electricity represented 47.9 % of the TFC and oil accounted 36.6 %. The reduction of fossil fuel is highly significant. Households represented 518 TWh in energy consumption and the tertiary amounted 645 TWh in 2014. The total decline of the residential and tertiary sector was by 4.7 % from the year 2004 [61].



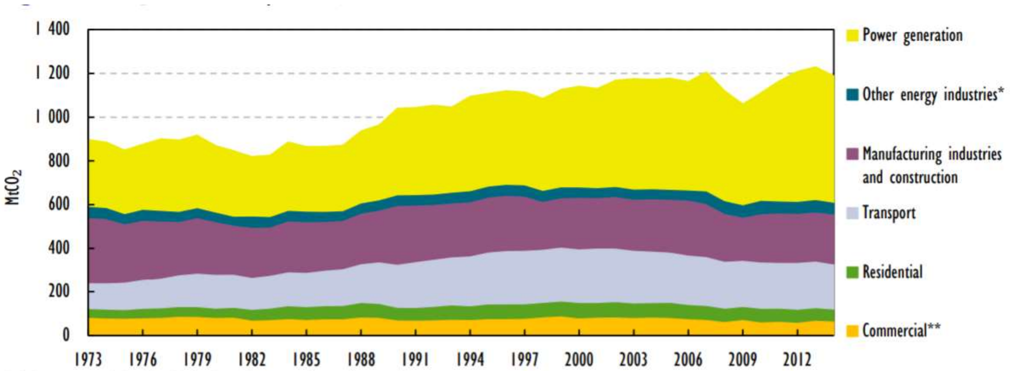
* Negligible.

Source: IEA (2016), *Energy Balances of OECD Countries 2016*, www.iea.org/statistics/.

Figure 41: TFC in the commercial and residential sector by source, 1973 – 2014 [61]

5.3.3 Greenhouse gas emissions and intensities

The main sources of CO_2 emissions in Japan are oil, coal, and natural gas. The main recent factor for the increase of CO_2 emissions are the great earthquake of 2011 and the nuclear power shut down, resulting in the use of fossil fuels increased in the power generation and increase of the carbon intensity. The carbon intensity form 1990 has decrease by 8 % by 2014. The total GHG emissions for 2014 was estimated to 1 189 million tons CO_2 equivalents, which represent a 14 % increase for the year of 1990, where power generation cover 46 %. The residential sector contributed to approximately 5 % of the total CO_2 emissions in 2014, a 12.3 % reduction from the year 2010 to 59.45 million tons CO_2 equivalent [61].



* *Other energy industries* includes other transformations and energy own-use.

** *Commercial* includes commercial and public services, agriculture/forestry and fishing.

Source: IEA (2016), *CO_2 Emissions from Fuel Combustion 2016*, OECD/IEA, Paris.

Figure 42: CO_2 emissions by sector, 1937-2014 [61]

6 Policies and regulations

This chapter forms the theoretical basis of the comparative study and the main subject regarding differences in policies, regulations and other instrumental means affecting the environmental footprint of new and existing buildings in Japan and Norway, and how they are affected by international demands in terms of climate agreements and the global environmental and sustainability movement with its agenda.

6.1 Global status and contributions to reducing global emissions

The Paris Agreement adopted at the 2015 Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) set the specific goal of holding global warming to well below 2 degrees Celsius (°C) compared to pre-industrial levels, and of pursuing efforts to limit warming to 1.5 °C [64]. The goal is achieved through efforts by Parties aim to reach global peaking of greenhouse gas emissions, where each country selects targets for the annual by 2030. The Agreement is the world's first comprehensive climate agreement, and a milestone in international efforts to establish a universal foundation for ambitious climate change action, and has for the first time, brought all nations into a common cause to undertake aggressive efforts to combat climate change and dealing with greenhouse gas emissions mitigation from the global industry as soon as possible to hold global warming to well below 2 degrees Celsius (°C). In addition, for the first time as an elemental part of the process, non-state actors, public energy stakeholders, non-governmental organizations, the private sector, regional and local entities were invited as well.

Building on national plans and contributions submitted by almost all Parties to the Convention during 2015, as *Intended Nationally Determined Contributions* (INDCs), the agreement entered into force on November 4, 2016, following a very quick ratification process, turning the intended into *Nationally Determined Contributions* (NDSs). According to the *Global Status Report 2017*, published by the United Nations Environment Program (UNEP), 193 countries have now submitted *Nationally Determined Contributions* (NDSs), 132 explicitly mention the building sector [2]. Further, among them 101 pointed to energy-efficiency opportunities to meet mitigation targets, and 49 countries committed to use renewable energy sources of energy in buildings, including Norway [2], [65]. Despite progress, the report also indicates concerns regarding that the majority of NDCs do not mention specific projects or targets related to energy performance standards or efficient building technology deployment, as well as explicit building-specific actions, such as, space heating, even though it accounts for almost 30 % of buildings-related carbon emission. On the other hand, they do emphasize on improving building envelope performance and enhancing cooling equipment, which cover the largest share of building-related emissions [2].

The Paris Agreement recognizes that the long-term goals will be achieved through time, where successive NDCs shall be submitted every five years to the UNFCCC secretariat, representing progressive efforts compared to the previous NDC and reflect its highest possible ambition [64]. Although, meeting the Paris Agreement's climate goals will require an instant and global shift toward decarbonizing human activities. According to UNEP report, *Renewable Energy and Energy Efficiency in Developing Countries: Contributions to Reducing Global Emissions*, the Intergovernmental Panel on Climate Change (IPCC) mention that in order for the world to likely have a chance of limiting warming in line with the 1.5 °C or 2 °C goals established in the Paris Agreement, global emissions will have to peak in the next few years, rapidly decline over the following three decades, and approaching zero by the year 2050 [66]. Unfortunately, reports point out that global efforts don't necessary seem to respond in the way reduction measured should been met with global greenhouse gases still rising.

The Emission Gap Report 2017 states that "A large gap exist between 2030 emission levels and those consistent with least-cost pathways to the 2 °C and 1.5 °C goals respectively" [66]. Further, the report explains that the emission gap the planet should close to achieve the 2 °C temperature goal, set in the Paris Agreement, stretches from 11-13 GTCO2e with the full implementation of both the conditional and unconditional NDCs for 2030. Unconditional targets are specifying what a country can do "on its own", to reduce its GHG emissions and conditional targets, is the specify reduction in GHG emissions that the country (low-income countries) expects to achieve, with help from other countries in terms of financial- or technological support [67]. Figure 43 illustrates different scenarios of global greenhouse gas emissions and the emission gap projected in 2030.

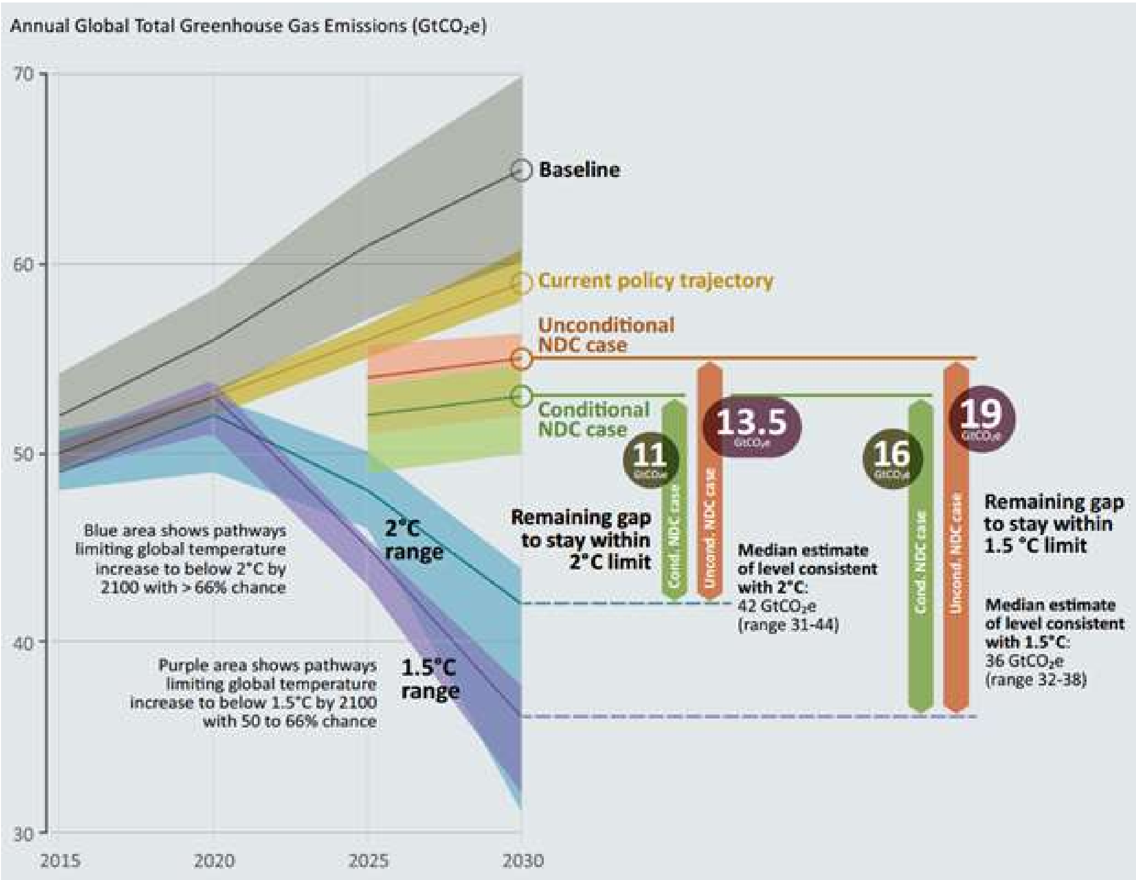


Figure 43 Annual global total greenhouse gas emissions and future scenarios

If least-cost trajectories are followed, the assessed global scenarios stipulate that the emissions of all greenhouse gases should not exceed 42 GtCo2e in 2030, for the 2 °C target to be achieved with higher than 66 % chance by 2100. Estimate level of greenhouse gases with the 1.5 °C target, illustrates it should not exceed 36 GtCo2e by 2100 with 50-60 % chance in doing so.

6.1.1 The Sustainable Development Agenda

Additional to the Paris Agreement, governments adopted another ambitious and universal agenda in 2015 – the 2030 Agenda for Sustainable Development with its 17 Sustainable Development Goals (SDSs). In the years after, the focus is now more than ever on their implementation and how national governments can advance them jointly to take advantage of their synergies [68]. Like the Paris Agreement, the SDGs are not legally binding, but nevertheless, countries are expected to take ownership and establish a national framework for achieving the 17 goals, like the NDSs in the Paris Agreement [69]. Also known as Global Goals, SDGs build on the success of the Millennium Development Goals (MDGs) established as the historic Millennium Declaration, by leaders of 189 countries gathered at the United Nations headquarter in September 2000. They thereby committed to achieve a set of eight measurable goals that ranged to *Eradicate Extreme Poverty and Hunger* (1st goal), to *Ensure Environmental Sustainability* (7th goal), as well as to promote *Global Partnership for Development* (8th goal), by the target date of 2015 [70]. Like the MDGs and the Paris Agreement, the new SDGs set goals and 169 targets to end poverty, protect the planet and ensure prosperity for all as part of the new sustainable development agenda, where each goal has specific targets to be achieved over the next 15 years [71].

6.1.2 World Green Building Council

World Green Building Council is a global network of Green Building Councils that pursuits sustainable transformation in the places we live, work and learn, as mentioned in Chapter 3. The network recognizes the Sustainable Development Agenda and it 17 Sustainable Development Goals as a key milestone and believe that these goals set forth a challenge for humanity to disconnect global economic growth from climate change, poverty and inequality [72].

Green building being both a building, the physical infrastructure of the building once its built, and the process of which combines materials and processes to maximize the overall efficiency, durability and economic savings. According to the World Green Building Council, it is also “an opportunity to not only save energy, water and carbon emissions but to educate, create jobs, strengthen communities, improve health and wellbeing, and much more” [72].

The 17 Sustainable Development Goals are wide ranging and consist of goals and targets which a building itself can’t cover, address or contribute to overall. Regardless, the World Green Building Council views the goals as a challenge that they believe green building can help to solve and has recognized buildings responsibility by pointed out several goals to which green buildings can, and already have, been contributing to in a significant way. Out of 17 goals, 9 are related to buildings, which are presented in Table 9

Table 9: Sustainable goals regarding buildings, presented by the World Green Building Council [72]

Sustainable development goals regarding buildings	
Goal 3: Ensure healthy lives and promote wellbeing for all at all stages	Green buildings can improve people’s health and wellbeing by: - Better air quality through a well-designed ventilation system - Greenery - Improved lightning - Reducing emissions from building - Global Project: *Better Places for People*
Goal 7: Ensure access to affordable, reliable, sustainable and modern energy for all	Green buildings can provide affordable and clean energy by: - Efficient use of energy, water and other resources - Integrates renewable energy, such as solar energy and low-carbon technologies - Energy and economic savings: “the cheapest energy is the energy we don’t use”

Goal 8: Promote inclusive and sustainable economic growth, employment and decent work for all	Green building promotes decent and economic growth by: - Being a growing global contributor to sustainability along with a growing global building industry, creates new full-time jobs, where the life-cycle of a green building and its concept impacts a wide variety of people, providing even more opportunities for inclusive employment.
Goal 9: Built resilient infrastructure, promote sustainable industrialization and foster innovation	Green building provides industry, innovation and infrastructure with: - A building that are designed to ensure resilient and adaptable in the face of the changing global climate - A building that not only consist of about future proof of buildings, but also the spaces in between. Infrastructure must be equally as sustainable and resilient to future risks - A building which pushes the boundaries on sustainability, such as net zero emissions buildings, a major driver for innovation and technology.
Goal 11: Make cities inclusive, safe, resilient and sustainable	Green building makes sustainable cities and communities safe by: - Being a key to long-term sustainability, where buildings are the foundation of cities - Provides high quality of life through a sustainable built-environment, which can contribute to the make-up for communities - Development of certification beyond a single green building, but also tools that facilitate the formation of green neighborhoods and districts
Goal 12: Ensure sustainable consumption and production patterns	Green building ensures responsible consumption and production by: - Preventing waste through recycling and reuse - Green Building's movement includes leading manufactures that generate products from what was previously considered to be waste – "Cradle to cradle" approach.
Goal 13: Take urgent actions to combat climate change and its impacts	Green building takes on climate action by: - Producing fewer emissions - Offering one of the most cost-effective ways, through energy efficiency and water conservation measures, in addition to promotion of renewable energy
Goal 15: Sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss	Green building safeguard life on land by: - Responsible use of sourced materials, such as timber - Green building certification tools recognize the need to reduce water consumption, and incorporates the value of biodiversity and its importance by ensuring it is protected
Goal 17: Revitalize the global partnership for sustainable development	Green Building introduces partnerships for the goals by: - Being one of a collective voice on the world stage when the World Green Building Council, UNEP, the French government and several other organizations came together to host the first ever "Buildings Day" as a part of the official COP21 agenda and to launch the Global Alliance for Building and Construction - Securing strong new partnerships such as with the World Resources Institute and the Global Environmental Facility - Recognizing the importance of effectively collaboration, and not only technical solutions

6.1.3 Pathways to sustainable buildings and construction

As mentioned in Chapter 4: *Building and energy market*, the Building and Construction-sector still accounts for nearly 40 % of global final energy consumption and according to the Global Status Report 2017, the buildings themselves represents 28 % of energy related carbon dioxide (CO2) emissions when upstream power generation is accounted for. Further, the report highlights that the floor area will double in the building sector, adding more than 230 billion m2 globally in new buildings construction by 2060 - demanding more energy, more advanced technologies and likely contribute to more emissions to the global environment [2]. Equally, there is a crucial need to address improvements related to energy performance in the world's existing building stock.

Progress however, are being made through the global sustainable movement, with stricter national energy codes, certification-systems, high-efficiency technologies, and the transformation to high energy-efficient and low carbon buildings. The Global Alliance for Building and Construction (GABC), being a collaboration initiative launched at COP21, has identified in the *Global Roadmap Towards Low-GHG and Resilient Buildings*, key priorities and strategies to reduce energy and the climate impact of buildings and construction [73].

Table 10: Pathways to sustainable buildings and constructions [18]

Pathways to sustainable buildings and constructions	
1. Urban planning policies for energy efficiency and renewabels	*"Use urban planning policies to impact the form and compactness of buildings to enable reduced energy demand and increased renewable energy capacity."*
2. Improve the performance of existing buildings	*"Increase the rate of building energy renovation and increase the level of energy efficiency in existing buildings."*
3. Achieve net-zero operating emissions	*"Increase uptake of net-zero operating emissions for new and existing buildings, including through system-level solutions such as zero-carbon district energy. "*
4. Improve energy management of all buildings	*"Reduce the operating energy and emissions through improved energy management tools and operational capacity building."*
5. Decarbonise building energy	*"Integrate renewable energy and reduce the carbon footprint of energy demand in buildings. "*
6. Reduce embodied energy and emissions	*"Reduce the environmental impact of materials and equipment in the buildings & construction value chain by taking a life-cycle approach."*
7. Reduce energy demand from appliances	*"Collaborate with global initiatives to reduce the energy demand from appliances, lighting and cooking."*
8. Upgrade adaptation	*"Reduce climate-change related risks of buildings by adapting building design and improving resilience."*
9. Increase awareness	*"Support training and capacity building including educational and informative tools to make the case for sustainable buildings and construction."*

These globally key priorities are being bridged and addressed in various national, European and International laws, that contains standards, codes, norms and stipulations that specify measurable standards of energy efficiency, as well as air quality thermal comfort and visual comfort, for buildings and facilities, as a base to an overall energy policy [18]. How strict and how optimized the currently available laws, standards and stipulations to fulfill their full potential however, are dependent on each national energy policy and building economy. Being regulatory instruments, building energy codes and standards set minimum requirements for energy efficiency and/or use of resources I buildings, like for instance, requirements that revolves energy sufficiency and renewable energy sources. According to the Global Status Report 2017, both mandatory and voluntary energy codes exist in more than 60 countries worldwide today [2]. In developing countries, however, there is still a critical need to implement mandatory building energy codes for new construction, especially when the global building sector by 2060 will be adding more than 230 billion m2, where more than 100 billion m2 are expected to be built in countries that currently have no mandatory building energy codes functioning [2].

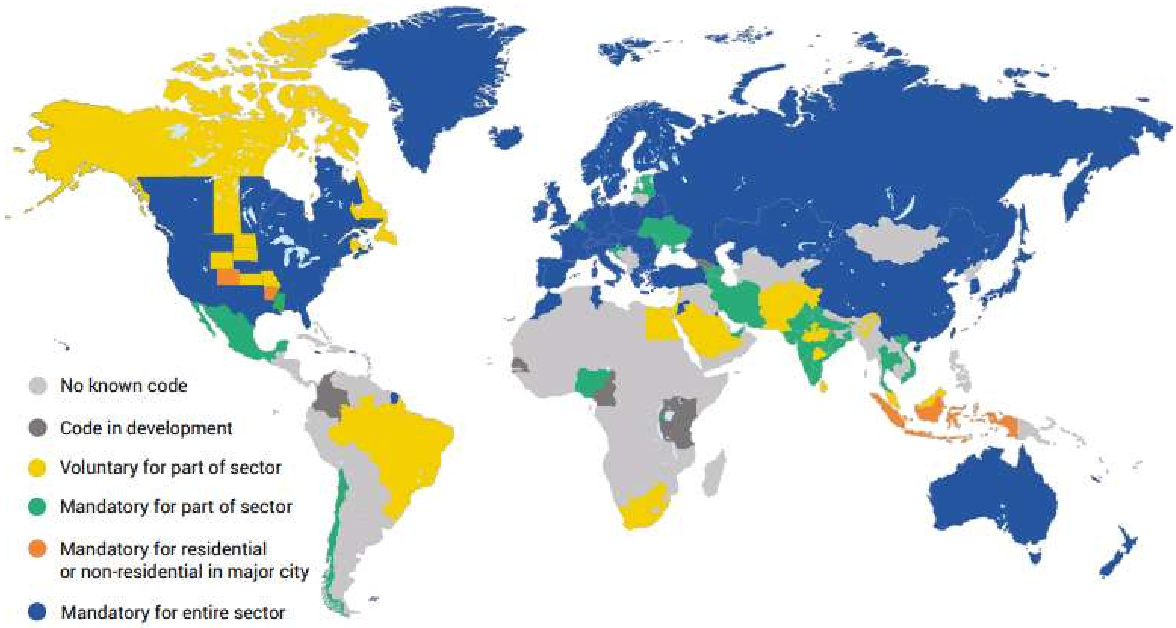


Figure 44: Building energy codes by country, state and province, 2016. [2]

6.2 Regulatory system in Norway

Norway is a constitutional monarchy and a parliamentary democracy with the legislative power vested in the Stortinget (The Norwegian Parliament) and the executive power is exercised by the Kings council through the government including 19 ministers divided by 15 ministry departments, headed by the prime minister. The executive power is formally vested by the King. The judicial branch is independent from the legislative and the executive branch.

6.2.1 Norwegian building control policy and regulatory system

The building and housing policy in Norway is subjected to the Housing and Building Department under the Ministry of Local Government and Modernization (MLGM). The ministry is responsible for promoting sustainable and lasting quality in buildings. The departments goals in terms of building policy are the promotion of well-designed, secure, energy-efficient and healthy buildings, and better and more efficient construction process. Political agreements such as White Papers and Climate Agreements sets the overall guidelines for the building policy and the Planning and Building Act (PBL), which is a statutory by the Norwegian Parliament.

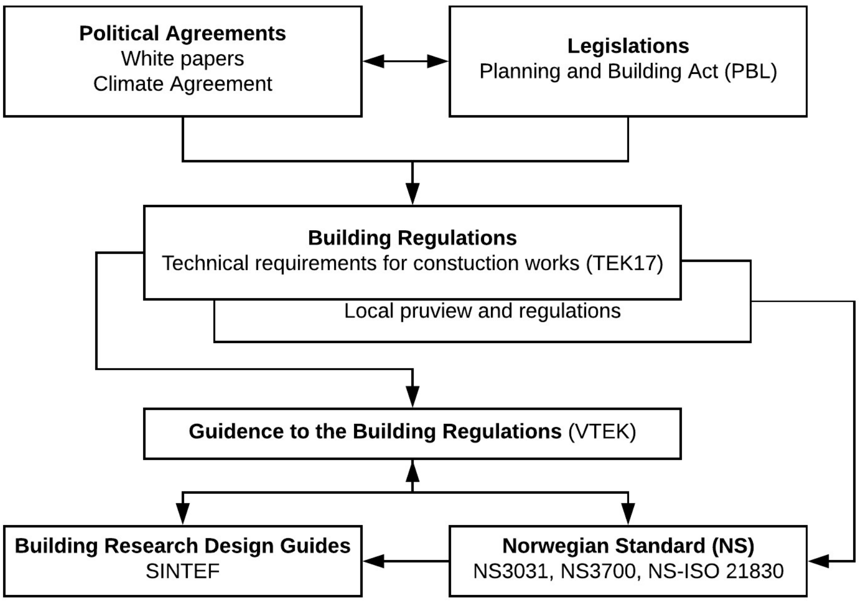


Figure 45: Building hierarchy in Norway

6.2.1.1 Planning and Building Act (PBL)

Planning and Building Act serve as a tool or safeguarding the public interest and managing land use. The act also includes the following objectives:

- Promote sustainability development to benefit of individuals, society and future generations
- Planning will help coordinate government, regional and municipal responsibilities and task, and provide grounds for decisions on the use and protection of resources.
- Constructions work will ensure that measures comply with law, regulation and planning.
- Planning and decisions shall ensure openness, predictability and participation for all concerned interests and authorities. Emphasis will be placed on long-term solutions and environmental and social consequences will be described.

- The principle of universal design should be considered in planning and the requirements for the individual construction measures. Considerations for children and adolescent's upbringing and aesthetic design of the environment

6.2.1.2 The Regulations on Technical Requirements for construction work (TEK)

The Regulations on technical requirements for construction work, TEK (Norwegian Building Regulation) is a largely function-based regulation subjected to the PBL, where the technical requirements are specified in the form of their functions or performance in all essential areas [74]. TEK describes minimum characteristics a construction must have to be lawfully raised in Norway. This include requirements regarding energy performance, universal design, materials, building envelope, fire safety, construction, heating systems, etc. Alongside the TEK there are also local purviews and regulations, in which the local government determine requirements for buildings due to regional difference. These requirements are based on structural demand due to snow accumulation and wind pressure (listed in Norwegian standards), maintaining the cultural aspects of an area in the determination of material and design, fire prevention measures and planning regulations. The TEK is passed by the MLGM.

The function requirements from the TEK are described in the Guidelines to the Building Regulations (VTEK) and give qualitative and quantitative performance criteria and pre-accepted solutions and performances which comply with the TEK. Where the TEK expresses requirements for functions, pre-accepted performance in the VTEK must express measurable performance or verifiable quality [74]. These guidelines are composed by the National Building Agency (DIBK) and are subjected to the MLGM. The DIBK works towards the local government and the building industry and works as a tool for the MLGM to realize the governments building policy as well as to increase the knowledge in the society – building industry and local government – about building codes and building quality. Within the VTEK references are made to the Norwegian standards and Building research design guides, which both serves as accept criteria for the building codes. The building research design guide describe how to achieve the requirements in the TEK in terms of architectural planning, building details, and building quality management and maintenance. The Norwegian standards are details of accept criteria in terms of construction safety; constructions of wood, steel and concrete buildings. International standards (EU/ISO) are adapted as a Norwegian standard by including a national annex to harmonize product standards.

6.2.2 Influential force from the European Union, EU climate and energy goals, and its directives

The facilitation of building sustainable in Norway has its origins in high energy consumption and greenhouse gas emissions in the construction industry. Building sustainable at a national level is influenced by requirements and demands from both the European Union (implemented in Norway through the EEA and EFTA) and the United Nations. Even though Norway is not a member of the European Union, it still shares internal market legislation with the EU through the European Economic Area EEA and European Free Trade Association (EFTA), where the objectives are to strengthen trade and economic relations between the EEA/EFTA States and the EU member states with equal conditions of competition throughout the EEA. Norway is therefore obligated to obtain some of the climate and energy goals, which includes implemented several EU directives and regulations related to climate and energy saving. In the aims of reducing energy consumptions and greenhouse gas emissions from the constructions sector, the EU directive are supplemented by the European Commission's support and a mandate in the European Committee of Standardization (CEN) which creates standards. The XXX below illustrates how Norway is influenced by the EU and the UN to reduce energy consumption and emissions of greenhouse gasses in the building and construction sector.

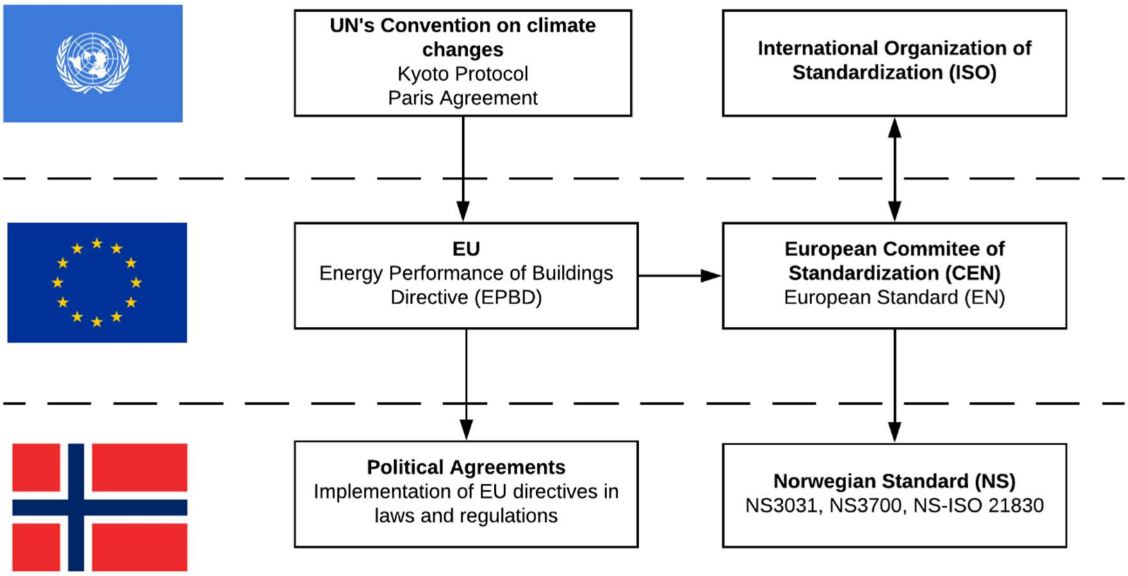


Figure 46: Influential force of the European Union and United Nations in terms of energy efficiency and environmental impact on buildings

6.2.2.1 Overview of the EU's climate and energy goals

The European Union (EU) is a great driving force for an increasing initiative regarding energy efficiency and climate adaption, and using the Paris Agreement as a base, includes a long-term goal of becoming a carbon neutral society by 2050. Earlier, the EU have agreed upon the 20-20-20 goals by 2020 and are statutory in the different directives:

- 20 % of the EU's energy production should come from renewable energy sources
- 20 % reduction of the final energy consumption from 1990 level
- 20 % reduction of GHG emissions from 1990 level

In 2014 there was a political agreement among the EU members of new energy and climate goals for the fiscal year 2030 which are an extension of the 2020 goals. The energy and climate goals for 2030 in the EU include a 40 % reduction of GHG emissions from 1990 level, both for EU in total and obligating the member countries of domestic emission goals. Further on the amount of renewable energy source production is to constitute 27 % of the total production in EU in total. The total final energy consumption is to be lowered by at least 27 %. Along with these goals, there is also proposed to introduce a comprehensive reporting system that provides an overview of the status of each of the member countries, this includes a compilation of a domestic plan regarding GHG emissions, renewable energy and energy efficiency for each of the member countries [75], [76].

6.2.2.2 EU directives

As a measure to comply with the requirements needed to reach the energy and climate goals, the EU's development of EU directives implements these requirements in both member countries and other countries such as Norway, through the EEA and EFTA.

Table 11: Overview of some of the EU directives affecting the energy and environmental aspects of buildings

EU Directives	Content and objective
Energy Performance of Buildings Directive I (2002/91/EC) [76]	- Statutory in 2003 (Norway: 2005) - How to reduce GHG emissions related to energy consumption in Buildings. - Calculation method for energy performance in buildings. - Minimum requirements for new buildings and building units. - Minimum requirements for rehabilitation for buildings, building components and technical systems. - Energy labeling of buildings. - Energy flexible heating system for buildings over 1000m^2, CHP.
Energy Performance of Buildings Directive II & III (2010/31/EU) [77].	- Revision of the EPBD (2002/91/EF) - Statutory in 2010 (Norway: N/A) - Stricter minimum requirements for rehabilitation for buildings, building components and technical systems. - From 2015, all new buildings should have a net zero energy consumption. - Regular inspection of heat and air conditioning. - Independent control of energy certificates and inspection reports. - Cost optimize energy performance requirement for buildings.
Renewable Energy Directive (2001/77/EC) [78].	- Statutory in 2001 (Norway: 2005) - Increase the renewable electricity production from 13.9 % (1997-level) to 22.1 in 2010. - Ensure the energy supply security. - Wind, sun, waves, tide, biogas, hydropower.
Energy Efficiency Directive I & II (2012/27/EU) [79].	- Statutory in 2012, revised in 2016 (Norway: N/A) - Energy efficiency goal of 30 % by 2030. - Long-term rehabilitation of government owned buildings - Consumer must be provided with meters that reflect the consumers actual energy consumption. - More accurate energy costs.
Ecodesign Directive (2009/125/EC) [80].	- Statutory in 2009 (Norway: 2011) - Reduce environmental impact of energy related products in their life cycle. - Requirements for efficiency, production, and product design.

The Energy Performance of Buildings Directive (2002/91/EC) form the basis for the Norwegian building codes regarding energy labeling for buildings and residential, and energy evaluation of technical installations. It also present minimum requirements for the energy performance in new buildings [81]. Through EU's development of EU directives, these requirements (e.g. the Energy Performance of Buildings Directive, EPBD, sets minimum energy requirements in new buildings) form the basis of the PBL.

6.2.3 National climate and energy strategy, and targets

The Norwegian strategy for energy efficiency and environmental aspects are, as mentioned, highly affected and driven by the central energy and climate policy in the EU, where a major alteration of energy is important to reduce the energy related environmental emissions and other aspects. Norway share the long-term goal of achieving a carbon neutral society by 2050. Five priority areas are identified in the climate and energy policy, for Norway to reach an ambitious leading position in the green change:

- Reducing emissions from transport sector.

- The development of low-emission industrial technology and clean production.
- GHG/ CO_2 management such as carbon capture and storage.
- Strengthen Norway's role as a supplier of renewable energy.
- Environmentally sound shipping.

6.2.3.1 Energy strategy and targets

The 2016 White Paper on energy policy to 2030 form the basis of Norway's contribution and efforts related to energy efficiency and the national target. Energy efficiency is in this context, a tool to meet energy policy objectives of the security of energy supply, environmentally sustainability and economic efficiency. The White Paper sets out an energy policy by 2030, where energy supply, climate challenges and business development are seen in context. Energy systems are of a significant importance in the Norwegian economy as it must be sustainable, economical, ecological and social. In many ways, Norway has a good basis to comply with the challenges and opportunities regarding the energy policy towards 2030: Energy supply with low GHG emissions; increased share of renewable energy in the TFC; energy efficient supply; vast access of renewable energy sources. Regarding energy policy, the Norwegian government have four priority areas for the energy policy towards 2030 [82], but has not yet prepared a specific strategy or action plan on energy efficiency [38]. The term energy efficiency contributes to lesser extent to GHG emissions in Norway than in countries where energy supply is more based on fossil fuel.

Table 12: Norwegian targets, intended strategy and objectives regarding energy policy

Target	Intended strategy and objectives
Strengthen energy supply security	- Facilitate flexible energy systems that enables rapid and efficient adaptions on fluctuations in the power and energy use, - Marked based operation of power systems and trading. - Stronger collaboration with the Nordic countries for good secure supply. - Facilitate new, effective solutions to contribute to security of supply in the future energy system.
Facilitate profitable production of renewable energy in Norway	- Facilitate to a long-term renewable power production developed according to socio-economic profitability and proper utilization of the residual potential of new hydropower. Through negotiations with the EU, Norway has committed that 67,5 % of the TFC is to be renewable energy. - Environmental improvements that can be achieved in existing hydropower stations and must be weighed against lost power generation and controllability. - Facilitate the potential of rehabilitation and expansion of hydroelectric power stations. This potential for new power through upgrades and extensions is estimated at 6 TWh/year. - Long term development of profitable wind power. Production profile of the wind power adapts to the Norwegian consumption. A national framework for wind power will contribute.
Develop and facilitate a more efficient and climate-friendly use of energy	- Enhance energy efficiency by contribute to Enova's effort for new energy efficient and climate-friendly technology to get established on the market. - Reduce energy intensity by 30 % by 2030, by tightening the energy requirements to a passive house level and reduce the requirements by approximately 25 % from 2016. - Acquires of a reduction of energy consumption in existing buildings by 10 TWh by 2030. And out phasing of fossil fuel as heating systems by 2020. - Energy efficiency must be adapted to a growing economy.

	- In designing the measures that affect energy consumption in building the government will emphasize the relationship and collaboration between the building industry and energy sector.
Facilitate industry development and business based on renewable energy resources	- Prioritize efforts ion climate policy to strengthen Norway as a supplier of renewable energy. - Strengthen a broad Norwegian business community – a more diverse community allows increase in competition, and contribution for rational development of transmission links for power abroad. - Facilitate for new industrial activities. - Future value creation depends in the ability to further innovation and knowledge development.

6.2.3.2 Climate strategy and targets

The climate policy of Norway is based on the objectives of the Framework Convention on Climate Change, Kyoto Protocol and the Paris Agreement (COP21) and been featured in the Norwegian policy agenda since the 1980s. According to Norway's intended Nationally Determined Contribution (INDC) Norway has fully committed to the UNFCCC negotiation process towards adopting COP21 protocol, another legal instrument on agreed outcome with legal force under the Convention, applicable to all Parties, in line with keeping global warming below 2°C [83]. After the Norwegian consent to the ratification of the Paris Agreement, Norway has ambitious targets regarding the climate policy for 2020, 2030 and 2050. A relevant strategy in the execution of these targets depend on the GHG emission trade – European Union Emission Trade System (EU ETS) which allows nations to fund reductions of emissions in developing countries or buy emission allowance to meet up with a nations emission targets. In 2017, the Norwegian have published a White Paper concerning the climate strategy for 2030 – a Norwegian adjustment for European collaboration [84], resulting in four major targets:

Table 13: Norwegian targets and strategies regarding climate policy [38], [84], [85]

Target	Objective	Strategy
Reduce GHG emissions by 30 % by 2020 from 1990-level	- An optional target through the legally binding commitment for 2013-2020 under the Kyoto protocol. - Ensure annual GHG emissions for the period 2013-2020 dies not exceed an average of 16 % lower than in 1990. - Compliance with the commitment under KP will imply the target for achieved.	- Using flexible mechanisms – project-based cooperation in developing countries enable Norway to get credited by funding of reduction of GHG emissions in developing countries. - GHG emission trade – European Emission Trading System and Norwegian Carbon Credit Program; purchase of emission reduction and methane destruction in developing countries.
Reduce GHG emissions by at least 40 % by 2030 from 1990-level	- Commitment through NDC under Paris Agreement. - Commitment period 2021-2030. - Covers all sectors and GHG. - Preliminary target for reduction of non-ETS emissions of 40 % below the 2005 level in 2030. - Estimates 20-25 million tons emissions domestic reductions + 5.5-11 million EU ETS units.	- Not debated by the Norwegian parliament. - Intending emphasis on domestic emission reduction, EU flexible mechanisms are necessary. - Will facilitate requirements will be met by cost efficient emission reduction and incorporate sufficient flexibility to allow adjustments as

		new knowledge becomes available and conditions change. - Increase biofuel quota obligation to 20 % in 2020.
Climate neutrality by 2030	- Must achieve emissions reduction abroad equivalent to remaining Norwegian GHG emissions.	- Government will provide the Norwegian Parliament with an account follow-up at a suitable time.
Low-emission society by 2015	- Promote a long-term transformation of Norway in a climate-friendly way. - Achieve emissions reductions of the order of 80-95 % from the level in reference year 1990.	- Participation of the EU ETS. - Set out in the 2012 cross-party agreement on climate policy - Provide more predictable framework conditions for a green transition, at the same time maintaining economic growth and creating new jobs.

Norway has set to uphold the ambitious reduction goal of 40 % by 2030 from the level in reference year 1990 in the event that there is no agreement on a collective delivery with the EU [83]. A 40 % reduction on 1990 emissions level provided in the INDC [83] represent 31.2 Mt CO_2e from 52 Mt CO_2e excluding LULUCF in 1990. The reduction of emissions constitutes 21.2 from Norway's INDC in 2030. Norway also states that only removals beyond the level in the base year will count towards the target of 40 % reduction by 2030, and the target net emissions constitutes 10 Mt CO_2e [86].

6.2.4 Domestic measures for energy efficiency and climate adaption for the Norwegian building stock

The Norwegian building sector has a major impact on the national climate and energy goals and targets. This relates to the use of materials, waste amounts arising from construction work, buildings envelope, elements and components thermal resistance, and technical systems.

Some of the domestic measures regarding climate adaption and the reduction of GHG emissions are implemented in the building code (§9-1 to §9-10). These regulations contain hazardous substances in construction materials, soil pollution, natural diversity, waste management and particle emissions form wood burning ovens: The regulation narrows it down to that construction works shall be designed, constructed, operated and demolished in such a way as to minimize the impact on natural resources and the external environment, and the construction waste must be handled accordingly. A measure to control this is the use of environmental labeling of products that are used in in buildings:

Table 14: Environmental label for Norwegian building products

Environmental Labels	
Swan label	- Official Nordic environmental label and considers the best environmental choice. - LCA of the products. - Strict requirements for management, use of energy and chemicals, safety and quality during use, biodegradability of waste
ECO product	- Database of evaluation building products. - Evaluation areas: indoor climate, content of hazardous substances, use of resources and greenhouse effect.

	- Third part verification of Environmental Product Declaration (EPD)
SINTEF technical approval	- Additional documentation of the CE label products. - To show that the product complies with the requirements of the building regulations and Norwegian construction practice

Domestic measures regarding energy efficiency are implemented in the building code (§14-1 to §14-5), and energy efficient measures such as energy requirements were first introduced in the building code in 1949. Since then the building codes and the energy requirements have been revised and made stricter, most recently in 2016, they serve as the main legal instrument for improving energy efficiency. To cope with the energy efficiency goals, the energy requirement for the total net energy in a building got stricter and are as today on a passive house level, calculations according to NS3031:2014, resulting in an energy efficient increase of 26 % for dwellings and 38 % for office buildings [85]. Consideration regarding further development of the energy requirements are construction costs, operating costs, the impact of energy requirements on other building qualities and the interaction with the energy system.

The stricter energy requirements also specify that the use of fossil fuel heating is prohibited and larger buildings, with more than 1000 m^2 heated usable floor space, must have multiple heating solutions. All new buildings and buildings subjected to major renovations are required to meet the total net energy need for space heating, cooling and hot water lower than specified in the regulations as shown in Table 15:

Table 15: Total net energy requirements for various building categories according the newest building codes [87].

Building category	Total net energy requirement [kWh/m^2 heated gross internal area per year]
Small houses and leisure homes with more than 150 m^2 of heated gross internal area	100 + 1600/m^2 heated gross internal area
Block of flats	95
Kindergarten	135
Office building	115
School building	110
University building	125
Hospital	223 (265)
Nursing home	195 (230)
Hotel building	170
Sports building	145
Business building	180
Culture building	130
Light industry/workshop	140 (160)

For residential buildings to meet the energy requirement set in the building code, they can also use energy efficient measure for individual building components, not only the total net energy (energy budget):

Table 16: Energy efficiency measures for individual building components in residential buildings [87].

	Energy-saving measures	Small house	Block of flats
1	U-value external walls [W/m^{2}K]	≤ 0.18	≤ 0.18
2	U-value roof [W/m^{2}K]	≤ 0.13	≤ 0.13

3	U-value floors [W/m²K]	≤ 0.10	≤ 0.10
4	U-value windows and doors [W/m²K]	≤ 0.80	≤ 0.80
5	Proportion of window and door areas of heated gross internal are (%)	≤ 25	≤ 25
6	Annual mean temperature efficiency ratio for heat recovery systems in ventilation system (%)	≥ 80	≥ 80
7	Specific fan power (SFP) in ventilation systems [kW/(m³/s)]	≤ 1.5	≤ 1.5
8	Air leakage rate per hour at 50 Pa pressure difference [h^{-1}]	≤ 0.6	≤ 0.6
9	Normalized thermal bridge value, where m² is stated as heated gross internal area [W/m²K]	≤ 0.05	≤ 0.05

For any building category, all new buildings must meet minimum requirements for the building components:

Table 17: Minimum requirements [87]

U-value external walls [W/m²K]	U-value roof [W/m²K]	U-value floors [W/m²K]	U-value windows and doors [W/m²K]	Air leakage rate per hour at 50 Pa pressure difference
≤ 0.22	≤ 0.18	≤ 0.18	≤ 1.2	≤ 1.5

The Norwegian Standards that contributes for the measures regarding energy efficiency and emissions in the Norwegian building stock are the *SN/TS 3031:2016 – Calculations of energy performance of buildings method and data, NS3701:2012 – Criteria for passive houses and low energy buildings – Non-residential* and *NS3700:2013 – Criteria for passive houses and low energy buildings – Residential buildings*. The SN/TS 3031 is a used for the calculations and documentations for the energy requirements for buildings, energy labeling, BREEAM NOR and the passive house standards (NS3700, NS3701) and include calculations of:

- Heat loss number
- Heat loss budget
- Net energy demand
- Delivered energy
- CO_2 emissions and primary energy

For a non-residential building to achieve the terms of passive house or low energy building following measures and requirements are necessary:

Table 18: Requirements for Passive house and low energy building [88]

Building category	Passive house	Low energy building
U-value windows and doors [W/m²K]	≤ 0.80	≤ 1,2
Normalized thermal bridge value, where m² is stated as heated gross internal area [W/m²K]	≤ 0.03	≤ 0.05
Annual mean temperature efficiency ratio for heat recovery systems in ventilation system (%)	≥ 80	≥ 70

Specific fan power (SFP) in ventilation systems [kW/(m³/s)]	≤ 1.5	≤ 2,0
Air leakage rate per hour at 50 Pa pressure difference	≤ 0.60	Residential: ≤ 1,0 Non-residential: ≤ 1,5
Only for non-residential buildings		
Demand-controlled lighting of daylight	At least 60 % of the power for lighting is demands-controlled	
Demand-controlled lighting of presence	At least one control zone per room, or per 30 m² in larger rooms	

Table 19: Overview of some of the measures for energy and climate policy of the Norwegian building stock

Energy Targets	Measures
Reduction of the energy consumption and increase the use of renewable energy in the building sector **(Regulatory measures)**	- Step by step reduction of energy requirements in the building codes (to passive house level) by reducing the total net energy requirement and the minimum requirements for building components, shown in Table 15, Table 16, Table 17. - Prohibition of fossil fuel as heating systems by 2020. - Requirement for heat recovery in ventilation systems and adaption to energy efficient heating systems; District heating; waterborne heating. - Ensure technical systems are efficient by regular energy evaluation. - Energy label requirement of building and household appliances. - Concession and connection obligation of district heating. - Requirements for building components when renovated.
Reduce the energy consumption by supporting energy efficiency and use of renewable energy in the building sector **(Economic measures)**	- Support schemes for investment, research and development. - Enova SF: financial and technical support for the adaption of energy effective measures, for individuals and businesses that support renovation of buildings, energy efficiency and heat production or for new buildings which exceed the building code regulations. - State Housing Bank: Financial support for building and improving existing buildings with energy efficient solutions to lower the energy consumption. - Financial support for increasing the competence of sustainable buildings and building quality among municipalities and the building industry.
Increase the competence of energy efficient buildings and effective information about energy consumption **(Competence measures)**	- Pilot projects regarding energy and climate friendly based building method and make documentation (research and development) - Individual initiative of market demand/ The state as a forerunner - Building Technical support programs - Enova's collaboration with educational institutions, entrepreneurship among youth and research centers: zero emission buildings (ZEB), zero emission neighborhood (ZEN). - Environmental and architectural design awards for buildings with good solutions for environmental impacts, energy consumption and esthetic designs.
Alteration of and increase use of new renewable energy sources in building	- Building codes that require use of renewable energy. Prohibition of fossil fuel as heating systems by 2020. - Pilot projects with renewable energy. - Financial support for the infrastructural establishment for district heating and cooling. - Taxation of GHG emissions
Climate adaption in the building industry	- Local government regulations on location of buildings to prevent exposure to flood, landslide etc.

The impact of these measures regarding the restricting of the energy requirements will accumulate over time. Because buildings have a long-life, the design of the technical requirements affect the energy consumption many years after the building is built. The Norwegian Water Resources and Energy Directorate (NVE) has estimated that the building stock will increase by 98 million new square meters by 2030 and accounting the newly restricted energy requirements, this will give an energy saving of approximately 18 TWh by 2030 [82]. All measures such as energy taxes and emission taxes, regulations, support schemes and technological development affect the development of energy consumption and emissions in buildings.

6.3 Political determinations – regulatory system in Japan

The government of Japan is a constitutional monarchy in which the administration includes two level of governments: central and local. Executive power is vested in the Cabinet, which consists of the Prime Minister and mot more than 17 Ministers of State. As in many states, the Government is divided into three independent branches: legislative (the Diet including the House of Representatives and the House of Councilors), executive (cabinet and ministries) and judicial. Based on laws and budgets adopted by the Diet, the cabinet exercises its executive power. As for the building and construction sector in Japan, the *central governmen*t and their main ministries involved are [60]:

- The Ministry of Land, Infrastructure, Transport and Tourism (MLIT) – in charge of building and construction regulations.
- The Ministry of Economy, Trade and Industry (METI) – in charge of building and trade (import/export), overall responsibility for energy policy - delegated to the Agency for Natural Resources and Energy (ANDRE).
- Ministry of the Environment – in charge of climate change and air pollution mitigation.
- Ministry of Land, Infrastructure, Transport and Tourism (MITT) – in charge of energy efficiency.
- The Ministry of Agriculture, Forestry and Fisheries (MAFF) – in charge of forestry management and wood production.
- The Ministry of Health, Labor and Welfare (MHLW) and the Ministry of the Environment (MOE) – in charge of the aspects of building construction materials BCM) under their jurisdiction.

Japan is divided in to several prefectures. In terms *local governments* within each prefecture, it consists of two levels: prefectural and municipal. As of 4. Mai, 2018, Japan had the following:

- 47 prefectures.
- 20 “Cabinet-Order designated cities”, which are Japanese cities (municipalities) that has a population greater than 500,000, with administrative and fiscal authority equivalent to those of prefecture.
- Cities are divided into several types; Cabinet-Order designated cities (*shitei toshi*), core city (*chūkakushi*), special city (*tokureishi*), city (*shi*).
- Tokyo legally classified as a special type of prefecture, called a *metropolis*. 23 wards constitute the core of the Tokyo metropolitan area.

Like in most countries, the central government (national assembly, cabinet and MLIT) legislates the building regulatory systems and the building codes (technical requirements). They are enforced nationally and provides regulation concerning site development, construction, equipment and the use of buildings, based on the Building Standard Law. Since regional differences occurs, the building regulations in Japan are administrated by local governments for prefectures, cities, municipalities, towns and wards in the Tokyo Metropolis. Based on the criteria in the building regulation (Building Standard Law), local governments determine figures to be used for;

- Structural calculations, such as snow accumulation, wind pressure and seismic force.
- Restricted zones for specific external finishing to prevention of fire.
- Specific procedures for construction work, like interim inspections through additional standards in accordance with regional conditions.

Within specific limits of not disrupting the overall safety of buildings, local governments may set more severe or more relaxed regulations than the national standard applied.

The Building Standard Law is the primary law concerning building codes in Japan [89]. It includes both the structural and the hygienic safety, as well as fire safety in regards evacuation plans. Other main laws related to building regulation are listed in Table 20.

Table 20: Building laws and related fields

Building codes items and related fields		Restrictive law (Mandatory)	Promotional laws (Optional)
Building Design		Kenchikushi Law	
Structural safety		Building Standard Law	Seismic Retrofitting Law
Hygienic safety			Building Management Law
Fire safety	Fire-resistance evacuation, etc.		
	Fire extinguishing equipment, etc.	Fire Service Law	
Accessibility		Barrier-Free Law	
Energy		Building Energy Efficiency Act	

6.3.1 Climate and energy strategy, and targets

On the global stage, Japan has diplomatic relations with nearly all independent nations. Japan is a member of the UN, the G8, the OECD, APEC (Asia-Pacific Economic Cooperation), ASEAN Plus Three (Association of Southeast Asian Nations), as well as a participant in the East Asia Summit. They also have industrial cooperation with the EU, through the EU-Japan Centre [90].

As of many nations, Japan's energy policy is being influenced by the overall eruptions in the global energy environment. The country has little domestic fossil fuel and are vulnerable by depending on import from abroad, faced for instance two serious oil crisis in 1973 and 1979, which threw the country into a deep economic depression. Japan were now forced to a radically overhaul in their energy policy, and in response, the government formulated the Sunshine Project in 1974 and the Moon Light Project in 1978, represented national strategic initiatives designed to promote the long-term R&D of solar cells, heat pumps, fuel cells, and other advanced technologies under the auspice of the Japanese Government [91], [92]. In the end of 1979, the Act on Rational Use of Energy (known as the "Energy Conservation Act") was enforced and became the foundation of Japan's energy efficiency and conservation policy. The Energy Conservation Act was at first targeted factories with a large amount of energy consumption, but has now after several revisions, including all major sectors in Japan, such as industrial, residential, commercial, and transportation [93]. Later on, Japan reorganized its long-lasting Sunshine Project towards a more comprehensive "New Sunshine Program", making Japan the first country to reach 1 GW of installed solar capacity in 2004 for residential solar panels [92], [94]. As an overall result of the initiatives, the stemming from this long-term strategy has resulted in Japan leading the world in breakthrough innovations such as high-efficiency solar power generation, the extensive adoption of heat pumps, and the introduction of residential-use of fuel cells to the world markets [93].

However, recent years have been challenging. Since 2011, Japan's energy policy has been dominated by efforts to overcome the impact from the Great East Japan Earthquake and the subsequent accidents at TEPCO's Fukushima Daiichi Nuclear Power Station (Fukushima Nuclear Accident). Earlier in 2009, at COP15 in Copenhagen, Japan pledged an ambitious 25 % cut in GHG emission from 1990 to 2020, compared to 1990 levels, which were heavily relying on increasing nuclear power's share in electricity supply from 30 % to 50 %, as part of the country's third Strategic Energy Plan (SEP) enforced in 2010

[61]. The expansion was abandoned, and the nuclear shutdown left a gap of around 30 % in electricity supply (mostly replaced by fossil fuels and liquified natural gas (LNG), but also coal and oil), import dependence shot to 94 %, electricity prices increased, and annual carbon dioxide emissions from power generation rose by more than 110 million tons (Mt) or more than one-fifth from 2010 to 2013, according to *International Energy Agency* data [61]. An unstainable situation for a country that had manage to overcome two oil crises and had increased their energy self-sufficiency over several decades. As a response, the government adopted the fourth Strategic Energy Plan in 2014 and based on it, METI (Ministry of Economy, Trade and Industry) prepared the "Long-term Energy Supply and Demand Outlook" to 2030, which was adopted in 2015 [95], [96].

6.3.2 The Strategic Energy Plan

In 2014, the government of Japan formulated the 4th Strategic Energy Plan for setting future direction of Japanese energy policy, under the "Basic Act on Energy Policy" [95]. Considering the significant impact on Japan's energy environment caused by the Fukushima Nuclear Accident in 2001, this new plan was a direct result. Based on the "Basic Act on Energy Policy", the first Strategic Energy Plan was drawn up in 2003, and later the second and the third plan was introduced in 2007 and 2010 [93]. In the 3rd Strategic Energy Plan, the target for 2030 described that the county's self-motivation energy and zero-emission power sources consisting of nuclear powers and renewable energies should be approximately 70 % [95]. However, after developing the third plan and given the circumstances caused by the Fukushima Nuclear Accident, Japan reconsidered its energy strategy from scratch and the 4th Strategic Energy Plan declared that the country will minimize its dependency on nuclear power. Furthermore, the plan highlights its principles through the energy policy "3E+S", meaning that Japan will ensure stable supply (Energy Security), and realize low cost energy supply by enhancing its efficiency ("Economic Efficiency") on the premise of "Safety", in addition to make maximum efforts to pursue environment suitability ("Environment") [95]. The 4th strategic energy plan highlights several key priorities the Japanese Government (GOJ) will pursue related to enhancing energy efficiency in each sector [95]: (Every priority in directly out taken from the plan)

- Achieve Net Zero Energy in newly constructed *commercial* buildings by 2020.
- Achieve Net Zero Energy in all newly constructed buildings on average by 2030.
- Achieve Net Zero Energy in newly constructed houses by 2020.
- Achieve Net Zero Energy in all newly constructed houses on an average by 2030.
- Keep on promoting energy efficiency measures through expansion of the Top Runner Program. The program set mandatory energy efficiency standards for products, based on the most efficient "Top Runner" on the marked. E.g. construction materials, insulation, electric water heater, LED lighting etc.
- Keep on promoting storage batteries in houses and buildings by lowering their cost and improving their performance through technological development and international standardization.
- Keep on promoting energy efficiency measures such as renovation and rebuilding of existing buildings and houses with high energy efficiency performances
- Encourage high-heat insulation performances for new buildings and houses and the introduction of energy efficient equipment

6.3.3 The Long-Term Energy Supply and Demand Outlook to 2030 and the Paris Agreement

Following the 4th Strategic Energy Plan, the Ministry of Economy, Trade and Industry (METI) established the Long-term Energy Supply and Demand Outlook in 2015 based on the targets established to realize "3E+S" policy. According to METI, the 2015 Outlook describes a forecast but also a vision of a desired future energy supply-demand structure to be realized, considering the Strategic Energy Plan, by executing the policies based on the essential direction of the energy policy, and assuming the policy goals to be achieved regarding *safety*, *energy security*, *economic efficiency* and *environment* [96].

The Outlook aims at a self-sufficiency ratio of around 25 % (before 2011; 20 %), and aims to contribute to a GHG emission reduction, while lowering electricity costs by promoting renewable energy and restarting nuclear power plants, under the most stringent level of new regulatory requirements in the world. By March 23, 7 nuclear reactors have so far cleared inspections confirming they meet the new regulatory safety standards and resumed operation. While another 17 reactors have applied to restart [97].

The Outlook being prepared with climate change objectives in mind and as a preparation for the COP 21 in Paris, Japan initiated their INDC towards post-2020 based on the Outlook, pledging to reduce GHG emissions by 26 % by fiscal year (FY) 2030 compared to FY 2013 (approx. 1.042 billion t- CO_2 eq. as 2030 emissions). Japan's *energy mix* is consistent with the long-term emission pathways up to 2050 to achieve the 2 degrees Celsius goal. With the goal, the country upholds in addition the goal of developed countries reducing GHG emissions in aggregate by 80 % or more by 2050 [96], [98]. To support these premises, the government is working together with the NESTI 2050 Strategy (National Energy and Environment Strategy for Technological Innovation towards 2050) and with the industry and academia to promote innovation in energy technology under the Environmental Energy Technological Innovation Plan. The government also adopted the Plan for Global Warming Countermeasures in 2016, which defines a path to achieve the country's 2030 target set out in Japan's INDC as well as the 2050 Strategy Goal.

Table 21: Estimated emissions of energy-originated CO_2 in each sector [98]. Value: Million t-$C0_2$eq.

	FY 2005	FY 2013	Estimated emissions of each sector in FY 2030
Energy-Originated CO_2	1,219	1,235	927
Industrial sector	457	429	401
Commercial and other	239	279	168
Residential sector	180	201	122
Transport sector	240	225	163
Energy conversion	104	101	73

Table 22: Estimated emissions of non-energy-originated CO_2, methane and nitrous oxide [98]. Value: Million t-CO_2eq.

	FY 2005	FY 2013	Estimated emissions of each gas in FY 2030
Non-Energy-Originated CO_2	85.4	75.9	70.8

Methane (CH_4)	39.0	36.0	31.6
Dinitrogen monoxide (N_2O)	25.5	22.5	21.1

Table 23: Primary Energy Supply in FY 2030 [99]

Oil	LPG	Coal	Natural Gas	Nuclear Power	Renewable Energy
30 %	3 %	25 %	18 %	10-11 %	13-14 %

Table 24: Power Source Energy Mix in FY 2030 [99].

Total Power Generation (Approx. 1065 billion kWh)								
Oil	Coal	LNG	Nuclear	Renewable Energy (22-24 %)				
				Hydroelectric Power	Solar Power	Wind Power	Biomass Power	Geothermal Power
3 %	26 %	27 %	20 – 22 %	8.8 – 9.2 %	7.0 %	1.7 %	3.7 – 4.6 %	1.0 – 1.1 %

As for the tables above, the commercial and residential sector will need to difference 111 and 79 million CO_2eq of estimated emissions decrease (Table 21), to achieve the goal, set for FY 2030. Furthermore, it is expected that as a source of electricity generation, renewable energy would significantly increase from around 12.2 % in FY 2014 to around 22-24 % in FY 2030, while nuclear dependency, which was around 30 % before the Fukushima Nuclear Accident, would decrease to 20-22 % (Table 24). As a result, it is expected that power sources of zero emission kinds, consisting of nuclear power and renewable energy in FY2030 should amount to approximately 44 %, while the base load rate such as hydroelectric power, coal-fired thermal power and nuclear power will amount to around 58 % [99].

The energy mix targets are ambitious, and expectations are high that Japan will be one of the leading nations to produce innovative technologies to contribute to large-scale reductions of greenhouse gases – particularly CO_2 – to solve global warming. Already in 2012, Japan introduced the Feed-In Tariff (FIT) scheme as a driving force to promote renewable energy, following many other developing nations. Its more than likely to think that the FIT will still be one of the key factors on how to further introduce and expand renewable energy to the maximum extent while minimizing the public burden. As for the scope and sectors involving energy and fuel combustion measures, the Outlook and the INDC encompasses energy industries, manufacturing industries and construction, agriculture and transport, as well as the commercial and residential sector. Key measures which forms the basis for the GHG emission reduction targets, regarding the commercial and residential sector, can be viewed in the following table stated by the Japan's INDC.

Table 25: Measures which form the basis for the bottom-up calculation of the GHG emission reduction target [12]

	FY 2013 (FY 2005) (Million t-CO_2)	FY 2030 emission targets (Million t-CO_2)	Measures
Energy-Originated CO_2	1,235 (1,219)	927	
Commercial and other sectors	279 (239)	168	- Promotion of compliances of energy saving standards for newly constructed buildings

			- Energy efficiency and conservation buildings (remodeling) - Introduction of commercial-use water heater (latent heat collection, heat pump, high-efficient boiler) - Introduction to highly efficient light - Improvement of energy efficiency and conservation performance of equipment by the Top Runner program - Thorough implementation of energy management with BEMS and energy efficiency diagnosis - Expansion of shared use of energy - Energy efficiency and conservation of/energy generation from renewable energy in water business and sewerage systems - Promotion of sorted collection and recycling - Low-carbonization of cities by improving thermal environments through measures against the urban heat island effect - Inter-ministry collaborative measures following the Roadmap of Global Warming Counter measures
Residential sector	201 (180)	122	- Promotion of compliance of energy saving standards for newly constructed housing and thermal insulation in renovation of existing buildings - Introduction of high-efficient water heater (latent collection, CO_2 refrigerant heat pump, fuel cell, solar water) - Introduction of high-efficient light - Improvement of energy efficiency and conservation performance of equipment by the Top Runner program - Thorough implementation of energy management in houses with HEMS and other smart meters - Increasing Johkasou energy efficiency conservation - Inter-ministry collaborative measures following the Roadmap of Global Warming Counter measures

6.3.4 Domestic measures for the improvement of energy efficiency in the Japanese building stock

Energy conservation measures have been implemented in Japan since 1947, but it wasn't until after the two-global oil crisis in 1973 and 1979, which made the government rethink and overhaul their energy policy. As a result, the Energy Conservation Act was established in 1979, and has since then advanced energy efficiency in four major sectors, including the buildings sector. Now, due to the increase in energy consumption and tight against supply after the Fukushima Nuclear Accident, the government has taken further action to strengthen their policy in the building sector. This has led to the "Building Energy Efficiency Act" – or the "Act on the Improvement of Energy Consumption Performance of Buildings".

The following subchapter will briefly explain the evolution towards the new Building Energy Efficiency Act, as well as addressing the advance in Japan's energy efficiency standards.

6.3.4.1 Act on the Improvement of Energy Consumption Performance of Building

In 1979, the "Energy Conservation Act" or the "Law Concerning the Rational Use of Energy" was established, in the light of the first and second oil crisis [100]. Since then, the Energy Conservation Act has advanced energy efficiency policies in four major sectors: Industry (Factories and Workplaces), Buildings (Commercial and Residential), Transportation and Machinery/ Equipment. The law has been revised and amended every few years, becoming the foundation of Japan's energy efficiency and conservation policy. In addition to encapsulate various policies, the law has also set out energy efficiency standards, with the main objective to contribute to the development of Japan's national economy through a sustainable implementation of energy- and CO_2 reducing measures within these four sectors.

Japan's building energy regulations has since 1979, been a part of the Energy Conservation Act. The Act has been subsequently revised every few years (1983, 1993, 2002, 2005, 2008 and 20013) and have introduced new requirements towards a more sustainable building sector [101]. The key obligation through its revisions, has been to increase the numbers and size of buildings required to submit energy conservation reports before the start of construction and after renovation. The energy conservation report is a plan or notification of energy-saving measures building owners are intended to implement, which shall be reviewed by local authorities under monitoring by METI and MLIT. Improvements shall only be *advised* if energy-saving measures is to be significantly insufficient, for specified building having a total floor area of between 300 m2 and 2000 m2. When energy-saving measures is to be significantly insufficient for specified buildings having a total floor area of 2000 m2 or more, improvements shall be instructed and imposed fines if building owners don't comply, in addition to furthermore publicize the construction client name [100].

The Energy Conservation Act has also required building owners and construction clients to take *appropriate* measures to reduce the heat loss through buildings envelope, and effective utilization of building operations, such as heating, ventilation, cooling, lighting and other relevant systems [100], [101]. Buildings have been developed through national building energy efficiency codes. One code that apply for commercial buildings: Criteria for Clients on the Rationalization of Energy Use for Buildings (CCREUB); and two codes that apply for residential buildings: Design and Construction Guidelines on the Rationalization of Energy Use for Buildings (DCGREUH) and Criteria for Clients on the Rationalization of Energy Use for Houses (CCREUH). The problem, however, is that compliance with the buildings' energy efficiency codes had not yet been mandatory [102].

In 2015, the "Act on the Improvement of Energy Consumption Performance of Buildings" (Building Energy Efficiency Act) was adopted by the Japanese government as a major pillar of energy-saving campaigns [103]. As the Long-Term Energy Supply and Demand Outlook stated that energy savings in the building sector (commercial and residential) will account for 49 % of national energy savings off all sectors, made the government to act on improvement of energy consumption performance of Japanese buildings [104]. The Building Energy Efficiency Act provides:

- *Regulatory measures* for mandatory compliance with energy efficiency standards for large-scale non-residential buildings

- *Incentive measures* - such as labeling system displaying compliance with energy efficiency standards and exception of floor-area ratio regulation for certified building

So far, those who built commercial buildings with a total floor space of 300 m2 or more have been required to report energy conservation measures and has served penalties if they don't comply with improvements by the authorities (Energy Efficiency Act). In addition, compliance with building energy standards had not been required. This new act, however, will require new large buildings with a total floor area of 2,000 m2 or more to comply with newly-constructed building energy efficiency standards, as well as planning to expand the coverage by including "small and medium sized" commercial buildings and houses with a floor area of 300 m2 or more, by 2020.

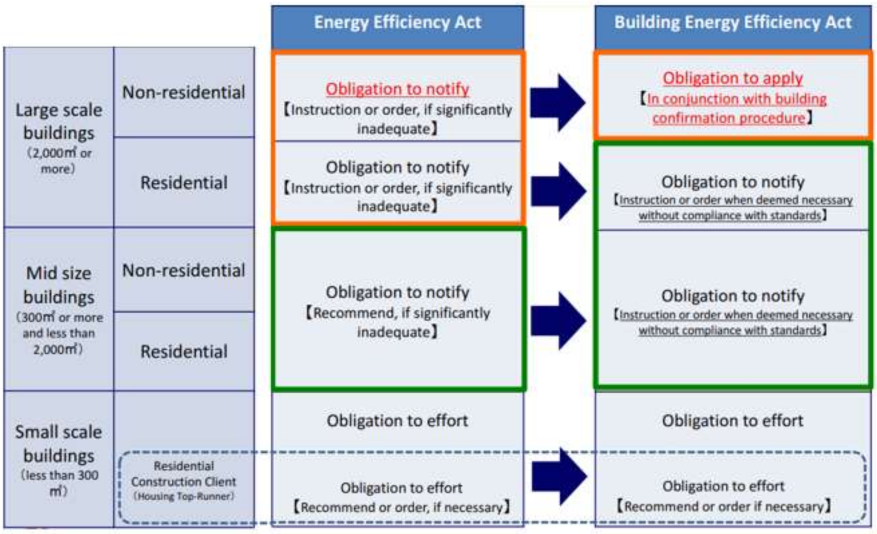


Figure 47:transition from the Energy Efficiency Act to the Building Energy Efficiency Act [105]

Large scale commercial buildings are especially the target by the new Building Efficiency Act, either as new construction, extension or as renovation projects. When construction clients attempt to undertake buildings with these characteristics, they must acquire certification of conformity (Obligation to apply) or notify as the same procedure as the Energy Efficiency Act. However, large scale commercial buildings that has been regulatory measured and don't comply with the energy efficiency standards, will become ineligible for certification of the Japanese Building Standard Law.

Incentive measures in the act is targeted all buildings, which include new construction of buildings, extensions, renovations, improvements, remodeling, and pre-installation/repairs of cooling system equipment that contribute to enhancing energy conservation performance. By acquiring building certification for the performance improvement plan, given by the local authorities, construction clients are qualified to receive benefits, such as exception of floor-ratio regulation.

6.3.4.2 Energy Efficiency Standard for non-residential buildings - Evaluation Method

The standards that apply in the Building Energy Efficiency Act are three folded: Energy consumption performance standards (Energy Efficiency Standards), certification standards, and residential construction client standards. There are two verification methods of these standards: a detailed calculation and an abbreviated calculation method. To evaluate the energy efficiency performance of non-residential buildings, the Building Energy Efficiency Act uses the following two standards:

Table 26: Energy Efficiency Standards by the Building Energy Efficiency Act for Non-Residential Buildings

Energy efficiency standards for Non-Residential Buildings	
1) Envelope Performance	Standard to evaluate for envelope performance (PAL*) to assess exterior walls and windows for non-residential buildings
2) Primary Energy Consumption Amount	Standards to evaluate primary energy consumption amount of buildings equipment and OA devices etc.

To comply with the energy efficiency standards, the building shall fulfill these criteria:

Table 27: Energy Efficiency Standard Compliances for Non-Residential Buildings

Energy Efficiency Standard Compliances for Non-Residential Buildings	
1) Envelope Performance	Exempt from application.
2) Primary Energy Consumption Amount	$\text{Primary Energy Consumption Amount} = \frac{\text{Design Value (excludes OA devices etc.)}}{\text{Standard Value (excludes OA devices etc.)}} \leq 1.0$

1) Standard for Envelope Performance: PAL* - Annual thermal load coefficient of perimeter zone

The performance of the buildings envelope for non-residential buildings, is exempt from application and compliance with the energy efficiency standards. The envelope performance is used as a necessary index, as the input from the outer skin matters in calculation of a building's primary energy consumption.

The calculation method for the envelope performance, is measured by the annual thermal load coefficient of the building's perimeter zone, PAL*.

$$\text{PAL}^* = \frac{\text{Annual thermal load of the perimeter zone (MJ/year)}}{\text{Total floor space of perimeter zone (m2)}}$$

PAL* is a yearly sum of heating and cooling loads through the thermal energy from the 1) temperature difference of perimeter zone with outside air, 2) solar radiation from exterior walls and windows, 3) heat load occurring in perimeter zone, 4) the amount of heat from the total air intake from the outside and the humidity levels in the perimeter zone. The perimeter zone is the inside space within 5 horizontal meters from the centerline of a wall of each floor that is in contact with the outside air. It encapsulates also the inside space of the floor directly below the roof, and the inside space that is directly above the floor in contact with the outside air.

As PAL* is only used as guidance index in calculation of the primary energy consumption by the energy efficiency standards, does it not comply with the certification standards for regulation of floor-area ratio exception for instance. PAL* is a -design value- of the buildings envelope performance design and must be equal or less than a reference -standard value- to be sufficient to get a certificate. The reference standard value is calculated based on the common climate conditions and the buildings envelope specifications. Certification standards criteria on compliance for non-residential buildings is shown in the table below:

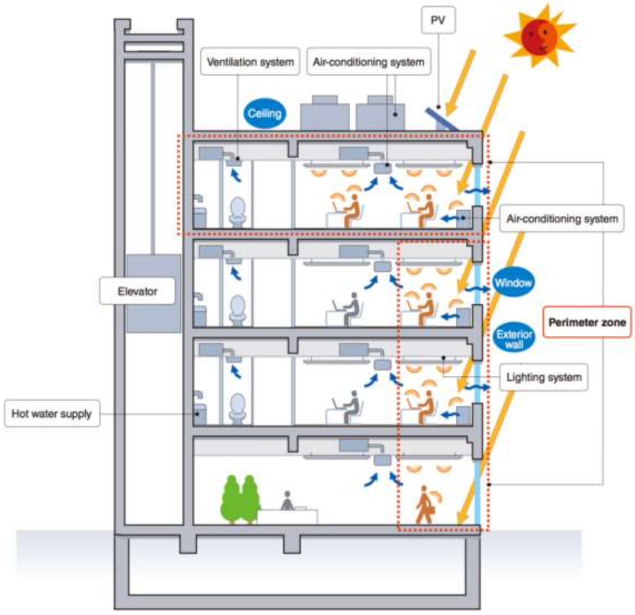
Table 28: Certification Standard Compliance for Non-Residential Buildings

Certification Standard for Non-Residential Buildings

Exterior/Envelope Performance	$PAL* = \frac{\text{Design Value}}{\text{Standard Value}} \leq 0.9$

2) Standard for Primary Energy Consumption Amount:

Primary energy consumption amount is the loads from energy consumptions from the building's design, which includes: Air conditioning system, Ventilation system, Lightning system, Hot water supply, Elevator, other Office Automation systems, subtracted the amount of primary energy from Renewable Energy Sources.



+ Air conditioning system primary energy consumption amount
+ ventilation system primary energy consumption amount
+ lighting system primary energy consumption amount
+ hot water supply primary energy consumption amount
+ elevator primary energy consumption amount
+ other (Office Automation) primary energy consumption amount
 - Reduction amount of primary energy consumption through PV and cogeneration system

= Primary Energy Consumption Amount

Figure 48: Building in relation to Primary Energy Consumption Amount [105]

Primary energy consumption amount is based on the Building Energy Index (BEI). This means that the calculated design specifications (design primary energy consumption amount value) is divided by a reference consumption. Same principle as PAL*. The value represents an index from two calculations under common regional conditions and building specifies, such as rooms and floor area and tells if a building is sufficient or not. By the mandatory energy efficiency standards in the Act, this index shall represent a value that is less or equal to one, for compliance (Table 27).

Compared to the old standard, the old standard used 5 criterion indices for each building equipment (envelope, HVAC, lightning, hot water, lifting equipment), where the values depended on the building type. The new calculation method, however, is developed to estimate the energy more accurate now in each room of the building. 202 types of room in total. Examples of rooms regarding offices, is shown in Table 29.

Table 29: Examples of rooms regarding calculation by the new Building Energy Efficiency Standards – Office [105].

Examples of room types: Office									
Office room	Meeting room	Tea room	Central control room	Locker room	Canteen	Hall	Lobby	Toilet	Smoking room

As for regional divisions, Japan is divided into eight conditions climate. Each of the condition climates represents difference in national criteria in terms of primary energy consumption amount and the thermal performance of a buildings envelope, both residential and non-residential. Sapporo represents climate zone 2, while Hokkaido is represented in climate zone in both 1 and 2 (Figure 49).

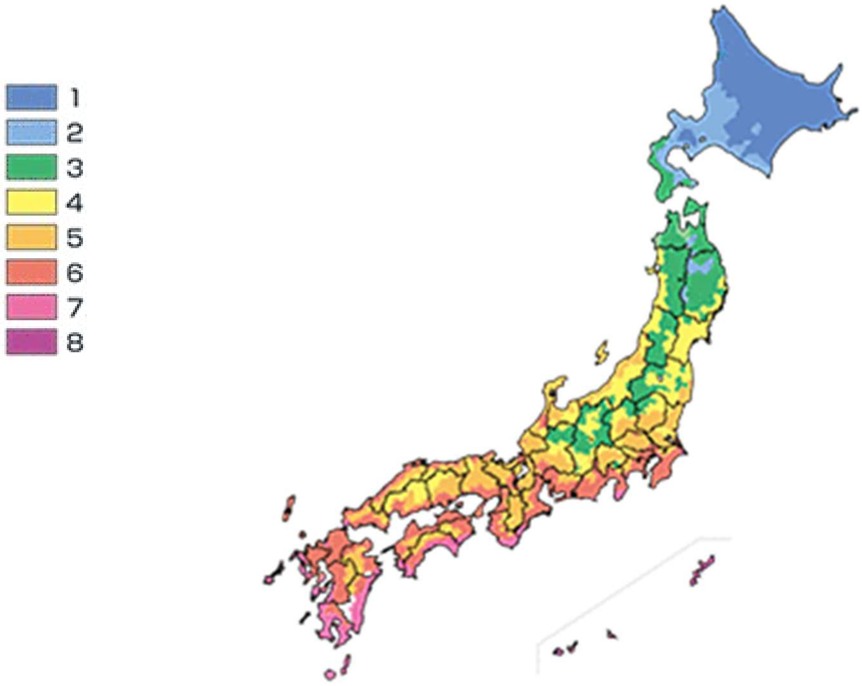


Figure 49: Region climate zones in Japan building energy regulations [106]

6.3.4.3 National variation in reference primary energy consumption amount

The reference on primary energy consumption varies throughout the country. Figure 50: Standard Reference Values for Office Buildings (10,000 m2) - Primary Energy Consumption (MJ/m2 year) represents standard reference values for office buildings with total floor area 10 000 m2 (Heisei 20th Energy Conservation Standard Second Edition – Non- Residential Buildings). As the country is divided into eight separate climate zones, each of them has their own criteria for primary energy consumption. The diagrams represent the buildings loads, in terms of air conditioning (heating & cooling), ventilation, lightning, hot water supply, elevators and other relevant building system equipment's.

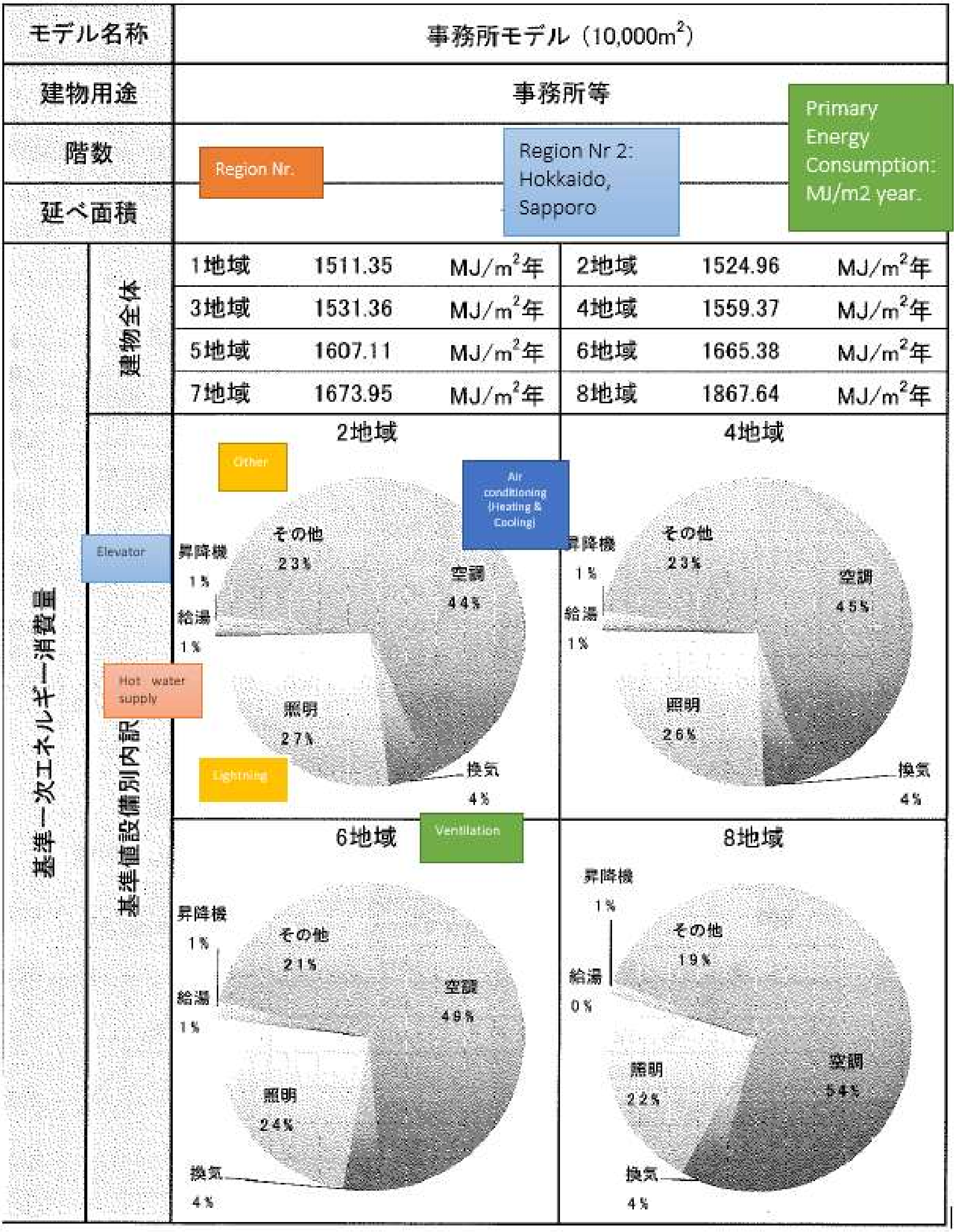


Figure 50: Standard Reference Values for Office Buildings (10,000 m2) - Primary Energy Consumption (MJ/m2 year)

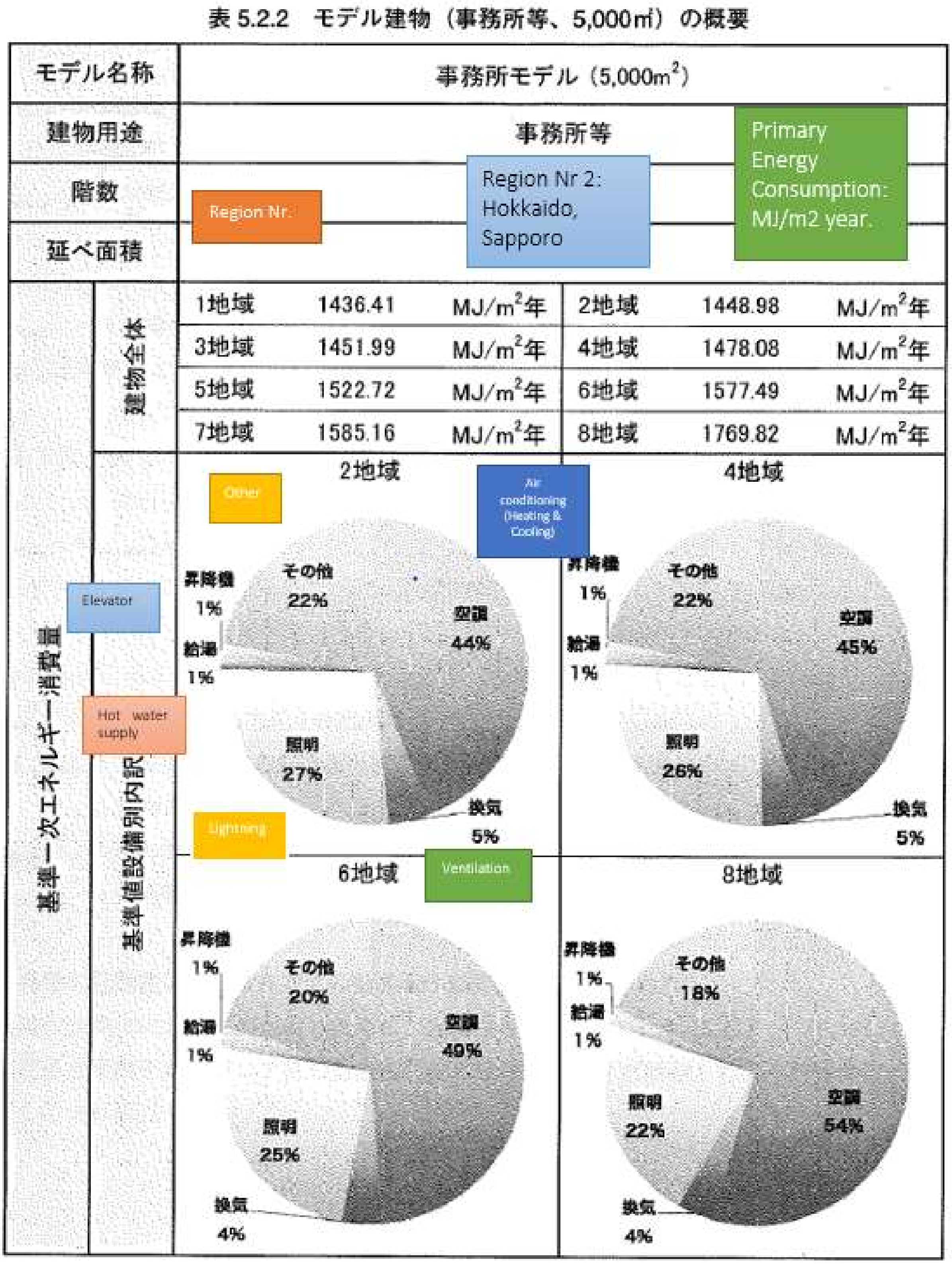


表 5.2.2 モデル建物（事務所等、5,000㎡）の概要

モデル名称	事務所モデル（5,000m²）					
建物用途	事務所等					
階数						
延べ面積						
基準一次エネルギー消費量 建物全体	1地域	1436.41	MJ/m²年	2地域	1448.98	MJ/m²年
	3地域	1451.99	MJ/m²年	4地域	1478.08	MJ/m²年
	5地域	1522.72	MJ/m²年	6地域	1577.49	MJ/m²年
	7地域	1585.16	MJ/m²年	8地域	1769.82	MJ/m²年

Figure 51: Standard Reference Values for Office Buildings (5000 m2) - Primary Energy Consumption (MJ/m2 year)

6.3.4.4 Energy Efficiency Standard for residential buildings - Evaluation Method

Like the energy efficiency standards for non-residential, the residential standards evaluate energy efficiency performance by primary energy consumption amount. In addition, while non-residential are exempt with the compliance with energy efficiency standards regarding the buildings envelope performance, residential are not. To evaluate the energy efficiency performance of residential buildings, the Building Energy Efficiency Act uses the following two standards:

Table 30: Energy Efficiency Standards for Residential Buildings.

Energy efficiency standards for Residential Buildings	
1) Envelope Performance	Standard to evaluate for envelope performance assess such as exterior walls and windows for residential buildings
2) Primary Energy Consumption Amount	Standards to evaluate primary energy consumption amount of buildings equipment and appliances etc.

To comply with the energy efficiency standards, the building shall fulfill these criteria:

Table 31: Energy Efficiency Standard Compliances for Non-Residential Buildings.

Energy Efficiency Standard Compliances for Residential Buildings	
1) Envelope Performance	U_A – Average outer shell heat transmission coefficient: Design Value $\leq$ Standard Value η_{AC} – Average solar heat gain coefficient during cooling period: Design Value $\leq$ Standard Value
2) Primary Energy Consumption Amount	$\text{Primary Energy Consumption Amount} = \frac{\text{Design Value (excludes OA devices etc.)}}{\text{Standard Value (excludes OA devices etc.)}} \leq 1.0$

1) <u>Standard for Envelope Performance for Residential Buildings</u>

The performance of the buildings envelope for residential buildings shall be compliance with the energy efficiency standard by two measures:

- Average outer shell heat transmission coefficient (U_A); The value obtained by averaging the amount of heat escaping from the inside of the residential to the outside, throughout the outer shell.

$$U_A = \frac{\text{Amount of total heat loss per unit of temperature difference}}{\text{Total surface area of exterior}}$$

- Average solar heat gain coefficient during cooling period (η_{AC}); The average of the proportion of solar radiation entering a room against the amount of solar radiation imposed on the entire surface of the exterior wall.

$$\eta_{AC} = \frac{\text{Amount of total solar heat gain per unit of solar radiation intensity}}{\text{Total surface area of exterior}} \times 100$$

The maximum allowed coefficients for both, U_A and η_{AC} varies throughout the country as same as the primary energy consumption amount. In regards for the coefficients, Table 32 shows each of the values for the several climate zones.

Table 32: Region classification of the coefficients U_A and $\boldsymbol{\eta_{AC}}$

Region classification	1	2	3	4	5	6	7	8
Reference value (U_A) [W/m2 K]	0.46	0.46	0.56	0.75	0.87	0.87	0.87	---
Reference value (η_{AC})	---	---	---	---	3.0	2.8	2.7	3.2

6.3.4.5 BELS – Building Energy Efficiency Labelling System

In 2014, the Ministry of Land, Infrastructure and Transport established the Building Energy-Efficiency Labelling System (BELS) certification. BELS have since 2016 been enforceable as new law, and in full operation since 2017 [107]. While CASBEE is a comprehensive environmental labelling method, BELS is the first public evaluation system specific to energy conservation in the Japanese house and non-residential building stock.

Third party institutions evaluate the performance, regardless of whether the building is newly constructed or existing. The evaluation result is represented by the numbers of stars (from one "★" to five stars "★★★★★") along with the building's BEI (Building Energy Index) [107]. Table 33 shows the BELS certification depending on the BEI Index.

Table 33: BELS certification depending on the BEI Index [x].

Ratings	Residential BEI (Housing) (Small: -300 m2)	Non-residential BEI (office, school, factory, etc.) (Medium: 300 m2 -2000 m2)	Non-residential BEI (hotel, hospital, department, store, restaurant, etc.) (Large: 2000 m2 -)
★★★★★	0.8	0.6	0.7
★★★★	0.85	0.7	0.75
★★★	0.9	0.8	0.8
★★	1.0	1.0	1.0
★	1.1	1.1	No compliance
New regulation: 1th of April, 2020:	All residential/non-residential buildings shall comply with: ★2 BEI ≤ 1.0		

7 Feasibility Study – Green Buildings in Cold Climate

This chapter encapsulates the literature study on the Green Building Concept and the definition of Cold Climate conditions (Chapter 3 and 4). It's a feasibility study in which will assess whether cold climate can be met by introducing concepts of green building. As a basis, the study will summarize the challenges each of the key elements has to encounter when met by cold climate conditions and will further highlight three innovative projects related to the Green Building concept within the cold climate boundaries.

7.1 Green Building challenges in Cold Climate conditions

Green Building is a term used for buildings confining to certain environmental and energy related criteria, were the criteria is usually based on what each nation emphasize the most based on their own characteristics. The characteristics can be wide-ranging in form of national prerequisites such as tradition, diverse building types and distinct climate conditions. The variety of climate conditions is often the challenge and introduces constraints to fulfill the true green potential.

The following table summarize the literature study in Chapter 3 and 4 and illustrates the goal and efforts the element of the Green Building structure tries to achieve in building a more sustainable environment, and the challenges and constraints the cold climate introduces.

Table 34: Green building design challenges in cold climate

Green Building Design	Goal	Efforts	Cold Climate Challenges
Sustainable Site Design	Integrate itself with the built environment and its surrounding	- Work with natural features by location and orientation - Optimize the use of passive solar energy and natural day lightning - Minimizing urban sprawl - Promote higher density - Shared public place - Alternate transportation method	- Frozen ground and permafrost - Higher possibility with remote locations - Snow, ice and harsh weather
Water Quality Conservation	Reducing water consumption and protecting water quality	- Reducing water consumption and protecting water quality - On-site mechanism: rainwater harvesting, green roofs, and advantage of recycling waste-waster - Water conserving landscapes and water saving fixtures	- Sanitary lines and equipment is exposed to freezing and splitting - Snow melting water and flood water penetration of water pipes and reducing water quality
Energy and Environment	Reduce energy consumption by protecting the environment of emissions	- High-performance building envelope: high efficiency windows and insulation - Low energy appliances - Integrate renewable energy sources - Passive solar design - Well-designed heating and cooling system	- Higher energy consumption due to large energy heating consumption during winter - Limited access to sunlight during winter, limits the implementation rate of renewable energy - Require proper construction by insulation of the buildings envelope
Indoor Environmental Quality	Protect occupant health and well-being by a good indoor climate	- Careful design by the choice of materials and products - Incorporate materials with less chemical content and off-gassing potential - Promote natural ventilation - Well-designed ventilation system - Clean construction to avoid mold and moisture and actions to reduce unnecessary dust and airborne toxins	- Tight building envelope keep the containments inside and spread. - Daylight exposure - Stricter ventilation requirements - Stricter requirements for building materials
Conservation of Materials	Reduce trash, pollution and	- Responsible waste management - Encourages materials that are obtained from natural, renewable sources	- Exposed to harsh weather conditions - Stricter requirements for building materials.

	degradation of environment	- Materials are non-toxic, multifunctional, durable and easy to salvage and recycle - Materials should be extracted locally	

Buildings in cold climate conditions faces many challenges. A sustainable site design is a site that integrates itself with the local and built environment, which is optimized by taking advantage of passive solar energy and promotes a higher density among buildings in general. Besides the harsh weather the cold climate introduces, which can affect sanitary lines and equipment's, it also comes with a higher possibility with remoteness as well as limited utilities. Protecting occupant health and well-being is one of the most crucial key of Green Building, were its in direct interrelationship with all the other elements of Green Building Design. Cold climate requires a high-performance envelope for a building to be sustainable, which will need proper ventilation and materials that are in greater extent non-toxic, for the occupants can experience a satisfying Indoor Environmental Quality. Additionally, a cold climate envelope requires proper construction by skilled craftsmen to secure a construction from moist and mold.

The biggest challenge, however, is the production of heat and energy during winter to cover the heat losses and heating requirement. Since daylight is often limited (especially in the high north) which makes the access to renewable energy such a solar power restricted, a building in the colder environment compensate with high-performance insulation, minimum air leakage and ventilation with high efficiency heat recovery that allows for the simplification of the heating system. To supplement also, heat pumps and district heating if accessible, is other alternatives.

Energy efficient buildings can be reached in cold climate by careful design and execution. It does, however, require methods and concepts that differ from the traditional ones, and that economic considerations often are more about investment costs than the buildings life cycle costs. The overall goal of the building energy efficiency performance is important which further defines the measures needed to implement.

7.1.1 Zero Emission Buildings (ZEB)

Zero Emission Buildings and are a great example with clear environmental and energy related goals. The vision of Zero *Emission* Buildings is to eliminate the greenhouse gas emission caused by buildings, with the main objective to develop competitive products and solutions for new and existing buildings that will lead to market penetration of buildings that have zero emissions of greenhouse gases related to their production, operation and demolition [108]. Zero emission Buildings is defined by different levels depending on how many phases of a building's lifespan that are counted in. The 5 most important definition in rising ambition, are:

- ZEB – **O**: *The Building renewable energy production compensate for greenhouse gas emissions from **operation** of the building*
- ZEB – **O ÷ EQ**: *The Building's renewable energy production compensate for greenhouse gas emissions from **operation** of the building minus the energy us for **equipment** (plug loads)*
- ZEB – **OM**: *The building's renewable energy production compensates for greenhouse gas emissions from **operation** and production of it building **materials***
- ZEB – **COM**: *The Building's renewable energy production compensate for greenhouse gas emissions from **construction**, **operation** and production of building **materials***
- ZEB – COMPLETE: *The building's renewable energy production compensates for greenhouse gas emissions from the entire lifespan of the building. Building materials – construction – operation and demolition/recycling.*

7.2 Innovative Projects Within the Cold Climate Boundary

As one of the basis for the feasibility study has been to collect new innovative solutions and ideas from already existing sustainable buildings within the cold climate boundaries. Data is collected from their respected concept studies and related articles. By doing so, the feasibility study will try to enlighten the new achievements in sustainable building development. The different projects are based upon their overall Green Building performance and the ones this study has chosen to highlight, are as follows:

- Powerhouse Brattørkaia: ZEB-COM ÷ EQ
- Powerhouse Kjørbo: ZEB-COM ÷ EQ
- Campus Evenstad: ZEB - COM

7.2.1 Powerhouse Brattørkaia: ZEB-COM ÷ EQ

Powerhouse Brattørkaia is the first new office building in Norway that aims to go in plus in the life cycle perspective. This means that it will produce cleaner, environmentally-friendly energy than it consumes, and the result is a completely new architectural concept for what will be the world's northernmost energy-positive building [109]. The project is based on an interdisciplinary alliance between the leading actors in the industry, with a wish to move the mindset from apparently impossible, to possible in terms of the world's environmental challenges related to energy use in buildings. The ambition is to develop and realize buildings that has a positive energy consumption throughout its entire lifespan (60 years). Several supporters have contributed in the development of Powerhouse Brattørkaia, where one of them is The Research Center on Zero Emission Buildings (ZEB) in Norway.

Figure 52: Powerhouse Brattørkaia. Arcitect: Snøhetta [110].

7.2.1.1 Sustainable design process

One of the innovation elements the Powerhouse project has emphasized is the interdisciplinary interaction among the building disciplines already from the start of development. The process can best be described as a spiral approaching a solution that achieves the overall goal of an energy-plus building, where a series of workshops has been held om which all disciplines has been represented. Between each workshop, each discipline has worked on questions and issues that has need to be addressed before the next, where each workshop represents one “round” in the spiral. Criteria and principles of the Powerhouse Bratterkøia can be viewed in Table 35.

Table 35: Criteria and Principles of Powerhouse Brattøkaia [109]

Criteria: Powerhouse Brattørkaia	Principles: Powerhouse Brattørkaia
• Represent Pluss-house standard for new buildings: Energy Class A (20,1 kwh/m2 per year) • Contribute to increase use of energy-efficient and energy-generating solutions • Present a new working form for construction projects • Represent something new in the field of technological solutions, visual design, economics and project form • The building shall be based on reasonable profitability	• Achieving the Powerhouse should not be at the expense of other qualities, such as architecture, indoor environment or other environmental qualities • The surplus of produced renewable energy delivered from the building must be available during the period • The system boundary of a Powerhouse project is the site on which the building is located. It means that energy production and associated installations must take place on each powerhouse property • If the building shares site and possible production area for renewable energy with other buildings, shall measures to achieve the goal prevent other buildings on the site from becoming Power house in the future.

7.2.1.2 Sustainable Site Design

The new office building is about 13.000 m^2 heated floor area, spread over 10 floors, with a location that gives the project access to seawater for energy efficient cooling and heating. The architectural concept builds on the term “Form follows environment” (“Form følger miljø”, in Norwegian), which the building geometry is clearly characterized by the environmental ambition. The project adds audience-oriented street level features, as well as many bicycle parking places and electrical-car parks, with few or no parking spaces for private cars. In regards with the construction phase of the building, the choice of materials will be based on the total environmental impact and short-term materials in terms of transport, would be favorized. Universal Design, public arena and an active urban space has also been emphasized.

7.2.1.3 Water Quality and Water Conservation

To reduce energy consumption to a minimum, a seawater-based heat pump and free-cooling against seawater is planned to be implemented as renewable energy sources for heating and cooling. Due to the location and changes in climates, new challenges pose treats in terms of rainfall, wind and sea level rise. In addition, spring-tide, strong winds from the nearby fjord, with an increasing flood danger poses challenges to create good, healthy and sunny outdoor spaces. A risk analysis shall be carried out for the site.

7.2.1.4 Energy and Environmental

As the ambition is to realize the world’s most environmentally non-residential building, ambitious measures need to be implemented. The energy requirement (excluding user equipment, ZEB-COM ÷ EQ) is 20.1 kWh/m^2 per year. This is being solved by solar energy harvesting as the main design driver for the project. With a 26-degree sloped south-facing roof the production of electricity and heat for the building will be provided by a roof covered by 3.000 m^2 of solar panels, heat exchangers and heat pumps, while sea water will contribute to both the heating and cooling system. The selection of solar panels has been based on a prerequisite related to its climate though, and that is that they have to withstand extreme weather conditions that may occur, such as heavy snow and ice. A compact building envelope with low U-values and high-effective heat recover is also accounted for.

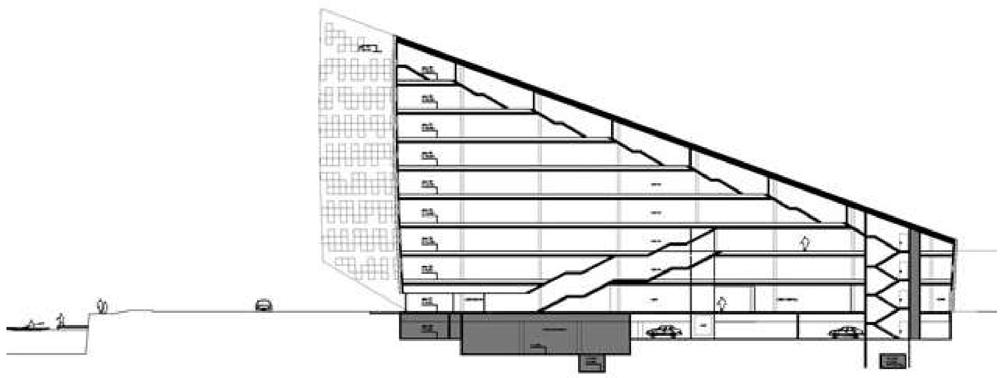


Figure 53: Powerhouse Brattørkai 26 degree sloped south-facing roof. Architect: Snøhetta AS.[110]

The objective for the energy requirement to produce materials, construction and disposal is at its maximum limit of 1.300 kWh/m2, converted to 21.8 kWh/m2 per year over the lifetime of the building. Average electricity production will be 46.3 kWh/m2 per year, making Powerhouse Brattørkaia a net energy supplier over its lifetime. Bound energy is estimated at 22 kWh/m2 per year. The project has a goal of environmental classification as BREEAM Outstanding and energy class A ++.

7.2.1.5 Indoor Environmental Quality

The building is to reduce energy consumption as well as secure an indoor environment during the use-phase by optimizing the ventilation principle with preheated air from the heat pump, high-efficiency heat recovery and a displacement ventilation system as a more efficient way to ventilate spaces than the more traditional mixing ventilation method. In addition, materials with thermal mass and low-emitting is emphasized, based on the requirement of stabilization of temperature fluctuations. Daylight conditions of the rooms are planned at a verifiable level and the energy of lightning as minimum as possible.

7.2.1.6 Material Conservation and Resources

Support systems are of metals and concrete. Since the materials has particularly high greenhouse gas footprints, it has been reasoned that by optimizing the support systems and reduce the weight of the materials, the greenhouse gas footprint can be significantly minimized. Furthermore, materials are selected based on low greenhouse gas emissions from cradle to grave principle.

7.2.2 Powerhouse Kjørbo: ZEB-COM ÷ EQ

Powerhouse Kjørbo is the world's first rehabilitation energy-plus house [111]. Like Powerhouse Brattøkai, the ambition is to develop and realize a building that produces more energy than its use by optimizing and combining known technology in new innovative ways. The project is based on total rehabilitation of existing buildings from the 80s, outside of Oslo. It's a two-phased construction project, where the first consist of two office building with a heated floor area of 5.200 m2. The two buildings are a part of a bigger complex including three other buildings, where construction phase two is the rehabilitation of one of the other three. After the rehabilitation the buildings energy requirement would be reduced with approx. 90 %, covered by solar cells and heat pumps. The installed solar cells will produce 200.000 kWh/ per year or approx. 40 kWh/m2 of heated floor area [112]. The electricity is used primarily by the buildings at Kjørbo, while the surplus is exported to the grid.

Figure 54: Powerhouse Kjørbo [113]

7.2.2.1 Sustainable Design Process

Powerhouse Kjørbo was the first project that the Powerhouse collaboration carried out and completed in 2014. The interdisciplinary design phase has contributed to new and innovative solutions from the outset. For the first time in history, a refurbished building consisting of two ordinary office blocks from the 80s has become transformed into a positive energy house. For the design phase, the project received the BREEAM-NOR certification: Outstanding [112]. There has been a strong focus on profitability and costs in the project, combined with simple robust and technical solutions. Contributions from Enova have made the project financially possible. After completion, measuring equipment has been placed to document temperatures, indoor climate and energy consumption in the building to provide a good picture of the building when the premises are used throughout all four seasons. In fact, this can all be viewed by an external link on Powerhouse own site.

The Powerhouse Alliance is aware of the responsibilities of the construction industry, and with the introduction of rehabilitating existing to energy-positive buildings, makes buildings a part of the solution instead of being part of the overall climate problem.

7.2.2.2 Sustainable Site Design

Powerhouse Kjørbo is in Sandvika, which is a juncture in Bærum. The upgraded site provides bicycle parking and charging stations for electric cars, as well as new green areas. Since Powerhouse Kjørbo is a part of a complex, was it a requirement from the municipality that the existing architectural expression should be kept. This has been an import premise and is largely been fulfilled.

7.2.2.3 Water Quality and Water Conservation

Ten energy wells are drilled in the ground on the site to supply cooling in the summer, and serves as a energy source for heat-pumps, radiators and the ventilation during the winter. In addition, the building also utilize heat from waste water through the buildings server rooms.

7.2.2.4 Energy and Environmental

Additionally, to the energy wells, solar modules are installed on the rooftops among the two buildings and a garage, which provides an annual energy production by approx. 200 000 kWh, where energy for ventilation, lightning, heating and cooling is estimated to approx. 100 000 kWh per year [113]. This results in a surplus production, where the power is used for the buildings as well as introduced to the local grid. In addition, it's been emphasized that the buildings shall have a compact and dense building envelope with well-insulated windows (Passive house).

7.2.2.5 Indoor Environmental Quality

Securing a good indoor environment has been an important area, and all internal areas have been upgraded to high-quality modern office spaces. The ventilation combines high-efficiency heat recovery, extremely low pressure drops, and an efficient demand-driven ventilation based on displacement. The ventilation system uses 90 % less energy than in normal building [113]. The entire ventilation system is designed so that air has a very low speed, which have made the staircase to work as the world's most beautiful ventilation channel. The air overflows from each cell office, to the landscape and towards the staircase.

Figure 55: Powerhouse Indoor Environmental Quality [113]

The prerequisite has been that the indoor climate should be at least as good as in a regular project, even when energy consumption is greatly reduced. This is solved primary by good and effective façades with sun shielding that secures the indoor climate. The project has in some areas exposed concrete in the ceiling, which will contribute with cooling when needed. Access to open windows, provides possibility to natural air. Overall, this provides a lower internal cooling, which contributes to a reduced energy consumption.

7.2.2.6 Conservation of materials and resources

From the outside, the buildings look just as they did before rehabilitation, but from the inside the Powerhouse is revolutionary. Materials were carefully chosen to ensure that materials with low-bound energy, possibility to reuse, non-toxic, locally produced external cladding, and otherwise a clean and dry construction process. The result is a façade that consist of coal-fired wood panels that are near maintenance free and which comply with the demand low-bound energy. The original structure of the buildings was preserved and materials such as glass and concrete were reused. For example, the windows from the original facade are reused in doors inside the office building

7.2.3 Campus Evenstad: ZEB-COM

In 2017, the Norwegian Directorate of Public Construction and Property (from now on referred to as; NDPCP) (Statsbygg) realized the country's first ZEB-COM building at Evenstad, which is a small Norwegian town on the east bank of Glomma river in the Stor-Elvdal municipality [114]. The building is a combined teaching/conference unit (336 m2), office area (774 m2) and about 30 m2 vestibule, with a total gross area of less than 1,200 m2. Campus Evenstad is NDPCP's environmental "pilot" in property management, with a clear ambition that the property will be a regional gathering point and demonstration facility for renewable energy, as Campus Evenstad Energy Center (CEEC). The new building of Campus Evenstad has been fitted into an already existing environment, that has included a park-built outdoor environment with an old farmhouse nearby. The building is built on strip fundament in low carbon concrete and uses massive wood as the primary structural building material because of its heat reservoir and positive effects on indoor climate and work environment. Wood fiber has been used as insulation and recuse of glass have also been emphasized in walls and doors. Hybrid ventilation and a thoughtful placement of sized windows have been installed to pursue natural daylight and reduce extra lightning.

The project has strived to reduce greenhouse gas emissions in all parts and phases of construction, testing new combinations of materials use and brand-new solutions, as well as traditionally.

Figure 56: Campus Evenstad and the new ZEB-COM

Defined as *ZEB-COM*, the building compensates greenhouse gas emissions that occur during the construction process, production of materials and operating energy consumption, by exports of self-produced heat and electricity to other users. In addition to a backup pellets boiler and newly installed solar collectors and solar panels on different facilities on the campus, a combined heat and power-plant (CHP) is implemented. The CHP-plant produces electricity and heat at the same time by locally produced wood-chippings which is gasified to biogas and burned in an internal combustion engine. The small-scale CHP-plant is the first of its kind in Norway, providing all the energy supply to the new building as well as supply the rest of the campus with both heat and electricity [114].

Campus Evenstad choose a gasified CHP-plant by wood-chipping based on:

- Area efficiency
- A solution well adapted to the resources at Evenstad
- An energy concept/system with a high degree of innovation which would provide new knowledge in Norwegian context
- A plant that complements existing energy supply and makes Evenstad one of Norway's most varied and innovative demonstration systems for renewable energy

Since the pellets boiler has been extended by the new CHP-plant, the pellets boiler will be providing the peak load, while the CHP-plant will serve as the base load by supplying heat, hot water and power to the campus. The dimensions (8 mm ≤ P ≤ 50 mm) and moisture content (≤ 15 %) of the pellets are all in accordance with the ISO standards. According to Statsbygg, the plant gives and output of 40 kW power and 100 kW heat, with an efficiency rate of 70 % divided by approximately 20 % electricity production and about 50 % from heat production. The plant has great flexibility and can run between 30 and 100 % of full effect. The campus is connected to ordinary electricity grids for both the purchase and sale of electricity. The experience after the first couple of months, has been great according the drifts personnel. Drift personnel experience after the first couple of months estimated the CHP-plant to have an operating time up towards 6000 full load hours, which is probably too high, considering the pre-project added a prerequisite of 3,500 hours [115].

Overall, the operating experience shows that the heat requirement of the entire Campus Evenstad (total of 11 000 m2 including all its facilities) is covered 100 % through own renewable energy production, while the local own electricity production will probably cover one third of the total electricity need.

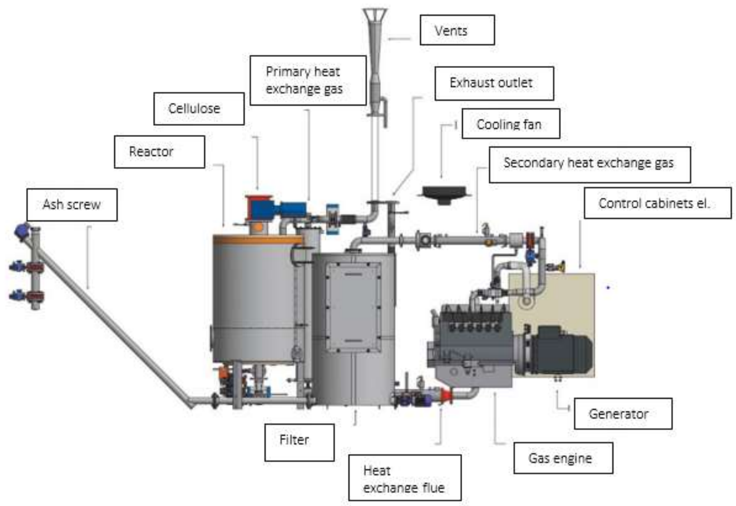


Figure 57: Illustration of different components of a CHP-plant [116]

8 Case study

This chapter is based on the literature study and will visualize the differences and similarities between Norway and Japan related to energy efficiency and environmental footprint impacts of existing buildings and support the comparative study. Therefor a comparative case study is chosen to identify and enlighten the differences between the building and energy codes as well as the climate applicable to Japan and Norway by looking at the energy performance and environmental footprint of a pretended existing office building located in cold-climate regions of the world like Sapporo, Japan and Narvik, Norway. The case study demands that the authors engage into several software programs.

8.1 Simulations

There will be four simulations to enlighten the differences in energy and climate policy regarding buildings, including climate aspects of the specific region to get a respective perspective in the difference of energy performance and environmental aspects of a typical office building. There will be two simulations located in Narvik, Norway. One simulation where the input data is based on Norwegian building requirements regarding building components, HVAC systems, and other standard values to comply with the Norwegian building Codes. The second simulation in Narvik, Norway will be based on Japanese building requirements to see the effect of change regarding energy consumption and energy related GHG emissions. The other two simulations will be in Sapporo, Japan, with the same concept as the two simulations in Norway – one with input data based on the Japanese building codes requirements and standard values, and one with Norwegian building requirements and standard values. The evidence of this case study will be collected by analyzing the distribution of energy consumption, amount of consumption, heat loss figures and CO_2 related emissions related to energy consumption, to be synthesized with the information collected about energy and climate policy in Japan and Norway.

8.1.1 SIMIEN

The simulations are performed by the Norwegian produced software program SIMIEN, developed by ProgramByggerne. SIMIEN is a tool for the evaluation of indoor air quality, energy related CO_2 emissions, power requirement and energy use in a building after the calculation method of NS 3031:2014. The data for the inputs include:

- Building category
- Climate data
- Energy supply
- Building components heat resistance and heat capacity
- The building envelopes infiltration
- Internal loads
    - Technical equipment
    - Lighting
    - Domestic hot water
    - Heat gain form people
- The buildings heating and cooling system

SIMIEN is based in a dynamic model of the building where the condition is calculated. Imprints from the climate (sun, wind, temperature, humidity and CO_2 levels), internal loads (lighting, technical equipment, water heating and persons) are used to calculate the change in condition of the building from time to time, with heat storage and heat dissipation from the building are considered. Since it is a

Norwegian produced software program, it does not contain climate data base from other places than in Norway. A new climate data base was established by collecting hour-based climate data from Sapporo, Japan, and implemented in the software with help from the software developers. An assumption is made that this creates a legit and credible comparative simulations. SIMIEN, version 6.009 is used for the simulations.

8.1.2 Reference office building

The geometry of the reference building is based on the authors assumptions of a typical design of a standard office building and supported by a Japanese reference building of an office building, to create a standard model of an office building that is respectable in both countries. The building is modelled with the building information modelling software program Autodesk Revit. Autodesk Revit allows the model to be exported into gbXML-files, which are supported by the SIMIEN software, and transfers the room/space volumes or energy settings from Revit to SIMIEN. The location input of the simulations will occur in Sapporo, Japan and Narvik, Norway. The building information from Revit are shown in Table 36:

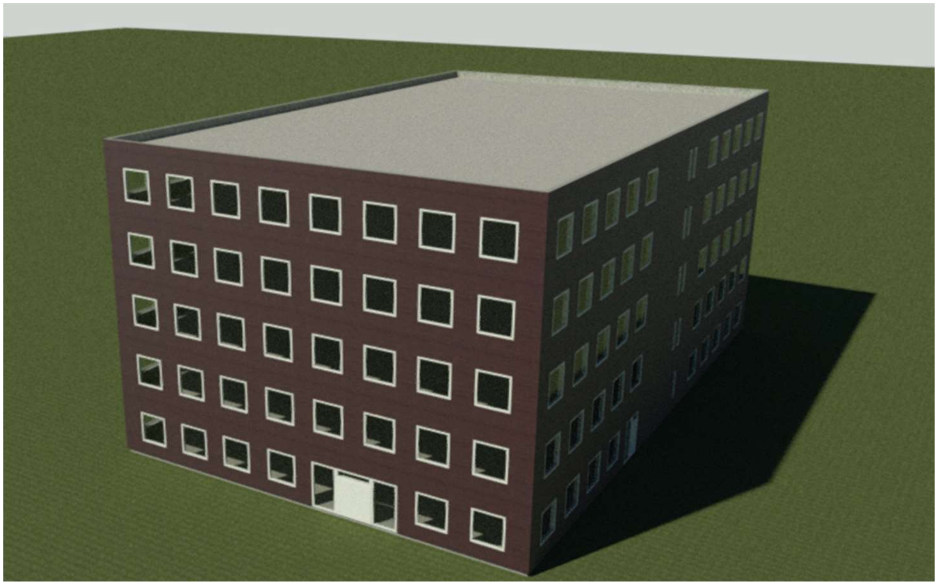


Figure 58: Modell of the standard office building made in Autodesk Revit

Table 36: General information of the reference structure of an office building

Building information	Standard Office Building			
Number of floors	5			
Length, width and height	25 x 40 x 17.5			
Floor height (indoor)	3.0			
Heated gross area	5 000			
Heated air volume	15 000			
Area of doors and windows	568			
Area external wall excluded windows/doors	1707			
Ground floor area	1 000			
Roof area	1 000			
Distribution of façade by cardinal direction [%]	North 19.3	East 30.7	South 19.3	West 30.7
Building structure (material)	Heavy structure (concrete)			

8.2 Input data for the energy performance and energy-based CO2 emission simulations

The input data are based on the present building codes and standards laws in Japan and Norway to fulfill the existing requirements for office buildings regarding energy performance and energy related CO_2 emissions. Where documentation is not available, assumptions are made with base of the literature study, standards and calculations. For the Japanese input data, values are based on assumptions and calculation made with help from Associate Professor Koki Kikuta at the Faculty of Engineering, the Division of Human environmental Systems and Laboratory of Building Environment at Hokkaido University, Sapporo, Japan.

8.2.1 Zonation

The building will not be divided into different zones when doing the simulations. This is because the office building will have the same function and purpose in every floor and that the level of design details is simple. According to SIMIEN, a building does not have to be divided into several zones when the building has one function (on building category), when doing energy evaluations [117].

8.2.2 Energy supply and system efficiency factors

The chosen energy supply is electricity and heat pump for both Japan and Norway, but with a different coverage per cent. Norwegian inputs are based on a literature review of common energy supply coverages and standard inputs for system efficiency factors a long with the requirement of flexible energy systems. The Japanese inputs are based on a professional assumption by Assoc. Prof. Kikuta, which are common for office buildings in Japan.

Table 37: Input data for the energy supply coverage

Coverage by energy supply	Japan		Norway	
	Electricity	Heat Pump	Electricity	Heat Pump
Room heating [%]	0	100	15	85
Domestic Hot Water [%]	100	0	30	70
Heating battery ventilation [%]	0	100	0	100
Cooling Battery ventilation [%]	0	100	100	0
Room cooling [%]	0	100	100	0
Specific electricity [%]	100	0	100	0

The CO_2 factor for CO_2 emissions related to the energy supply are stationary for the country in the simulations, as well as the energy price. The Norwegian CO_2emission factor is based on the requirement for CO_2 emissions for passive house and low-energy buildings [118] and a Nordic based carbon intensity for electricity production [119], resulting in a low carbon intensity due to the low emission hydropower production in Norway and Narvik. Even with the same type of energy source, Japan and Sapporo will have a higher CO_2 emission factor due to most of the electricity production originate from fossil fuel. The CO_2 emission factor is set by the Hokkaido Electric Power CO., Inc. [120].

Table 38: Input data for energy supply system efficiency factors, CO_2-emission and energy prices

System efficiency factors	Japan		Norway	
	Electricity	Heat Pump	Electricity	Heat Pump
Room heating	-	2.74	0.84	2.85
Domestic Hot Water	0.67	-	0.98	3.30

Heating battery ventilation	-	2.74	-	3.04
Cooling Battery ventilation	-	3.24	2.50	-
Room cooling	-	3.24	2.50	-
CO_2 emissions [g/kWh]	640	640	130	130
Energy price [NOK/kWh]	1.33	1.33	0.80	0.80

8.2.3 Building structure

The building structure variables in a Norwegian perspective is based on the minimum requirements in the Norwegian building codes and standardized values along with the requirements for energy consumption. For the Japanese building structure, the U-values are made from calculations of standard building elements in Japan, due to lack of thermal requirements for building elements. As for the simulations, the Japanese building structure will also be in Norway and vice versa for the Norwegian building structure. The thermal bridge is based on the building structure material and composition of building elements. The structure material indicates the buildings heat capacity, where a heavy structure generates a high heat capacity.

Table 39: Input data for the building structures.

Building structure	Japan		Norway	
	Input data	Comment	Input data	Comment
U-value external walls [W/m²K]	0.61	Calculated value	0.21	TEK 17
U-value roof [W/m²K]	0.32	Calculated value	0.18	TEK 17
U-value floors [W/m²K]	0.5	Calculated value	0.18	TEK 17
U-value windows and doors [W/m²K]	2.64	Calculated value	1.0	TEK 17
Air leakage rate per hour at 50 Pa pressure difference [h^{-1}]	1.5	Calculated value	1.5	TEK 17
Normalized thermal bridge value, where m² is stated as heated gross internal area [W/m²K]	0.12	Standard value for concrete structure	0.12	Standard value for concrete structure

8.2.4 Technical systems

The technical system input data are divided into heating, cooling, ventilation and internal loads. Values for technical systems are based on requirements, standards and assumptions from literature study.

Table 40: Input data for the heating system of the office building

Heating	Japan		Norway	
	Input data	Comment	Input data	Comment
Working hours [h/d/w]	14 / 5 / 52	Energy Conservation Law (Heisei 25)	12 / 5 / 52	NS 3031, table A.3
Set temperature [°C]	26 / -	Act on maintenance and sanitation of buildings	21 / 19	NS 3031, table A.3
Set temperature for summer [°C]	22 / -	Act on maintenance and sanitation of buildings	21 / 19	Same set temperature the whole year
Maximal delivered power of heating [W/m²]	95	Assumption	50	Assumption
Waterborne heating in/out [°C]	-	-	35/30	Assumption

Cooling is a necessity due to exceeding high operative air temperatures during the summer. This system is highly affected by the climate and the period for cooling will therefor change when relocation the building to another country.

Table 41: Input data for the cooling system of the office building

Cooling	Japan		Norway	
	Input data	Comment	Input data	Comment
Summer cooling	May 1st to October 1st	Energy Conservation Law (Heisei 25)	June 1st to September 1st	Assumption
Set temperature [°C]	26	Assumption	22	Assumption
Maximal delivered power of heating [W/m²]	95	Assumption	40	Assumption

A CAV ventilation system is chosen for the office building, for both in Japan in Norway, to get similar comparison objects. The building has also no presumption of a variable amounts of person. This is constant. The input for the recovery of the heat exchanger is based on standard values and building code requirements for energy consumption.

Table 42: Input data for ventilation in the office building

CAV Ventilation	Japan		Norway	
	Input data	Comment	Input data	Comment
Working hours [h/d/w]	14 / 5 / 52	Energy Conservation Law (Heisei 25)	12 / 5 / 52	NS 3031, table A.3
Heat exchanger recovery [%]	≥ 60	Standard assumption	≥ 80	TEK17
Air supply (working hours [m³]/outside working hours [m³]	5/0	Energy Conservation Law (Heisei 25)	7/2	NS 3031, table A.3
Constant air supply temperature [°C]	22	Act on maintenance and sanitation of buildings	19	NS 3031, table A.3
SFP-factor [kW/(m³/s)]	1.7	Calculated value	1.5	NS 3701, table 9

The input data for the internal loads and its working hours are based on standard values, i.e. the Energy Conservation Law for Japan. The Norwegian inputs are based on the NS 3031, where lighting is reduced by 20 % due to automatic lighting system for the building to comply with the given energy consumption requirement.

Table 43: Input data for internal loads in the office building

Internal loads Office Building	Japan		Norway	
	Input data	Notice	Input data	Notice
Lighting [W/m²]	12	Energy Conservation Law (Heisei 25)	6.4	NS 3031, table A.1
Technical Equipment [W/m²]	12	Energy Conservation Law (Heisei 25)	11	NS 3031, table A.1

Heat gain persons [W/m²]	11,9	Energy Conservation Law (Heisei 25)	4	NS 3031, table A.2
Domestic hot water [kWh/m²] (W/m²)	5,5 (0,88)	Energy Conservation Law (Heisei 25)	5 (0,8)	NS 3031, table A.1

8.2.5 Other

Other instrumental means that affect total energy consumption in the building is the convective share for the waterborne distribution system, and solar protection. These inputs will be the same for Japan and Norway. A convective share of 50 % is set as input, and is a standard value set by SIMIEN. The solar protection is variable and manually controlled and will be activated according to solar flux.

8.3 Results

The heat loss budgets for the two buildings are defined by the structure and thermal resistance of the building components. The Norwegian buildings total heat loss is 0.73 W/m^{2}K and 1.14 W/m^{2}K for the Japanese office building. The result of a higher heat loss for the Japanese building is primary the heat loss for building components such as external walls, windows/doors and ventilation.

Table 44: Heat loss budget of the Norwegian office building

Norwegian Office building Heat loss budget [W/m^{2}K]	
External walls	0.07
Roof	0.04
Floor	0.03
Windows/Doors	0.11
Thermal Bridges	0.12
Infiltration	0.10
Ventilation	0.25
Total heat loss	0.73

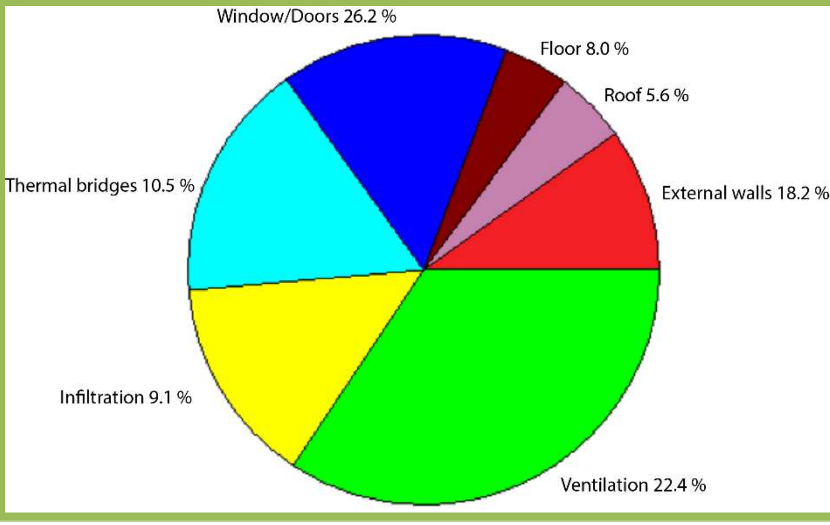
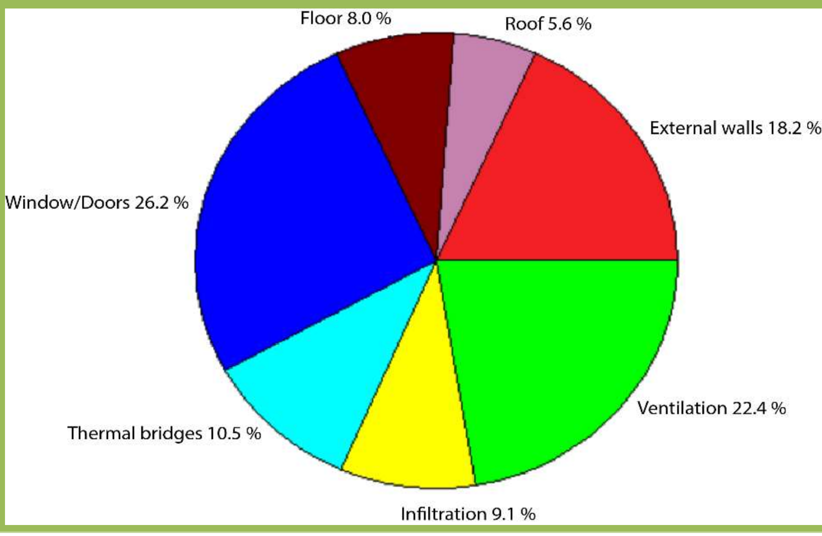


Table 45: Heat loss budget of the Japanese office building

Japanese Office building Heat loss budget [W/m^{2}K]	
External walls	0.21
Roof	0.06
Floor	0.09
Windows/Doors	0.30
Thermal Bridges	0.12
Infiltration	0.10
Ventilation	0.26
Total heat loss	1.14



8.3.1 Simulation 1: Norwegian office building in Narvik

The first simulation, simulates a standard office building with Norwegian requirements based on Norwegian Building codes, located in Narvik. The specific energy demand is 114.5 kWh/m^2 which is less than 115 kWh/m^2, resulting as satisfied according to requirements in the Norwegian Building codes.

Table 46: Energy budget for Simulation 1 – Norwegian office building in Narvik

Energy budget		
Energy Post	Energy Demand	Specific Energy Demand

Room heating	99 893 kWh	20.0 kWh/m^2
Ventilation heating	76 207 kWh	15.2 kWh/m^2
Domestic hot water	25 056 kWh	5.0 kWh/m^2
Fans	61 311 kWh	12.3 kWh/m^2
Pumps	8 154 kWh	1.6 kWh/m^2
Lighting	100 224 kWh	20.0 kWh/m^2
Technical Equipment	172 258 kWh	34.5 kWh/m^2
Room cooling	22 022 kWh	4.4 kWh/m^2
Ventilation cooling	7 301 kWh	1.5 kWh/m^2
Total net energy demand	572 425 kWh	114.5 kWh/m^2

Figure 59 illustrates the distribution the energy demand. It indicates which energy post demand most of the total energy demand. Technical equipment demands the most (30.1 %) followed by both lighting and room heating (17.5 % each).

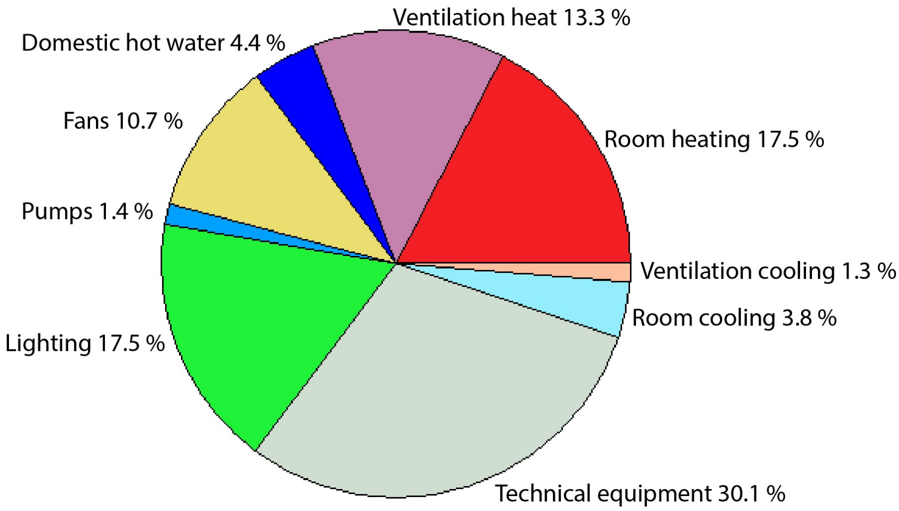


Figure 59: Energy distribution by energy post for simulation 1 – Norwegian office building in Narvik

The CO_2 emissions are based on the energy consumption, which is low due to the use of renewable energy (hydropower). This results in an annual of total energy related CO_2emission at 58 453 kg CO_2 equivalent.

Table 47: Annual energy related CO_2 emissions for Simulation 1 – Norwegian office building in Narvik

Annual CO_2-emissions		
Energy supply	Emissions	Specific Emissions
Direct use of electricity	49 360 kg	9.9 kg/m^2
Electricity for heat pump systems	9 093 kg	1.8 kg/m^2
Total emissions	58 453 kg	11.7 kg/m^2
Net CO2-emissons	58 453 kg	11.7 kg/m^2

8.3.2 Simulation 2: Japanese office building located in Sapporo

The second simulation, simulates a standard office building with Japanese requirements based on Japanese Building codes, located in Sapporo. The specific energy demand (design value) is 211.7

kWh/m^2 which complies with Japanese building regulations where the design value over standard value must be less than one. Standard value is set to 402.5 kWh/m^2, according to Figure 51: Standard Reference Values for Office Buildings (5000 m2) - Primary Energy Consumption (MJ/m2 year).

Table 48: Energy budget for Simulation 2 – Japanese office building in Sapporo

Energy budget		
Energy Post	Energy Demand	Specific Energy Demand
Room heating	122 341 kWh	24.5 kWh/m^2
Ventilation heating	124 093 kWh	24.8 kWh/m^2
Domestic hot water	27 562 kWh	5.5 kWh/m^2
Fans	40 060 kWh	8.0 kWh/m^2
Pumps	1 404 kWh	0.3 kWh/m^2
Lighting	203 617 kWh	40.7 kWh/m^2
Technical Equipment	203 617 kWh	40.7 kWh/m^2
Room cooling	328 801 kWh	65.8 kWh/m^2
Ventilation cooling	6 879 kWh	1.4 kWh/m^2
Total net energy demand	1 058 375 kWh	211.7 kWh/m^2

Figure 60 illustrates the distribution the energy demand. It indicates which energy post contribute most of the total energy demand. Room cooling has the highest demand (31.1) followed by both lighting and technical equipment (19.2 % each).

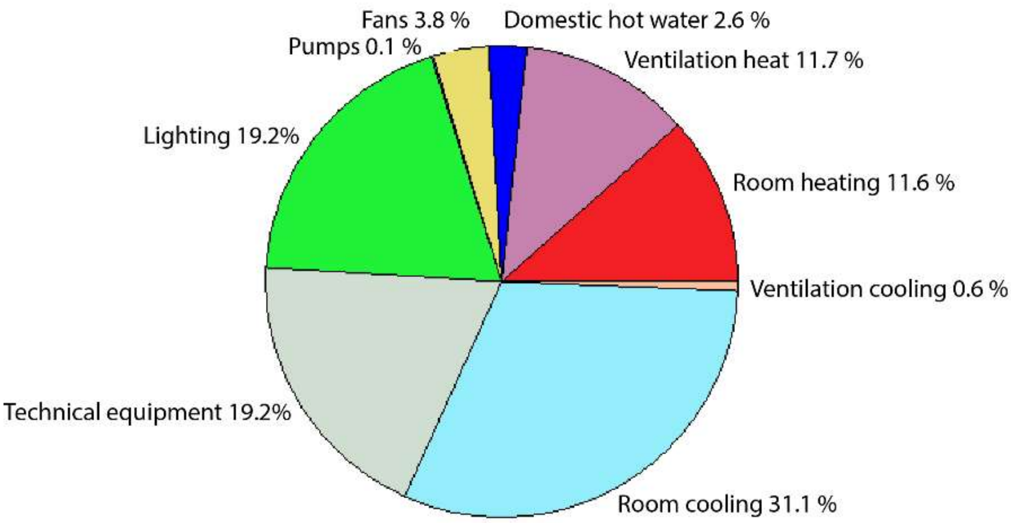


Figure 60: Energy distribution by energy post for simulation 2 – Japanese office building in Sapporo

The annual energy related CO_2 emissions are 437 363 kg, equivalent to 87.5 kg/m^2. This is the highest CO_2 emissions of all the simulations.

Table 49: Annual energy related CO_2 emissions for Simulation 2 – Japanese office building in Sapporo

Annual CO_2-emissions		
Energy supply	Emissions	Specific Emissions
Direct use of electricity	313 494 kg	62.7 kg/m^2
Electricity for heat pump systems	123 869 kg	24.8 kg/m^2

Total emissions	437 363 kg	87.5 kg/m^2
Net CO_2-emissons	437 363 kg	87.5 kg/m^2

8.3.3 Simulation 3: Japanese office building in Narvik

The third simulation, simulates a standard office building with Japanese requirements based on Japanese Building codes, located in Narvik. The specific energy demand is 229.9 kWh/m^2 which is twice as much for the Norwegian building located in Narvik. It does not meet the energy demand requirements of office buildings in Norway but satisfy the requirements for an office building in Japan.

Table 50: Energy budget for Simulation 3 – Japanese office building in Narvik

Energy budget		
Energy Post	Energy Post	Energy Post
Room heating	244 965 kWh	49.0 kWh/m^2
Ventilation heating	195 560 kWh	39.1 kWh/m^2
Domestic hot water	27 562 kWh	5.5 kWh/m^2
Fans	40 060 kWh	8.0 kWh/m^2
Pumps	1 185 kWh	0.2 kWh/m^2
Lighting	203 617 kWh	40.7 kWh/m^2
Technical Equipment	203 617 kWh	40.7 kWh/m^2
Room cooling	232 727 kWh	46.5 kWh/m^2
Ventilation cooling	280 kWh	0.1 kWh/m^2
Total net energy demand	1 149 572 kWh	229.9 kWh/m^2

Figure 61 illustrates the distribution of the energy demand. Room cooling, and room heating are the most dominant with over 20 % each. This is an indication of vast heat loss through the building components.

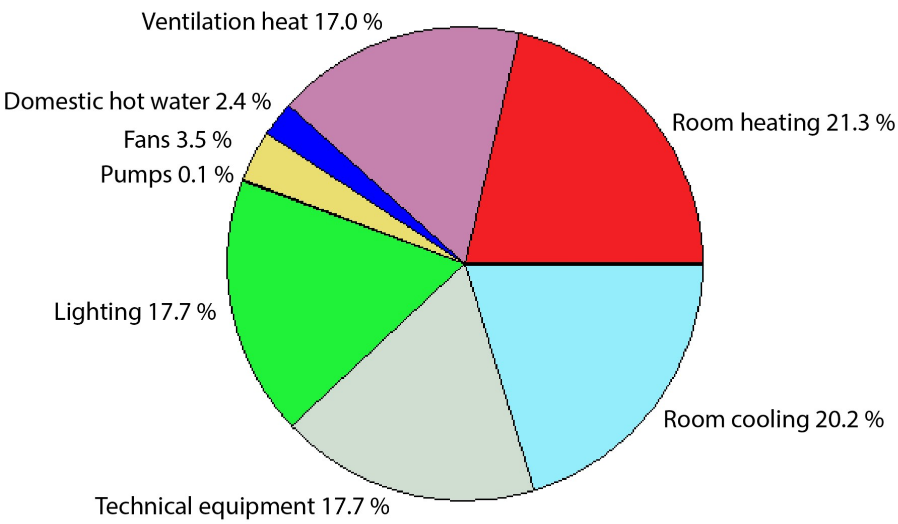


Figure 61: Energy distribution by energy post for simulation 3 – Japanese office building in Narvik

The annual energy related CO_2 emissions are generally low, at 95 521 kg – 19.3 kg/m^2. The emissions are higher due to a higher energy demand.

Table 51: Annual energy related CO_2 emissions for Simulation 3 – Japanese office building in Narvik

Annual CO_2-emissions		
Energy supply	Emissions	Specific Emissions
Direct use of electricity	61 885 kg	12.4 kg/m^2
Electricity for heat pump systems	34 636 kg	6.9 kg/m^2
Total emissions	96 521 kg	19.3 kg/m^2
Net CO_2-emissons	96 521 kg	19.3 kg/m^2

8.3.4 Simulation 4: Norwegian office building in Sapporo

The fourth simulation, simulates a standard office building with Norwegian requirements based on Norwegian Building codes, located in Sapporo. The specific energy demand is 122.4 kWh/m^2 which is over 100 kWh/m^2 lower than the Japanese building located in Sapporo. The building satisfy the energy demand of and office building in Japan, but not the requirement in Norway.

Table 52: Energy budget for Simulation 4 – Norwegian office building in Sapporo

Energy budget		
Energy Post	Energy Post	Energy Post
Room heating	49 221 kWh	9.8 kWh/m^2
Ventilation heating	45 382 kWh	9.1 kWh/m^2
Domestic hot water	25 056 kWh	5.0 kWh/m^2
Fans	61 311 kWh	12.3 kWh/m^2
Pumps	8 519 kWh	1.7 kWh/m^2
Lighting	100 224 kWh	20.0 kWh/m^2
Technical Equipment	172 258 kWh	34.5 kWh/m^2
Room cooling	54 418 kWh	10.9 kWh/m^2
Ventilation cooling	95 783 kWh	19.2 kWh/m^2
Total net energy demand	612 172 kWh	122.4 kWh/m^2

The distribution of the energy demand, Figure 62, illustrate the requsite of room cooling (8.9 %) and ventilation cooling (15.6 %). Other energy demanding energy posts are technical equipment (28.1 %) and lighting (16.4 %).

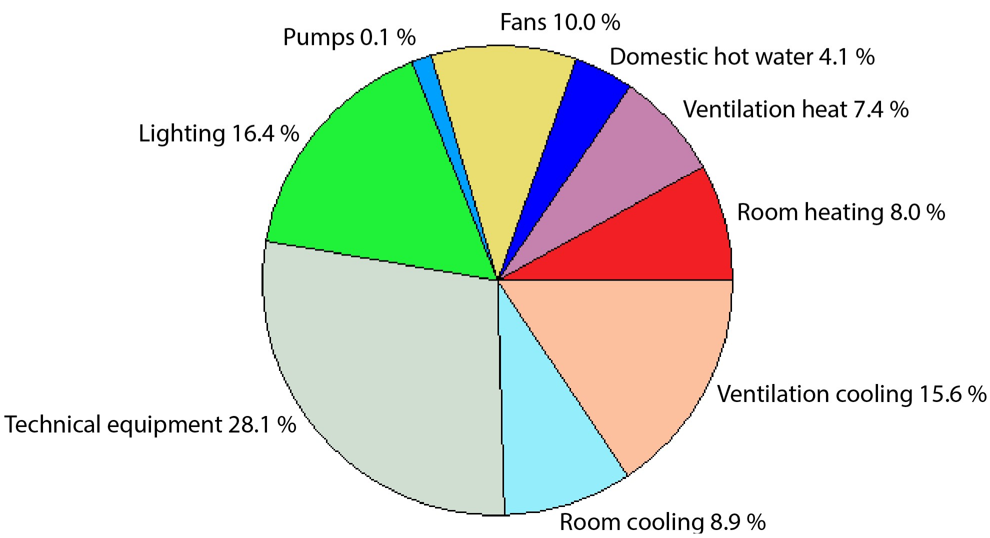


Figure 62: Energy distribution by energy post for simulation 4 – Norwegian office building in Sapporo

The annual CO_2 emissions ends up at the amount of 294 300 kg, equivalent to 59.0 kg/m^2. Which is much higher than the Norwegian building in Narvik, due to different CO_2 emission factor.

Table 53: Annual energy related CO_2 emissions for Simulation 4 – Norwegian office building in Sapporo

Annual CO_2-emissions		
Energy supply	Emissions	Specific Emissions
Direct use of electricity	268 175 kg	54.1 kg/m^2
Electricity for heat pump systems	26 124 kg	4.9 kg/m^2
Total emissions	294 300 kg	59.0 kg/m^2
Net CO_2-emissons	294 300 kg	59.0 kg/m^2

9 Discussion and analysis

This chapter will discuss and analyze the differences between Japan and Norway, regarding policy and building regulations, building stock and energy consumption, energy related CO2 emissions, climate and the main measures and strategy for reduction of energy consumptions and energy related CO2 emissions. This will give an overview of the reason and the status of the means that affect the environmental footprint of buildings.

9.1 Climate

The climate approach of this master thesis regarding buildings starts with a comparison of the climates in Norway and Japan. An assessment of the different definitions of cold-climate region conducted to see which parts of each country falls within the boundary lines. The report has observed that Norway lies within all the definitions of cold-climate regions, while only the northern part of Japan falls within the boundaries. The climate impact on buildings in these locations includes all aspects of building development. The two countries are almost the same size but different latitudes creates vaster different climates at lower latitudes than in the higher latitudes. The daylight duration is one of the most significant differences due to location, as Norway lacks daylight during the winter and receives daylight throughout the day during the summer.

The climate changes are generally the same all over the world. Only a tiny increase of the average temperature has consequence. The expecting changes are considered the same in Norway and northern Japan. Japan is more exposed to the rising of sea levels as much of the building stock are placed in the low lands and the matter of fact that Japan is an island nation.

Buildings are highly affected by the climate in the terms of energy consumptions. Data collected form the two countries show that the energy consumption was greater in certain years compared to others. This is mainly a result of a cold weather year where increase of the heating demand occurred. The heating degree day indicate that the amount of heating is significant in the regions within cold-climate regions. The thermal properties of the building components are exceedingly crucial for the energy consumption in cold climate. This is one of the reasons why the energy consumption in buildings in Japan are considerably higher than in Norway.

9.2 Building and energy market

The building stock differences between Japan and Norway are great. The building stock in Japan represent at least over ten times as many buildings in Norway, and this also affects the energy consumption and the demand of energy. The rate of new constructed buildings in Japan is so high that they are forced to tear them down after a short while, henceforth suffering of the short building life syndrome, where socioeconomics trumps the physical integrity. An average lifetime expectancy of buildings in Japan are from approximately 30 – 50 years. For the building stock in Norway it is the opposite. It reached its lowest increase of buildings of all time 2016, which might be a result of more multi-dwellings than single dwellings constructed. The life expectancy of buildings in Norway is, based on the literature review, from 60 – 80 years.

High energy consumption in buildings in Japan reflect the thermal properties of the building, as well in Norway for existing building. High energy consumption in the existing building stock also result in high CO_2 emissions. Electricity in buildings are the most used in both countries, but from different energy source, where CO_2 emissions derive dependent on the energy source. In Norway, almost all the electricity production is based on renewable energy such as hydropower. The main electricity production source in Japan use to be nuclear power, but after the great earthquake in 2011, the nuclear powerplant were forced to shut down until further notice and resulting in the increase of the use of fossil fuel to cope with the energy demand. Security of energy supply is highly important for both countries.

9.3 Policies and regulations

The policies and regulations regarding energy and environment are much affected by the nations intended nationally determined contribution submitted as a part of the Paris agreement. These are based on the same concept of reducing energy consumption and energy related CO_2 emissions. The measures for the countries regarding buildings, narrows down to energy efficiency requirements in buildings. Norway has for many years embraced the development of energy efficiency in buildings, partly due to the implementation of EU directives. Strict requirements are set on the building components as well as the total net energy demand for all building categories, resulting in low heat loss coefficients and efficient HVAC systems. The energy demand requirements for office buildings are in Norway < 115 kWh/m^2 and approximately 402 kWh/m^2 in Japan.

As Japan saw the building sector as a potential energy-saving area, large scale commercial/non-residential buildings are especially the target in their new Building Energy Efficiency Act. The requirement for non-residential buildings are primary based on the net energy performance of the buildings while the residential building includes building envelope requirements. The major focus for both countries are the aims of reducing energy consumptions, primary on newly built constructions, when the real energy efficiency potential lies within already existing buildings. Both countries have targets regarding the reduction of energy consumption in existing building, such as extensions and renovation.

The redistribution of the energy usage is a great challenge in Japan due to its dependence of import and lack of renewable resources to comply with the massive energy demand. Norway also face challenges regarding the redistribution of energy to secure energy supply, but not as vast as Japan, since nearly all electricity production is renewable and comes from hydropower. Historical crises have in a great way affect the legislation in Japan. The oil crises in the 1970s, the great earthquake in 2011 and eventual other crisis form the foundation of change within a country and form the strategy and target in the prevention of other disasters.

The impact on the measures regarding energy efficiency affects the society for many years ahead. It is therefore important to make the measures flexible, so development can happen.

9.4 Energy simulations

The building envelope, structure and the input data are based on the achievement of complying with the existing building regulations in Japan and Norway, which was collected as a literature review. The building structure was based on the authors assumptions of an office building structure and a standard Japanese design for energy simulations. The total of four simulations was executed and serves as a supplement and confirmation of the differences in energy efficiency and environmental impacts in a building. The results from the simulations illustrate a stricter requirement for building energy performance in Norway than in Japan. Where the Norwegian building placed in Narvik had an energy demand of 114.5 kWh/m^2 (in accordance with the technical building regulations in Norway: < 115 kWh/m^2), the Japanese building located in Sapporo had an energy demand of 211.7 kWh/m^2 (In accordance with the building performance of energy act: < 402.5 kWh/m^2). The thermal properties of building components in the terms of heat loss figures are the main reason of the difference in energy demand in Japan and Norway. As Norway has strict thermal requirements for the different building components and total net energy demand, and Japan only has an overall energy performance requirement based on the total energy demand.

The two buildings in Japan and Norway were also simulated for the relocation of each other, to state the impacts of difference in climate on the building energy performance. The Norwegian building relocated to Sapporo, ended up with an energy demand of 122.4 kWh/m^2, an increase of 8 kWh/m^2 due to redistribution of heating and cooling. This indicates a warmer climate in Sapporo than in Narvik and increase in cooling demand. The Japanese building in Narvik ends up with a higher increase of energy demand than the Norwegian building in Sapporo. This is because of the heat loss figures for the Japanese building is greater than in the Norwegian building, resulting in a higher demand of heating during the winter, but a lower demand for cooling during the summer, as the summers in Narvik is colder than the summer in Sapporo.

The CO2 emissions are closely related to the energy supply and consumption. The buildings are based on the same supply by electricity and heat pump. The outcome of CO2 indicates energy consumption of renewable sources. Since the electricity production in Norway are primary based on the renewable energy hydropower, the CO2 emission factor is significantly low, but due the Nordic collaboration for electricity production, the CO2 emission factor would be a little higher. The electricity production in Japan was after the great earthquake of 2011 and nuclear shutdown based of fossil fuels (oil and coal) and natural gas, therefore the CO2 emission factor would be significantly higher than the one in Norway. The results are reflected by the energy source and ends up by 58.5 tons annually CO2 equivalent in Norway and 437.4 tons CO2 equivalent in Japan. For the relocated simulations the annually CO2 equivalent from the Norwegian building in Sapporo is reduced from the Japanese Building in Sapporo, from 437.4 tons to 294.3 tons, equivalent to approximately 33 % reduction. The Japanese building in Narvik has an increased annually CO2 equivalent emissions from the Norwegian building in Narvik by almost 40 %, but still much lower than the buildings located in Sapporo, Japan.

9.4.1 Elements of uncertainty

There are some elements of uncertainty to be considered in the discussion, which regard several aspects of the simulation. The input data with documentations (e.g. TEK, Heisei 25/28) are theoretical realistic and acceptable. All other input data are considered as theoretical insecure, but a qualification of the energy simulations. The assessed elements are as follows:

- The use of simulation software program may affect the result in the means of calculation method regarding energy performance in buildings. As for the simulations located in Norway, it would be sufficient to use a Norwegian based simulation software. As for the simulations located in Japan it would me more sufficient to use the energy simulation software based on Japanese methods of calculation (e.g. BEST).
- Implementation of the Japanese input data into the SIMIEN, may involve misunderstandings in converting data and finding documentation. E.g. the climate data base for Sapporo may not be of equivalent quality and level of detail as the Norwegian climate data base. This result in indistinct evaluation if the build s energy performance.
- The building structure of the office building may not represent the average structure for an office building in Norway and Japan. The structure is based on assumptions and a standard office design for energy performance simulations in Japan.

- Zonation of the building impacts in great means buildings with high window area. Therefore, it should be considered that the buildings window area represents 11.3 % of the heated gross area, resulting in possible higher cooling demand when the building is considered as one zone. Several zones make it possible to use different ventilation systems (VAV and CAV) and will result in a more realistic simulation, when defining the zones properly for different use (Meeting room, office area etc.).

9.5 Measures for achievement of green building concepts in buildings located in cold climate

The measures that is necessary for the achievement of the green building concept is based on the feasibility study and the literature review. Together, they have highlighted that buildings faces several challenges and are exposed to several treats on the development of buildings in cold climates in general. Location is the key – both globally and locally, especially if the goal is to reach and realize the true potential of what defines a sustainable and green building. Permafrost, snow, ice and harsh weather is determined by its location in the global perspective and prerequisites, while locally depends often on the countries and building owners priorities when it comes to funding of sustainable development in the colder regions. Historically has the cold climate been counter measured by increased heating by fire and wood. Traditionally, has building counter measured cold climates by higher levels of insulation and new implemented materials and windows. Now, we see collaboration projects that don't just counter measure cold climate in regards with the thermal aspect of the buildings but includes the total elements of what makes a building sustainable in the overall perspective.

Green buildings can be reached in cold climates; the Powerhouse and ZEB projects is perfect examples of that. It does however require careful design and execution through concepts, methods and costs that differ from the traditional ones. Common to them all, is that they have been carefully designed through a system, that examines and tries to find the most sustainable path for the building development. They also use renewable energy as their mantra and conserve materials by the scope of low-bound energy and recycle. Additionally, they fight colder environments by high insulations levels and takes climate into account when choosing energy sources, like Powerhouse Brattørkaia's requirements when choosing solar panels in harsh and cold environments.

10 Conclusion

The purpose of this master thesis project was to enlighten and analyze how the differences in policies, regulations and other instrumental means affect the environmental footprint and energy consumptions of buildings in cold regions such as northern Japan and northern Norway. Through a case study this was visualized with the use of simulations, where the input data was based on each of the counties requirements and standard values. After the feasibility study was conducted, parallels were drawn into the case study on how the buildings in the case study can obtain some of the concepts of green building by implementation.

The master thesis project included a three month long stay in Japan at Hokkaido University, to study the policies, regulations and other means that affect the energy consumption in buildings and the environmental footprint in Japan, which also includes the gathering of input data and standard values for the case study and the simulations.

The result show great difference between the two countries regarding energy efficiency in existing and new buildings and the major means that affect the environmental footprint are: locations, cultural and historic background, policy and regulation strategies based on each nation prerequisites and available resources. The feasibility study has also illustrated that concepts of green buildings can be met by introduction of the cold climate, within the defined boundaries of cold-climate regions of the world.

11 Further work

Essential topics for further work with this report as a base, would be a more detailed and realistic case study where existing buildings, in the same building category, are compared to each other. It would also be interesting to implement "green features" to an existing building within Narvik and Sapporo, to examine to what extent the Green Building potential can be implemented.

For further study of the topics in the report it would be highly recommended to involve Japanese students in the project, which already have the basic knowledge and an overall overview of the building regulatory systems in Japan. Furthermore, this will lead to a greater coverage of literature since building laws and regulations are primary in Japanese.

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13 Appendix

Appendix A – Results from SIMIEN – Norwegian Building in Narvik

Appendix B – Results from SIMIEN – Japanese Building in Sapporo

Appendix C – Results from SIMIEN – Japanese Building in Narvik

Appendix D – Results from SIMIEN – Norwegian building in Sapporo

SIMIEN

Resultater årssimulering

Simuleringsnavn: Årssimulering
Tid/dato simulering: 19:47 13/5-2018
Programversjon: 6.009
Simuleringsansvarlig: N.B.Alseth & L.Andersen
Firma: Undervisningslisens
Inndatafil: C:\...\NB in Narvik.smi
Prosjekt: Standard Office Building
Sone: Norwegian Building in Narvik

Energibudsjett		
Energipost	Energibehov	Spesifikt energibehov
1a Romoppvarming	99893 kWh	20,0 kWh/m²
1b Ventilasjonsvarme (varmebatterier)	76207 kWh	15,2 kWh/m²
2 Varmtvann (tappevann)	25056 kWh	5,0 kWh/m²
3a Vifter	61311 kWh	12,3 kWh/m²
3b Pumper	8154 kWh	1,6 kWh/m²
4 Belysning	100224 kWh	20,0 kWh/m²
5 Teknisk utstyr	172258 kWh	34,5 kWh/m²
6a Romkjøling	22022 kWh	4,4 kWh/m²
6b Ventilasjonskjøling (kjølebatterier)	7301 kWh	1,5 kWh/m²
Totalt netto energibehov, sum 1-6	572425 kWh	114,5 kWh/m²

Levert energi til bygningen (beregnet)		
Energivare	Levert energi	Spesifikk levert energi
1a Direkte el.	379691 kWh	75,9 kWh/m²
1b El. til varmepumpesystem	69945 kWh	14,0 kWh/m²
1c El. til solfangersystem	0 kWh	0,0 kWh/m²
2 Olje	0 kWh	0,0 kWh/m²
3 Gass	0 kWh	0,0 kWh/m²
4 Fjernvarme	0 kWh	0,0 kWh/m²
5 Biobrensel	0 kWh	0,0 kWh/m²
6. Annen energikilde	0 kWh	0,0 kWh/m²
7. Solstrøm til egenbruk	-0 kWh	-0,0 kWh/m²
Totalt levert energi, sum 1-7	449636 kWh	89,9 kWh/m²
Solstrøm til eksport	-0 kWh	-0,0 kWh/m²
Netto levert energi	449636 kWh	89,9 kWh/m²

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Dekning av energibudsjett fordelt på energikilder						
Energikilder	Romoppv.	Varmebatterier	Varmtvann	Kjølebatterier	Romkjøling	El. spesifikt
El.	3,0 kWh/m²	0,0 kWh/m²	1,5 kWh/m²	1,5 kWh/m²	4,4 kWh/m²	68,4 kWh/m²
Olje	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Gass	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Fjernvarme	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Biobrensel	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Varmepumpe	17,0 kWh/m²	15,2 kWh/m²	3,5 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Sol	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Annen	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Sum	20,0 kWh/m²	15,2 kWh/m²	5,0 kWh/m²	1,5 kWh/m²	4,4 kWh/m²	68,4 kWh/m²

Årlige utslipp av CO_2		
Energivare	Utslipp	Spesifikt utslipp
1a Direkte el.	49360 kg	9,9 kg/m²
1b El. til varmepumpesystem	9093 kg	1,8 kg/m²
1c El. til solfangersystem	0 kg	0,0 kg/m²
2 Olje	0 kg	0,0 kg/m²
3 Gass	0 kg	0,0 kg/m²
4 Fjernvarme	0 kg	0,0 kg/m²
5 Biobrensel	0 kg	0,0 kg/m²
6. Annen energikilde	0 kg	0,0 kg/m²
7. Solstrøm til egenbruk	-0 kg	-0,0 kg/m²
Totalt utslipp, sum 1-7	58453 kg	11,7 kg/m²
Solstrøm til eksport	-0 kg	-0,0 kg/m²
Netto CO_2-utslipp	58453 kg	11,7 kg/m²

SIMIEN
Resultater årssimulering

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Tid/dato simulering: 19:47 13/5-2018
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Inndatafil: C:\...\NB in Narvik.smi
Prosjekt: Standard Office Building
Sone: Norwegian Building in Narvik

Kostnad kjøpt energi		
Energivare	Energikostnad	Spesifikk energikostnad
1a Direkte el.	303753 kr	60,8 kr/m²
1b El. til varmepumpesystem	55956 kr	11,2 kr/m²
1c El. til solfangersystem	0 kr	0,0 kr/m²
2 Olje	0 kr	0,0 kr/m²
3 Gass	0 kr	0,0 kr/m²
4 Fjernvarme	0 kr	0,0 kr/m²
5 Biobrensel	0 kr	0,0 kr/m²
6. Annen energikilde	0 kr	0,0 kr/m²
7. Solstrøm til egenbruk	-0 kr	-0,0 kr/m²
Årlige energikostnader, sum 1-7	359708 kr	71,9 kr/m²
Solstrøm til eksport	0 kr	0,0 kr/m²
Netto energikostnad	359708 kr	71,9 kr/m²

Simuleringsnavn: Årssimulering
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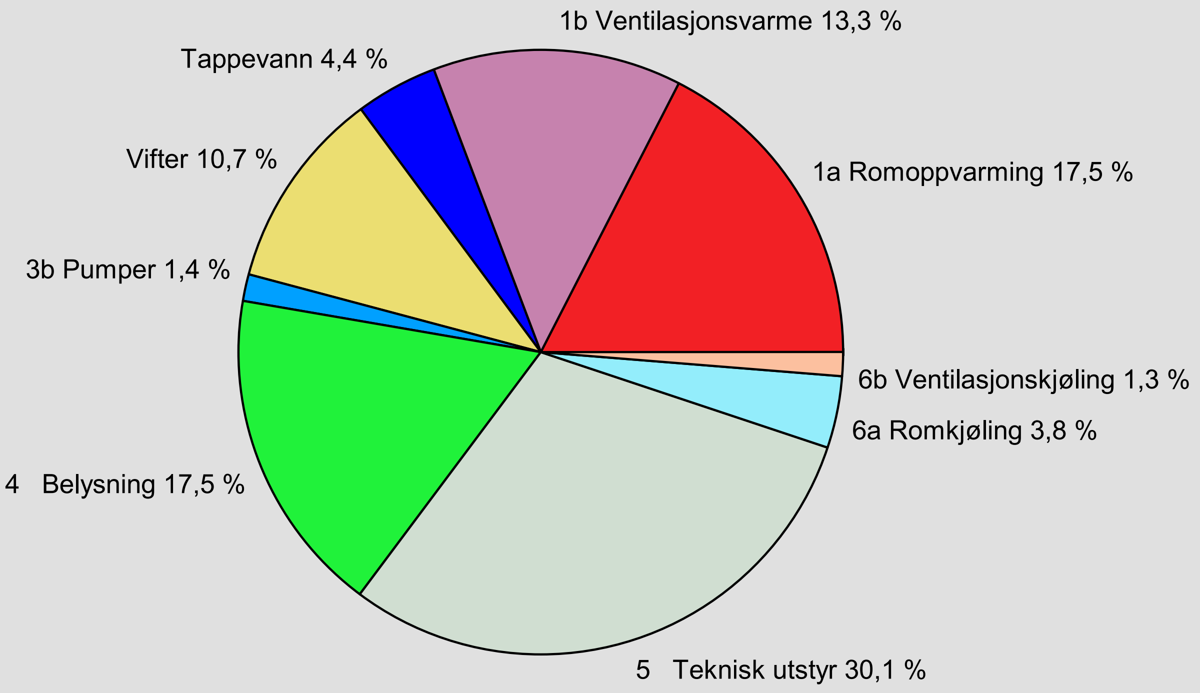
Årlig energibudsjett



1a Romoppvarming	99893 kWh
1b Ventilasjonsvarme (varmebatterier)	76207 kWh
2 Varmtvann (tappevann)	25056 kWh
3a Vifter	61311 kWh
3b Pumper	8154 kWh
4 Belysning	100224 kWh
5 Teknisk utstyr	172258 kWh
6a Romkjøling	22022 kWh
6b Ventilasjonskjøling (kjølebatterier)	7301 kWh
Totalt netto energibehov, sum 1-6	572425 kWh

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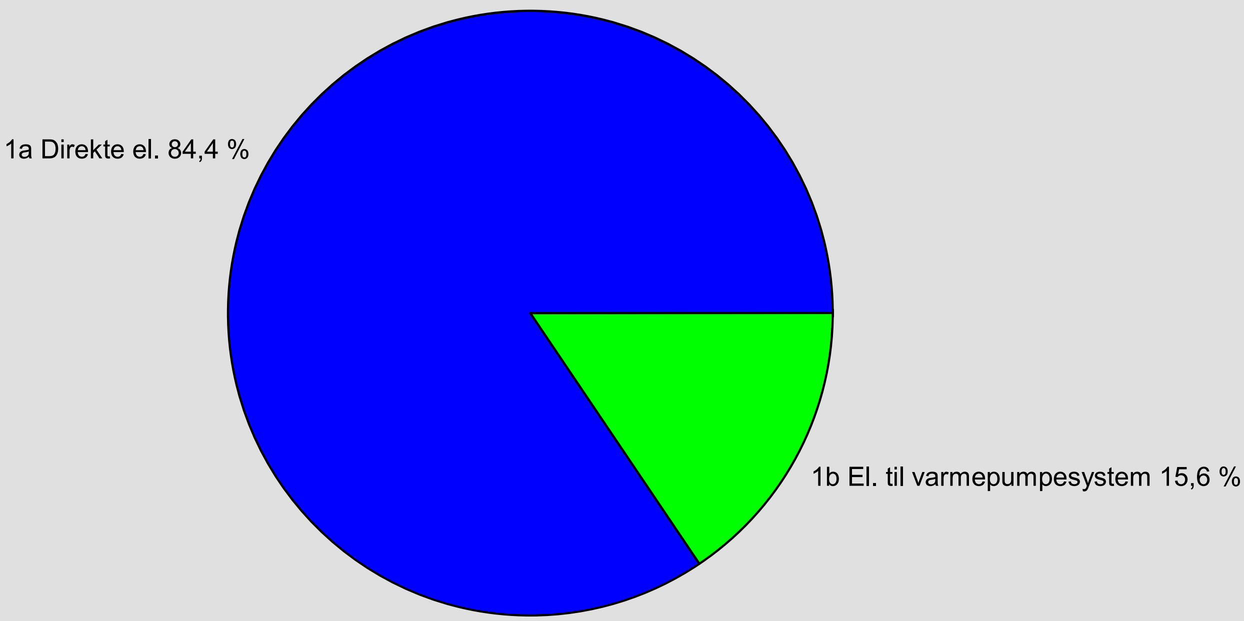
Inndatafil: C:\...\NB in Narvik.smi
Prosjekt: Standard Office Building
Sone: Norwegian Building in Narvik

Levert energi til bygningen (beregnet)



1a Direkte el.	379691 kWh
1b El. til varmepumpesystem	69945 kWh
1c El. til solfangersystem	0 kWh
2 Olje	0 kWh
3 Gass	0 kWh
4 Fjernvarme	0 kWh
5 Biobrensel	0 kWh
6. Annen energikilde	0 kWh
Totalt levert energi, sum 1-7	449636 kWh

SIMIEN

Resultater årssimulering

Simuleringsnavn: Årssimulering
Tid/dato simulering: 19:47 13/5-2018
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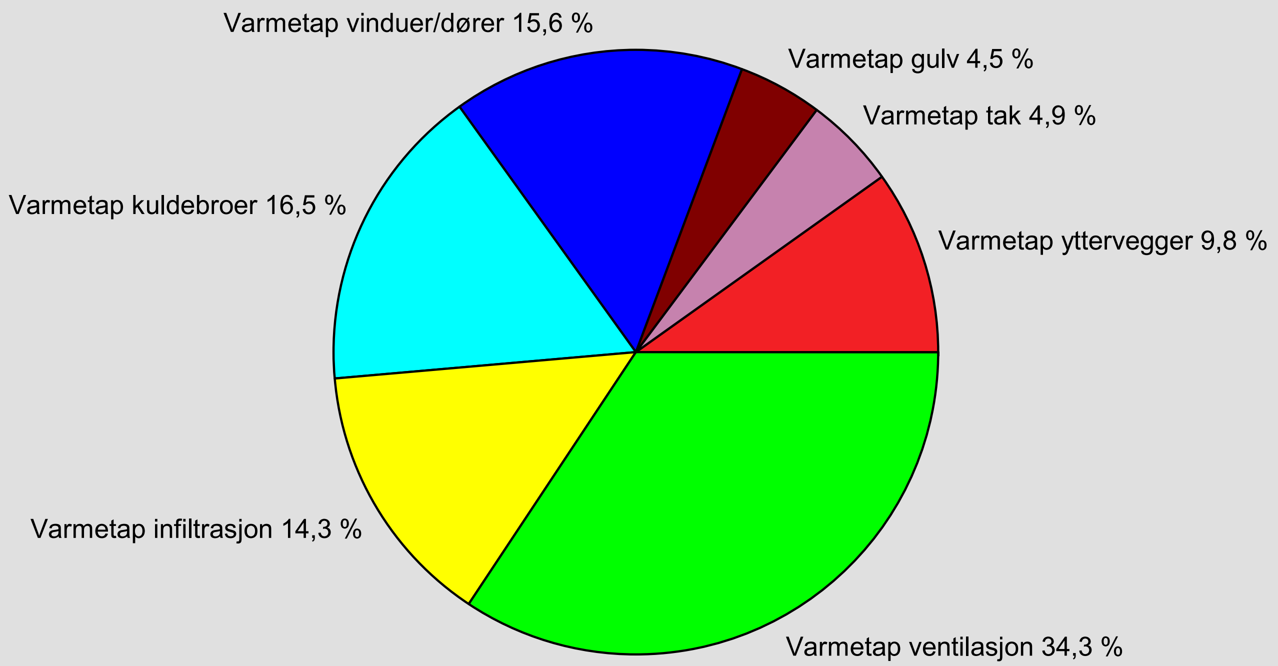
Firma: Undervisningslisens
Inndatafil: C:\...\NB in Narvik.smi
Prosjekt: Standard Office Building
Sone: Norwegian Building in Narvik

Varmetapsbudsjett (varmetapstall)



Varmetapstall yttervegger	0,07 W/m²K
Varmetapstall tak	0,04 W/m²K
Varmetapstall gulv på grunn/mot det fri	0,03 W/m²K
Varmetapstall glass/vinduer/dører	0,11 W/m²K
Varmetapstall kuldebroer	0,12 W/m²K
Varmetapstall infiltrasjon	0,10 W/m²K
Varmetapstall ventilasjon	0,25 W/m²K
Totalt varmetapstall	0,73 W/m²K

Simuleringsnavn: Årssimulering
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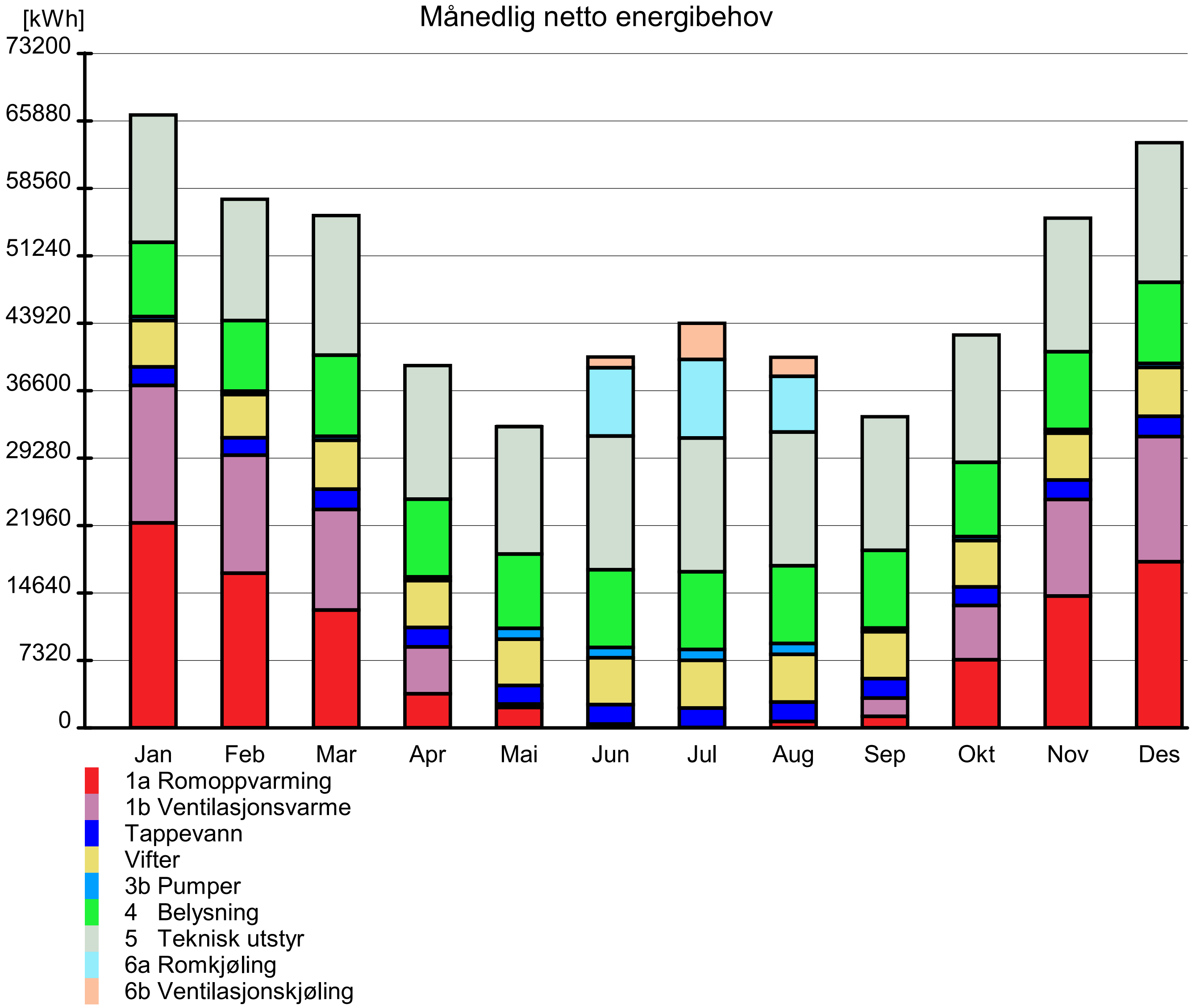

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Programversjon: 6.009
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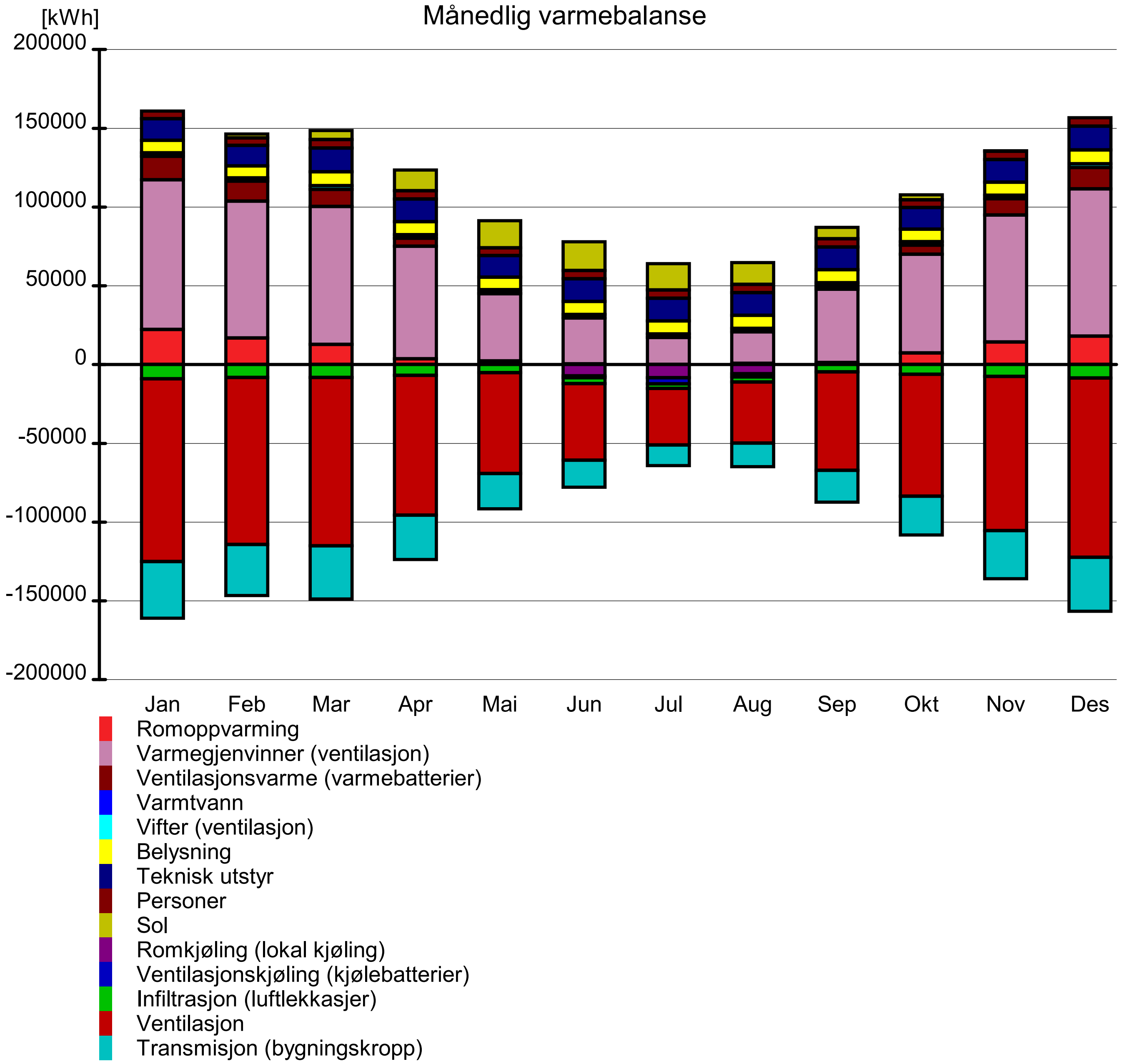

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Månedlige temperaturdata (lufttemperatur)

Måned	Midlere ute	Maks. ute	Min. ute	Midlere sone	Maks. sone	Min. sone
Januar	-4,3 °C	5,8 °C	-14,7 °C	19,7 °C	21,4 °C	19,0 °C
Februar	-4,0 °C	6,3 °C	-14,6 °C	19,8 °C	22,6 °C	19,0 °C
Mars	-1,7 °C	7,8 °C	-11,6 °C	20,0 °C	23,5 °C	19,0 °C
April	2,1 °C	12,0 °C	-6,2 °C	20,7 °C	24,9 °C	19,0 °C
Mai	7,2 °C	17,6 °C	-0,5 °C	20,9 °C	26,4 °C	19,0 °C
Juni	10,8 °C	24,4 °C	2,6 °C	21,0 °C	24,1 °C	19,0 °C
Juli	13,5 °C	26,7 °C	6,0 °C	21,3 °C	24,3 °C	19,0 °C
August	12,4 °C	22,3 °C	4,6 °C	20,8 °C	23,4 °C	19,0 °C
September	8,2 °C	17,2 °C	-0,6 °C	21,2 °C	26,4 °C	19,0 °C
Oktober	3,9 °C	12,5 °C	-4,6 °C	20,1 °C	23,4 °C	19,0 °C
November	-0,5 °C	8,8 °C	-8,8 °C	19,8 °C	22,2 °C	19,0 °C
Desember	-2,7 °C	6,2 °C	-13,3 °C	19,8 °C	21,9 °C	19,0 °C

Månedlige temperaturdata (operativ temperatur)

Måned	Midlere ute	Maks. ute	Min. ute	Midlere sone	Maks. sone	Min. sone
Januar	-4,3 °C	5,8 °C	-14,7 °C	19,9 °C	21,7 °C	19,0 °C
Februar	-4,0 °C	6,3 °C	-14,6 °C	20,0 °C	22,5 °C	18,9 °C
Mars	-1,7 °C	7,8 °C	-11,6 °C	20,3 °C	23,4 °C	19,0 °C
April	2,1 °C	12,0 °C	-6,2 °C	21,2 °C	24,6 °C	19,0 °C
Mai	7,2 °C	17,6 °C	-0,5 °C	21,6 °C	25,5 °C	20,7 °C
Juni	10,8 °C	24,4 °C	2,6 °C	21,8 °C	24,0 °C	21,3 °C
Juli	13,5 °C	26,7 °C	6,0 °C	22,1 °C	24,5 °C	20,4 °C
August	12,4 °C	22,3 °C	4,6 °C	21,5 °C	23,6 °C	21,5 °C
September	8,2 °C	17,2 °C	-0,6 °C	21,7 °C	25,9 °C	20,3 °C
Oktober	3,9 °C	12,5 °C	-4,6 °C	20,5 °C	23,5 °C	19,0 °C
November	-0,5 °C	8,8 °C	-8,8 °C	20,1 °C	22,4 °C	18,9 °C
Desember	-2,7 °C	6,2 °C	-13,3 °C	20,0 °C	22,2 °C	19,0 °C

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Resultater årssimulering

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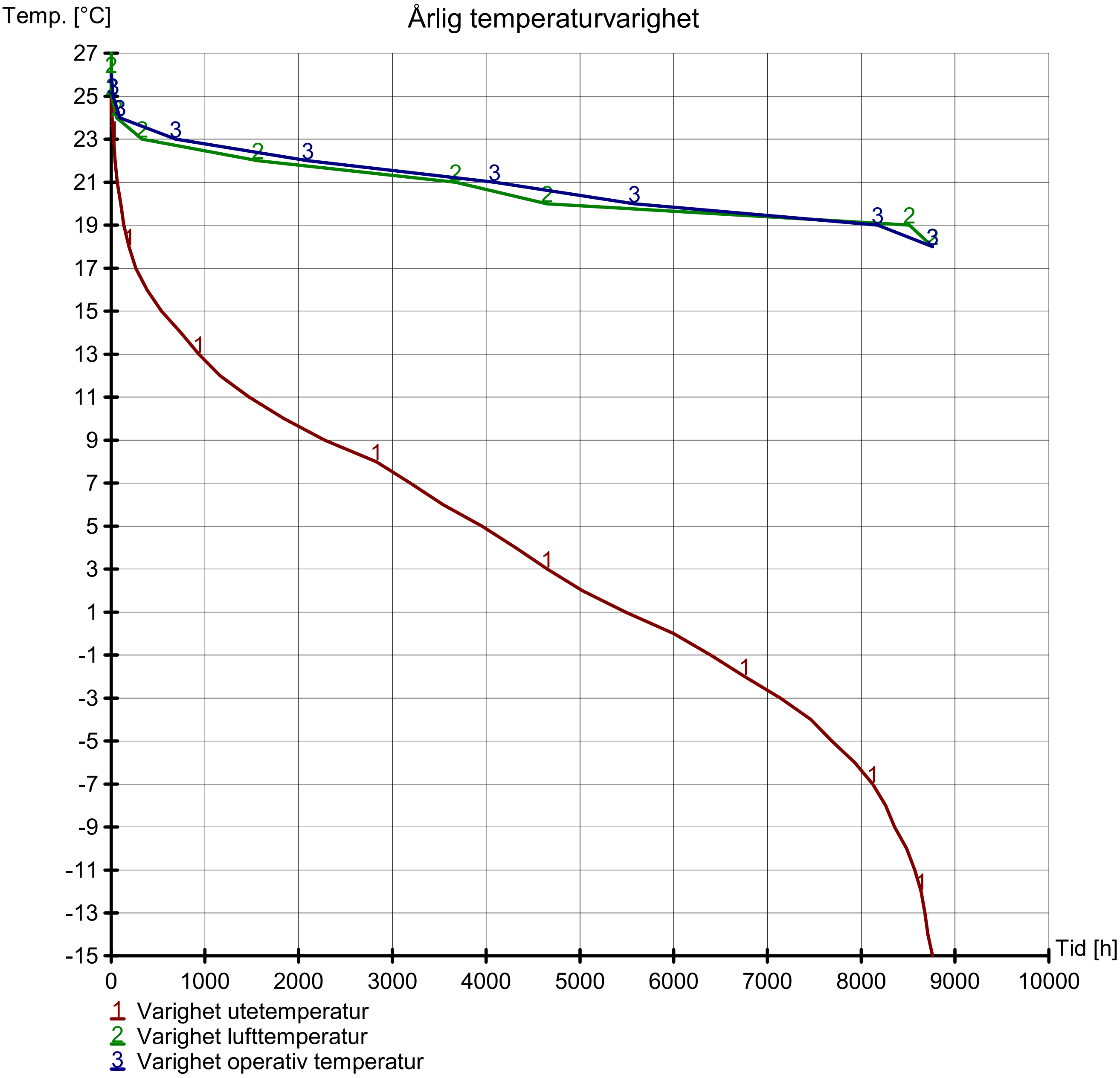

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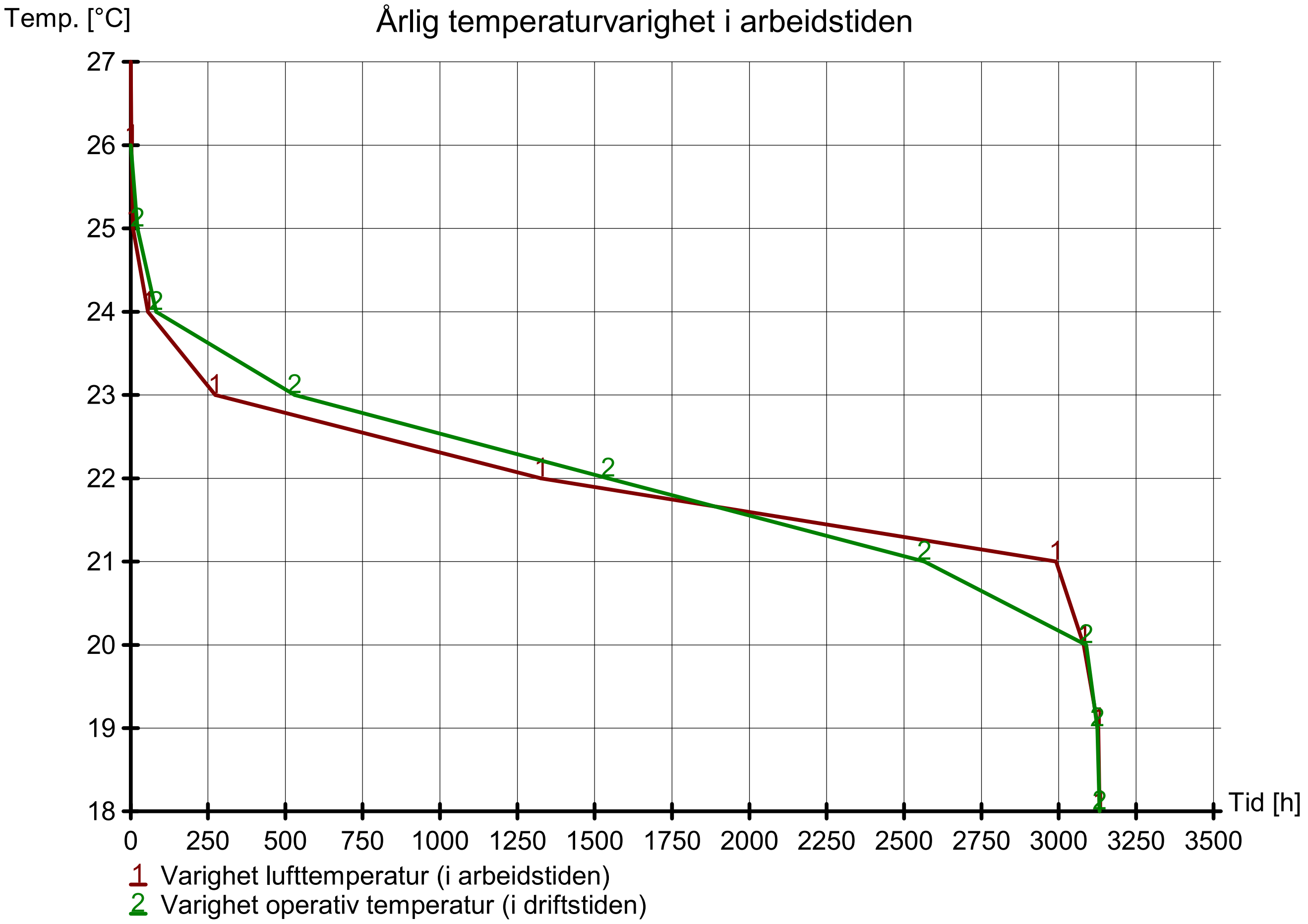

Årlig varighet operativ temperatur i arbeidstiden	
Beskrivelse	Operativ temperatur
Antall timer over 26°C	0

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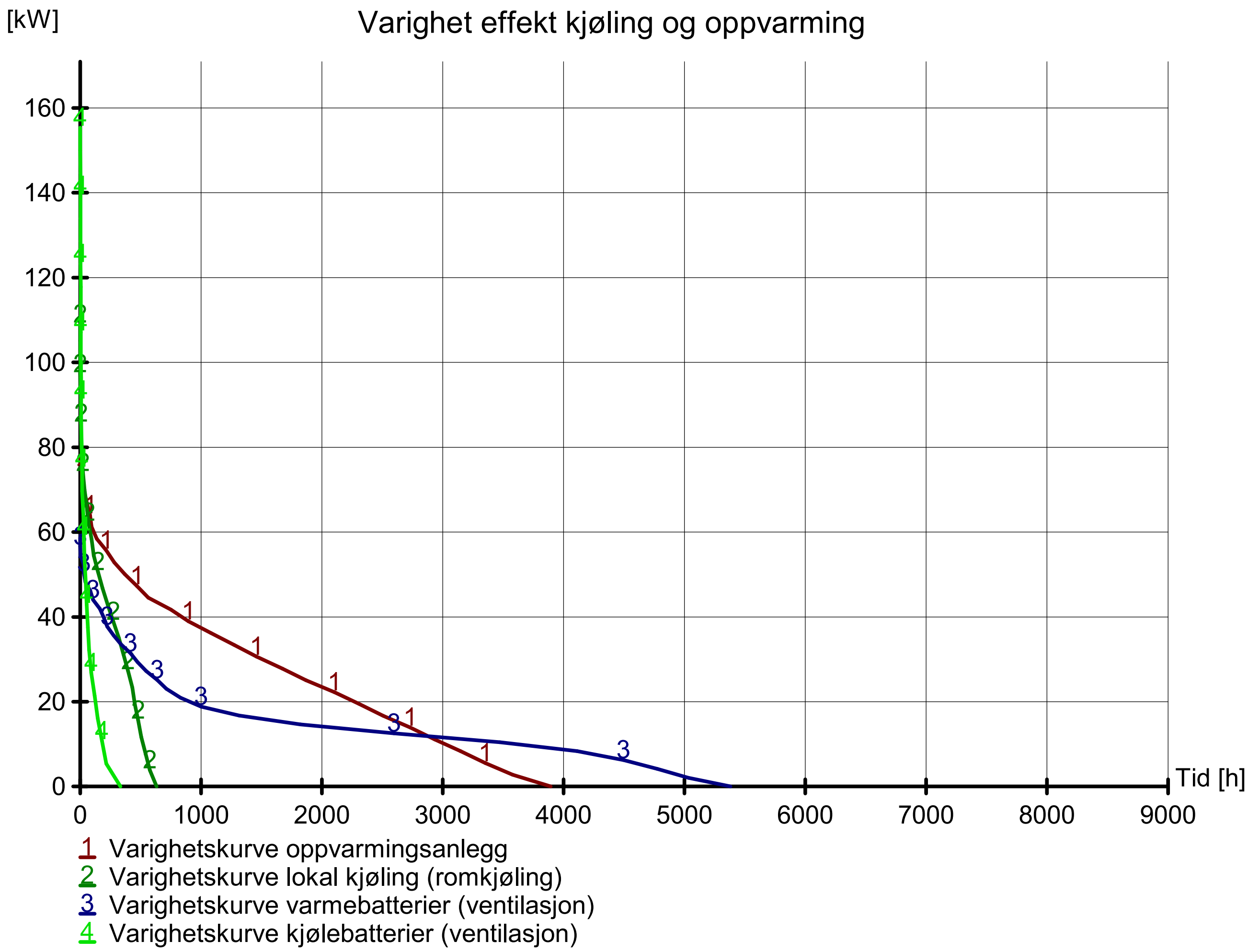

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Dekningsgrad effekt/energi oppvarming

Effekt (dekning)	Dekningsgrad energibruk
104 kW (90 %)	100 %
92 kW (80 %)	100 %
81 kW (70 %)	99 %
69 kW (60 %)	98 %
58 kW (50 %)	94 %
46 kW (40 %)	86 %
35 kW (30 %)	74 %
23 kW (20 %)	55 %
12 kW (10 %)	31 %
Nødvendig effekt til oppvarming av tappevann er ikke inkludert	-

Dokumentasjon av sentrale inndata (1)

Beskrivelse	Verdi	Dokumentasjon
Areal yttervegger [m²]:	1707	
Areal tak [m²]:	1000	
Areal gulv [m²]:	1000	
Areal vinduer og ytterdører [m²]:	568	
Oppvarmet bruksareal (BRA) [m²]:	5000	
Oppvarmet luftvolum [m³]:	15000	
U-verdi yttervegger [W/m²K]	0,21	
U-verdi tak [W/m²K]	0,18	
U-verdi gulv [W/m²K]	0,16	
U-verdi vinduer og ytterdører [W/m²K]	1,00	
Areal vinduer og dører delt på bruksareal [%]	11,4	
Normalisert kuldebroverdi [W/m²K]:	0,12	
Normalisert varmekapasitet [Wh/m²K]	49	
Lekkasjetall (n50) [1/h]:	1,50	
Temperaturvirkningsgr. varmegjenvinner [%]:	80	

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Dokumentasjon av sentrale inndata (2)

Beskrivelse	Verdi	Dokumentasjon
Estimert virkningsgrad gjenvinner justert for frostsikring [%]:	80,0	
Spesifikk vifteeffekt (SFP) [kW/m³/s]:	1,50	
Luftmengde i driftstiden [m³/hm²]	7,00	
Luftmengde utenfor driftstiden [m³/hm²]	2,00	
Systemvirkningsgrad oppvarmingsanlegg:	2,10	
Installert effekt romoppv. og varmebatt. [W/m²]:	80	
Settpunkttemperatur for romoppvarming [°C]	20,0	
Systemeffektfaktor kjøling:	2,50	
Settpunkttemperatur for romkjøling [°C]	22,0	
Installert effekt romkjøling og kjølebatt. [W/m²]:	70	
Spesifikk pumpeeffekt romoppvarming [kW/(l/s)]:	0,50	
Spesifikk pumpeeffekt romkjøling [kW/(l/s)]:	0,60	
Spesifikk pumpeeffekt varmebatteri [kW/(l/s)]:	0,50	
Spesifikk pumpeeffekt kjølebatteri [kW/(l/s)]:	0,60	
Driftstid oppvarming (timer)	12,0	

Dokumentasjon av sentrale inndata (3)

Beskrivelse	Verdi	Dokumentasjon
Driftstid kjøling (timer)	12,0	
Driftstid ventilasjon (timer)	12,0	
Driftstid belysning (timer)	12,0	
Driftstid utstyr (timer)	12,0	
Oppholdstid personer (timer)	12,0	
Effektbehov belysning i driftstiden [W/m²]	6,40	
Varmetilskudd belysning i driftstiden [W/m²]	6,40	
Effektbehov utstyr i driftstiden [W/m²]	11,00	
Varmetilskudd utstyr i driftstiden [W/m²]	11,00	
Effektbehov varmtvann på driftsdager [W/m²]	0,80	
Varmetilskudd varmtvann i driftstiden [W/m²]	0,00	
Varmetilskudd personer i oppholdstiden [W/m²]	4,00	
Total solfaktor for vindu og solskjerming:	0,38	
Gjennomsnittlig karmfaktor vinduer:	0,20	
Solskjermingsfaktor horisont/utspring (N/Ø/S/V):	1,00/1,00/1,00/1,00	

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Inndata bygning

Beskrivelse	Verdi
Bygningskategori	Kontorbygg
Simuleringsansvarlig	N.B.Alseth _L.Andersen
Kommentar	

Inndata klima

Beskrivelse	Verdi
Klimasted	Narvik
Breddegrad	68° 16'
Lengdegrad	17° 15'
Tidssone	GMT + 1
Årsmiddeltemperatur	3,8 °C
Midlere solstråling horisontal flate	77 W/m²
Midlere vindhastighet	4,4 m/s

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Inndata energiforsyning

Beskrivelse	Verdi
1a Direkte el.	Systemvirkningsgrad romoppv,: 0,81 Systemvirkningsgrad varmtvann: 1,00 Systemvirkningsgrad varmebatterier: 0,88 Kjølefaktor romkjøling: 2,50 Kjølefaktor kjølebatterier: 2,50 Energipris: 0,80 kr/kWh CO2-utslipp: 130 g/kWh Andel romoppvarming: 15,0% Andel oppv, tappevann: 30,0% Andel varmebatteri: 0,0 % Andel kjølebatteri: 100,0 % Andel romkjøling: 100,0 % Andel el, spesifikt: 100,0 %
1b El. til varmepumpesystem	Systemvirkningsgrad romoppv,: 2,45 Systemvirkningsgrad varmtvann: 2,60 Systemvirkningsgrad varmebatterier: 2,67 Kjølefaktor romkjøling: 2,50 Kjølefaktor kjølebatterier: 2,50 Energipris: 0,80 kr/kWh CO2-utslipp: 130 g/kWh Andel romoppvarming: 85,0% Andel oppv, tappevann: 70,0% Andel varmebatteri: 100,0 % Andel kjølebatteri: 0,0 % Andel romkjøling: 0,0 % Andel el, spesifikt: 0,0 %

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Inndata ekspertverdier

Beskrivelse	Verdi
Konvektiv andel varmetilskudd belysning	0,30
Konvektiv andel varmetilsk. teknisk utstyr	0,50
Konvektiv andel varmetilsikudd personer	0,50
Konvektiv andel varmetilsikudd sol	0,50
Konvektiv varmoverføringskoeff. vegger	2,50
Konvektiv varmoverføringskoeff. himling	2,00
Konvektiv varmoverføringskoeff. gulv	3,00
Bypassfaktor kjølebatteri	0,25
Innv. varmemotstand på vinduruter	0,13
Midlere lufthastighet romluft	0,15
Turbulensintensitet romluft	25,00
Avstand fra vindu	0,60
Termisk konduktivitet akk. sjikt [W/m²K]:	20,00

Inndata rom/sone

Beskrivelse	Verdi
Oppvarmet gulvareal	5000,0 m²
Oppvarmet luftvolum	15000,0 m³
Normalisert kuldebroverdi	0,12 W/(m²K)
Varmekapasitet møbler/interiør	2,0 Wh/m² (Lett møblert rom)
Lekkasjetall (luftskifte v. 50pa)	1,50 ach
Skjerming i terrenget	Moderat skjerming
Fasadesituasjon	Flere eksponerte fasader
Driftsdager i Januar	21
Driftsdager i Februar	20
Driftsdager i Mars	23
Driftsdager i April	22
Driftsdager i Mai	21
Driftsdager i Juni	22
Driftsdager i Juli	22
Driftsdager i August	22
Driftsdager i September	22
Driftsdager i Oktober	21
Driftsdager i November	22
Driftsdager i Desember	23

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Inndata oppvarming

Beskrivelse	Verdi
Navn:	Heating (oppvarming)
Settpunkttemperatur i driftstid	21,0 °C
Settpunkttemperatur utenfor driftstiden	19,0 °C
Maks. kapasitet	50 W/m^2
Konvektiv andel oppvarming	0,50
Driftstid	12:00 timer drift pr døgn
Vannbårent oppvarmingsanlegg	Ja
Turtemperatur	35,0 °C
Returtemperatur	30,0 °C
Spesifikk pumpeeffekt	0,50 kW/(l/s)

Inndata CAV

Beskrivelse	Verdi
Navn:	Ventilation (CAV ventilasjon)
Ventilasjonstype	Balansert ventilasjon
Driftstid	12:00 timer drift pr døgn
Luftmengde	I driftstiden: tilluft = 7.0 m^3/hm^2, avtrekk = 7.0 m^3/hm^2 Utenfor driftstiden: tilluft = 2.0 m^3/hm^2, avtrekk = 2.0 m^3/hm^2 Helg/feridag: tilluft = 2.0 m^3/hm^2, avtrekk = 2.0 m^3/hm^2
Tilluftstemperatur	Normal: 19.0 °C Fra Mai til August: 17.0 °C
Varmebatteri	Ja Maks. kapasitet: 30 W/m^2
Vannbåren distribusjon til varmebatteri	Delta-T: 30.0 °C SPP: 0.5 kW/(l/s)
Kjølebatteri	
Vannbåren distribusjon til kjølebatteri	Delta-T: 6.0 °C SPP: 0.6 kW/(l/s)
Varmegjenvinner	Ja, temperaturvirkningsgrad: 0.80
Vifter	Plassering tilluftsvifte: Etter gjenvinner Plassering avtrekksvifte: Etter gjenvinner
SFP-faktor vifter	1.50 $kW/m^3/s$

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Inndata belysning

Beskrivelse	Verdi
Navn:	Internal Loads (internlaster, belysning)
Effekt/Varmetilskudd belysning	I driftstiden; Effekt: 6,4 W/m²; Varmetilskudd: 100 % Utenfor driftstiden; Effekt: 0,0 W/m²; Varmetilskudd: 100 % På helg/feriedager; Effekt: 0,0 W/m²; Varmetilskudd: 100 % Antall timer drift pr døgn: 12:00

Inndata teknisk utstyr (internlast)

Beskrivelse	Verdi
Navn:	Internal Loads (internlaster, teknisk utstyr)
Effekt/Varmetilskudd teknisk utstyr	I driftstiden; Effekt: 11,0 W/m²; Varmetilskudd: 100 % Utenfor driftstiden; Effekt: 0,0 W/m²; Varmetilskudd: 100 % På helg/feriedager; Effekt: 0,0 W/m²; Varmetilskudd: 100 % Antall timer drift pr døgn: 12:00

Inndata oppvarming av tappevann

Beskrivelse	Verdi
Navn:	Internal Loads (internlaster, tappevann)
Tappevann	Driftsdag; Midlere effekt: 0,8 W/m²; Varmetilskudd: 0 %; Vanndamp: 0,0 g/m² Helg/feriedag: Midlere effekt: 0,0 W/m²; Varmetilskudd: 0 %; ; Vanndamp: 0,0 g/m²

Inndata varmetilskudd personer (internlast)

Beskrivelse	Verdi
Navn:	Internal Loads (internlaster, varmetilskudd personer)
Varmetilskudd personer	I arbeidstiden: 4,0 W/m² Utenfor arbeidstiden: 0,0 W/m² Ferie/helgedager: 0,0 W/m² Antall arbeidstimer: 12:00

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Inndata lokal kjøling

Beskrivelse	Verdi
Navn:	Cooling (lokal kjøling)
Settpunkttemperatur	22,0 °C
Maks, kapasitet	40 W/m²
Konvektiv andel kjøling	0,50
Driftstid	12:00 timer drift pr døgn
Kjøling på helge/feriedager	Nei
Kjøling via vannbårent anlegg	Nei
Kjølingen er bare aktiv i deler av året	Startdato: 1. Juni Stoppdato: 1. September

Inndata fasade/yttervegg

Beskrivelse	Verdi
Navn:	South Facade (fasade)
Totalt areal	437,5 m²
Retning (0=Nord, 180=Sør)	180°
Innv. akkumulerende sjikt	Tung vegg Varmekapasitet 63,0 Wh/m²K
Konstruksjon	Egendefinert Uverdi: 0,21 W/m²K
Utvendig absorptionskoeffisient	0,80

Inndata vinduselement

Beskrivelse	Verdi
Navn:	Window 1 (Vindu(er) på South Facade)
Antall vinduer	38
Høyde vindu(er)	1,80 m
Bredde vindu(er)	1,80 m
Karm-/ramme faktor	0,20
Total U-verdi (rute+karm/rammekonstr.)	1,00 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

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Inndata vinduselement

Beskrivelse	Verdi
Navn:	Window 2 (Vindu(er) på South Facade)
Antall vinduer	2
Høyde vindu(er)	1,50 m
Bredde vindu(er)	2,60 m
Karm-/ramme faktor	0,20
Total U-verdi (rute+karm/rammekonstr.)	1,00 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

Inndata vinduselement

Beskrivelse	Verdi
Navn:	Window 3 (Vindu(er) på South Facade)
Antall vinduer	1
Høyde vindu(er)	2,10 m
Bredde vindu(er)	0,50 m
Karm-/ramme faktor	0,20
Total U-verdi (rute+karm/rammekonstr.)	1,00 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

Inndata ytterdør

Beskrivelse	Verdi
Navn:	Door 1 (ytterdør)
Areal inkl. karm/ramme	4,4 m²
Dørtype	Egendefinert Uverdi: 1,20 W/m²K

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Inndata fasade/yttervegg

Beskrivelse	Verdi
Navn:	West Facade (fasade)
Totalt areal	700,0 m²
Retning (0=Nord, 180=Sør)	270°
Innv. akkumulerende sjikt	Tung vegg Varmekapasitet 63,0 Wh/m²K
Konstruksjon	Egendefinert Uverdi: 0,21 W/m²K

Inndata vinduselement

Beskrivelse	Verdi
Navn:	Window 1 (Vindu(er) på West Facade)
Antall vinduer	50
Høyde vindu(er)	1,80 m
Bredde vindu(er)	1,80 m
Karm-/ramme faktor	0,20
Total U-verdi (rute+karm/rammekonstr.)	1,00 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

Inndata fasade/yttervegg

Beskrivelse	Verdi
Navn:	North Facade (fasade)
Totalt areal	437,5 m²
Retning (0=Nord, 180=Sør)	0°
Innv. akkumulerende sjikt	Tung vegg Varmekapasitet 63,0 Wh/m²K
Konstruksjon	Egendefinert Uverdi: 0,21 W/m²K

Simuleringsnavn: Årssimulering
Tid/dato simulering: 19:47 13/5-2018
Programversjon: 6.009
Simuleringsansvarlig: N.B.Alseth & L.Andersen
Firma: Undervisningslisens
Inndatafil: C:\...\NB in Narvik.smi
Prosjekt: Standard Office Building
Sone: Norwegian Building in Narvik

Inndata vinduselement

Beskrivelse	Verdi
Navn:	Window 1 (Vindu(er) på North Facade)
Antall vinduer	40
Høyde vindu(er)	1,80 m
Bredde vindu(er)	1,80 m
Karm-/ramme faktor	0,20
Total U-verdi (rute+karm/rammekonstr.)	1,00 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

Inndata fasade/yttervegg

Beskrivelse	Verdi
Navn:	East Facade (fasade)
Totalt areal	700,0 m²
Retning (0=Nord, 180=Sør)	90°
Innv. akkumulerende sjikt	Tung vegg Varmekapasitet 63,0 Wh/m²K
Konstruksjon	Egendefinert Uverdi: 0,21 W/m²K

Inndata vinduselement

Beskrivelse	Verdi
Navn:	Window 1 (Vindu(er) på East Facade)
Antall vinduer	39
Høyde vindu(er)	1,80 m
Bredde vindu(er)	1,80 m
Karm-/ramme faktor	0,20
Total U-verdi (rute+karm/rammekonstr.)	1,00 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

Simuleringsnavn: Årssimulering
Tid/dato simulering: 19:47 13/5-2018
Programversjon: 6.009
Simuleringsansvarlig: N.B.Alseth & L.Andersen
Firma: Undervisningslisens
Inndatafil: C:\...\NB in Narvik.smi
Prosjekt: Standard Office Building
Sone: Norwegian Building in Narvik

Inndata vinduselement

Beskrivelse	Verdi
Navn:	Window 4 (Vindu(er) på East Facade)
Antall vinduer	9
Høyde vindu(er)	1,80 m
Bredde vindu(er)	0,50 m
Karm-/ramme faktor	0,20
Total U-verdi (rute+karm/rammekonstr.)	1,00 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

Inndata vinduselement

Beskrivelse	Verdi
Navn:	Window 5 (Vindu(er) på East Facade)
Antall vinduer	1
Høyde vindu(er)	2,60 m
Bredde vindu(er)	1,00 m
Karm-/ramme faktor	0,20
Total U-verdi (rute+karm/rammekonstr.)	1,00 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

Inndata vinduselement

Beskrivelse	Verdi
Navn:	Window 6 (Vindu(er) på East Facade)
Antall vinduer	1
Høyde vindu(er)	0,50 m
Bredde vindu(er)	1,00 m
Karm-/ramme faktor	0,20
Total U-verdi (rute+karm/rammekonstr.)	1,00 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

Simuleringsnavn: Årssimulering
Tid/dato simulering: 19:47 13/5-2018
Programversjon: 6.009
Simuleringsansvarlig: N.B.Alseth & L.Andersen
Firma: Undervisningslisens
Inndatafil: C:\...\NB in Narvik.smi
Prosjekt: Standard Office Building
Sone: Norwegian Building in Narvik

Inndata ytterdør

Beskrivelse	Verdi
Navn:	Door 2 (ytterdør)
Areal inkl. karm/ramme	2,1 m²
Dørtype	Egendefinert Uverdi: 1,20 W/m²K

Inndata gulv mot friluft/kryprom/grunn

Beskrivelse	Verdi
Navn:	Floor (gulv)
Oppvarmet gulvareal	1000,0 m²
Gulvtype	Gulv mot uoppvarmet sone
Uoppvarmet sone	Ventilert uoppvarmet parkeringskjeller Varmetapsfaktor: 0,91
Innv. akk. sjikt gulv	Tungt gulv Varmekapasitet 63,0 Wh/m²K
Gulvkonstruksjon	Egendefinert Uverdi: 0,18 W/m²K

Inndata yttertak

Beskrivelse	Verdi
Navn:	Roof (yttertak)
Totalt areal	1000,0 m²
Retning (0=Nord, 180=Sør)	180°
Takvinkel	0,0°
Innv. akkumulerende sjikt	Tung himling Varmekapasitet 63,0 Wh/m²K
Konstruksjon	Egendefinert Uverdi: 0,18 W/m²K
Utvendig absorptionskoeffisient	0,80

SIMIEN
Resultater årssimulering

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Tid/dato simulering: 11:41 13/5-2018
Programversjon: 6.009
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Firma: Undervisningslisens
Inndatafil: C:\...\JB in Sapporo.smi
Prosjekt: Standard Office Building
Sone: Japanese Building in Sapporo

Energibudsjett		
Energipost	Energibehov	Spesifikt energibehov
1a Romoppvarming	122341 kWh	24,5 kWh/m²
1b Ventilasjonsvarme (varmebatterier)	124093 kWh	24,8 kWh/m²
2 Varmtvann (tappevann)	27562 kWh	5,5 kWh/m²
3a Vifter	40060 kWh	8,0 kWh/m²
3b Pumper	1404 kWh	0,3 kWh/m²
4 Belysning	203617 kWh	40,7 kWh/m²
5 Teknisk utstyr	203617 kWh	40,7 kWh/m²
6a Romkjøling	328801 kWh	65,8 kWh/m²
6b Ventilasjonskjøling (kjølebatterier)	6879 kWh	1,4 kWh/m²
Totalt netto energibehov, sum 1-6	1058375 kWh	211,7 kWh/m²

Levert energi til bygningen (beregnet)		
Energivare	Levert energi	Spesifikk levert energi
1a Direkte el.	489835 kWh	98,0 kWh/m²
1b El. til varmepumpesystem	193545 kWh	38,7 kWh/m²
1c El. til solfangersystem	0 kWh	0,0 kWh/m²
2 Olje	0 kWh	0,0 kWh/m²
3 Gass	0 kWh	0,0 kWh/m²
4 Fjernvarme	0 kWh	0,0 kWh/m²
5 Biobrensel	0 kWh	0,0 kWh/m²
6. Annen energikilde	0 kWh	0,0 kWh/m²
7. Solstrøm til egenbruk	-0 kWh	-0,0 kWh/m²
Totalt levert energi, sum 1-7	683379 kWh	136,7 kWh/m²
Solstrøm til eksport	-0 kWh	-0,0 kWh/m²
Netto levert energi	683379 kWh	136,7 kWh/m²

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Prosjekt: Standard Office Building
Sone: Japanese Building in Sapporo

Dekning av energibudsjett fordelt på energikilder

Energikilder	Romoppv.	Varmebatterier	Varmtvann	Kjølebatterier	Romkjøling	El. spesifikt
El.	0,0 kWh/m²	0,0 kWh/m²	5,5 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	89,7 kWh/m²
Olje	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Gass	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Fjernvarme	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Biobrensel	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Varmepumpe	24,5 kWh/m²	24,8 kWh/m²	0,0 kWh/m²	1,4 kWh/m²	65,8 kWh/m²	0,0 kWh/m²
Sol	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Annen	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Sum	24,5 kWh/m²	24,8 kWh/m²	5,5 kWh/m²	1,4 kWh/m²	65,8 kWh/m²	89,7 kWh/m²

Årlige utslipp av CO2

Energivare	Utslipp	Spesifikt utslipp
1a Direkte el.	313494 kg	62,7 kg/m²
1b El. til varmepumpesystem	123869 kg	24,8 kg/m²
1c El. til solfangersystem	0 kg	0,0 kg/m²
2 Olje	0 kg	0,0 kg/m²
3 Gass	0 kg	0,0 kg/m²
4 Fjernvarme	0 kg	0,0 kg/m²
5 Biobrensel	0 kg	0,0 kg/m²
6. Annen energikilde	0 kg	0,0 kg/m²
7. Solstrøm til egenbruk	-0 kg	-0,0 kg/m²
Totalt utslipp, sum 1-7	437363 kg	87,5 kg/m²
Solstrøm til eksport	-0 kg	-0,0 kg/m²
Netto CO2-utslipp	437363 kg	87,5 kg/m²

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Kostnad kjøpt energi

Energivare	Energikostnad	Spesifikk energikostnad
1a Direkte el.	651480 kr	130,3 kr/m²
1b El. til varmepumpesystem	257415 kr	51,5 kr/m²
1c El. til solfangersystem	0 kr	0,0 kr/m²
2 Olje	0 kr	0,0 kr/m²
3 Gass	0 kr	0,0 kr/m²
4 Fjernvarme	0 kr	0,0 kr/m²
5 Biobrensel	0 kr	0,0 kr/m²
6. Annen energikilde	0 kr	0,0 kr/m²
7. Solstrøm til egenbruk	-0 kr	-0,0 kr/m²
Årlige energikostnader, sum 1-7	908895 kr	181,8 kr/m²
Solstrøm til eksport	0 kr	0,0 kr/m²
Netto energikostnad	908895 kr	181,8 kr/m²

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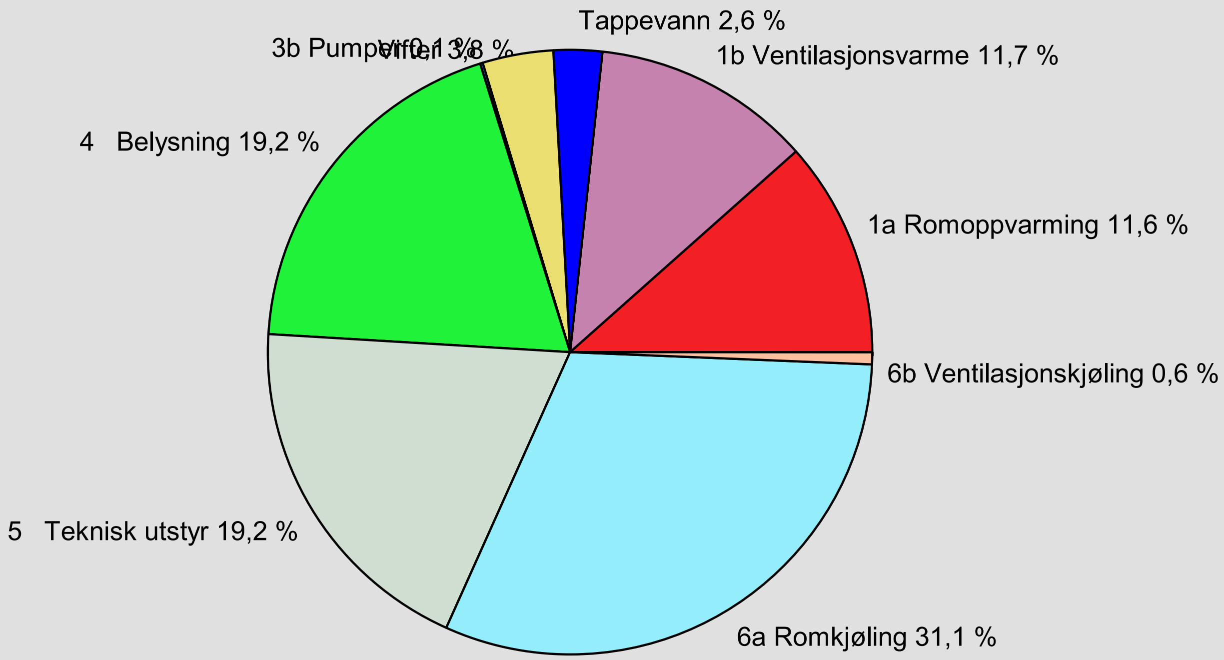
Årlig energibudsjett



1a Romoppvarming	122341 kWh
1b Ventilasjonsvarme (varmebatterier)	124093 kWh
2 Varmtvann (tappevann)	27562 kWh
3a Vifter	40060 kWh
3b Pumper	1404 kWh
4 Belysning	203617 kWh
5 Teknisk utstyr	203617 kWh
6a Romkjøling	328801 kWh
6b Ventilasjonskjøling (kjølebatterier)	6879 kWh
Totalt netto energibehov, sum 1-6	1058375 kWh

SIMIEN

Resultater årssimulering

Simuleringsnavn: Årssimulering
Tid/dato simulering: 11:41 13/5-2018
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Inndatafil: C:\...\JB in Sapporo.smi
Prosjekt: Standard Office Building
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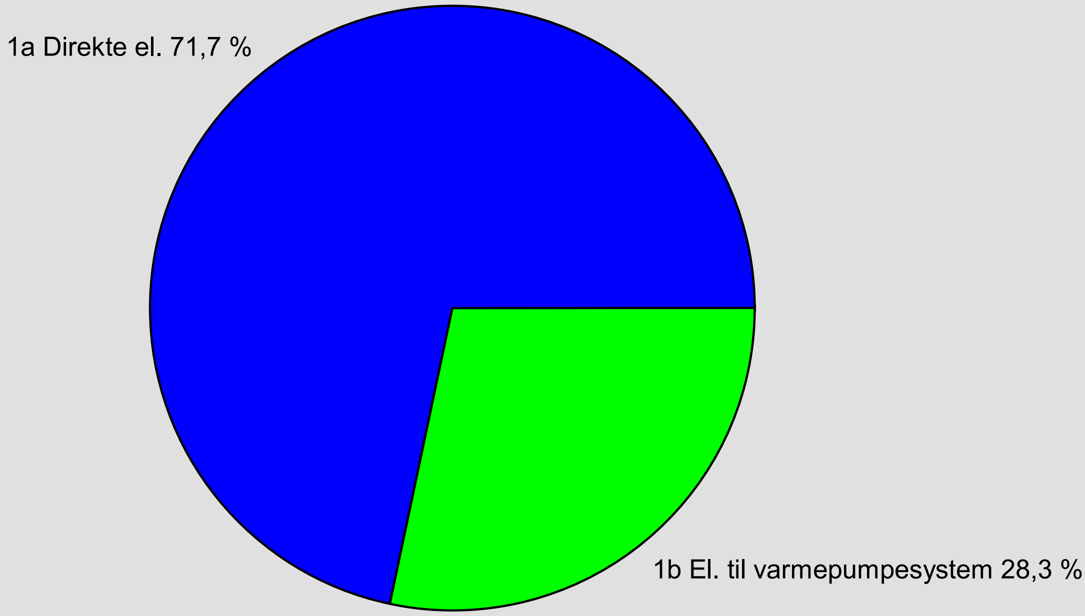
Levert energi til bygningen (beregnet)



1a Direkte el.	489835 kWh
1b El. til varmepumpesystem	193545 kWh
1c El. til solfangersystem	0 kWh
2 Olje	0 kWh
3 Gass	0 kWh
4 Fjernvarme	0 kWh
5 Biobrensel	0 kWh
6. Annen energikilde	0 kWh
Totalt levert energi, sum 1-7	683379 kWh

Simuleringsnavn: Årssimulering
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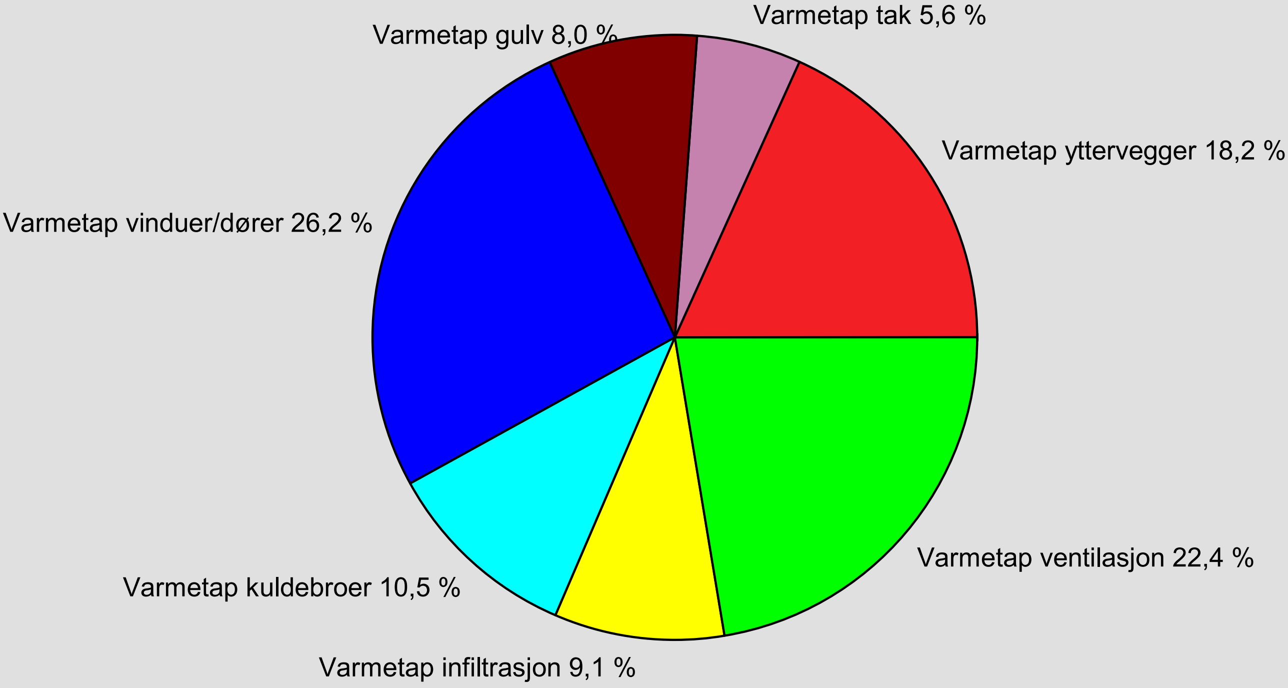
Inndatafil: C:\...\JB in Sapporo.smi
Prosjekt: Standard Office Building
Sone: Japanese Building in Sapporo

Varmetapsbudsjett (varmetapstall)



Varmetapstall yttervegger	0,21 W/m²K
Varmetapstall tak	0,06 W/m²K
Varmetapstall gulv på grunn/mot det fri	0,09 W/m²K
Varmetapstall glass/vinduer/dører	0,30 W/m²K
Varmetapstall kuldebroer	0,12 W/m²K
Varmetapstall infiltrasjon	0,10 W/m²K
Varmetapstall ventilasjon	0,26 W/m²K
Totalt varmetapstall	1,14 W/m²K

SIMIEN

Resultater årssimulering

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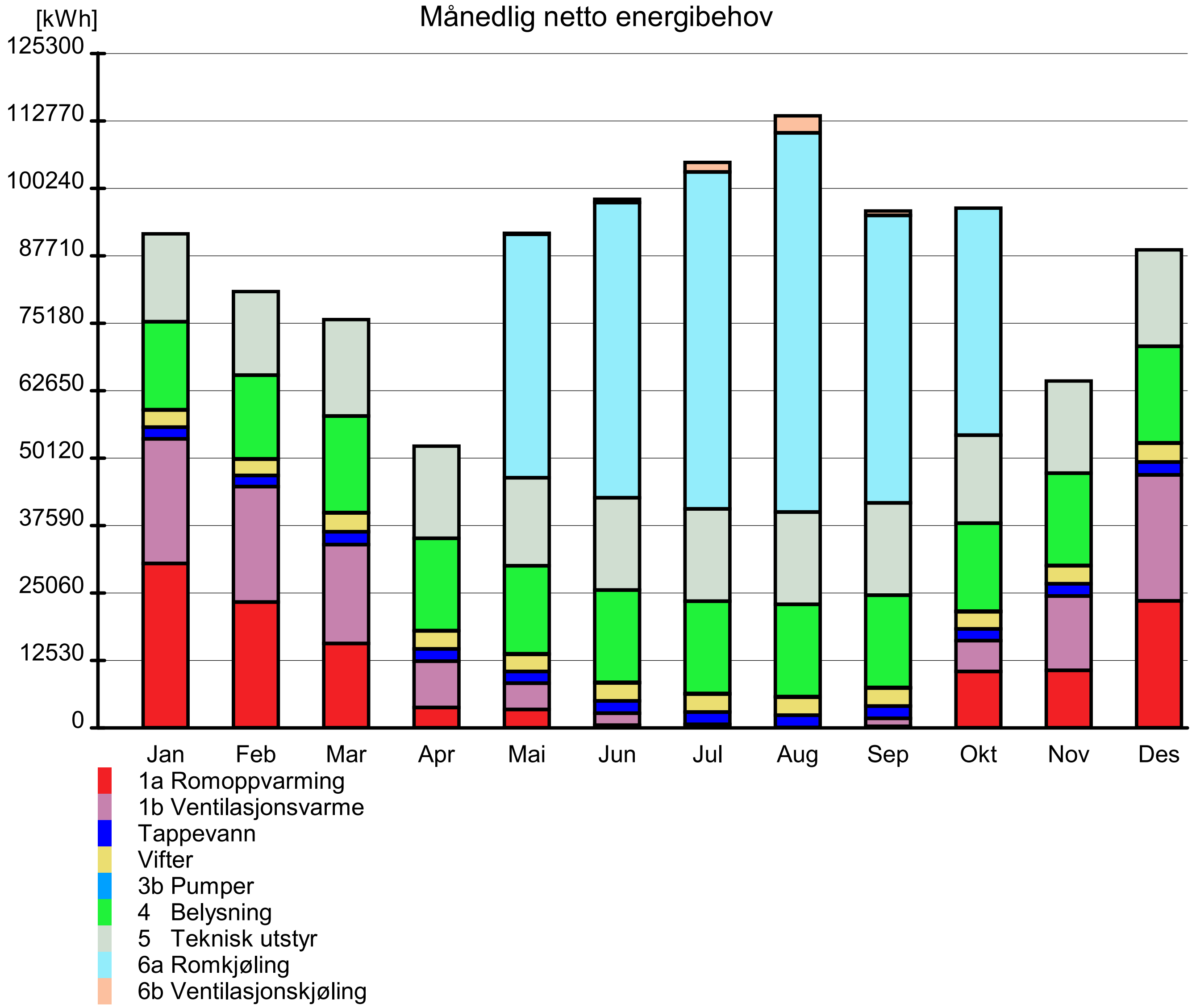

SIMIEN

Resultater årssimulering

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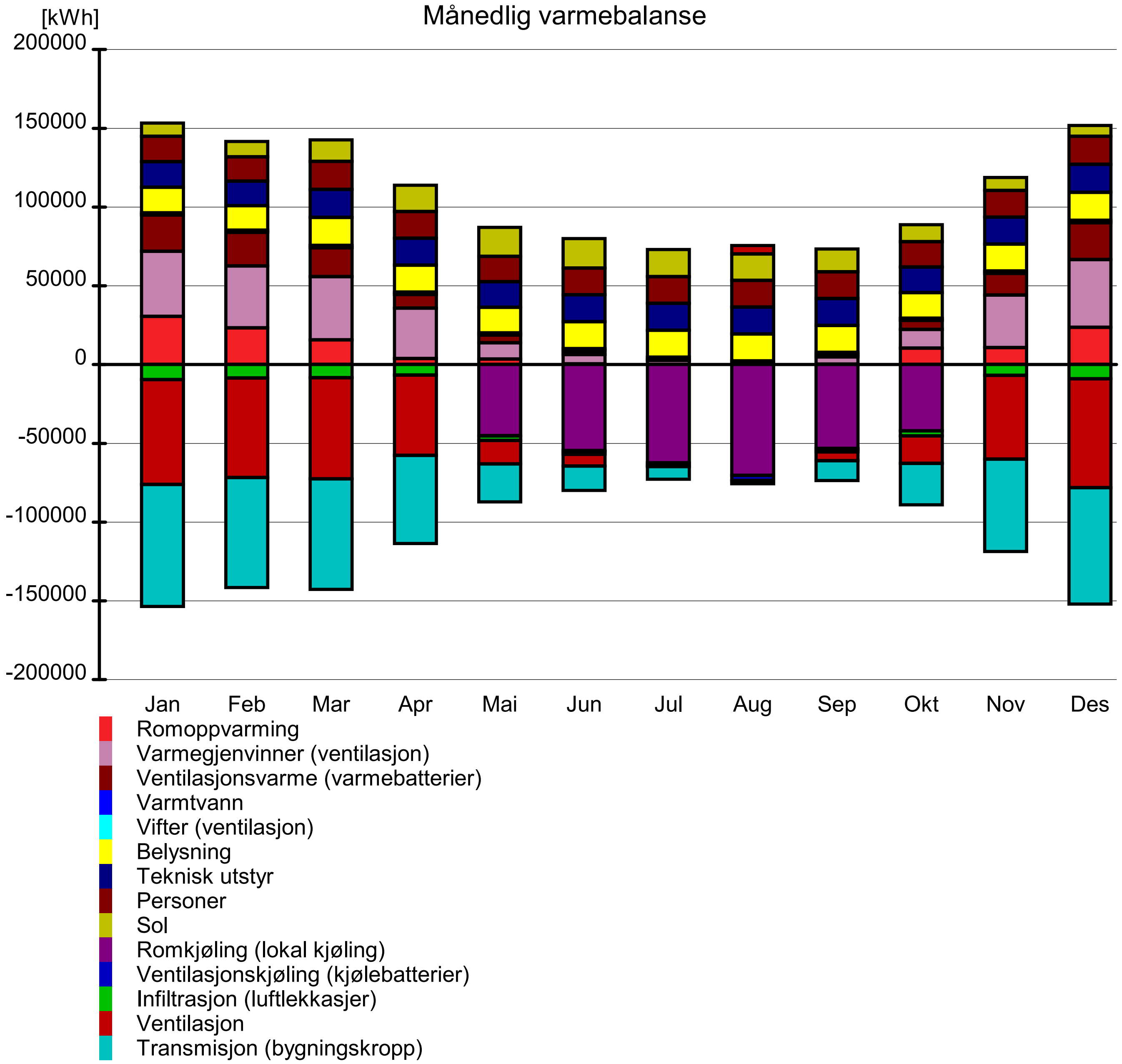

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Sone: Japanese Building in Sapporo

Månedlige temperaturdata (lufttemperatur)						
Måned	Midlere ute	Maks. ute	Min. ute	Midlere sone	Maks. sone	Min. sone
Januar	-3,3 °C	5,3 °C	-10,3 °C	22,1 °C	28,8 °C	19,0 °C
Februar	-2,8 °C	6,6 °C	-11,1 °C	22,4 °C	29,2 °C	19,0 °C
Mars	1,2 °C	12,4 °C	-7,8 °C	23,2 °C	31,3 °C	19,0 °C
April	7,4 °C	18,2 °C	-1,2 °C	25,7 °C	35,6 °C	19,0 °C
Mai	13,1 °C	25,5 °C	3,5 °C	21,0 °C	25,8 °C	19,0 °C
Juni	17,0 °C	26,7 °C	8,8 °C	21,8 °C	28,0 °C	19,0 °C
Juli	20,4 °C	32,2 °C	13,7 °C	22,6 °C	29,0 °C	20,0 °C
August	22,2 °C	30,6 °C	14,7 °C	22,8 °C	29,3 °C	20,2 °C
September	18,0 °C	27,6 °C	9,2 °C	21,8 °C	29,2 °C	19,0 °C
Oktober	12,1 °C	22,5 °C	2,8 °C	20,5 °C	23,5 °C	19,0 °C
November	4,8 °C	18,7 °C	-4,2 °C	23,8 °C	32,4 °C	19,0 °C
Desember	-1,4 °C	7,9 °C	-8,6 °C	22,5 °C	29,4 °C	19,0 °C

Månedlige temperaturdata (operativ temperatur)						
Måned	Midlere ute	Maks. ute	Min. ute	Midlere sone	Maks. sone	Min. sone
Januar	-3,3 °C	5,3 °C	-10,3 °C	22,0 °C	27,1 °C	19,0 °C
Februar	-2,8 °C	6,6 °C	-11,1 °C	22,3 °C	27,7 °C	18,9 °C
Mars	1,2 °C	12,4 °C	-7,8 °C	23,3 °C	29,8 °C	18,9 °C
April	7,4 °C	18,2 °C	-1,2 °C	26,1 °C	33,2 °C	19,0 °C
Mai	13,1 °C	25,5 °C	3,5 °C	21,1 °C	24,9 °C	20,4 °C
Juni	17,0 °C	26,7 °C	8,8 °C	21,9 °C	26,5 °C	21,2 °C
Juli	20,4 °C	32,2 °C	13,7 °C	22,7 °C	27,5 °C	21,9 °C
August	22,2 °C	30,6 °C	14,7 °C	22,9 °C	27,8 °C	21,5 °C
September	18,0 °C	27,6 °C	9,2 °C	22,0 °C	27,6 °C	20,0 °C
Oktober	12,1 °C	22,5 °C	2,8 °C	20,6 °C	22,3 °C	19,0 °C
November	4,8 °C	18,7 °C	-4,2 °C	24,0 °C	32,0 °C	18,9 °C
Desember	-1,4 °C	7,9 °C	-8,6 °C	22,5 °C	28,0 °C	19,0 °C

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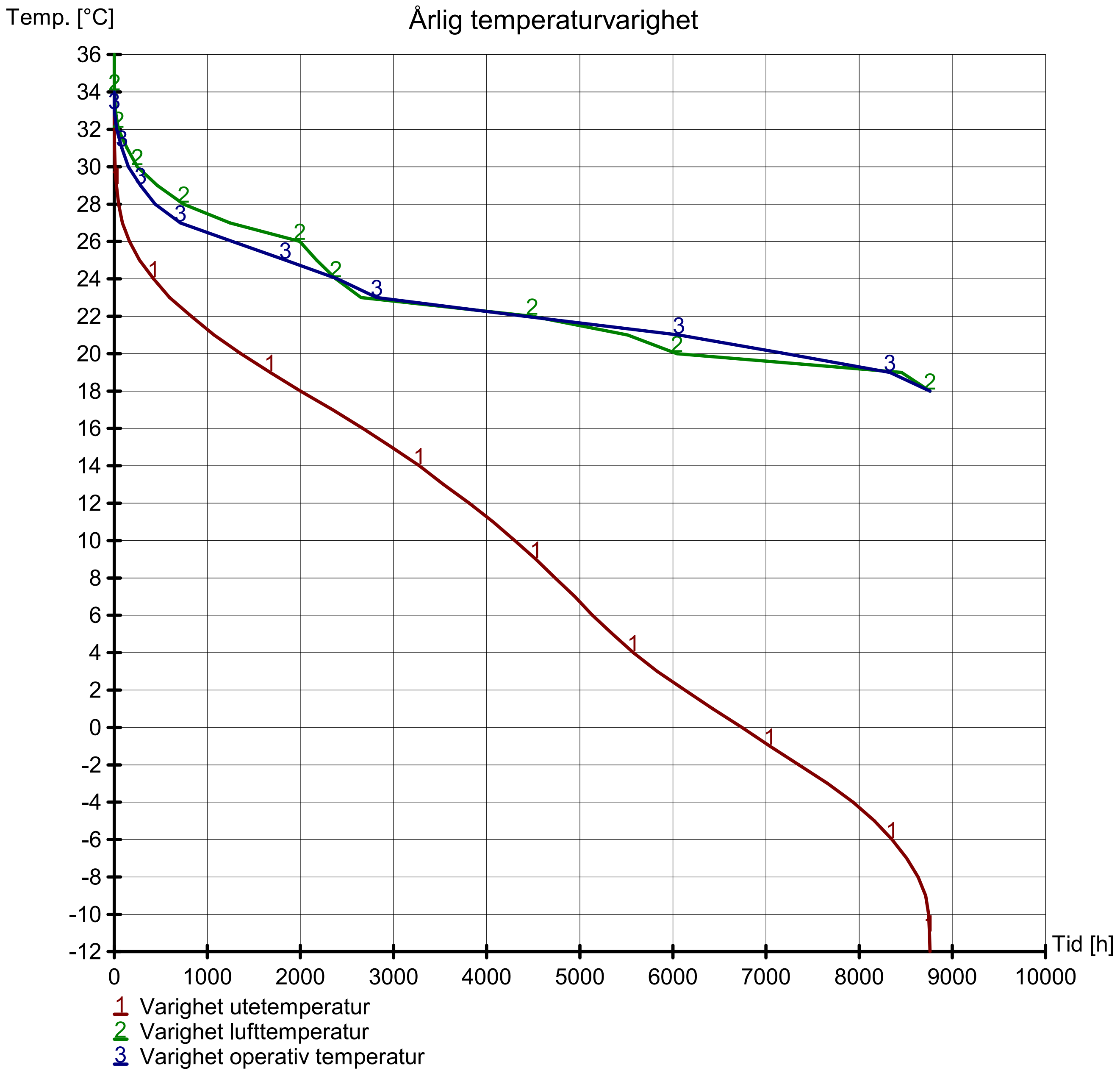

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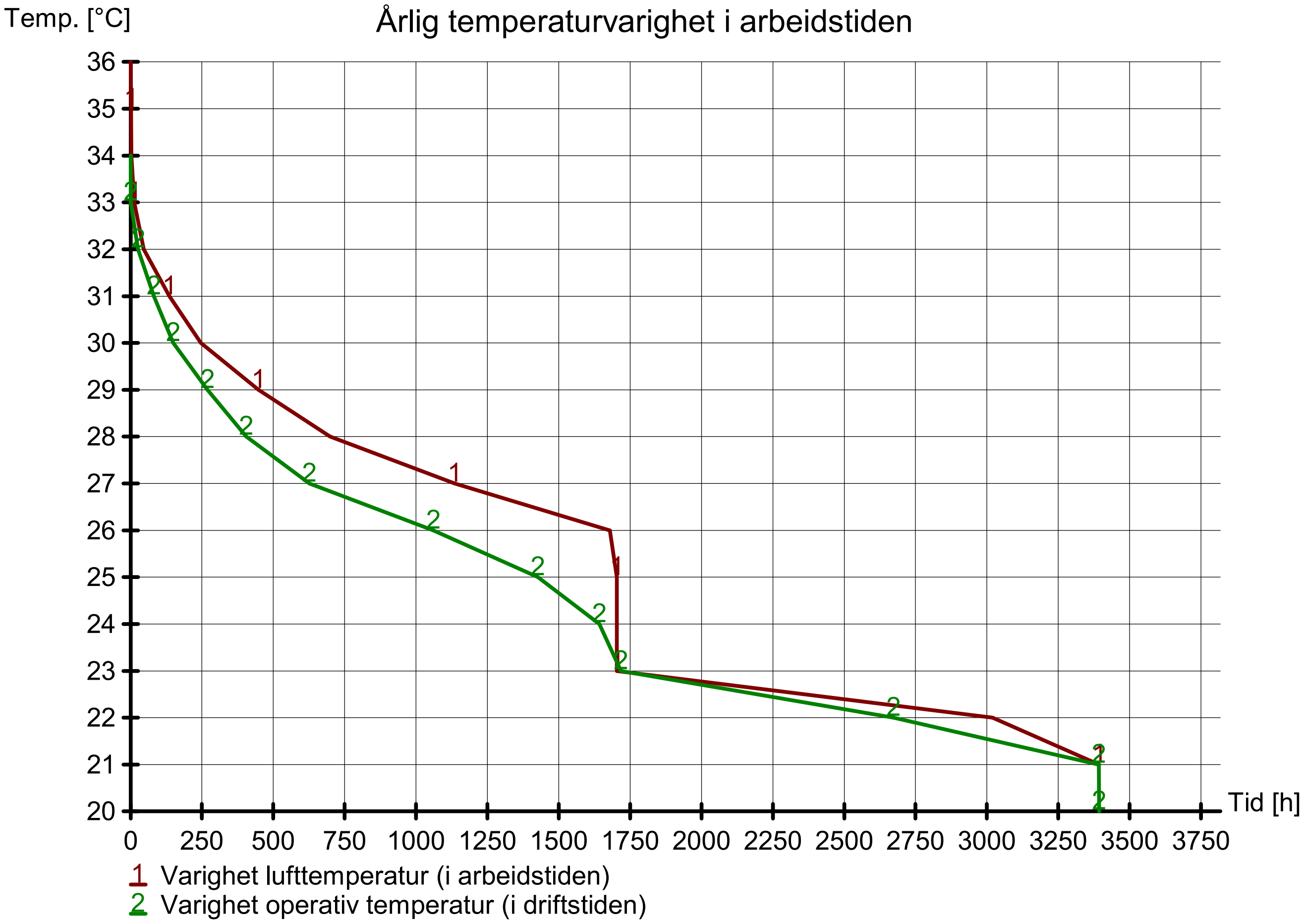

Årlig varighet operativ temperatur i arbeidstiden	
Beskrivelse	Operativ temperatur
Antall timer over 26°C	1061

SIMIEN

Resultater årssimulering

Simuleringsnavn: Årssimulering
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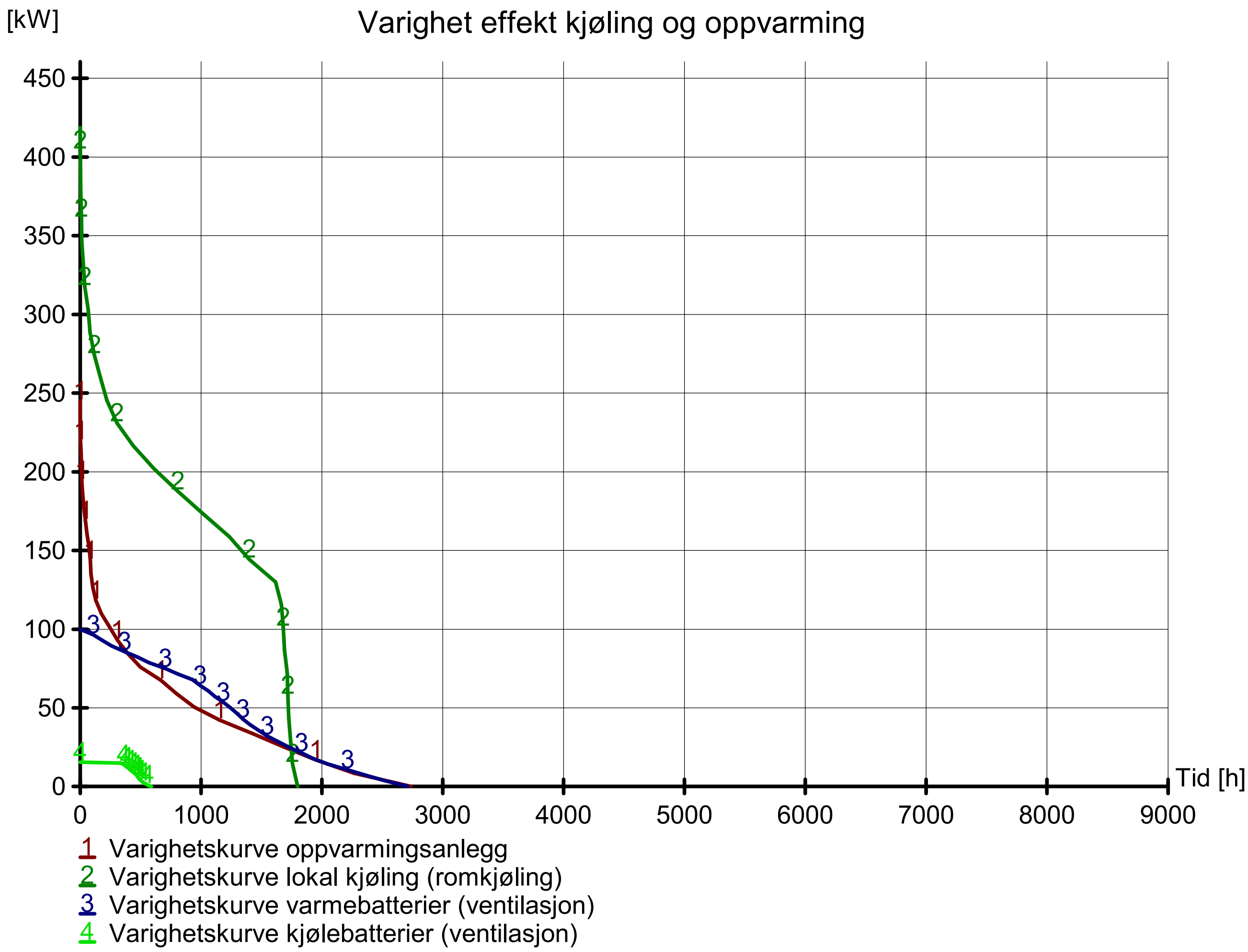

SIMIEN
Resultater årssimulering

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Dekningsgrad effekt/energi oppvarming

Effekt (dekning)	Dekningsgrad energibruk
213 kW (90 %)	100 %
189 kW (80 %)	100 %
166 kW (70 %)	100 %
142 kW (60 %)	99 %
118 kW (50 %)	98 %
95 kW (40 %)	95 %
71 kW (30 %)	86 %
47 kW (20 %)	68 %
24 kW (10 %)	40 %
Nødvendig effekt til oppvarming av tappevann er ikke inkludert	-

Dokumentasjon av sentrale inndata (1)

Beskrivelse	Verdi	Dokumentasjon
Areal yttervegger [m²]:	1707	
Areal tak [m²]:	1000	
Areal gulv [m²]:	1000	
Areal vinduer og ytterdører [m²]:	568	
Oppvarmet bruksareal (BRA) [m²]:	5000	
Oppvarmet luftvolum [m³]:	15000	
U-verdi yttervegger [W/m²K]	0,61	
U-verdi tak [W/m²K]	0,32	
U-verdi gulv [W/m²K]	0,46	
U-verdi vinduer og ytterdører [W/m²K]	2,64	
Areal vinduer og dører delt på bruksareal [%]	11,4	
Normalisert kuldebroverdi [W/m²K]:	0,12	
Normalisert varmekapasitet [Wh/m²K]	49	
Lekkasjetall (n50) [1/h]:	1,50	
Temperaturvirkningsgr. varmegjenvinner [%]:	60	

Simuleringsnavn: Årssimulering
Tid/dato simulering: 11:41 13/5-2018
Programversjon: 6.009
Simuleringsansvarlig: N.B.Alseth & L.Andersen
Firma: Undervisningslisens
Inndatafil: C:\...\JB in Sapporo.smi
Prosjekt: Standard Office Building
Sone: Japanese Building in Sapporo

Dokumentasjon av sentrale inndata (2)

Beskrivelse	Verdi	Dokumentasjon
Estimert virkningsgrad gjenvinner justert for frostsikring [%]:	60,0	
Spesifikk vifteeffekt (SFP) [kW/m³/s]:	1,70	
Luftmengde i driftstiden [m³/hm²]	5,00	
Luftmengde utenfor driftstiden [m³/hm²]	0,00	
Systemvirkningsgrad oppvarmingsanlegg:	2,09	
Installert effekt romoppv. og varmebatt. [W/m²]:	115	
Settpunkttemperatur for romoppvarming [°C]	23,1	
Systemeffektfaktor kjøling:	3,24	
Settpunkttemperatur for romkjøling [°C]	22,0	
Installert effekt romkjøling og kjølebatt. [W/m²]:	98	
Spesifikk pumpeeffekt romoppvarming [kW/(l/s)]:	0,00	
Spesifikk pumpeeffekt romkjøling [kW/(l/s)]:	0,60	
Spesifikk pumpeeffekt varmebatteri [kW/(l/s)]:	0,50	
Spesifikk pumpeeffekt kjølebatteri [kW/(l/s)]:	0,60	
Driftstid oppvarming (timer)	14,0	

Dokumentasjon av sentrale inndata (3)

Beskrivelse	Verdi	Dokumentasjon
Driftstid kjøling (timer)	14,0	
Driftstid ventilasjon (timer)	13,0	
Driftstid belysning (timer)	13,0	
Driftstid utstyr (timer)	13,0	
Oppholdstid personer (timer)	13,0	
Effektbehov belysning i driftstiden [W/m²]	12,00	
Varmetilskudd belysning i driftstiden [W/m²]	12,00	
Effektbehov utstyr i driftstiden [W/m²]	12,00	
Varmetilskudd utstyr i driftstiden [W/m²]	12,00	
Effektbehov varmtvann på driftsdager [W/m²]	0,88	
Varmetilskudd varmtvann i driftstiden [W/m²]	0,00	
Varmetilskudd personer i oppholdstiden [W/m²]	11,90	
Total solfaktor for vindu og solskjerming:	0,38	
Gjennomsnittlig karmfaktor vinduer:	0,20	
Solskjermingsfaktor horisont/utspring (N/Ø/S/V):	1,00/1,00/1,00/1,00	

SIMIEN

Resultater årssimulering

Simuleringsnavn: Årssimulering
Tid/dato simulering: 11:41 13/5-2018
Programversjon: 6.009
Simuleringsansvarlig: N.B.Alseth & L.Andersen
Firma: Undervisningslisens
Inndatafil: C:\...\JB in Sapporo.smi
Prosjekt: Standard Office Building
Sone: Japanese Building in Sapporo

Inndata bygning

Beskrivelse	Verdi
Bygningskategori	Kontorbygg
Simuleringsansvarlig	N.B.Alseth _L.Andersen
Kommentar	

Inndata klima

Beskrivelse	Verdi
Klimasted	Sapporo
Breddegrad	43° 5'
Lengdegrad	141° 18'
Tidssone	GMT + 9
Årsmiddeltemperatur	9,1 °C
Midlere solstråling horisontal flate	142 W/m²
Midlere vindhastighet	3,4 m/s

Simuleringsnavn: Årssimulering
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Inndata energiforsyning

Beskrivelse	Verdi
1a Direkte el.	Systemvirkningsgrad romoppv,: 0,81 Systemvirkningsgrad varmtvann: 0,67 Systemvirkningsgrad varmebatterier: 0,88 Kjølefaktor romkjøling: 2,50 Kjølefaktor kjølebatterier: 2,50 Energipris: 1,33 kr/kWh CO2-utslipp: 640 g/kWh Andel romoppvarming: 0,0% Andel oppv, tappevann: 100,0% Andel varmebatteri: 0,0 % Andel kjølebatteri: 0,0 % Andel romkjøling: 0,0 % Andel el, spesifikt: 100,0 %
1b El. til varmepumpesystem	Systemvirkningsgrad romoppv,: 2,74 Systemvirkningsgrad varmtvann: 2,60 Systemvirkningsgrad varmebatterier: 2,74 Kjølefaktor romkjøling: 3,24 Kjølefaktor kjølebatterier: 3,24 Energipris: 1,33 kr/kWh CO2-utslipp: 640 g/kWh Andel romoppvarming: 100,0% Andel oppv, tappevann: 0,0% Andel varmebatteri: 100,0 % Andel kjølebatteri: 100,0 % Andel romkjøling: 100,0 % Andel el, spesifikt: 0,0 %

SIMIEN
Resultater årssimulering

Simuleringsnavn: Årssimulering
Tid/dato simulering: 11:41 13/5-2018
Programversjon: 6.009
Simuleringsansvarlig: N.B.Alseth & L.Andersen
Firma: Undervisningslisens
Inndatafil: C:\...\JB in Sapporo.smi
Prosjekt: Standard Office Building
Sone: Japanese Building in Sapporo

Inndata ekspertverdier

Beskrivelse	Verdi
Konvektiv andel varmetilskudd belysning	0,30
Konvektiv andel varmetilsk. teknisk utstyr	0,50
Konvektiv andel varmetilsikudd personer	0,50
Konvektiv andel varmetilsikudd sol	0,50
Konvektiv varmoverføringskoeff. vegger	2,50
Konvektiv varmoverføringskoeff. himling	2,00
Konvektiv varmoverføringskoeff. gulv	3,00
Bypassfaktor kjølebatteri	0,25
Innv. varmemotstand på vinduruter	0,13
Midlere lufthastighet romluft	0,15
Turbulensintensitet romluft	25,00
Avstand fra vindu	0,60
Termisk konduktivitet akk. sjikt [W/m²K]:	20,00

Inndata rom/sone

Beskrivelse	Verdi
Oppvarmet gulvareal	5000,0 m²
Oppvarmet luftvolum	15000,0 m³
Normalisert kuldebroverdi	0,12 W/(m²K)
Varmekapasitet møbler/interiør	2,0 Wh/m² (Lett møblert rom)
Lekkasjetall (luftskifte v. 50pa)	1,50 ach
Skjerming i terrenget	Moderat skjerming
Fasadesituasjon	Flere eksponerte fasader
Driftsdager i Januar	21
Driftsdager i Februar	20
Driftsdager i Mars	23
Driftsdager i April	22
Driftsdager i Mai	21
Driftsdager i Juni	22
Driftsdager i Juli	22
Driftsdager i August	22
Driftsdager i September	22
Driftsdager i Oktober	21
Driftsdager i November	22
Driftsdager i Desember	23

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Prosjekt: Standard Office Building
Sone: Japanese Building in Sapporo

Inndata oppvarming

Beskrivelse	Verdi
Navn:	Heating (oppvarming)
Settpunkttemperatur i driftstid	26,0 °C
Settpunkttemperatur utenfor driftstiden	19,0 °C
Maks. kapasitet	95 W/m²
Konvektiv andel oppvarming	0,50
Driftstid	14:00 timer drift pr døgn
Annen drifsstrategi i sommermåneder	Fra Mai til September
Settpunkttemperatur i driftstiden (sommer)	22,0 °C
Settpunttemperatur uten driftstiden (sommer)	19,0 °C
Driftstid sommermåneder	14:00 timer drift pr døgn
Vannbårent oppvarmingsanlegg	Nei

Inndata CAV

Beskrivelse	Verdi
Navn:	Ventilation (CAV ventilasjon)
Ventilasjonstype	Balansert ventilasjon
Driftstid	13:00 timer drift pr døgn
Luftmengde	I driftstiden: tilluft = 5.0 m³/hm², avtrekk = 5.0 m³/hm² Utenfor driftstiden: tilluft = 0.0 m³/hm², avtrekk = 0.0 m³/hm² Helg/feridag: tilluft = 0.0 m³/hm², avtrekk = 0.0 m³/hm²
Tilluftstemperatur	Normal: 26.0 °C Fra Mai til Oktober: 22.0 °C
Varmebatteri	Ja Maks. kapasitet: 20 W/m²
Vannbåren distribusjon til varmebatteri	Delta-T: 30.0 °C SPP: 0.5 kW/(l/s)
Kjølebatteri	
Vannbåren distribusjon til kjølebatteri	Delta-T: 6.0 °C SPP: 0.6 kW/(l/s)
Varmegjenvinner	Ja, temperaturvirkningsgrad: 0.60
Vifter	Plassering tilluftsvifte: Etter gjenvinner Plassering avtrekksvifte: Etter gjenvinner
SFP-faktor vifter	1.70 kW/m³/s

Simuleringsnavn: Årssimulering
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Programversjon: 6.009
Simuleringsansvarlig: N.B.Alseth & L.Andersen
Firma: Undervisningslisens
Inndatafil: C:\...\JB in Sapporo.smi
Prosjekt: Standard Office Building
Sone: Japanese Building in Sapporo

Inndata belysning

Beskrivelse	Verdi
Navn:	Internal Loads (internlaster, belysning)
Effekt/Varmetilskudd belysning	I driftstiden; Effekt: 12,0 W/m²; Varmetilskudd: 100 % Utenfor driftstiden; Effekt: 0,0 W/m²; Varmetilskudd: 100 % På helg/feriedager; Effekt: 0,0 W/m²; Varmetilskudd: 100 % Antall timer drift pr døgn: 13:00

Inndata teknisk utstyr (internlast)

Beskrivelse	Verdi
Navn:	Internal Loads (internlaster, teknisk utstyr)
Effekt/Varmetilskudd teknisk utstyr	I driftstiden; Effekt: 12,0 W/m²; Varmetilskudd: 100 % Utenfor driftstiden; Effekt: 0,0 W/m²; Varmetilskudd: 100 % På helg/feriedager; Effekt: 0,0 W/m²; Varmetilskudd: 100 % Antall timer drift pr døgn: 13:00

Inndata oppvarming av tappevann

Beskrivelse	Verdi
Navn:	Internal Loads (internlaster, tappevann)
Tappevann	Driftsdag; Midlere effekt: 0,9 W/m²; Varmetilskudd: 0 %; Vanndamp: 0,0 g/m² Helg/feriedag: Midlere effekt: 0,0 W/m²; Varmetilskudd: 0 %; ; Vanndamp: 0,0 g/m²

Inndata varmetilskudd personer (internlast)

Beskrivelse	Verdi
Navn:	Internal Loads (internlaster, varmetilskudd personer)
Varmetilskudd personer	I arbeidstiden: 11,9 W/m² Utenfor arbeidstiden: 0,0 W/m² Ferie/helgedager: 0,0 W/m² Antall arbeidstimer: 13:00

Simuleringsnavn: Årssimulering
Tid/dato simulering: 11:41 13/5-2018
Programversjon: 6.009
Simuleringsansvarlig: N.B.Alseth & L.Andersen
Firma: Undervisningslisens
Inndatafil: C:\...\JB in Sapporo.smi
Prosjekt: Standard Office Building
Sone: Japanese Building in Sapporo

Inndata lokal kjøling

Beskrivelse	Verdi
Navn:	Cooling (lokal kjøling)
Settpunkttemperatur	22,0 °C
Maks, kapasitet	95 W/m²
Konvektiv andel kjøling	0,50
Driftstid	14:00 timer drift pr døgn
Kjøling på helge/feriedager	Nei
Kjøling via vannbårent anlegg	Nei
Kjølingen er bare aktiv i deler av året	Startdato: 1. Mai Stoppdato: 1. November

Inndata fasade/yttervegg

Beskrivelse	Verdi
Navn:	South Facade (fasade)
Totalt areal	437,5 m²
Retning (0=Nord, 180=Sør)	180°
Innv. akkumulerende sjikt	Tung vegg Varmekapasitet 63,0 Wh/m²K
Konstruksjon	Egendefinert Uverdi: 0,61 W/m²K
Utvendig absorptionskoeffisient	0,80

Inndata vinduselement

Beskrivelse	Verdi
Navn:	Window 1 (Vindu(er) på South Facade)
Antall vinduer	38
Høyde vindu(er)	1,80 m
Bredde vindu(er)	1,80 m
Karm-/ramme faktor	0,20
Total U-verdi (rute+karm/rammekonstr.)	2,64 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

Simuleringsnavn: Årssimulering
Tid/dato simulering: 11:41 13/5-2018
Programversjon: 6.009
Simuleringsansvarlig: N.B.Alseth & L.Andersen
Firma: Undervisningslisens
Inndatafil: C:\...\JB in Sapporo.smi
Prosjekt: Standard Office Building
Sone: Japanese Building in Sapporo

Inndata vinduselement	
Beskrivelse	Verdi
Navn:	Window 2 (Vindu(er) på South Facade)
Antall vinduer	2
Høyde vindu(er)	1,50 m
Bredde vindu(er)	2,60 m
Karm-/ramme faktor	0,20
Total U-verdi (rute+karm/rammekonstr.)	2,64 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

Inndata vinduselement	
Beskrivelse	Verdi
Navn:	Window 3 (Vindu(er) på South Facade)
Antall vinduer	1
Høyde vindu(er)	2,10 m
Bredde vindu(er)	0,50 m
Karm-/ramme faktor	0,20
Total U-verdi (rute+karm/rammekonstr.)	2,64 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

Inndata ytterdør	
Beskrivelse	Verdi
Navn:	Door 1 (ytterdør)
Areal inkl. karm/ramme	4,4 m²
Dørtype	Egendefinert Uverdi: 2,64 W/m²K

Simuleringsnavn: Årssimulering
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Simuleringsansvarlig: N.B.Alseth & L.Andersen
Firma: Undervisningslisens
Inndatafil: C:\...\JB in Sapporo.smi
Prosjekt: Standard Office Building
Sone: Japanese Building in Sapporo

Inndata fasade/yttervegg

Beskrivelse	Verdi
Navn:	West Facade (fasade)
Totalt areal	700,0 m²
Retning (0=Nord, 180=Sør)	270°
Innv. akkumulerende sjikt	Tung vegg Varmekapasitet 63,0 Wh/m²K
Konstruksjon	Egendefinert Uverdi: 0,61 W/m²K

Inndata vinduselement

Beskrivelse	Verdi
Navn:	Window 1 (Vindu(er) på West Facade)
Antall vinduer	50
Høyde vindu(er)	1,80 m
Bredde vindu(er)	1,80 m
Karm-/ramme faktor	0,20
Total U-verdi (rute+karm/rammekonstr.)	2,64 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

Inndata fasade/yttervegg

Beskrivelse	Verdi
Navn:	North Facade (fasade)
Totalt areal	437,5 m²
Retning (0=Nord, 180=Sør)	0°
Innv. akkumulerende sjikt	Tung vegg Varmekapasitet 63,0 Wh/m²K
Konstruksjon	Egendefinert Uverdi: 0,61 W/m²K

Simuleringsnavn: Årssimulering
Tid/dato simulering: 11:41 13/5-2018
Programversjon: 6.009
Simuleringsansvarlig: N.B.Alseth & L.Andersen
Firma: Undervisningslisens
Inndatafil: C:\...\JB in Sapporo.smi
Prosjekt: Standard Office Building
Sone: Japanese Building in Sapporo

Inndata vinduselement

Beskrivelse	Verdi
Navn:	Window 1 (Vindu(er) på North Facade)
Antall vinduer	40
Høyde vindu(er)	1,80 m
Bredde vindu(er)	1,80 m
Karm-/ramme faktor	0,20
Total U-verdi (rute+karm/rammekonstr.)	2,64 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

Inndata fasade/yttervegg

Beskrivelse	Verdi
Navn:	East Facade (fasade)
Totalt areal	700,0 m²
Retning (0=Nord, 180=Sør)	90°
Innv. akkumulerende sjikt	Tung vegg Varmekapasitet 63,0 Wh/m²K
Konstruksjon	Egendefinert Uverdi: 0,61 W/m²K

Inndata vinduselement

Beskrivelse	Verdi
Navn:	Window 1 (Vindu(er) på East Facade)
Antall vinduer	39
Høyde vindu(er)	1,80 m
Bredde vindu(er)	1,80 m
Karm-/ramme faktor	0,20
Total U-verdi (rute+karm/rammekonstr.)	2,64 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

Simuleringsnavn: Årssimulering
Tid/dato simulering: 11:41 13/5-2018
Programversjon: 6.009
Simuleringsansvarlig: N.B.Alseth & L.Andersen
Firma: Undervisningslisens
Inndatafil: C:\...\JB in Sapporo.smi
Prosjekt: Standard Office Building
Sone: Japanese Building in Sapporo

Inndata vinduselement

Beskrivelse	Verdi
Navn:	Window 4 (Vindu(er) på East Facade)
Antall vinduer	9
Høyde vindu(er)	1,80 m
Bredde vindu(er)	0,50 m
Karm-/ramme faktor	0,20
Total U-verdi (rute+karm/rammekonstr.)	2,64 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

Inndata vinduselement

Beskrivelse	Verdi
Navn:	Window 5 (Vindu(er) på East Facade)
Antall vinduer	1
Høyde vindu(er)	2,60 m
Bredde vindu(er)	1,00 m
Karm-/ramme faktor	0,20
Total U-verdi (rute+karm/rammekonstr.)	2,64 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

Inndata vinduselement

Beskrivelse	Verdi
Navn:	Window 6 (Vindu(er) på East Facade)
Antall vinduer	1
Høyde vindu(er)	0,50 m
Bredde vindu(er)	1,00 m
Karm-/ramme faktor	0,20
Total U-verdi (rute+karm/rammekonstr.)	2,64 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

Simuleringsnavn: Årssimulering
Tid/dato simulering: 11:41 13/5-2018
Programversjon: 6.009
Simuleringsansvarlig: N.B.Alseth & L.Andersen
Firma: Undervisningslisens
Inndatafil: C:\...\JB in Sapporo.smi
Prosjekt: Standard Office Building
Sone: Japanese Building in Sapporo

Inndata ytterdør

Beskrivelse	Verdi
Navn:	Door 2 (ytterdør)
Areal inkl. karm/ramme	2,1 m²
Dørtype	Egendefinert Uverdi: 2,64 W/m²K

Inndata gulv mot friluft/kryprom/grunn

Beskrivelse	Verdi
Navn:	Floor (gulv)
Oppvarmet gulvareal	1000,0 m²
Gulvtype	Gulv mot uoppvarmet sone
Uoppvarmet sone	Ventilert uoppvarmet parkeringskjeller Varmetapsfaktor: 0,91
Innv. akk. sjikt gulv	Tungt gulv Varmekapasitet 63,0 Wh/m²K
Gulvkonstruksjon	Egendefinert Uverdi: 0,50 W/m²K

Inndata yttertak

Beskrivelse	Verdi
Navn:	Roof (yttertak)
Totalt areal	1000,0 m²
Retning (0=Nord, 180=Sør)	180°
Takvinkel	0,0°
Innv. akkumulerende sjikt	Tung himling Varmekapasitet 63,0 Wh/m²K
Konstruksjon	Egendefinert Uverdi: 0,32 W/m²K
Utvendig absorptionskoeffisient	0,80

SIMIEN

Resultater årssimulering

Simuleringsnavn: Årssimulering
Tid/dato simulering: 19:48 13/5-2018
Programversjon: 6.009
Simuleringsansvarlig: N.B.Alseth & L.Andersen
Firma: Undervisningslisens
Inndatafil: C:\...\JB in Narvik.smi
Prosjekt: Standard Office Building
Sone: Japanese Building in Narvik

Energibudsjett		
Energipost	Energibehov	Spesifikt energibehov
1a Romoppvarming	244965 kWh	49,0 kWh/m²
1b Ventilasjonsvarme (varmebatterier)	195560 kWh	39,1 kWh/m²
2 Varmtvann (tappevann)	27562 kWh	5,5 kWh/m²
3a Vifter	40060 kWh	8,0 kWh/m²
3b Pumper	1185 kWh	0,2 kWh/m²
4 Belysning	203617 kWh	40,7 kWh/m²
5 Teknisk utstyr	203617 kWh	40,7 kWh/m²
6a Romkjøling	232727 kWh	46,5 kWh/m²
6b Ventilasjonskjøling (kjølebatterier)	280 kWh	0,1 kWh/m²
Totalt netto energibehov, sum 1-6	1149572 kWh	229,9 kWh/m²

Levert energi til bygningen (beregnet)		
Energivare	Levert energi	Spesifikk levert energi
1a Direkte el.	476040 kWh	95,2 kWh/m²
1b El. til varmepumpesystem	266432 kWh	53,3 kWh/m²
1c El. til solfangersystem	0 kWh	0,0 kWh/m²
2 Olje	0 kWh	0,0 kWh/m²
3 Gass	0 kWh	0,0 kWh/m²
4 Fjernvarme	0 kWh	0,0 kWh/m²
5 Biobrensel	0 kWh	0,0 kWh/m²
6. Annen energikilde	0 kWh	0,0 kWh/m²
7. Solstrøm til egenbruk	-0 kWh	-0,0 kWh/m²
Totalt levert energi, sum 1-7	742472 kWh	148,5 kWh/m²
Solstrøm til eksport	-0 kWh	-0,0 kWh/m²
Netto levert energi	742472 kWh	148,5 kWh/m²

SIMIEN

Resultater årssimulering

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Programversjon: 6.009
Simuleringsansvarlig: N.B.Alseth & L.Andersen
Firma: Undervisningslisens
Inndatafil: C:\...\JB in Narvik.smi
Prosjekt: Standard Office Building
Sone: Japanese Building in Narvik

Dekning av energibudsjett fordelt på energikilder						
Energikilder	Romoppv.	Varmebatterier	Varmtvann	Kjølebatterier	Romkjøling	El. spesifikt
El.	0,0 kWh/m^2	0,0 kWh/m^2	5,5 kWh/m^2	0,0 kWh/m^2	0,0 kWh/m^2	89,7 kWh/m^2
Olje	0,0 kWh/m^2	0,0 kWh/m^2	0,0 kWh/m^2	0,0 kWh/m^2	0,0 kWh/m^2	0,0 kWh/m^2
Gass	0,0 kWh/m^2	0,0 kWh/m^2	0,0 kWh/m^2	0,0 kWh/m^2	0,0 kWh/m^2	0,0 kWh/m^2
Fjernvarme	0,0 kWh/m^2	0,0 kWh/m^2	0,0 kWh/m^2	0,0 kWh/m^2	0,0 kWh/m^2	0,0 kWh/m^2
Biobrensel	0,0 kWh/m^2	0,0 kWh/m^2	0,0 kWh/m^2	0,0 kWh/m^2	0,0 kWh/m^2	0,0 kWh/m^2
Varmepumpe	49,0 kWh/m^2	39,1 kWh/m^2	0,0 kWh/m^2	0,1 kWh/m^2	46,5 kWh/m^2	0,0 kWh/m^2
Sol	0,0 kWh/m^2	0,0 kWh/m^2	0,0 kWh/m^2	0,0 kWh/m^2	0,0 kWh/m^2	0,0 kWh/m^2
Annen	0,0 kWh/m^2	0,0 kWh/m^2	0,0 kWh/m^2	0,0 kWh/m^2	0,0 kWh/m^2	0,0 kWh/m^2
Sum	49,0 kWh/m^2	39,1 kWh/m^2	5,5 kWh/m^2	0,1 kWh/m^2	46,5 kWh/m^2	89,7 kWh/m^2

Årlige utslipp av CO_2		
Energivare	Utslipp	Spesifikt utslipp
1a Direkte el.	61885 kg	12,4 kg/m^2
1b El. til varmepumpesystem	34636 kg	6,9 kg/m^2
1c El. til solfangersystem	0 kg	0,0 kg/m^2
2 Olje	0 kg	0,0 kg/m^2
3 Gass	0 kg	0,0 kg/m^2
4 Fjernvarme	0 kg	0,0 kg/m^2
5 Biobrensel	0 kg	0,0 kg/m^2
6. Annen energikilde	0 kg	0,0 kg/m^2
7. Solstrøm til egenbruk	-0 kg	-0,0 kg/m^2
Totalt utslipp, sum 1-7	96521 kg	19,3 kg/m^2
Solstrøm til eksport	-0 kg	-0,0 kg/m^2
Netto CO_2-utslipp	96521 kg	19,3 kg/m^2

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Kostnad kjøpt energi

Energivare	Energikostnad	Spesifikk energikostnad
1a Direkte el.	380832 kr	76,2 kr/m²
1b El. til varmepumpesystem	213145 kr	42,6 kr/m²
1c El. til solfangersystem	0 kr	0,0 kr/m²
2 Olje	0 kr	0,0 kr/m²
3 Gass	0 kr	0,0 kr/m²
4 Fjernvarme	0 kr	0,0 kr/m²
5 Biobrensel	0 kr	0,0 kr/m²
6. Annen energikilde	0 kr	0,0 kr/m²
7. Solstrøm til egenbruk	-0 kr	-0,0 kr/m²
Årlige energikostnader, sum 1-7	593978 kr	118,8 kr/m²
Solstrøm til eksport	0 kr	0,0 kr/m²
Netto energikostnad	593978 kr	118,8 kr/m²

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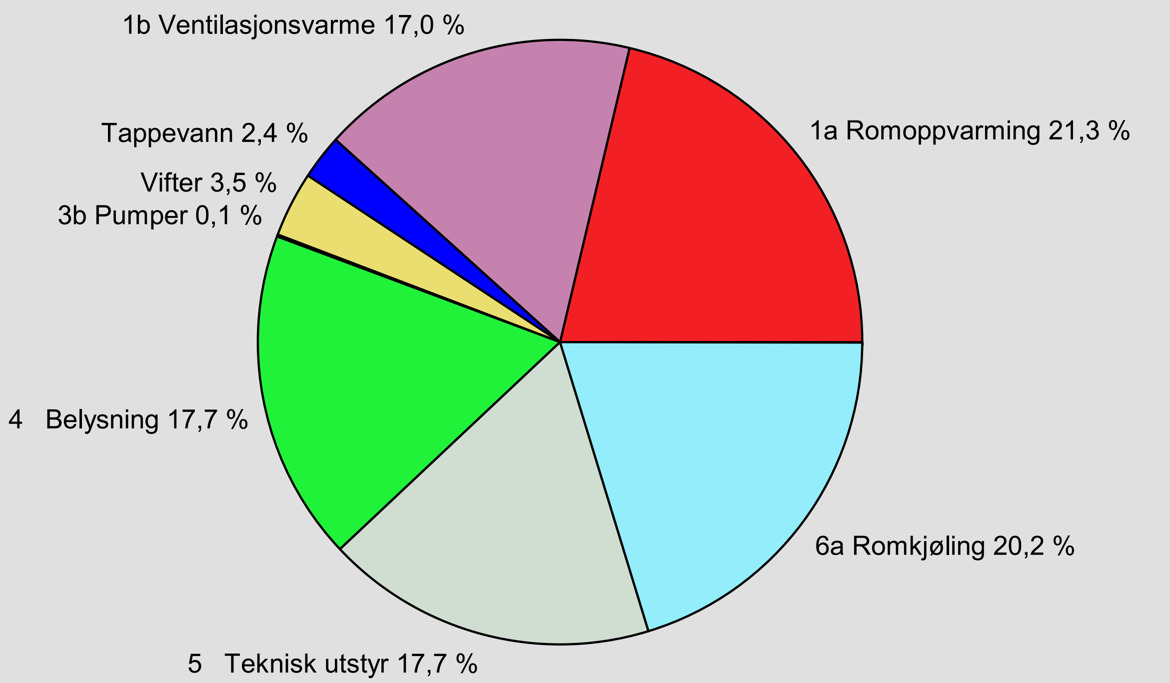
Årlig energibudsjett



1a Romoppvarming	244965 kWh
1b Ventilasjonsvarme (varmebatterier)	195560 kWh
2 Varmtvann (tappevann)	27562 kWh
3a Vifter	40060 kWh
3b Pumper	1185 kWh
4 Belysning	203617 kWh
5 Teknisk utstyr	203617 kWh
6a Romkjøling	232727 kWh
6b Ventilasjonskjøling (kjølebatterier)	280 kWh
Totalt netto energibehov, sum 1-6	1149572 kWh

SIMIEN

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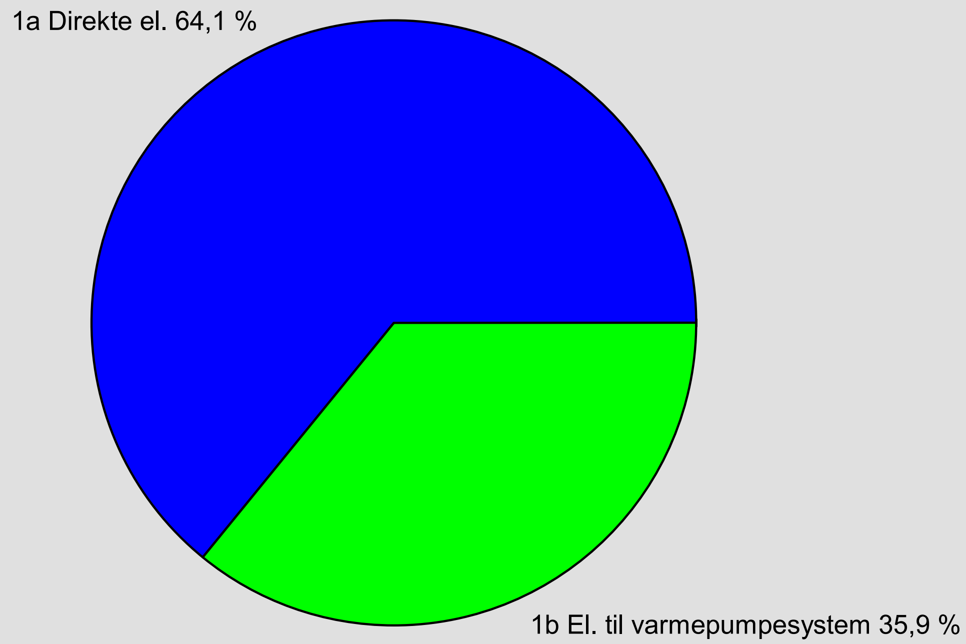
Levert energi til bygningen (beregnet)



1a Direkte el.	476040 kWh
1b El. til varmepumpesystem	266432 kWh
1c El. til solfangersystem	0 kWh
2 Olje	0 kWh
3 Gass	0 kWh
4 Fjernvarme	0 kWh
5 Biobrensel	0 kWh
6. Annen energikilde	0 kWh
Totalt levert energi, sum 1-7	742472 kWh

SIMIEN

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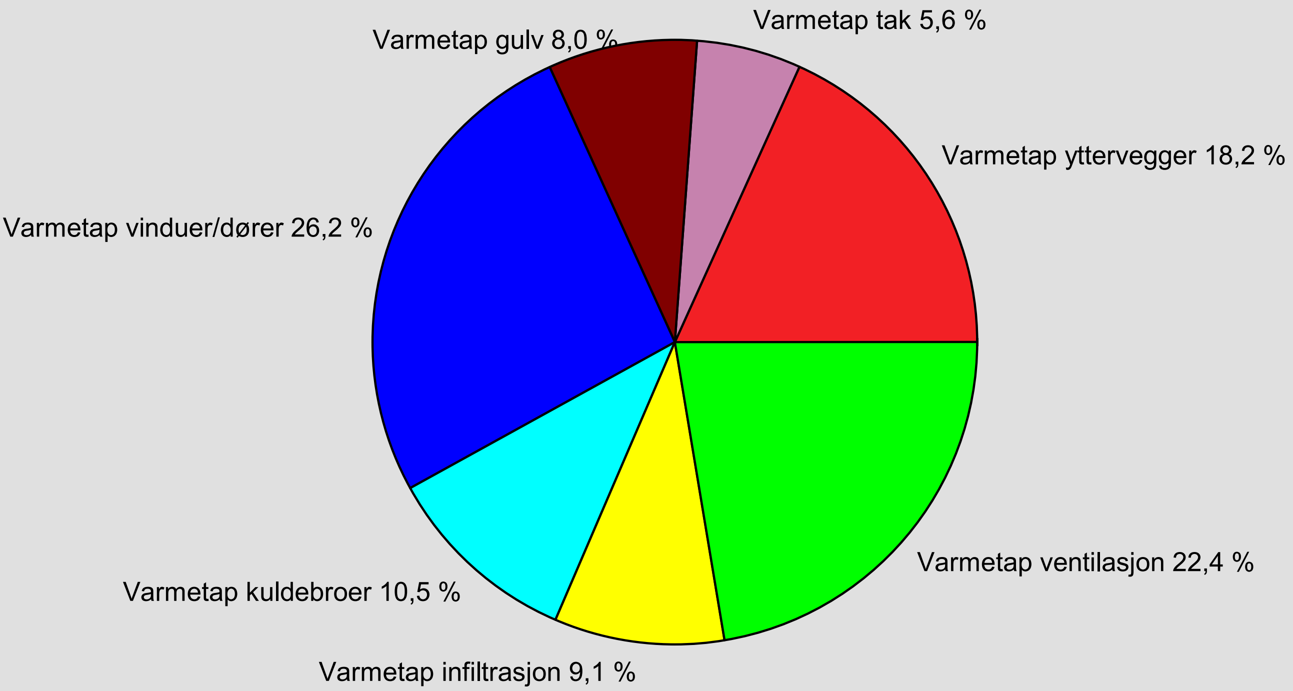
Varmetapsbudsjett (varmetapstall)



Varmetapstall yttervegger	0,21 W/m²K
Varmetapstall tak	0,06 W/m²K
Varmetapstall gulv på grunn/mot det fri	0,09 W/m²K
Varmetapstall glass/vinduer/dører	0,30 W/m²K
Varmetapstall kuldebroer	0,12 W/m²K
Varmetapstall infiltrasjon	0,10 W/m²K
Varmetapstall ventilasjon	0,26 W/m²K
Totalt varmetapstall	1,14 W/m²K

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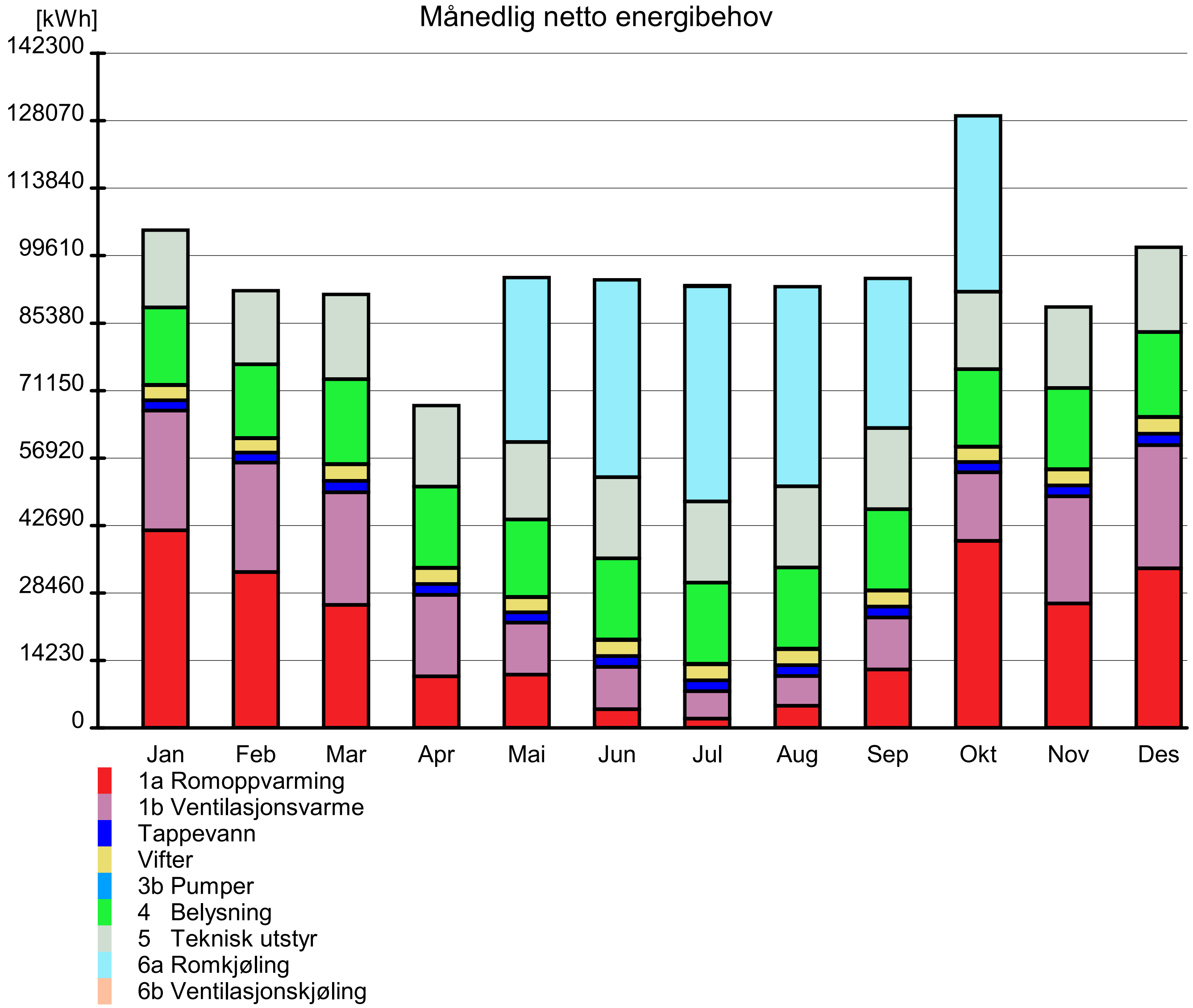

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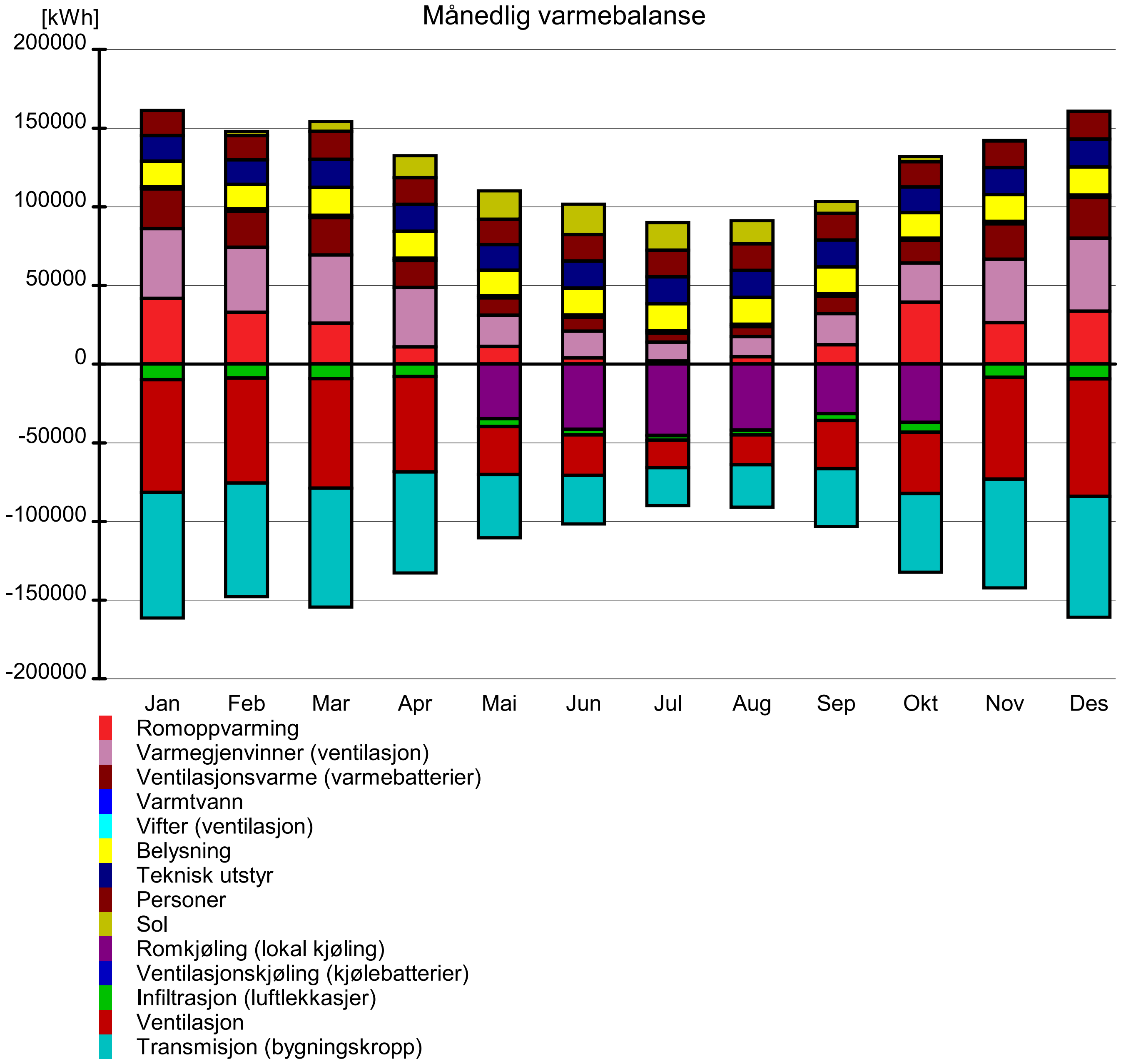

SIMIEN
Resultater årssimulering

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Månedlige temperaturdata (lufttemperatur)

Måned	Midlere ute	Maks. ute	Min. ute	Midlere sone	Maks. sone	Min. sone
Januar	-4,3 °C	5,8 °C	-14,7 °C	21,8 °C	27,2 °C	19,0 °C
Februar	-4,0 °C	6,3 °C	-14,6 °C	22,1 °C	28,4 °C	19,0 °C
Mars	-1,7 °C	7,8 °C	-11,6 °C	22,4 °C	29,8 °C	19,0 °C
April	2,1 °C	12,0 °C	-6,2 °C	23,5 °C	31,3 °C	19,0 °C
Mai	7,2 °C	17,6 °C	-0,5 °C	20,4 °C	22,3 °C	19,0 °C
Juni	10,8 °C	24,4 °C	2,6 °C	20,8 °C	24,0 °C	19,0 °C
Juli	13,5 °C	26,7 °C	6,0 °C	21,0 °C	24,6 °C	19,0 °C
August	12,4 °C	22,3 °C	4,6 °C	20,7 °C	24,2 °C	19,0 °C
September	8,2 °C	17,2 °C	-0,6 °C	20,4 °C	22,7 °C	19,0 °C
Oktober	3,9 °C	12,5 °C	-4,6 °C	20,2 °C	22,0 °C	19,0 °C
November	-0,5 °C	8,8 °C	-8,8 °C	22,3 °C	28,7 °C	19,0 °C
Desember	-2,7 °C	6,2 °C	-13,3 °C	22,2 °C	28,4 °C	19,0 °C

Månedlige temperaturdata (operativ temperatur)

Måned	Midlere ute	Maks. ute	Min. ute	Midlere sone	Maks. sone	Min. sone
Januar	-4,3 °C	5,8 °C	-14,7 °C	21,8 °C	26,6 °C	19,0 °C
Februar	-4,0 °C	6,3 °C	-14,6 °C	22,0 °C	27,1 °C	18,8 °C
Mars	-1,7 °C	7,8 °C	-11,6 °C	22,4 °C	28,4 °C	18,9 °C
April	2,1 °C	12,0 °C	-6,2 °C	23,7 °C	30,0 °C	19,0 °C
Mai	7,2 °C	17,6 °C	-0,5 °C	20,4 °C	22,3 °C	19,0 °C
Juni	10,8 °C	24,4 °C	2,6 °C	20,8 °C	23,0 °C	19,0 °C
Juli	13,5 °C	26,7 °C	6,0 °C	21,1 °C	23,4 °C	19,6 °C
August	12,4 °C	22,3 °C	4,6 °C	20,8 °C	23,0 °C	19,0 °C
September	8,2 °C	17,2 °C	-0,6 °C	20,4 °C	22,1 °C	19,0 °C
Oktober	3,9 °C	12,5 °C	-4,6 °C	20,2 °C	22,0 °C	19,0 °C
November	-0,5 °C	8,8 °C	-8,8 °C	22,3 °C	28,3 °C	18,8 °C
Desember	-2,7 °C	6,2 °C	-13,3 °C	22,2 °C	27,8 °C	19,0 °C

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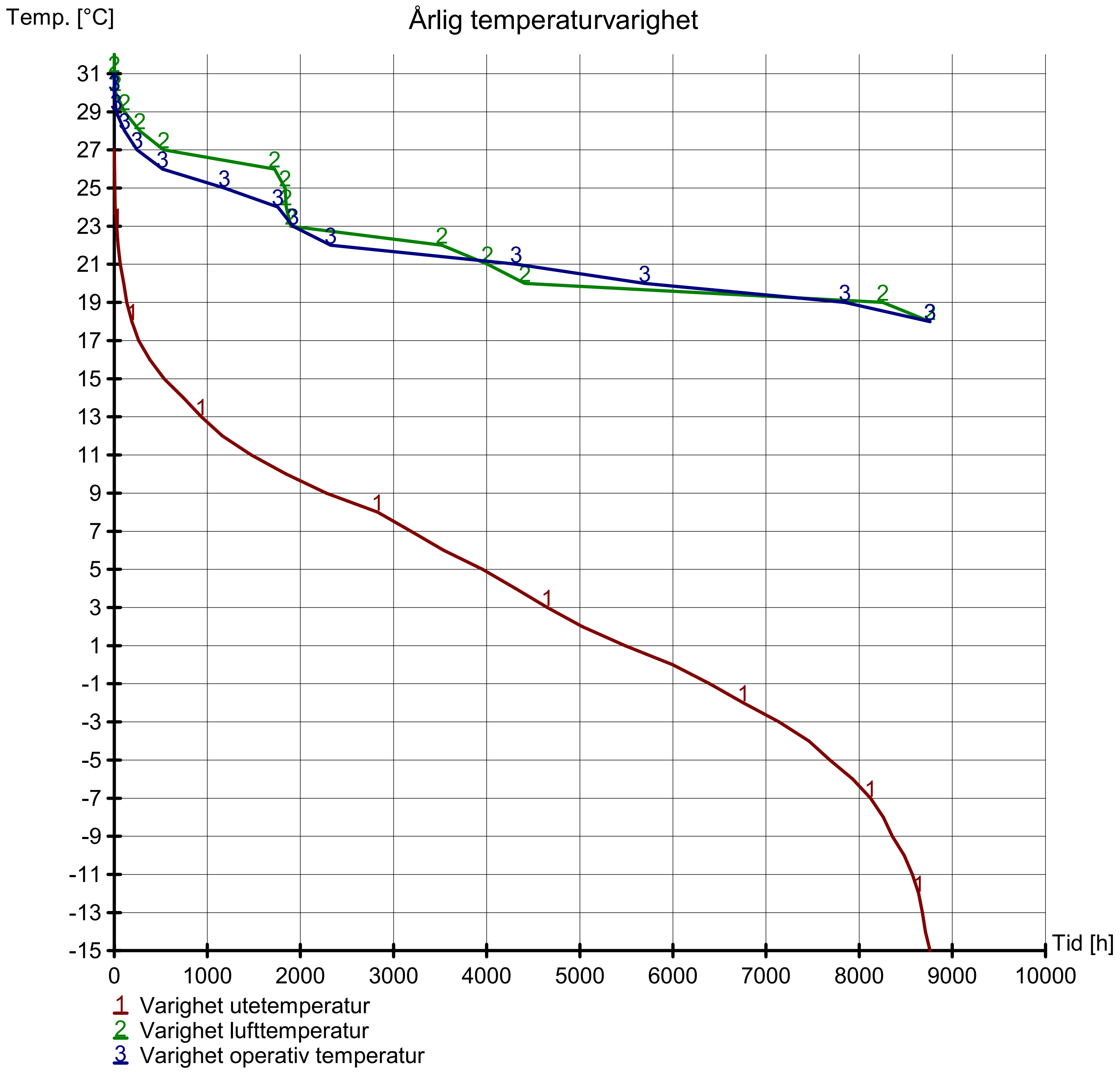

SIMIEN

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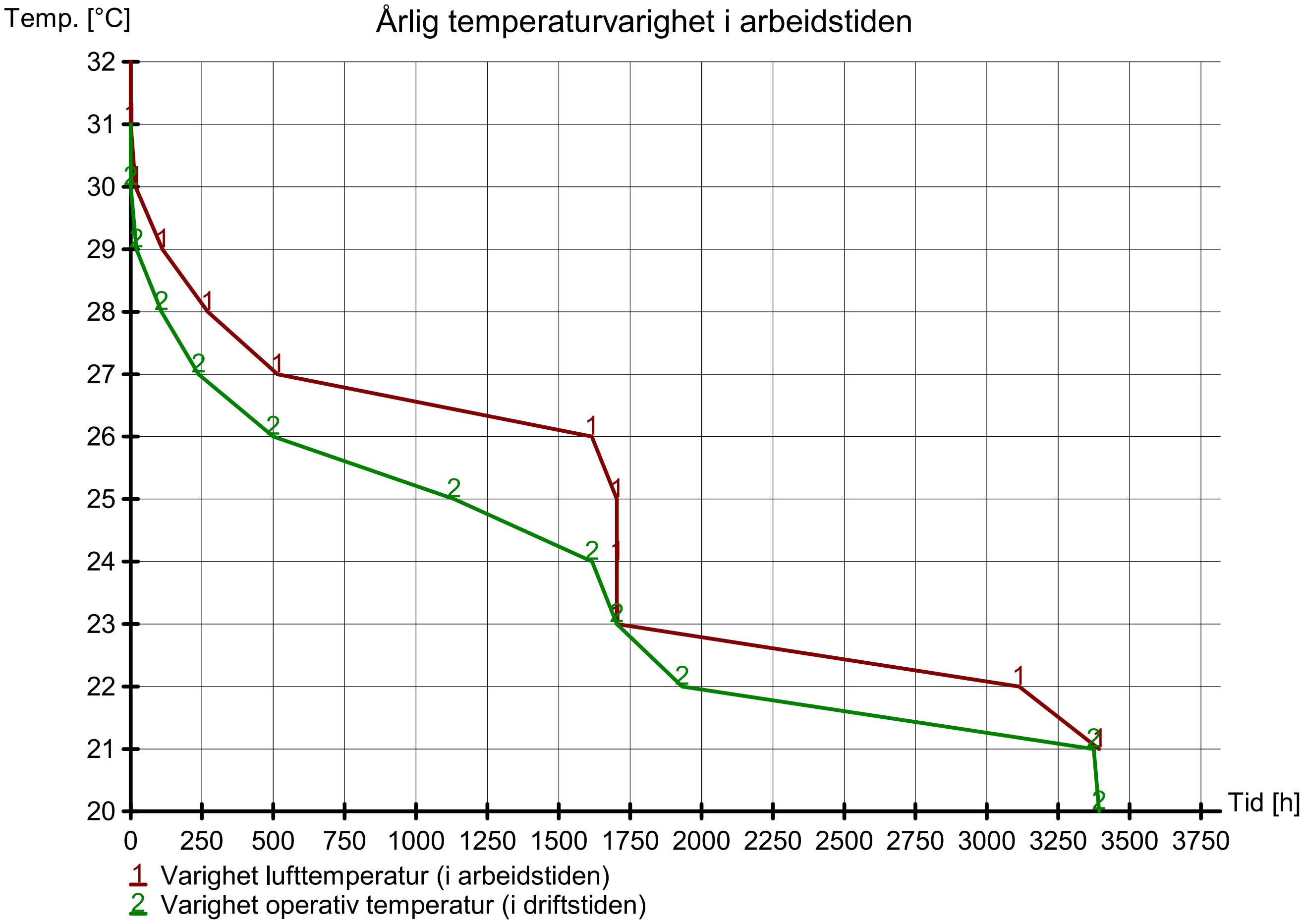

Årlig varighet operativ temperatur i arbeidstiden	
Beskrivelse	Operativ temperatur
Antall timer over 26°C	500

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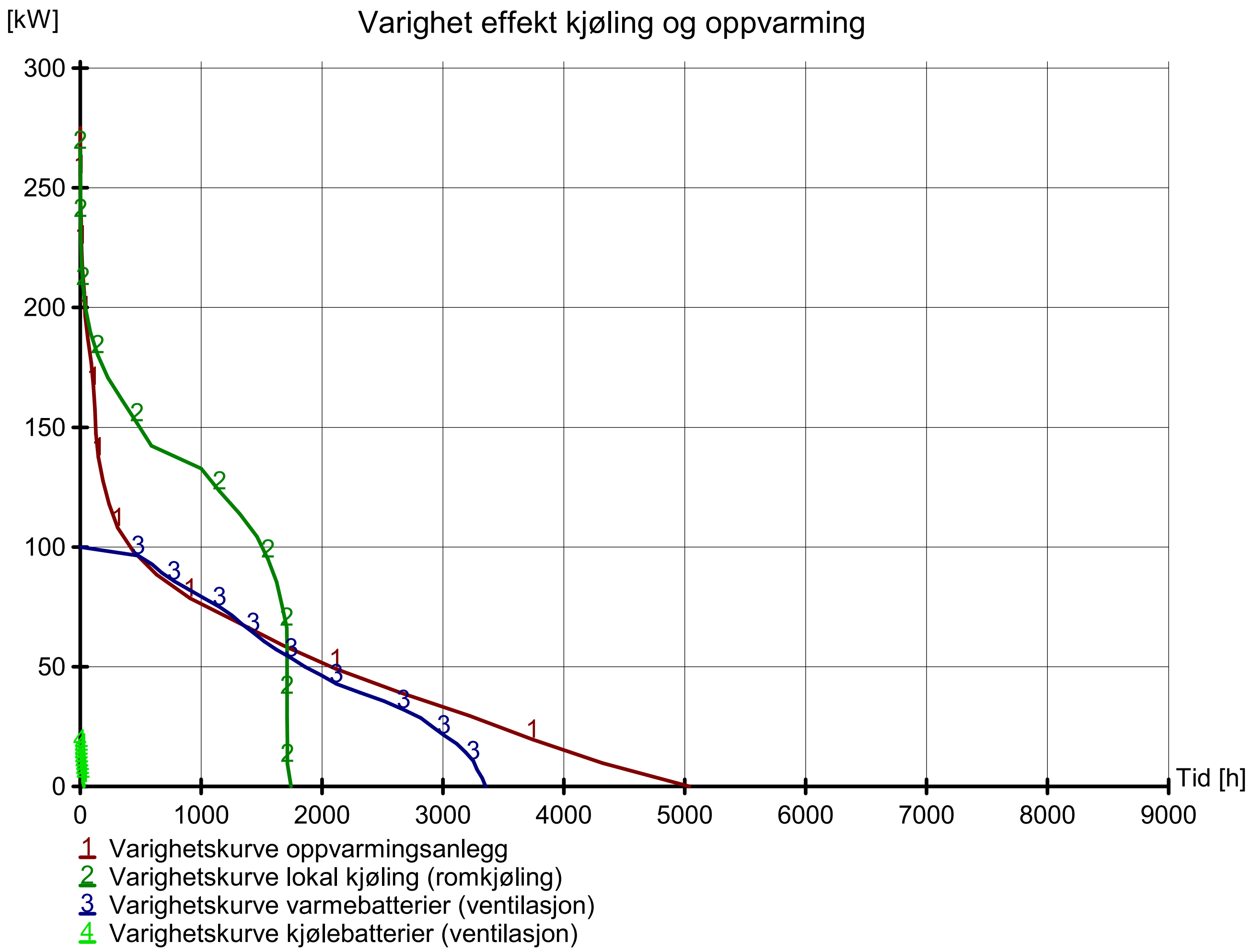

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Dekningsgrad effekt/energi oppvarming	
Effekt (dekning)	Dekningsgrad energibruk
248 kW (90 %)	100 %
220 kW (80 %)	100 %
193 kW (70 %)	100 %
165 kW (60 %)	99 %
138 kW (50 %)	97 %
110 kW (40 %)	93 %
83 kW (30 %)	85 %
55 kW (20 %)	69 %
28 kW (10 %)	41 %
Nødvendig effekt til oppvarming av tappevann er ikke inkludert	-

Dokumentasjon av sentrale inndata (1)		
Beskrivelse	Verdi	Dokumentasjon
Areal yttervegger [m²]:	1707	
Areal tak [m²]:	1000	
Areal gulv [m²]:	1000	
Areal vinduer og ytterdører [m²]:	568	
Oppvarmet bruksareal (BRA) [m²]:	5000	
Oppvarmet luftvolum [m³]:	15000	
U-verdi yttervegger [W/m²K]	0,61	
U-verdi tak [W/m²K]	0,32	
U-verdi gulv [W/m²K]	0,46	
U-verdi vinduer og ytterdører [W/m²K]	2,64	
Areal vinduer og dører delt på bruksareal [%]	11,4	
Normalisert kuldebroverdi [W/m²K]:	0,12	
Normalisert varmekapasitet [Wh/m²K]	49	
Lekkasjetall (n50) [1/h]:	1,50	
Temperaturvirkningsgr. varmegjenvinner [%]:	60	

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Dokumentasjon av sentrale inndata (2)

Beskrivelse	Verdi	Dokumentasjon
Estimert virkningsgrad gjenvinner justert for frostsikring [%]:	60,0	
Spesifikk vifteeffekt (SFP) [kW/m³/s]:	1,70	
Luftmengde i driftstiden [m³/hm²]	5,00	
Luftmengde utenfor driftstiden [m³/hm²]	0,00	
Systemvirkningsgrad oppvarmingsanlegg:	2,33	
Installert effekt romoppv. og varmebatt. [W/m²]:	115	
Settpunkttemperatur for romoppvarming [°C]	23,1	
Systemeffektfaktor kjøling:	2,50	
Settpunkttemperatur for romkjøling [°C]	22,0	
Installert effekt romkjøling og kjølebatt. [W/m²]:	98	
Spesifikk pumpeeffekt romoppvarming [kW/(l/s)]:	0,00	
Spesifikk pumpeeffekt romkjøling [kW/(l/s)]:	0,60	
Spesifikk pumpeeffekt varmebatteri [kW/(l/s)]:	0,50	
Spesifikk pumpeeffekt kjølebatteri [kW/(l/s)]:	0,60	
Driftstid oppvarming (timer)	14,0	

Dokumentasjon av sentrale inndata (3)

Beskrivelse	Verdi	Dokumentasjon
Driftstid kjøling (timer)	14,0	
Driftstid ventilasjon (timer)	13,0	
Driftstid belysning (timer)	13,0	
Driftstid utstyr (timer)	13,0	
Oppholdstid personer (timer)	13,0	
Effektbehov belysning i driftstiden [W/m²]	12,00	
Varmetilskudd belysning i driftstiden [W/m²]	12,00	
Effektbehov utstyr i driftstiden [W/m²]	12,00	
Varmetilskudd utstyr i driftstiden [W/m²]	12,00	
Effektbehov varmtvann på driftsdager [W/m²]	0,88	
Varmetilskudd varmtvann i driftstiden [W/m²]	0,00	
Varmetilskudd personer i oppholdstiden [W/m²]	11,90	
Total solfaktor for vindu og solskjerming:	0,38	
Gjennomsnittlig karmfaktor vinduer:	0,20	
Solskjermingsfaktor horisont/utspring (N/Ø/S/V):	1,00/1,00/1,00/1,00	

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Inndata bygning

Beskrivelse	Verdi
Bygningskategori	Kontorbygg
Simuleringsansvarlig	N.B.Alseth _L.Andersen
Kommentar	

Inndata klima

Beskrivelse	Verdi
Klimasted	Narvik
Breddegrad	68° 16'
Lengdegrad	17° 15'
Tidssone	GMT + 1
Årsmiddeltemperatur	3,8 °C
Midlere solstråling horisontal flate	77 W/m²
Midlere vindhastighet	4,4 m/s

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Inndata energiforsyning

Beskrivelse	Verdi
1a Direkte el.	Systemvirkningsgrad romoppv,: 0,81 Systemvirkningsgrad varmtvann: 1,00 Systemvirkningsgrad varmebatterier: 0,88 Kjølefaktor romkjøling: 2,50 Kjølefaktor kjølebatterier: 2,50 Energipris: 0,80 kr/kWh CO2-utslipp: 130 g/kWh Andel romoppvarming: 0,0% Andel oppv, tappevann: 100,0% Andel varmebatteri: 0,0 % Andel kjølebatteri: 0,0 % Andel romkjøling: 0,0 % Andel el, spesifikt: 100,0 %
1b El. til varmepumpesystem	Systemvirkningsgrad romoppv,: 2,45 Systemvirkningsgrad varmtvann: 2,60 Systemvirkningsgrad varmebatterier: 2,67 Kjølefaktor romkjøling: 2,50 Kjølefaktor kjølebatterier: 2,50 Energipris: 0,80 kr/kWh CO2-utslipp: 130 g/kWh Andel romoppvarming: 100,0% Andel oppv, tappevann: 0,0% Andel varmebatteri: 100,0 % Andel kjølebatteri: 100,0 % Andel romkjøling: 100,0 % Andel el, spesifikt: 0,0 %

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Inndata ekspertverdier

Beskrivelse	Verdi
Konvektiv andel varmetilskudd belysning	0,30
Konvektiv andel varmetilsk. teknisk utstyr	0,50
Konvektiv andel varmetilsikudd personer	0,50
Konvektiv andel varmetilsikudd sol	0,50
Konvektiv varmoverføringskoeff. vegger	2,50
Konvektiv varmoverføringskoeff. himling	2,00
Konvektiv varmoverføringskoeff. gulv	3,00
Bypassfaktor kjølebatteri	0,25
Innv. varmemotstand på vinduruter	0,13
Midlere lufthastighet romluft	0,15
Turbulensintensitet romluft	25,00
Avstand fra vindu	0,60
Termisk konduktivitet akk. sjikt [W/m²K]:	20,00

Inndata rom/sone

Beskrivelse	Verdi
Oppvarmet gulvareal	5000,0 m²
Oppvarmet luftvolum	15000,0 m³
Normalisert kuldebroverdi	0,12 W/(m²K)
Varmekapasitet møbler/interiør	2,0 Wh/m² (Lett møblert rom)
Lekkasjetall (luftskifte v. 50pa)	1,50 ach
Skjerming i terrenget	Moderat skjerming
Fasadesituasjon	Flere eksponerte fasader
Driftsdager i Januar	21
Driftsdager i Februar	20
Driftsdager i Mars	23
Driftsdager i April	22
Driftsdager i Mai	21
Driftsdager i Juni	22
Driftsdager i Juli	22
Driftsdager i August	22
Driftsdager i September	22
Driftsdager i Oktober	21
Driftsdager i November	22
Driftsdager i Desember	23

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Programversjon: 6.009
Simuleringsansvarlig: N.B.Alseth & L.Andersen
Firma: Undervisningslisens
Inndatafil: C:\...\JB in Narvik.smi
Prosjekt: Standard Office Building
Sone: Japanese Building in Narvik

Inndata oppvarming

Beskrivelse	Verdi
Navn:	Heating (oppvarming)
Settpunkttemperatur i driftstid	26,0 °C
Settpunkttemperatur utenfor driftstiden	19,0 °C
Maks. kapasitet	95 W/m²
Konvektiv andel oppvarming	0,50
Driftstid	14:00 timer drift pr døgn
Annen drifsstrategi i sommermåneder	Fra Mai til September
Settpunkttemperatur i driftstiden (sommer)	22,0 °C
Settpunttemperatur uten driftstiden (sommer)	19,0 °C
Driftstid sommermåneder	14:00 timer drift pr døgn
Vannbårent oppvarmingsanlegg	Nei

Inndata CAV

Beskrivelse	Verdi
Navn:	Ventilation (CAV ventilasjon)
Ventilasjonstype	Balansert ventilasjon
Driftstid	13:00 timer drift pr døgn
Luftmengde	I driftstiden: tilluft = 5.0 m³/hm², avtrekk = 5.0 m³/hm² Utenfor driftstiden: tilluft = 0.0 m³/hm², avtrekk = 0.0 m³/hm² Helg/feridag: tilluft = 0.0 m³/hm², avtrekk = 0.0 m³/hm²
Tilluftstemperatur	Normal: 26.0 °C Fra Mai til Oktober: 22.0 °C
Varmebatteri	Ja Maks. kapasitet: 20 W/m²
Vannbåren distribusjon til varmebatteri	Delta-T: 30.0 °C SPP: 0.5 kW/(l/s)
Kjølebatteri	
Vannbåren distribusjon til kjølebatteri	Delta-T: 6.0 °C SPP: 0.6 kW/(l/s)
Varmegjenvinner	Ja, temperaturvirkningsgrad: 0.60
Vifter	Plassering tilluftsvifte: Etter gjenvinner Plassering avtrekksvifte: Etter gjenvinner
SFP-faktor vifter	1.70 kW/m³/s

Simuleringsnavn: Årssimulering
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Inndata belysning

Beskrivelse	Verdi
Navn:	Internal Loads (internlaster, belysning)
Effekt/Varmetilskudd belysning	I driftstiden; Effekt: 12,0 W/m²; Varmetilskudd: 100 % Utenfor driftstiden; Effekt: 0,0 W/m²; Varmetilskudd: 100 % På helg/feriedager; Effekt: 0,0 W/m²; Varmetilskudd: 100 % Antall timer drift pr døgn: 13:00

Inndata teknisk utstyr (internlast)

Beskrivelse	Verdi
Navn:	Internal Loads (internlaster, teknisk utstyr)
Effekt/Varmetilskudd teknisk utstyr	I driftstiden; Effekt: 12,0 W/m²; Varmetilskudd: 100 % Utenfor driftstiden; Effekt: 0,0 W/m²; Varmetilskudd: 100 % På helg/feriedager; Effekt: 0,0 W/m²; Varmetilskudd: 100 % Antall timer drift pr døgn: 13:00

Inndata oppvarming av tappevann

Beskrivelse	Verdi
Navn:	Internal Loads (internlaster, tappevann)
Tappevann	Driftsdag; Midlere effekt: 0,9 W/m²; Varmetilskudd: 0 %; Vanndamp: 0,0 g/m² Helg/feriedag: Midlere effekt: 0,0 W/m²; Varmetilskudd: 0 %; ; Vanndamp: 0,0 g/m²

Inndata varmetilskudd personer (internlast)

Beskrivelse	Verdi
Navn:	Internal Loads (internlaster, varmetilskudd personer)
Varmetilskudd personer	I arbeidstiden: 11,9 W/m² Utenfor arbeidstiden: 0,0 W/m² Ferie/helgedager: 0,0 W/m² Antall arbeidstimer: 13:00

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Inndata lokal kjøling

Beskrivelse	Verdi
Navn:	Cooling (lokal kjøling)
Settpunkttemperatur	22,0 °C
Maks, kapasitet	95 W/m²
Konvektiv andel kjøling	0,50
Driftstid	14:00 timer drift pr døgn
Kjøling på helge/feriedager	Nei
Kjøling via vannbårent anlegg	Nei
Kjølingen er bare aktiv i deler av året	Startdato: 1. Mai Stoppdato: 1. November

Inndata fasade/yttervegg

Beskrivelse	Verdi
Navn:	South Facade (fasade)
Totalt areal	437,5 m²
Retning (0=Nord, 180=Sør)	180°
Innv. akkumulerende sjikt	Tung vegg Varmekapasitet 63,0 Wh/m²K
Konstruksjon	Egendefinert Uverdi: 0,61 W/m²K
Utvendig absorptionskoeffisient	0,80

Inndata vinduselement

Beskrivelse	Verdi
Navn:	Window 1 (Vindu(er) på South Facade)
Antall vinduer	38
Høyde vindu(er)	1,80 m
Bredde vindu(er)	1,80 m
Karm-/ramme faktor	0,20
Total U-verdi (rute+karm/rammekonstr.)	2,64 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

Simuleringsnavn: Årssimulering
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Inndatafil: C:\...\JB in Narvik.smi
Prosjekt: Standard Office Building
Sone: Japanese Building in Narvik

Inndata vinduselement

Beskrivelse	Verdi
Navn:	Window 2 (Vindu(er) på South Facade)
Antall vinduer	2
Høyde vindu(er)	1,50 m
Bredde vindu(er)	2,60 m
Karm-/ramme faktor	0,20
Total U-verdi (rute+karm/rammekonstr.)	2,64 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

Inndata vinduselement

Beskrivelse	Verdi
Navn:	Window 3 (Vindu(er) på South Facade)
Antall vinduer	1
Høyde vindu(er)	2,10 m
Bredde vindu(er)	0,50 m
Karm-/ramme faktor	0,20
Total U-verdi (rute+karm/rammekonstr.)	2,64 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

Inndata ytterdør

Beskrivelse	Verdi
Navn:	Door 1 (ytterdør)
Areal inkl. karm/ramme	4,4 m²
Dørtype	Egendefinert Uverdi: 2,64 W/m²K

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Firma: Undervisningslisens
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Prosjekt: Standard Office Building
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Inndata fasade/yttervegg

Beskrivelse	Verdi
Navn:	West Facade (fasade)
Totalt areal	700,0 m²
Retning (0=Nord, 180=Sør)	270°
Innv. akkumulerende sjikt	Tung vegg Varmekapasitet 63,0 Wh/m²K
Konstruksjon	Egendefinert Uverdi: 0,61 W/m²K

Inndata vinduselement

Beskrivelse	Verdi
Navn:	Window 1 (Vindu(er) på West Facade)
Antall vinduer	50
Høyde vindu(er)	1,80 m
Bredde vindu(er)	1,80 m
Karm-/ramme faktor	0,20
Total U-verdi (rute+karm/rammekonstr.)	2,64 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

Inndata fasade/yttervegg

Beskrivelse	Verdi
Navn:	North Facade (fasade)
Totalt areal	437,5 m²
Retning (0=Nord, 180=Sør)	0°
Innv. akkumulerende sjikt	Tung vegg Varmekapasitet 63,0 Wh/m²K
Konstruksjon	Egendefinert Uverdi: 0,61 W/m²K

Simuleringsnavn: Årssimulering
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Simuleringsansvarlig: N.B.Alseth & L.Andersen
Firma: Undervisningslisens
Inndatafil: C:\...\JB in Narvik.smi
Prosjekt: Standard Office Building
Sone: Japanese Building in Narvik

Inndata vinduselement

Beskrivelse	Verdi
Navn:	Window 1 (Vindu(er) på North Facade)
Antall vinduer	40
Høyde vindu(er)	1,80 m
Bredde vindu(er)	1,80 m
Karm-/ramme faktor	0,20
Total U-verdi (rute+karm/rammekonstr.)	2,64 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

Inndata fasade/yttervegg

Beskrivelse	Verdi
Navn:	East Facade (fasade)
Totalt areal	700,0 m²
Retning (0=Nord, 180=Sør)	90°
Innv. akkumulerende sjikt	Tung vegg Varmekapasitet 63,0 Wh/m²K
Konstruksjon	Egendefinert Uverdi: 0,61 W/m²K

Inndata vinduselement

Beskrivelse	Verdi
Navn:	Window 1 (Vindu(er) på East Facade)
Antall vinduer	39
Høyde vindu(er)	1,80 m
Bredde vindu(er)	1,80 m
Karm-/ramme faktor	0,20
Total U-verdi (rute+karm/rammekonstr.)	2,64 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

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Simuleringsansvarlig: N.B.Alseth & L.Andersen
Firma: Undervisningslisens
Inndatafil: C:\...\JB in Narvik.smi
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Sone: Japanese Building in Narvik

Inndata vinduselement

Beskrivelse	Verdi
Navn:	Window 4 (Vindu(er) på East Facade)
Antall vinduer	9
Høyde vindu(er)	1,80 m
Bredde vindu(er)	0,50 m
Karm-/ramme faktor	0,20
Total U-verdi (rute+karm/rammekonstr.)	2,64 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

Inndata vinduselement

Beskrivelse	Verdi
Navn:	Window 5 (Vindu(er) på East Facade)
Antall vinduer	1
Høyde vindu(er)	2,60 m
Bredde vindu(er)	1,00 m
Karm-/ramme faktor	0,20
Total U-verdi (rute+karm/rammekonstr.)	2,64 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

Inndata vinduselement

Beskrivelse	Verdi
Navn:	Window 6 (Vindu(er) på East Facade)
Antall vinduer	1
Høyde vindu(er)	0,50 m
Bredde vindu(er)	1,00 m
Karm-/ramme faktor	0,20
Total U-verdi (rute+karm/rammekonstr.)	2,64 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

SIMIEN

Resultater årssimulering

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Inndata ytterdør

Beskrivelse	Verdi
Navn:	Door 2 (ytterdør)
Areal inkl. karm/ramme	2,1 m²
Dørtype	Egendefinert Uverdi: 2,64 W/m²K

Inndata gulv mot friluft/kryprom/grunn

Beskrivelse	Verdi
Navn:	Floor (gulv)
Oppvarmet gulvareal	1000,0 m²
Gulvtype	Gulv mot uoppvarmet sone
Uoppvarmet sone	Ventilert uoppvarmet parkeringskjeller Varmetapsfaktor: 0,91
Innv. akk. sjikt gulv	Tungt gulv Varmekapasitet 63,0 Wh/m²K
Gulvkonstruksjon	Egendefinert Uverdi: 0,50 W/m²K

Inndata yttertak

Beskrivelse	Verdi
Navn:	Roof (yttertak)
Totalt areal	1000,0 m²
Retning (0=Nord, 180=Sør)	180°
Takvinkel	0,0°
Innv. akkumulerende sjikt	Tung himling Varmekapasitet 63,0 Wh/m²K
Konstruksjon	Egendefinert Uverdi: 0,32 W/m²K
Utvendig absorptionskoeffisient	0,80

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Resultater årssimulering

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Firma: Undervisningslisens
Inndatafil: C:\...\NB in Sapporo.smi
Prosjekt: Standard Office Building
Sone: Norwegian Building in Sapporo

Energibudsjett		
Energipost	Energibehov	Spesifikt energibehov
1a Romoppvarming	49221 kWh	9,8 kWh/m²
1b Ventilasjonsvarme (varmebatterier)	45382 kWh	9,1 kWh/m²
2 Varmtvann (tappevann)	25056 kWh	5,0 kWh/m²
3a Vifter	61311 kWh	12,3 kWh/m²
3b Pumper	8519 kWh	1,7 kWh/m²
4 Belysning	100224 kWh	20,0 kWh/m²
5 Teknisk utstyr	172258 kWh	34,5 kWh/m²
6a Romkjøling	54418 kWh	10,9 kWh/m²
6b Ventilasjonskjøling (kjølebatterier)	95783 kWh	19,2 kWh/m²
Totalt netto energibehov, sum 1-6	612172 kWh	122,4 kWh/m²

Levert energi til bygningen (beregnet)		
Energivare	Levert energi	Spesifikk levert energi
1a Direkte el.	422726 kWh	84,5 kWh/m²
1b El. til varmepumpesystem	38578 kWh	7,7 kWh/m²
1c El. til solfangersystem	0 kWh	0,0 kWh/m²
2 Olje	0 kWh	0,0 kWh/m²
3 Gass	0 kWh	0,0 kWh/m²
4 Fjernvarme	0 kWh	0,0 kWh/m²
5 Biobrensel	0 kWh	0,0 kWh/m²
6. Annen energikilde	0 kWh	0,0 kWh/m²
7. Solstrøm til egenbruk	-0 kWh	-0,0 kWh/m²
Totalt levert energi, sum 1-7	461304 kWh	92,3 kWh/m²
Solstrøm til eksport	-0 kWh	-0,0 kWh/m²
Netto levert energi	461304 kWh	92,3 kWh/m²

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Resultater årssimulering

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Dekning av energibudsjett fordelt på energikilder

Energikilder	Romoppv.	Varmebatterier	Varmtvann	Kjølebatterier	Romkjøling	El. spesifikt
El.	1,5 kWh/m²	0,0 kWh/m²	1,5 kWh/m²	19,2 kWh/m²	10,9 kWh/m²	68,5 kWh/m²
Olje	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Gass	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Fjernvarme	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Biobrensel	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Varmepumpe	8,4 kWh/m²	9,1 kWh/m²	3,5 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Sol	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Annen	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Sum	9,8 kWh/m²	9,1 kWh/m²	5,0 kWh/m²	19,2 kWh/m²	10,9 kWh/m²	68,5 kWh/m²

Årlige utslipp av CO_2

Energivare	Utslipp	Spesifikt utslipp
1a Direkte el.	270545 kg	54,1 kg/m²
1b El. til varmepumpesystem	24690 kg	4,9 kg/m²
1c El. til solfangersystem	0 kg	0,0 kg/m²
2 Olje	0 kg	0,0 kg/m²
3 Gass	0 kg	0,0 kg/m²
4 Fjernvarme	0 kg	0,0 kg/m²
5 Biobrensel	0 kg	0,0 kg/m²
6. Annen energikilde	0 kg	0,0 kg/m²
7. Solstrøm til egenbruk	-0 kg	-0,0 kg/m²
Totalt utslipp, sum 1-7	295234 kg	59,0 kg/m²
Solstrøm til eksport	-0 kg	-0,0 kg/m²
Netto CO_2-utslipp	295234 kg	59,0 kg/m²

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Resultater årssimulering

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Kostnad kjøpt energi		
Energivare	Energikostnad	Spesifikk energikostnad
1a Direkte el.	562226 kr	112,4 kr/m²
1b El. til varmepumpesystem	51308 kr	10,3 kr/m²
1c El. til solfangersystem	0 kr	0,0 kr/m²
2 Olje	0 kr	0,0 kr/m²
3 Gass	0 kr	0,0 kr/m²
4 Fjernvarme	0 kr	0,0 kr/m²
5 Biobrensel	0 kr	0,0 kr/m²
6. Annen energikilde	0 kr	0,0 kr/m²
7. Solstrøm til egenbruk	-0 kr	-0,0 kr/m²
Årlige energikostnader, sum 1-7	613534 kr	122,7 kr/m²
Solstrøm til eksport	0 kr	0,0 kr/m²
Netto energikostnad	613534 kr	122,7 kr/m²

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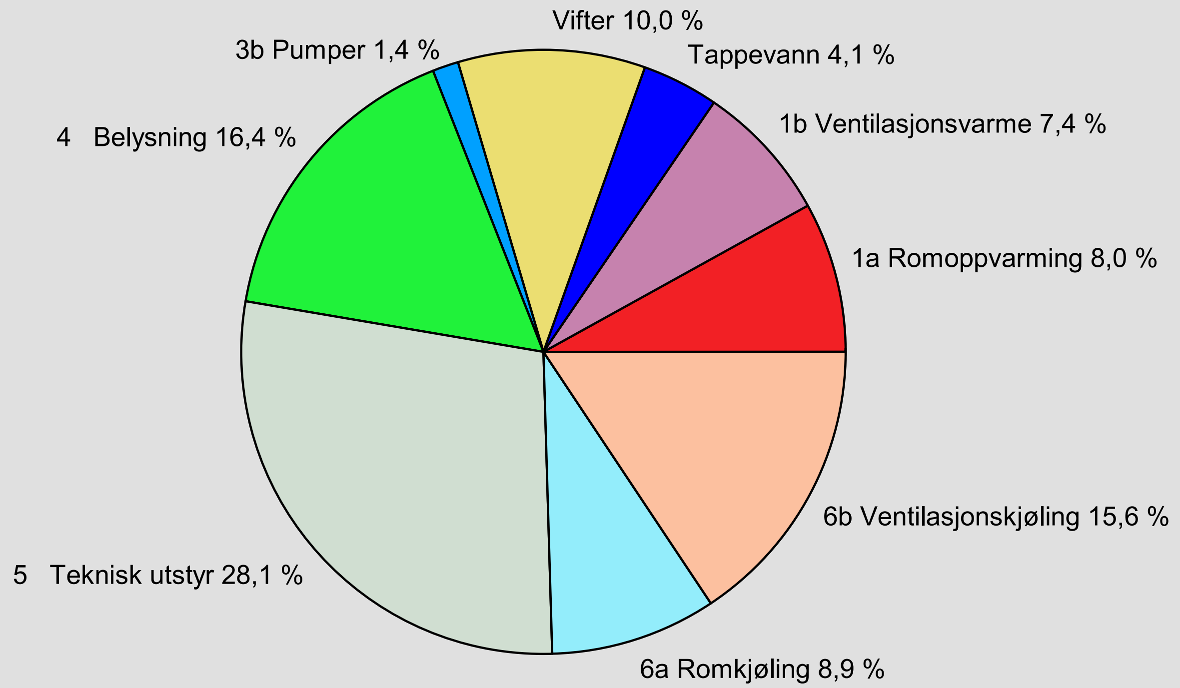
Årlig energibudsjett



1a Romoppvarming	49221 kWh
1b Ventilasjonsvarme (varmebatterier)	45382 kWh
2 Varmtvann (tappevann)	25056 kWh
3a Vifter	61311 kWh
3b Pumper	8519 kWh
4 Belysning	100224 kWh
5 Teknisk utstyr	172258 kWh
6a Romkjøling	54418 kWh
6b Ventilasjonskjøling (kjølebatterier)	95783 kWh
Totalt netto energibehov, sum 1-6	612172 kWh

SIMIEN

Resultater årssimulering

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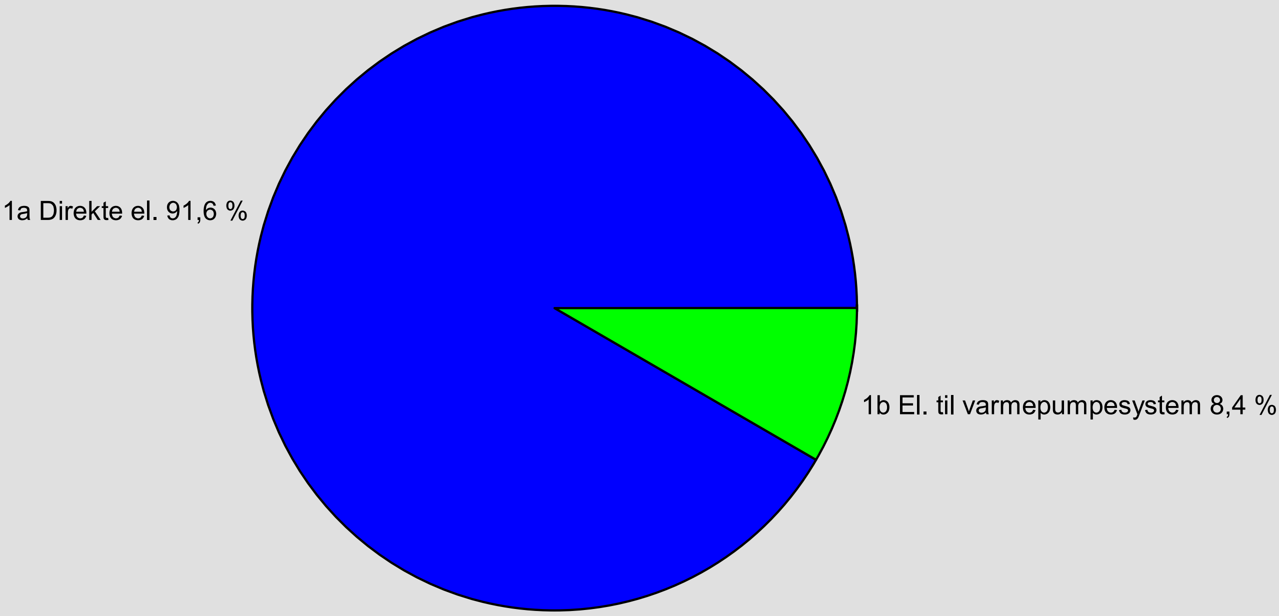
Levert energi til bygningen (beregnet)



1a Direkte el.	422726 kWh
1b El. til varmepumpesystem	38578 kWh
1c El. til solfangersystem	0 kWh
2 Olje	0 kWh
3 Gass	0 kWh
4 Fjernvarme	0 kWh
5 Biobrensel	0 kWh
6. Annen energikilde	0 kWh
Totalt levert energi, sum 1-7	461304 kWh

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Resultater årssimulering

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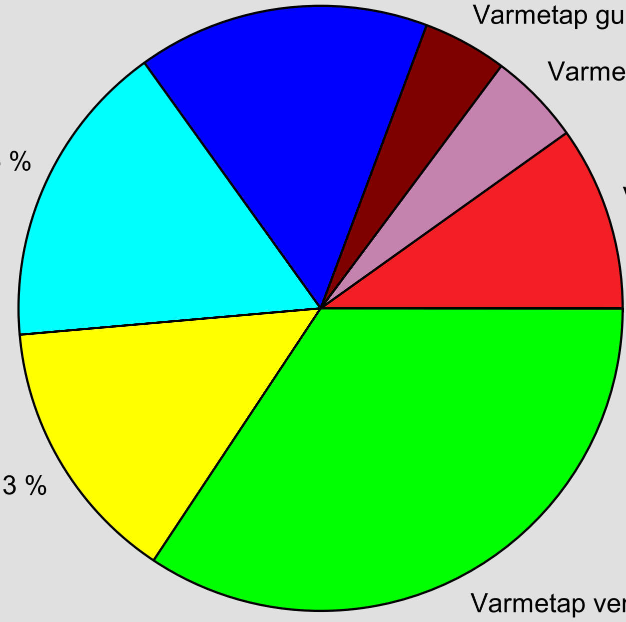
Varmetapsbudsjett (varmetapstall)



Varmetapstall yttervegger	0,07 W/m²K
Varmetapstall tak	0,04 W/m²K
Varmetapstall gulv på grunn/mot det fri	0,03 W/m²K
Varmetapstall glass/vinduer/dører	0,11 W/m²K
Varmetapstall kuldebroer	0,12 W/m²K
Varmetapstall infiltrasjon	0,10 W/m²K
Varmetapstall ventilasjon	0,25 W/m²K
Totalt varmetapstall	0,73 W/m²K

SIMIEN

Resultater årssimulering

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Programversjon: 6.009
Simuleringsansvarlig: N.B.Alseth & L.Andersen
Firma: Undervisningslisens
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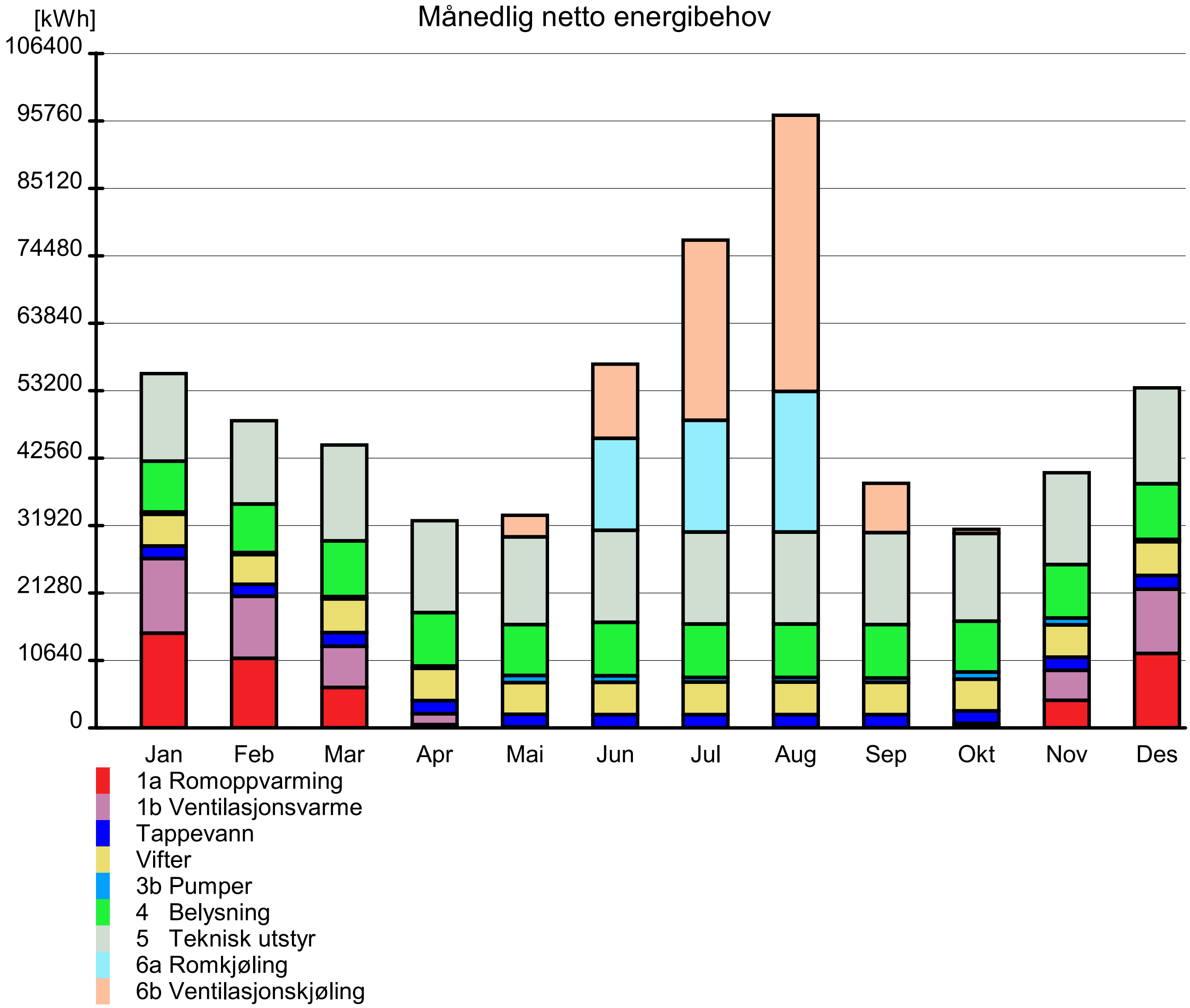

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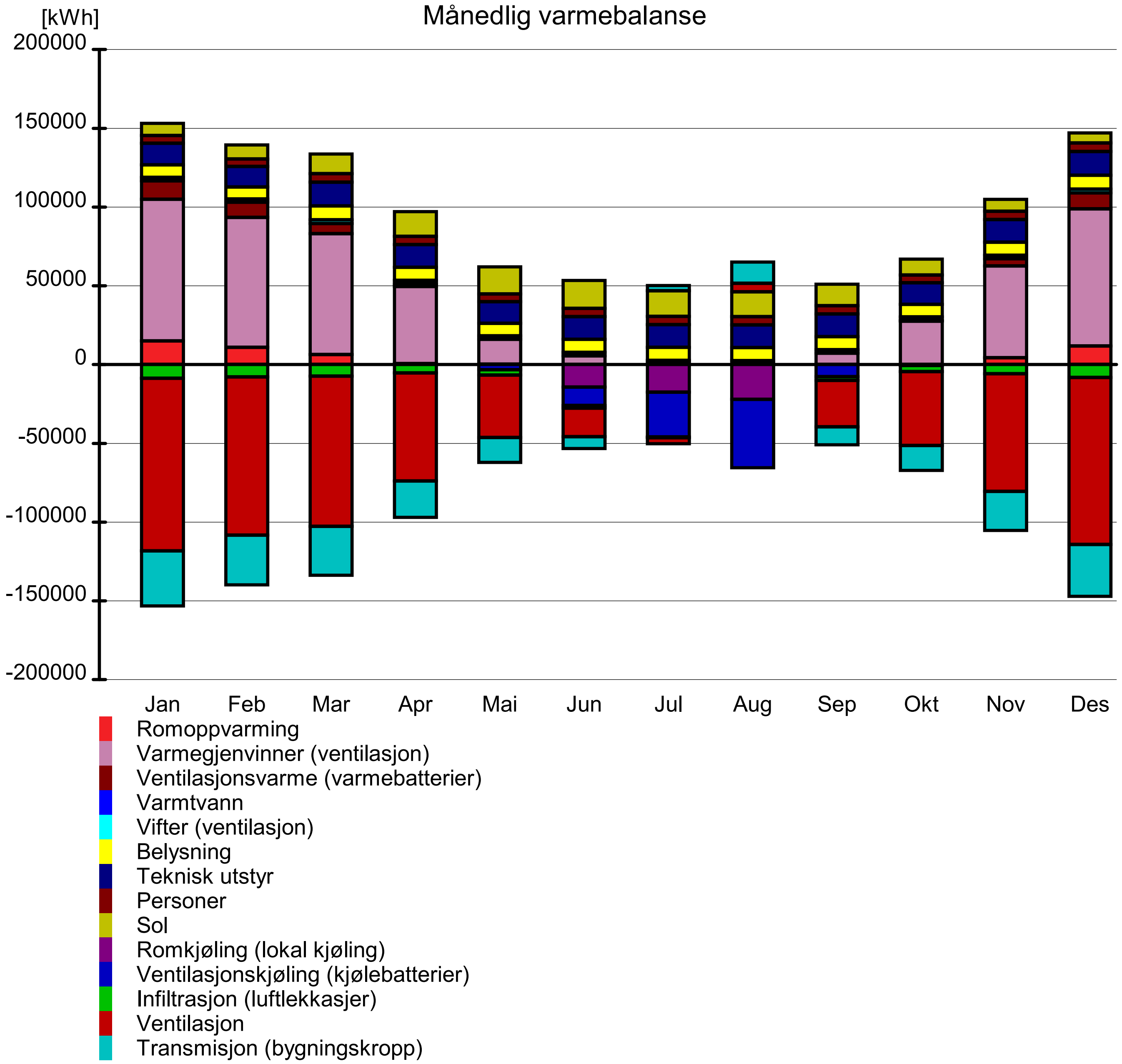

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Månedlige temperaturdata (lufttemperatur)

Måned	Midlere ute	Maks. ute	Min. ute	Midlere sone	Maks. sone	Min. sone
Januar	-3,3 °C	5,3 °C	-10,3 °C	19,9 °C	23,1 °C	19,0 °C
Februar	-2,8 °C	6,6 °C	-11,1 °C	20,1 °C	23,5 °C	19,0 °C
Mars	1,2 °C	12,4 °C	-7,8 °C	20,5 °C	24,5 °C	19,0 °C
April	7,4 °C	18,2 °C	-1,2 °C	22,0 °C	26,1 °C	19,0 °C
Mai	13,1 °C	25,5 °C	3,5 °C	22,1 °C	27,7 °C	19,0 °C
Juni	17,0 °C	26,7 °C	8,8 °C	21,6 °C	25,3 °C	19,0 °C
Juli	20,4 °C	32,2 °C	13,7 °C	22,0 °C	25,4 °C	19,7 °C
August	22,2 °C	30,6 °C	14,7 °C	22,0 °C	25,5 °C	19,9 °C
September	18,0 °C	27,6 °C	9,2 °C	24,6 °C	28,7 °C	21,2 °C
Oktober	12,1 °C	22,5 °C	2,8 °C	22,4 °C	27,3 °C	19,0 °C
November	4,8 °C	18,7 °C	-4,2 °C	20,7 °C	24,8 °C	19,0 °C
Desember	-1,4 °C	7,9 °C	-8,6 °C	20,0 °C	23,3 °C	19,0 °C

Månedlige temperaturdata (operativ temperatur)

Måned	Midlere ute	Maks. ute	Min. ute	Midlere sone	Maks. sone	Min. sone
Januar	-3,3 °C	5,3 °C	-10,3 °C	20,2 °C	22,9 °C	19,0 °C
Februar	-2,8 °C	6,6 °C	-11,1 °C	20,4 °C	23,4 °C	19,0 °C
Mars	1,2 °C	12,4 °C	-7,8 °C	20,9 °C	24,5 °C	19,0 °C
April	7,4 °C	18,2 °C	-1,2 °C	22,7 °C	26,5 °C	21,7 °C
Mai	13,1 °C	25,5 °C	3,5 °C	23,0 °C	27,0 °C	23,1 °C
Juni	17,0 °C	26,7 °C	8,8 °C	22,5 °C	25,0 °C	22,2 °C
Juli	20,4 °C	32,2 °C	13,7 °C	22,8 °C	25,2 °C	22,5 °C
August	22,2 °C	30,6 °C	14,7 °C	22,8 °C	25,2 °C	22,6 °C
September	18,0 °C	27,6 °C	9,2 °C	25,6 °C	28,4 °C	24,3 °C
Oktober	12,1 °C	22,5 °C	2,8 °C	23,2 °C	27,1 °C	19,2 °C
November	4,8 °C	18,7 °C	-4,2 °C	21,1 °C	25,1 °C	19,0 °C
Desember	-1,4 °C	7,9 °C	-8,6 °C	20,3 °C	23,2 °C	19,0 °C

SIMIEN

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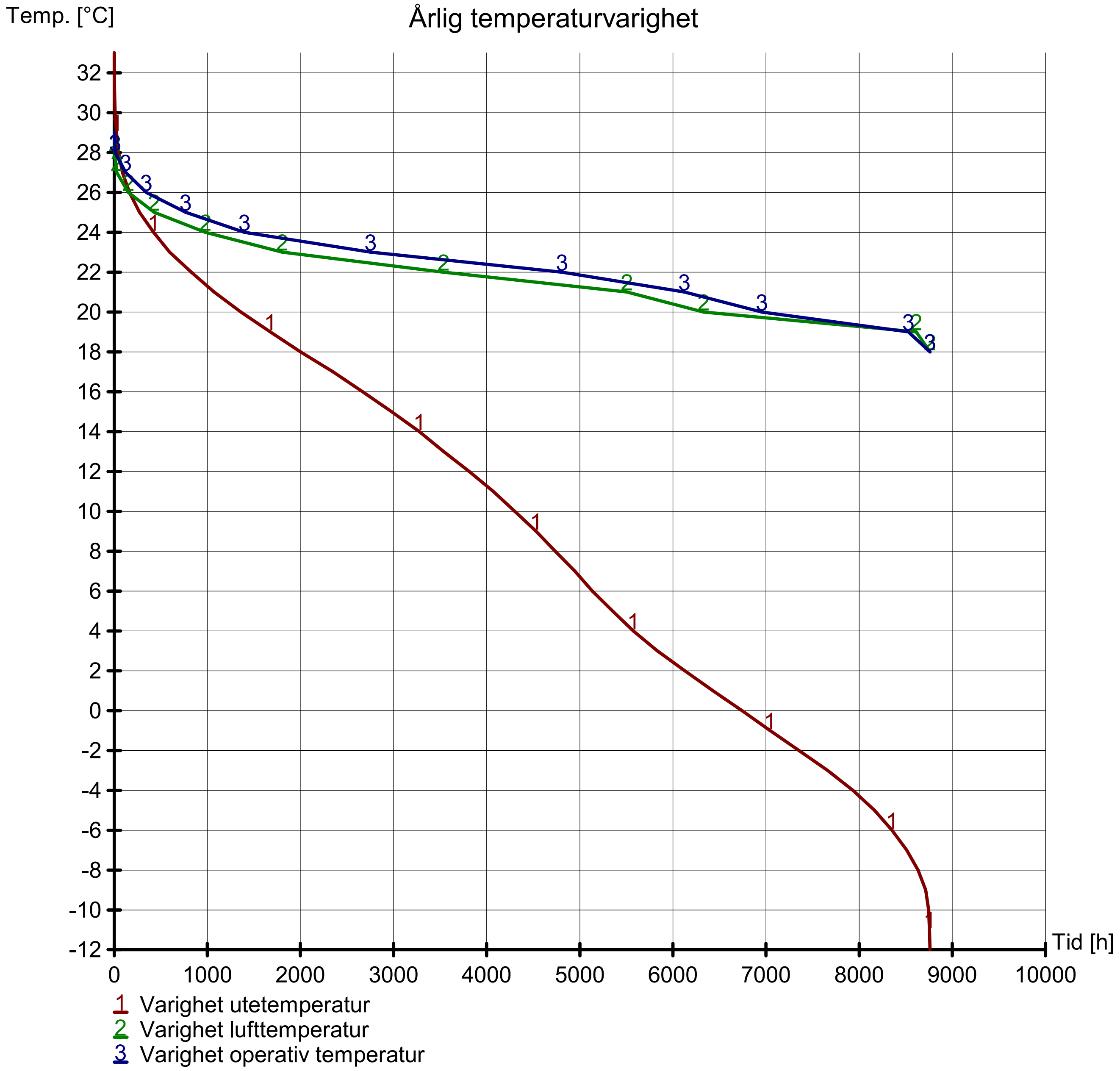

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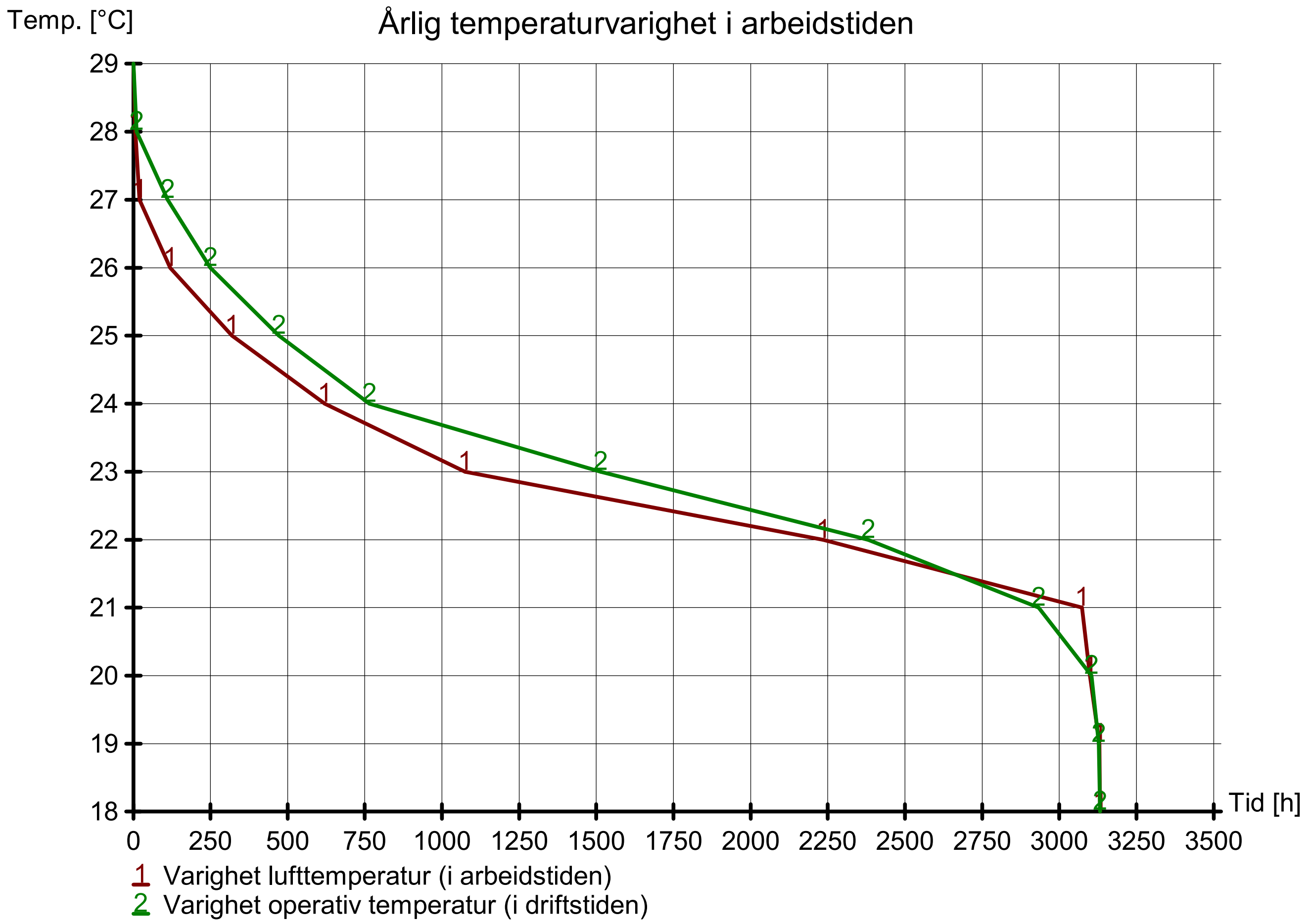

Årlig varighet operativ temperatur i arbeidstiden	
Beskrivelse	Operativ temperatur
Antall timer over 26°C	250

SIMIEN

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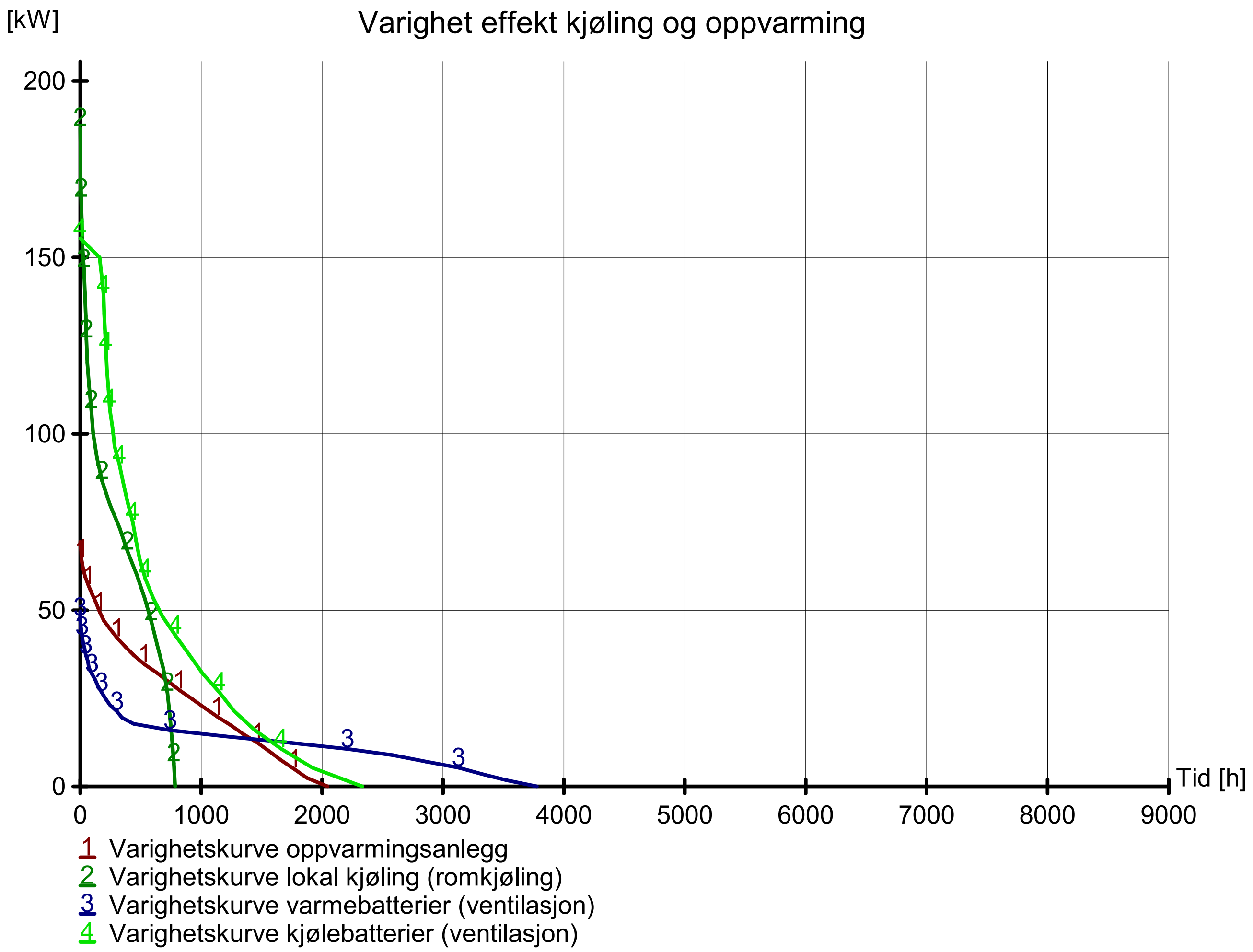

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Dekningsgrad effekt/energi oppvarming

Effekt (dekning)	Dekningsgrad energibruk
83 kW (90 %)	100 %
74 kW (80 %)	100 %
64 kW (70 %)	98 %
55 kW (60 %)	96 %
46 kW (50 %)	91 %
37 kW (40 %)	82 %
28 kW (30 %)	70 %
18 kW (20 %)	54 %
9 kW (10 %)	31 %
Nødvendig effekt til oppvarming av tappevann er ikke inkludert	-

Dokumentasjon av sentrale inndata (1)

Beskrivelse	Verdi	Dokumentasjon
Areal yttervegger [m²]:	1707	
Areal tak [m²]:	1000	
Areal gulv [m²]:	1000	
Areal vinduer og ytterdører [m²]:	568	
Oppvarmet bruksareal (BRA) [m²]:	5000	
Oppvarmet luftvolum [m³]:	15000	
U-verdi yttervegger [W/m²K]	0,21	
U-verdi tak [W/m²K]	0,18	
U-verdi gulv [W/m²K]	0,16	
U-verdi vinduer og ytterdører [W/m²K]	1,00	
Areal vinduer og dører delt på bruksareal [%]	11,4	
Normalisert kuldebroverdi [W/m²K]:	0,12	
Normalisert varmekapasitet [Wh/m²K]	49	
Lekkasjetall (n50) [1/h]:	1,50	
Temperaturvirkningsgr. varmegjenvinner [%]:	80	

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Dokumentasjon av sentrale inndata (2)		
Beskrivelse	Verdi	Dokumentasjon
Estimert virkningsgrad gjenvinner justert for frostsikring [%]:	80,0	
Spesifikk vifteeffekt (SFP) [kW/m³/s]:	1,50	
Luftmengde i driftstiden [m³/hm²]	7,00	
Luftmengde utenfor driftstiden [m³/hm²]	2,00	
Systemvirkningsgrad oppvarmingsanlegg:	2,03	
Installert effekt romoppv. og varmebatt. [W/m²]:	80	
Settpunkttemperatur for romoppvarming [°C]	20,0	
Systemeffektfaktor kjøling:	2,50	
Settpunkttemperatur for romkjøling [°C]	22,0	
Installert effekt romkjøling og kjølebatt. [W/m²]:	70	
Spesifikk pumpeeffekt romoppvarming [kW/(l/s)]:	0,50	
Spesifikk pumpeeffekt romkjøling [kW/(l/s)]:	0,60	
Spesifikk pumpeeffekt varmebatteri [kW/(l/s)]:	0,50	
Spesifikk pumpeeffekt kjølebatteri [kW/(l/s)]:	0,60	
Driftstid oppvarming (timer)	12,0	

Dokumentasjon av sentrale inndata (3)		
Beskrivelse	Verdi	Dokumentasjon
Driftstid kjøling (timer)	12,0	
Driftstid ventilasjon (timer)	12,0	
Driftstid belysning (timer)	12,0	
Driftstid utstyr (timer)	12,0	
Oppholdstid personer (timer)	12,0	
Effektbehov belysning i driftstiden [W/m²]	6,40	
Varmetilskudd belysning i driftstiden [W/m²]	6,40	
Effektbehov utstyr i driftstiden [W/m²]	11,00	
Varmetilskudd utstyr i driftstiden [W/m²]	11,00	
Effektbehov varmtvann på driftsdager [W/m²]	0,80	
Varmetilskudd varmtvann i driftstiden [W/m²]	0,00	
Varmetilskudd personer i oppholdstiden [W/m²]	4,00	
Total solfaktor for vindu og solskjerming:	0,38	
Gjennomsnittlig karmfaktor vinduer:	0,20	
Solskjermingsfaktor horisont/utspring (N/Ø/S/V):	1,00/1,00/1,00/1,00	

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Inndata bygning

Beskrivelse	Verdi
Bygningskategori	Kontorbygg
Simuleringsansvarlig	N.B.Alseth _L.Andersen
Kommentar	

Inndata klima

Beskrivelse	Verdi
Klimasted	Sapporo
Breddegrad	43° 5'
Lengdegrad	141° 18'
Tidssone	GMT + 9
Årsmiddeltemperatur	9,1 °C
Midlere solstråling horisontal flate	142 W/m²
Midlere vindhastighet	3,4 m/s

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Inndata energiforsyning

Beskrivelse	Verdi
1a Direkte el.	Systemvirkningsgrad romoppv,: 0,81 Systemvirkningsgrad varmtvann: 0,67 Systemvirkningsgrad varmebatterier: 0,88 Kjølefaktor romkjøling: 2,50 Kjølefaktor kjølebatterier: 2,50 Energipris: 1,33 kr/kWh CO2-utslipp: 640 g/kWh Andel romoppvarming: 15,0% Andel oppv, tappevann: 30,0% Andel varmebatteri: 0,0 % Andel kjølebatteri: 100,0 % Andel romkjøling: 100,0 % Andel el, spesifikt: 100,0 %
1b El. til varmepumpesystem	Systemvirkningsgrad romoppv,: 2,74 Systemvirkningsgrad varmtvann: 2,60 Systemvirkningsgrad varmebatterier: 2,74 Kjølefaktor romkjøling: 3,24 Kjølefaktor kjølebatterier: 3,24 Energipris: 1,33 kr/kWh CO2-utslipp: 640 g/kWh Andel romoppvarming: 85,0% Andel oppv, tappevann: 70,0% Andel varmebatteri: 100,0 % Andel kjølebatteri: 0,0 % Andel romkjøling: 0,0 % Andel el, spesifikt: 0,0 %

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Inndata ekspertverdier

Beskrivelse	Verdi
Konvektiv andel varmetilskudd belysning	0,30
Konvektiv andel varmetilsk. teknisk utstyr	0,50
Konvektiv andel varmetilsikudd personer	0,50
Konvektiv andel varmetilsikudd sol	0,50
Konvektiv varmoverføringskoeff. vegger	2,50
Konvektiv varmoverføringskoeff. himling	2,00
Konvektiv varmoverføringskoeff. gulv	3,00
Bypassfaktor kjølebatteri	0,25
Innv. varmemotstand på vinduruter	0,13
Midlere lufthastighet romluft	0,15
Turbulensintensitet romluft	25,00
Avstand fra vindu	0,60
Termisk konduktivitet akk. sjikt [W/m²K]:	20,00

Inndata rom/sone

Beskrivelse	Verdi
Oppvarmet gulvareal	5000,0 m²
Oppvarmet luftvolum	15000,0 m³
Normalisert kuldebroverdi	0,12 W/(m²K)
Varmekapasitet møbler/interiør	2,0 Wh/m² (Lett møblert rom)
Lekkasjetall (luftskifte v. 50pa)	1,50 ach
Skjerming i terrenget	Moderat skjerming
Fasadesituasjon	Flere eksponerte fasader
Driftsdager i Januar	21
Driftsdager i Februar	20
Driftsdager i Mars	23
Driftsdager i April	22
Driftsdager i Mai	21
Driftsdager i Juni	22
Driftsdager i Juli	22
Driftsdager i August	22
Driftsdager i September	22
Driftsdager i Oktober	21
Driftsdager i November	22
Driftsdager i Desember	23

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Inndata oppvarming

Beskrivelse	Verdi
Navn:	Heating (oppvarming)
Settpunkttemperatur i driftstid	21,0 °C
Settpunkttemperatur utenfor driftstiden	19,0 °C
Maks. kapasitet	50 W/m²
Konvektiv andel oppvarming	0,50
Driftstid	12:00 timer drift pr døgn
Vannbårent oppvarmingsanlegg	Ja
Turtemperatur	35,0 °C
Returtemperatur	30,0 °C
Spesifikk pumpeeffekt	0,50 kW/(l/s)

Inndata CAV

Beskrivelse	Verdi
Navn:	Ventilation (CAV ventilasjon)
Ventilasjonstype	Balansert ventilasjon
Driftstid	12:00 timer drift pr døgn
Luftmengde	I driftstiden: tilluft = 7.0 m³/hm², avtrekk = 7.0 m³/hm² Utenfor driftstiden: tilluft = 2.0 m³/hm², avtrekk = 2.0 m³/hm² Helg/feridag: tilluft = 2.0 m³/hm², avtrekk = 2.0 m³/hm²
Tilluftstemperatur	Normal: 19.0 °C Fra Mai til August: 17.0 °C
Varmebatteri	Ja Maks. kapasitet: 30 W/m²
Vannbåren distribusjon til varmebatteri	Delta-T: 30.0 °C SPP: 0.5 kW/(l/s)
Kjølebatteri	
Vannbåren distribusjon til kjølebatteri	Delta-T: 6.0 °C SPP: 0.6 kW/(l/s)
Varmegjenvinner	Ja, temperaturvirkningsgrad: 0.80
Vifter	Plassering tilluftsvifte: Etter gjenvinner Plassering avtrekksvifte: Etter gjenvinner
SFP-faktor vifter	1.50 kW/m³/s

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Inndata belysning

Beskrivelse	Verdi
Navn:	Internal Loads (internlaster, belysning)
Effekt/Varmetilskudd belysning	I driftstiden; Effekt: 6,4 W/m²; Varmetilskudd: 100 % Utenfor driftstiden; Effekt: 0,0 W/m²; Varmetilskudd: 100 % På helg/feriedager; Effekt: 0,0 W/m²; Varmetilskudd: 100 % Antall timer drift pr døgn: 12:00

Inndata teknisk utstyr (internlast)

Beskrivelse	Verdi
Navn:	Internal Loads (internlaster, teknisk utstyr)
Effekt/Varmetilskudd teknisk utstyr	I driftstiden; Effekt: 11,0 W/m²; Varmetilskudd: 100 % Utenfor driftstiden; Effekt: 0,0 W/m²; Varmetilskudd: 100 % På helg/feriedager; Effekt: 0,0 W/m²; Varmetilskudd: 100 % Antall timer drift pr døgn: 12:00

Inndata oppvarming av tappevann

Beskrivelse	Verdi
Navn:	Internal Loads (internlaster, tappevann)
Tappevann	Driftsdag; Midlere effekt: 0,8 W/m²; Varmetilskudd: 0 %; Vanndamp: 0,0 g/m² Helg/feriedag: Midlere effekt: 0,0 W/m²; Varmetilskudd: 0 %; ; Vanndamp: 0,0 g/m²

Inndata varmetilskudd personer (internlast)

Beskrivelse	Verdi
Navn:	Internal Loads (internlaster, varmetilskudd personer)
Varmetilskudd personer	I arbeidstiden: 4,0 W/m² Utenfor arbeidstiden: 0,0 W/m² Ferie/helgedager: 0,0 W/m² Antall arbeidstimer: 12:00

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Inndata lokal kjøling

Beskrivelse	Verdi
Navn:	Cooling (lokal kjøling)
Settpunkttemperatur	22,0 °C
Maks, kapasitet	40 W/m²
Konvektiv andel kjøling	0,50
Driftstid	12:00 timer drift pr døgn
Kjøling på helge/feriedager	Nei
Kjøling via vannbårent anlegg	Nei
Kjølingen er bare aktiv i deler av året	Startdato: 1. Juni Stoppdato: 1. September

Inndata fasade/yttervegg

Beskrivelse	Verdi
Navn:	South Facade (fasade)
Totalt areal	437,5 m²
Retning (0=Nord, 180=Sør)	180°
Innv. akkumulerende sjikt	Tung vegg Varmekapasitet 63,0 Wh/m²K
Konstruksjon	Egendefinert Uverdi: 0,21 W/m²K
Utvendig absorptionskoeffisient	0,80

Inndata vinduselement

Beskrivelse	Verdi
Navn:	Window 1 (Vindu(er) på South Facade)
Antall vinduer	38
Høyde vindu(er)	1,80 m
Bredde vindu(er)	1,80 m
Karm-/ramme faktor	0,20
Total U-verdi (rute+karm/rammekonstr.)	1,00 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

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Inndata vinduselement

Beskrivelse	Verdi
Navn:	Window 2 (Vindu(er) på South Facade)
Antall vinduer	2
Høyde vindu(er)	1,50 m
Bredde vindu(er)	2,60 m
Karm-/ramme faktor	0,20
Total U-verdi (rute+karm/rammekonstr.)	1,00 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

Inndata vinduselement

Beskrivelse	Verdi
Navn:	Window 3 (Vindu(er) på South Facade)
Antall vinduer	1
Høyde vindu(er)	2,10 m
Bredde vindu(er)	0,50 m
Karm-/ramme faktor	0,20
Total U-verdi (rute+karm/rammekonstr.)	1,00 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

Inndata ytterdør

Beskrivelse	Verdi
Navn:	Door 1 (ytterdør)
Areal inkl. karm/ramme	4,4 m²
Dørtype	Egendefinert Uverdi: 1,20 W/m²K

SIMIEN

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Inndata fasade/yttervegg

Beskrivelse	Verdi
Navn:	West Facade (fasade)
Totalt areal	700,0 m²
Retning (0=Nord, 180=Sør)	270°
Innv. akkumulerende sjikt	Tung vegg Varmekapasitet 63,0 Wh/m²K
Konstruksjon	Egendefinert Uverdi: 0,21 W/m²K

Inndata vinduselement

Beskrivelse	Verdi
Navn:	Window 1 (Vindu(er) på West Facade)
Antall vinduer	50
Høyde vindu(er)	1,80 m
Bredde vindu(er)	1,80 m
Karm-/ramme faktor	0,20
Total U-verdi (rute+karm/rammekonstr.)	1,00 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

Inndata fasade/yttervegg

Beskrivelse	Verdi
Navn:	North Facade (fasade)
Totalt areal	437,5 m²
Retning (0=Nord, 180=Sør)	0°
Innv. akkumulerende sjikt	Tung vegg Varmekapasitet 63,0 Wh/m²K
Konstruksjon	Egendefinert Uverdi: 0,21 W/m²K

Simuleringsnavn: Årssimulering
Tid/dato simulering: 11:45 13/5-2018
Programversjon: 6.009
Simuleringsansvarlig: N.B.Alseth & L.Andersen
Firma: Undervisningslisens
Inndatafil: C:\...\NB in Sapporo.smi
Prosjekt: Standard Office Building
Sone: Norwegian Building in Sapporo

Inndata vinduselement

Beskrivelse	Verdi
Navn:	Window 1 (Vindu(er) på North Facade)
Antall vinduer	40
Høyde vindu(er)	1,80 m
Bredde vindu(er)	1,80 m
Karm-/ramme faktor	0,20
Total U-verdi (rute+karm/rammekonstr.)	1,00 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

Inndata fasade/yttervegg

Beskrivelse	Verdi
Navn:	East Facade (fasade)
Totalt areal	700,0 m²
Retning (0=Nord, 180=Sør)	90°
Innv. akkumulerende sjikt	Tung vegg Varmekapasitet 63,0 Wh/m²K
Konstruksjon	Egendefinert Uverdi: 0,21 W/m²K

Inndata vinduselement

Beskrivelse	Verdi
Navn:	Window 1 (Vindu(er) på East Facade)
Antall vinduer	39
Høyde vindu(er)	1,80 m
Bredde vindu(er)	1,80 m
Karm-/ramme faktor	0,20
Total U-verdi (rute+karm/rammekonstr.)	1,00 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

Simuleringsnavn: Årssimulering
Tid/dato simulering: 11:45 13/5-2018
Programversjon: 6.009
Simuleringsansvarlig: N.B.Alseth & L.Andersen
Firma: Undervisningslisens
Inndatafil: C:\...\NB in Sapporo.smi
Prosjekt: Standard Office Building
Sone: Norwegian Building in Sapporo

Inndata vinduselement

Beskrivelse	Verdi
Navn:	Window 4 (Vindu(er) på East Facade)
Antall vinduer	9
Høyde vindu(er)	1,80 m
Bredde vindu(er)	0,50 m
Karm-/ramme faktor	0,20
Total U-verdi (rute+karm/rammekonstr.)	1,00 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

Inndata vinduselement

Beskrivelse	Verdi
Navn:	Window 5 (Vindu(er) på East Facade)
Antall vinduer	1
Høyde vindu(er)	2,60 m
Bredde vindu(er)	1,00 m
Karm-/ramme faktor	0,20
Total U-verdi (rute+karm/rammekonstr.)	1,00 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

Inndata vinduselement

Beskrivelse	Verdi
Navn:	Window 6 (Vindu(er) på East Facade)
Antall vinduer	1
Høyde vindu(er)	0,50 m
Bredde vindu(er)	1,00 m
Karm-/ramme faktor	0,20
Total U-verdi (rute+karm/rammekonstr.)	1,00 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

Simuleringsnavn: Årssimulering
Tid/dato simulering: 11:45 13/5-2018
Programversjon: 6.009
Simuleringsansvarlig: N.B.Alseth & L.Andersen
Firma: Undervisningslisens
Inndatafil: C:\...\NB in Sapporo.smi
Prosjekt: Standard Office Building
Sone: Norwegian Building in Sapporo

Inndata ytterdør

Beskrivelse	Verdi
Navn:	Door 2 (ytterdør)
Areal inkl. karm/ramme	2,1 m²
Dørtype	Egendefinert Uverdi: 1,20 W/m²K

Inndata gulv mot friluft/kryprom/grunn

Beskrivelse	Verdi
Navn:	Floor (gulv)
Oppvarmet gulvareal	1000,0 m²
Gulvtype	Gulv mot uoppvarmet sone
Uoppvarmet sone	Ventilert uoppvarmet parkeringskjeller Varmetapsfaktor: 0,91
Innv. akk. sjikt gulv	Tungt gulv Varmekapasitet 63,0 Wh/m²K
Gulvkonstruksjon	Egendefinert Uverdi: 0,18 W/m²K

Inndata yttertak

Beskrivelse	Verdi
Navn:	Roof (yttertak)
Totalt areal	1000,0 m²
Retning (0=Nord, 180=Sør)	180°
Takvinkel	0,0°
Innv. akkumulerende sjikt	Tung himling Varmekapasitet 63,0 Wh/m²K
Konstruksjon	Egendefinert Uverdi: 0,18 W/m²K
Utvendig absorptionskoeffisient	0,80

Green Buildings in Cold Climate

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Submitted 16 May 2018

Abstract

The building and construction sector accounts for over 35 % of the total final energy consumption and generated 40 % of the energy related greenhouse gas emissions in the world. Reducing energy consumption in buildings is critical to reduce the overall energy demand and greenhouse gas emissions to contribute to the major focus of a more sustainable and safer energy supply especially in the colder regions of the world. Hence, the main challenge lays within reducing the energy demands of existing building.

The purpose of this master thesis project has been to enlighten and analyse how the differences in policies, regulations and other instrumental means affect the environmental footprint and energy consumptions of buildings in cold regions such as northern Japan and northern Norway. Simulations has been conducted as a part of a case study to further enlighten and visualize by figures the differences between Japan and Norway. In addition, an assessment of feasibility and potential measures that complies with cold climate aspects regarding energy efficiency is conducted. This has been executed as a collaboration project and exchange stay about green/sustainable buildings in colder regions of the world between UiT – The Arctic University of Norway in Narvik and Hokkaido University in Sapporo, Japan, including an exchange stay in Sapporo.

1. Introduction

Natural causes have always changed the global climate, but in the past 150 years, human impact has affected and changed the climate more than ever before. Human impacts the global earth by the way we live, conserves and build our social environment. A considerable social value of a country is the building and construction sector. The global building and construction sector accounted for over 35 % of total final energy consumption in 2016, representing an increase of the equal amount since 1990, and generated approximately 40 % of the global energy-related greenhouse gas emissions [1]. Measures are being made to counter the environmental emissions, especially in the building and construction sector this last decade. The world has seen several standards of concept that enhances energy efficiency in buildings, where the term Green Building often is used as the pathway for the worlds sustainable building development.

In cold climates, like Norway and northern Japan, the pathway for sustainable development faces often challenges that differ from the ones that are in other warmer areas of the globe. The green building term as well. Cold climate introduces often a higher energy consumption and considerable amounts of greenhouse gas emissions and waste in the environment. Policies are being revised and new standards are being advanced or developed, to deal and counter measure – both the climate and the human interaction.

This report aims to assess whether cold climates can be met by introducing concepts of Green Buildings. In addition, the report will enlighten the differences in policies in regulation between Norway and Japan, affects the environmental footprints of buildings.

2. Definition of Green-building concept

Green building is a term used for buildings confining to a certain environmental and energy related criteria. It can be perceived as the theory, science and structure of how buildings can ensure environmentally sustainability throughout its whole life-cycle: from planning to design, construction, operation, maintenance, renovation and deconstruction [2]. USGBS LEED Green Building Rating System, one of the world's most developed rating system addresses five of the most *central* elements from which the concept is derived [3]

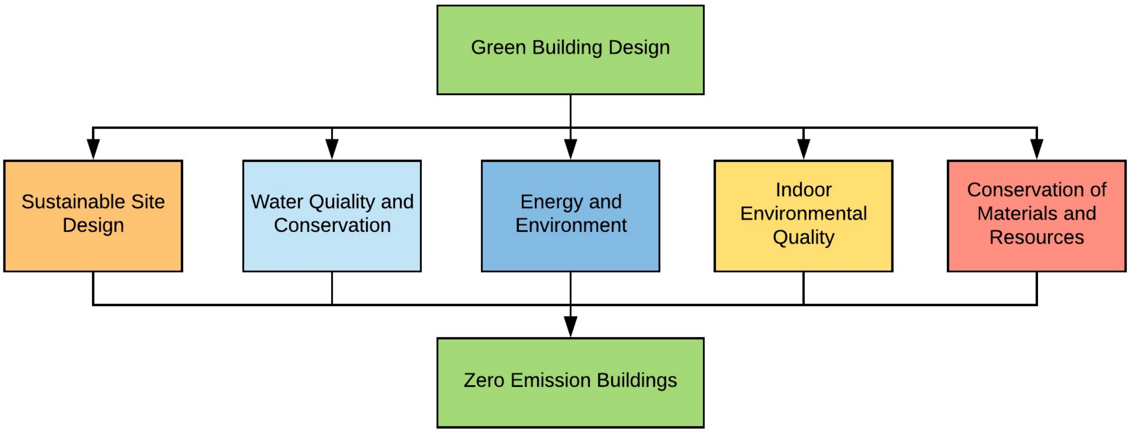

Figure 1: Structure of key elements of the concept Green Building

The structure of a green building project includes how to assess and measure each of the key elements in the figure above and implement them in the most sustainable way. The interrelationship is important and the coexistence between the building site, site features, the path of the sun, and the location and orientation of the building and elements such as windows and external shading devices have a significant impact on the quality and effectiveness of natural day lightning. These elements also affect direct solar loads and the overall energy performance of the building. Zero Emission Buildings is a great example of the term Green Building.

3. Definition of cold climate

Today, the definition of cold climate isn't yet established. Cold climate could either be addressed by several parameters, such as; air temperature, permafrost and ice on rivers, or it can be addressed boundary conditions, such as; air temperature, snow depth, frozen ground and heating degree days. In general, a cold climate environment exists wherever frost affects engineering systems [4] and are characterized by long cold winters with low air temperatures, snow, ice, frozen ground, ice fog and whiteout [5].

Main challenges for buildings in cold climate include; ensuring the buildings envelope is acceptable, structural aspects regarding foundation, mechanical and plumbing, electrical, controls, fire and safety, and site services. The challenges of building in cold-climate regions are generally like those in other climates, but the cruciality of an eventual failure of the solutions to the challenges are greater and more sever in cold climate due to higher air temperature differences, i.e. a hindrance in a temperate climate may threaten health and life safety in a cold climate [6].

4. Building and energy market – Japan & Norway

Norway is one of few countries in Europe that does not depend on imports for its energy supply, whereas Japan depend significantly of imports from abroad. The energy consumptions in building are highly affected by factors like energy prices, building codes, energy taxes, requirement to energy effective appliances, population and economic growth which are affected by the increase of building stock area. The energy consumption in both the Norwegian and Japanese building stock is used primary for room heating (through ventilation and radiators), technical equipment, lighting and cooling.

In 2015, the energy consumption in the Norwegian building stock accounted for about 77 TWh, where the biggest and most important energy carrier is electricity; 83 % in households and 80 % in tertiary sector in 2015. In terms of greenhouse gas emissions, the building stock represented a share of 2 % of the total GHG emissions in Norway [7].

In Japan, the energy consumption in the residential and commercial sector amounted approximately 1160 TWh in 2014 where like Norway, electricity is the major energy supply (54.8 %) followed by oil (27.9 %) and gas (15.6 %). The residential sector contributed to approximately 5 % of the total CO_2 emissions in 2014 [8]

5. Polices and Regulations – Japan & Norway

The policies and regulations regarding energy and environment are much affected by the nations intended nationally determined contribution submitted as a part of the Paris agreement. These are based on the same concept of reducing energy consumption and energy related CO_2 emissions. The measures for the countries regarding buildings, narrows down to energy efficiency requirements in buildings. Norway has for many years embraced the development of energy efficiency in buildings, partly due to the implementation of EU directives. Strict requirements are set on the building components as well as the total net energy demand for all building categories, resulting in low heat loss coefficients and efficient HVAC systems.

As Japan saw the building sector as a potential energy-saving area, large scale commercial/non-residential buildings are especially the target in their new Building Energy Efficiency Act. The requirement for non-residential buildings are primary based on the net energy performance of the buildings while the residential building includes building envelope requirements. The major focus for both countries are the aims of reducing energy consumptions, primary on newly built constructions, when the real energy efficiency potential lies within already existing buildings. Both countries have targets regarding the reduction of energy consumption in existing building, such as extensions and renovation.

The redistribution of the energy usage is a great challenge in Japan due to its dependence of import and lack of renewable resources to comply with the massive energy demand. Norway also face challenges regarding the redistribution of energy to secure energy supply, but not as vast as Japan, since nearly all electricity production is renewable and comes from hydropower. Historical crises have in a great way affect the legislation in Japan. The oil crises in the 1970s, the great earthquake in 2011 and eventual other crisis form the foundation of change within a country and form the strategy and target in the prevention of other disasters.

The impact on the measures regarding energy efficiency affects the society for many years ahead. It is therefore important to make the measures flexible, so development can happen.

6. Feasibility Study – Green Building in Cold Climate

The basis for the feasibility study has been a literature review and by collecting new innovative solutions and ideas from already existing sustainable buildings within the cold climate boundaries. Data is collected from concept studies and articles from the chosen buildings. The different buildings are based upon their overall Green Building performance and the buildings this report has chosen to highlight, are as follows:

- Powerhouse Brattørkaia; 13.000 m2 heated floor area, new office building
- Powerhouse Kjørbo; 5.200 m2 heated floor area, two-office rehabilitation project
- Campus Evenstad; 1.100 m2 heated floor area, combined teaching and office building

Buildings in cold climate conditions faces many challenges, and ranges from snow, ice, harsh weather, remoteness, and limited utilities. The biggest challenge, however, is the production of heat and energy during winter to cover the heat losses and heating requirement. Historically has the cold climate been counter-measured by increased heating by fire and wood. Traditionally, has building counter-measured cold climates by higher levels of insulation and new implemented materials and windows. Now, we see collaboration projects that don't just counter-measure cold climate in regards with the thermal aspect of the buildings but includes the total elements of what makes a building green and sustainable in the overall perspective.

Powerhouse Brattørkaia and Kjørbo, and Campus Evenstad are all buildings that compensates greenhouse gas emissions by producing their own, and exports self-produced energy. They also use renewable energy as their mantra and with a 26-degree sloped south-faced roof, Powerhouse Brattørkaia produces 46.3 kWh/m2 per year as average electricity production, while bound energy is estimated at 22 kWh/m2 per year. Powerhouse Kjørbo on the other hand, produces 200.000 kWh/per year or around 44 kWh/m2 of heated floor area. Campus Evenstad has a CHP-plant implemented, which produces electricity and heat at the same time. The output is 40 kW power and 100 kW heat, with an efficiency rate of 70 % divided by approximately 20/50 % - electricity and heat production. Common to them all, is that they have been carefully designed through a system, that examines and tries to find the most sustainable path for the building development. Aside from renewable energy, the projects conserve materials by the scope of low-bound energy, high-performance insulation, and secures a good indoor environment by natural daylighting and includes - both natural and mechanical air conditioning.

7. Case study – Results

The case study will visualize the differences and similarities between Norway and Japan related to energy efficiency and environmental footprint impacts of a standard design office building and will support the findings in the literature review. Four simulations are conducted using SIMIEN, where two are in Narvik Norway and two in Sapporo Japan. The input data are based on the literature review of building requirements and assumptions.

7.1. Simulation 1 – Norwegian building in Narvik

The first simulation, simulates a standard office building with Norwegian requirements based on Norwegian Building codes, located in Narvik. The specific energy demand is 114.5 kWh/m^2 which is less than 115 kWh/m^2, resulting as satisfied according to requirements in the Norwegian Building codes. Technical equipment demands the most energy (30.1 %) followed by both lighting and room heating (17.5 % each). The CO_2 emissions are based on the energy consumption, which is low due to the use of renewable energy (hydropower). This results in an annual of total energy related CO_2emission at 58 453 kg CO_2 equivalent.

7.2. Simulation 2 – Japanese building in Sapporo

The second simulation, simulates a standard office building with Japanese requirements based on Japanese Building codes, located in Sapporo. The specific energy demand (design value) is 211.7 kWh/m^2 which complies with Japanese building regulations where the design value over standard value must be less than one. Standard value is set to 402.5 kWh/m^2. Room cooling has the highest energy demand (31.1) followed by both lighting and technical equipment (19.2 % each). The annual energy related CO_2 emissions are 437 363 kg, equivalent to 87.5 kg/m^2. This is the highest CO_2 emissions of all the simulations.

7.3. Simulation 3 – Japanese building in Narvik

The third simulation, simulates a standard office building with Japanese requirements based on Japanese Building codes, located in Narvik. The specific energy demand is 229.9 kWh/m^2 which is twice as much for the Norwegian building located in Narvik. It does not meet the energy demand requirements of office buildings in Norway but satisfy the requirements for an office building in Japan. Room cooling, and room heating demands the most energy with over 20 % each. This is an indication of vast heat loss through the building components. The annual energy related CO_2 emissions are generally low, at 95 521 kg – 19.3 kg/m^2. The emissions are higher due to a higher energy demand.

7.4. Simulation 4 – Norwegian building in Sapporo

The fourth simulation, simulates a standard office building with Norwegian requirements based on Norwegian Building codes, located in Sapporo. The specific energy demand is 122.4 kWh/m^2 which is over 100 kWh/m^2 lower than the Japanese building located in Sapporo. The building satisfies the energy demand of and office building in Japan, but not the requirement in Norway. The distribution of the energy demand are a requsite of room cooling (8.9 %) and ventilation cooling (15.6 %). Other energy demanding energy posts are technical equipment (28.1 %) and lighting (16.4 %). The annual CO_2 emissions ends up at the amount of 294 300 kg, equivalent to 59.0 kg/m^2. Which is much higher than the Norwegian building in Narvik, due to different CO_2 emission factor.

8. Discussion

The report has observed that Norway lies within all the definitions of cold-climate regions, while only the northern part of Japan falls within the boundaries. The climate impact on buildings in these locations includes all aspects of building development. The two countries are almost the same size but different latitudes creates vaster different climates at lower latitudes than in the higher latitudes. The daylight duration is one of the most significant differences due to location, as Norway lacks daylight during the winter and receives daylight throughout the day during the summer.

Buildings are highly affected by the climate in the terms of energy consumptions. Data collected form the two countries show that the energy consumption was greater in certain years compared to others. This is mainly a result of a cold weather year where increase of the heating demand occurred. The heating degree day indicate that the amount of heating is significant in the regions within cold-climate regions. The thermal properties of the building components are exceedingly crucial for the energy consumption in cold climate. This is one of the reasons why the energy consumption in buildings in Japan are considerably higher than in Norway.

Energy consumptions and energy related CO_2 emissions in buildings are significantly affected by the policy and regulation of each country. The regulations are approved and legislated through central and local governments. It may seem that difference of the regulations and policies is that Japan has further behind in the means of energy efficiency by requirements than Norway but are now side by side in the means of future measures and targets. Regarding the current requirements of energy efficiency in Japanese buildings, Norway is still far ahead with an energy demand of < 115 kWh/m^2 for office buildings, the requirement in Japan is < 402 kWh/m^2 for the same building.

9. Conclusions

This report was about assessing whether cold climates could be met by introducing concepts of green buildings. In addition, the report has tried to enlighten the differences in policies and regulation affect the environmental footprint of buildings, in Norway and Japan.

The result show great difference between the two countries regarding energy efficiency in existing and new buildings and the major means that affect the environmental footprint are: locations, cultural and historic background, policy and regulation strategies based on each nation prerequisites and available resources. The feasibility study has also illustrated that concepts of green buildings can be met by introduction of the cold climate, within the defined boundaries of cold-climate regions of the world.

10. References

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