UiT THE ARCTIC UNIVERSITY OF NORWAY

Faculty of Engineering Science and Technology

Sustainable University Buildings

Creating a concept of a sustainable campus for UiT Narvik

—

Oddrun Pettersen Røsok

Master's thesis in Integrated Building Technology May 2017

SHO6261

Mastergradsoppgave i teknologi

Sustainable University Buildings

Bærekraftige universitetsbygninger

Oddrun Pettersen Røsok

Mai, 2017

Fakultet for ingeniørvitenskap og teknologi
Institutt for bygg, energi og materialteknologi

Tittel: Sustainable University Buildings Bærekraftige universitetsbygninger		*Dato:* 12.5.2017 *Gradering:* Åpen
Forfatter: Oddrun Pettersen Røsok		*Antall sider:* 50 *Vedlegg:* 7
Fakultet: Ingeniørvitenskap og teknologi	*Institutt:* Bygg, energi og materialteknologi - Master Integrert bygningsteknologi	
Veileder: Førsteamanuensis Raymond Riise		
Oppdragsgiver: UiT Narvik	*Oppdragsgiver kontaktperson:* Førsteamanuensis Raymond Riise	

Sammendrag:

Hensikten med masteroppgaven var å bestemme elementer i et selvlaget konsept for UiT Narvik som bærekraftig campus, samt forslag til hvordan man oppnår målene i konseptet. Konseptet var basert på studium av tre forskjellige universiteter som allerede jobber mot å bli bærekraftig campus. Arbeidet med denne oppgaven inkluderte opphold ved Universitetet i Hokkaido, Japan. Det ble laget et konsept for UiT Narvik, og en stor del av konseptet er at UiT Narviks bygning må oppnå lavenergi- standard med tilhørende tilfredsstillende energimerke. Resten av kravene i konseptet fokuserer på å redusere universitetets miljø-påvirkning.

Abstract:

The purpose of the master thesis was to determine the elements in a self- made concept for UiT Narvik as a sustainable campus, along with suggestions on how to achieve the goals in the concept. The concept was based on the study of three different universities that are already working towards becoming sustainable campuses. A part of working with this thesis was a trip to Japan to stay at Hokkaido University in Sapporo. A concept was made for UiT Narvik, and a big part of the it is that UiT Narvik's building has to achieve a low- energy standard, with an associated satisfactory energy label. The rest of the requirements in the concept are solely focusing on reducing the environmental footprint of the University.

Fakultet for ingeniørvitenskap og teknologi
Institutt for bygg, energi og materialteknologi

UiT NORGES ARKTISKE UNIVERSITET

Fakultet for ingeniørvitenskap og teknologi

MASTEROPPGAVE

for

Oddrun Pettersen Røsok

(Studentnummer 501927)

Vår 2017

Bærekraftige universitets- og høgskolebygninger

Sustainable university and college buildings

Bakgrunn

Grønt skifte er noe man i disse tider snakker mye om. Dette innebærer at man i samfunnet endrer en rekke elementer som til sammen bidrar til klima- og miljøvennlig omstilling. De globale klima- og miljøutfordringene krever omstilling til et samfunn hvor vekst og utvikling skjer innen naturens tålegrenser. Det må skje en overgang til produkter og tjenester som gir minst mulig negative konsekvenser for klima og miljø. Samfunnet må følgelig igjennom et såkalt grønt skifte.
Bygningssektoren står for en betydelig andel av klimagassutslippene i samfunnet, bl.a. gjennom høy energibruk til produksjon av bygningselementer og ikke minst til drift i bygningenes livsløp. Opp mot 40% av all stasjonær energiproduksjon går med til å sikre at våre bygg har komfortable og produksjonsfremmende miljø. Arbeidet med å øke energieffektivitet i eksisterende bygg er i gang, og nye byggeregler strammes stadig oftere inn for å redusere energibruken. Dog er det den eksisterende bygningsmasse som er utfordringen, og det finnes i dag svært mange energikrevende bygninger. Offentlige yrkesbygg utgjør også en betydelig andel av eksisterende bygningsmasse. I denne kategorien finnes universitets- og høgskolebygg av svært varierende standard.
Flere utenlandske universiteter har fått øynene opp for at deres bygninger bør gå foran som gode eksempler når det gjelder bærekraftighet og miljøpåvirkning. Eksempelvis har universitetet i Hokkaido (Sapporo) satset sterkt på begrepet «bærekraftig campus», som innebærer et grønt skifte internt på universitetet. Hokkaido har også nylig utviklet og innført et vurderingssystem for hvor godt de ulike enheter og elementer på campus klarer å følge opp klima- og miljøsynet, basert på konseptet «bærekraftig campus». Konseptet omfatter mange ulike forhold, eksempelvis sikkerhet, avfallshåndtering, logistikk, grønne områder, etc., og ikke minst energieffektivitet.

Begrensning av oppgaven

Eventuelle begrensinger av arbeidet i forhold til understående punkter gjøres i samråd med veileder.

Arbeidet skal omfatte (men nødvendigvis <u>ikke begrenses</u> til):

1. Innledende arbeid med avgrensninger og definisjoner.
2. Gjennomgå nye norske byggeregler med fokus på energieffektivitet
3. Utføre en studie av konseptet «bærekraftig campus» og overføre relevante deler av dette til norske forhold.
4. Gjøre en case-studie med UiT campus Narvik som utgangspunkt, med fokus på hvordan campus kan utvikles i henhold til konseptet «bærekraftig campus».
5. Spesielt utrede hvordan bygningsmassen ved UiT campus Narvik kan gjøres mer energieffektiv.
6. Det skal utarbeides en vitenskapelig artikkel/paper basert på besvarelsen, maks 6 sider. (Artikkelen kan sees på som er kortversjon av hele besvarelsen.)

Samarbeidspartner

Oppgaven gjennomføres i samarbeid med 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 MUNIN.

Utleveringsdato:	09.01.2017
Innleveringsdato:	15.05.2017
Kontaktperson bedrift:	Prof. Masahiko Fujii Hokkaido University, Japan Telefon: E-post: mfujii@ees.hokudai.ac.jp
Veileder UiT - IVT:	Førsteamanuensis Raymond Riise Telefon: 76 96 62 97 / 957 22 023 E-post: raymond.riise@uit.no

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

Raymond Riise
Faglig ansvarlig/veileder

Preface

This thesis about *Sustainable University Buildings* is submitted to fulfill the formal requirements for the two- year education in Master of Technology in Building Technology Engineering (MSc), at the Department of Building, Energy and Material Technology, The Arctic University of Norway, UiT Narvik. The Master program is a continuation of a Bachelor degree in Renewable Energy Engineering, completed at the former Narvik University College, from 2012 to 2015.

The thesis was written and conducted January 9th to May 15th 2017, under the supervision of Associate Professor Raymond Riise. A part of the thesis was written in Japan in conjunction with being an exchange student at Hokkaido University. The concept "sustainable campus" is new and not yet completely defined, thus this task was chosen to contribute to the concept "sustainable campus" and create a concept tailored for UiT Narvik.

Acknowledgement

I would like to thank the academic responsible Associate Professor Raymond Riise at UiT Narvik and co-supervisor Masahiko Fujii at Hokkaido University for the supervision and guidance. Furthermore, I would like to thank Tor Kristiansen at Statsbygg, and coordinator Maki Ikegami at Hokkaido University for providing necessary information. Finally, I want to thank family and friends for developing conversations and support. A warm thank you, Robin, for the discussions, the great motivation and the push I needed throughout this final project.

Oddrun Pettersen Røsok

Narvik 12th of May 2017

Sammendrag

Et universitet som fokuserer på å bli et "bærekraftig campus" må inkludere mange problemområder. Konseptet er i dag fremdeles vagt og ikke helt definert. Det finnes nettverk som hjelper universiteter med å oppnå status som bærekraftig campus, ved å sette en grunnlinje med prinsipper medlemsuniversitetene må følge. Hensikten med denne masteroppgaven er å fastslå hvilke elementer som skal inkluderes i et selvlaget konsept for UiT Narvik, for at dette universitetet skal bli et bærekraftig campus, basert på studium av tre forskjellige universiteter som allerede jobber mot å bli et bærekraftig campus.

En del av arbeidet med oppgaven var en tur til Japan som utvekslingsstudent på Universitetet i Hokkaido, Sapporo. Oppholdet varte i to måneder og var ment for å undersøke det ovennevnte universitetets konsept og finne ut om deres konsept har anvendelige løsninger som kan benyttes hos UiT Narvik. Opplysningene var ikke tilstrekkelige, så i samråd med hovedveileder i Norge ble det besluttet å inkludere to nye selvvalgte universiteter, Harvard University og NTNU, for å få en stor nok database å jobbe med. Alle tre universitetene er medlemmer av samme nettverk, the International Sustainable Campus Network. Et studium av norske byggeforskrifter inngår som en del av problembeskrivelsen, og ble endret i samråd med hovedveileder til å passe innholdet i konseptet til UiT Narvik.

Det ble laget et konsept for UiT Narvik, basert på egne vurderinger av hva som inngår i et bærekraftig campus. Opplysninger fra de tre universitetene gikk gjennom en evalueringsprosess for å finne ut hvilket universitet som egner seg best som grunnlag for konseptet til UiT Narvik. En stor del av konseptet er at UiT Narviks bygning skal oppnå lavenergi- standard med tilhørende tilfredsstillende energimerke. Resten av kravene i UiT Narviks konsept fokuserer på å redusere universitetets miljøavtrykk.

Norsk Standard med kriterier for yrkesbygninger som passivhus og lavenergibygninger, ga grunnlag for tiltak med tilhørende simuleringer i SIMIEN. Metoden som ble brukt under simuleringene var prøv- og-feil- metoden. Siste simulering viste at UiT Narviks bygning tilfredsstilte alle kravene til lavenergien-standarden. Til slutt ble det klart at konseptet fortsatt er vagt i den forstand at det er vanskelig å vite nøyaktig *når* et campus kan kalle seg bærekraftig. Ideen om et "bærekraft- merke " dukket opp, med et graderingssystem fra "bestått" til "fremragende". En grov forklaring på dette merket står beskrevet i slutten av rapporten, for å gi et inntrykk av hva den skal inneholde. På grunn av begrenset tid kunne ikke dette nye konseptet bearbeides og vurderes nok til å fullføres.

Abstract

A university that focuses on becoming a "sustainable campus" must include many problem areas to process, although the concept is today still vague and not yet completely defined. There are networks that help universities achieve the standard of a sustainable campus, by setting a baseline with principles the university members need to follow. The purpose of this master thesis is to determine the elements that should be included in a self- made concept for UiT Narvik, along with suggestions on how to achieve the goals in the concept. The concept is based on the study of three different universities that are already working towards becoming sustainable campuses.

A part of working with this thesis was a trip to Japan to stay at Hokkaido University in Sapporo. The stay lasted two months to investigate the University's concept and find out if the University has applicable solutions to the concept of UiT Narvik. The information acquired was insufficient so in consultation with the supervisor it was decided to include two new universities of own choice to get a big enough database to work with, Harvard University and NTNU. All three universities are members of the same network, the International Sustainable Campus Network. A study of the Norwegian building regulations is included as a part of the problem description, and altered in consultation with the supervisor to fit the content of the concept at UiT Narvik.

A concept was made for UiT Narvik, based on personal assessments of what is part of a sustainable campus. Information acquired from the three universities went through an evaluation process to find out which university has the best suitable concept to use as a basis for the concept at UiT Narvik. A big part of the sustainable campus concept is that UiT Narvik's building has to achieve the Norwegian low-energy standard, with an associated satisfactory energy label. The rest of the requirements in the concept are solely focusing on reducing the environmental footprint of the University.

The Norwegian Standard with criteria for commercial passive houses and low- energy buildings, made the basis for the measures with associated simulations in SIMIEN. The method used during the simulations was trial- and error. In the end, the building satisfied all requirements of the low energy standard. Lastly, it became evident that the concept is still vague in the regard that it is difficult to know exactly *when* a campus can call itself sustainable. The idea of a "sustainability label" emerged, with a grading system from "pass" to "outstanding". A rough explanation of this label is at the end of the report, to give an impression of what it should contain. Due to limited time, this new concept could not be processed and reviewed enough to be completed.

Table of contents

List of figures

List of tables

1. Introduction

1.1. Background

A "green change" is the change in different elements that contribute to a climate and environmentally friendly conversion. Global climate and environmental challenges require reorganization of the society so that growth and development occurs within nature's tolerance limits. A transition to environmentally friendly products and services is required. Thus, the society must consequently through a so-called "green change". The building sector accounts for a significant share of greenhouse gas emissions, and public commercial buildings such as universities represent a significant portion of the existing structure. Building regulations continuously tightens to reduce energy consumption.

Universities across the world have realized that the issue with environmental stress on nature needs tackling, and are currently developing the concept "sustainable campus", to create environmentally friendly universities. The concept implies a "green change" within the university society of faculties, students, staff and associated companies. Hokkaido University in Sapporo Japan, Harvard University in Massachusetts USA, and the Norwegian University of Science and Technology (NTNU) in Trondheim Norway are all members of the International Sustainable Campus Network (ISCN), a society that strives to guide universities in becoming sustainable campuses. The definition of a sustainable campus is different for each university, since they can "tailor" the concept as long as they follow ISCN's principles. The Arctic University of Norway, UiT Narvik, is currently not a member of ISCN, and does not have a plan on becoming a sustainable campus for now.

1.2. Sustainable campus

The concept "sustainable campus" is currently vague. There are no clear guidelines or objectives to fulfil to achieve the status of a sustainable campus. The only definition are ISCN's three principles that explain in a general way which areas a university needs to focus on to become sustainable. The principles focus on buildings and their sustainability impacts, campus- wide planning and target settings, and integration of research, teaching, facilities and outreach. Several certification methods already exist, such as LEED and BREEAM, explained later in the report. However, the concept made in this thesis is one that will cover more areas than the existing certification methods.

1.3. Problem description

A concept "sustainable campus" is to be tailored for UiT Narvik. It was supposed to be based on the already existing concept at Hokkaido University. The content of the problem description has changed over time. It became evident during the stay in Japan that the information acquired at Hokkaido University was insufficient. In consultation with the supervisor, it was decided to include two more universities, Harvard University and NTNU, who strive to become sustainable as well, to look at their concepts before creating the concept for UiT Narvik. The content of the sustainable campus concept is based on personal assessments. The author's background is from Renewable Energy Engineering, thus it seemed natural that the concept would have great emphasis on energy efficiency and environmental footprint, as these areas could have great impact on the environment. The thesis has not looked into building engineering, as the focus is on creating a concept and achieving a certain standard for the university. The financial aspect of becoming a sustainable campus in general is not included. When looking at the building's energy efficiency and measures, SIMIEN was used.

The report assumes that the reader has basic knowledge of energy efficiency in buildings, low- energy buildings, energy labelling and the software SIMIEN.

2. Sustainable campus

The theoretical basis of this chapter is based on a literature study of a network that works with sustainable campuses, as well as three universities that are all members of this network. This will form the basis for the development of a concept for a sustainable campus at UiT Narvik.

2.1. International Sustainable Campus Network

The International Sustainable Campus Network (ISCN), a non- profit association, provides a global forum online to support leading universities, colleges and corporate campuses in exchanging information, ideas and practices to achieve sustainable campuses and integrate sustainability in research and teaching. The ISCN has 83 member schools from more than 30 countries, where Hokkaido University and Harvard University are on the list. Norway is also on this list, with NTNU being the only member. (ISCN, 2017).

The ISCN promotes continuous improvement through innovation and learning of sustainability on campus. The key goals are in the ISCN- GULF (Global University Leaders Forum) Sustainable Charter (ISCN-GULF, 2017). The charter was developed to support universities in reaching goals to become a sustainable campus, by setting targets and reporting on their development and performance, based on the three principles of ISCN. The report will not look into the details of the charter. Figure 2.1.1 is an illustration of the principles.

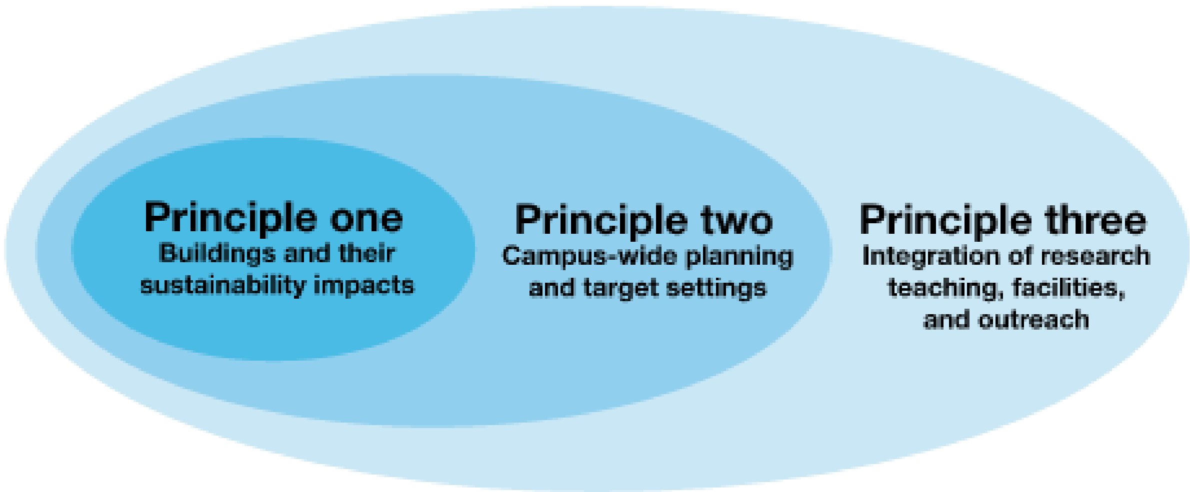


Figure 2.1.1. The three principles of the ISCN © ISCN.

Principle one | Buildings and their sustainability impacts.

To demonstrate respect for nature and society, sustainability considerations should be an integral part of planning, construction, renovation and operation of buildings on campus. (ISCN- GULF, 2017).

This principle focuses on low carbon economy, by minimizing environmental impacts such as energy and water consumption, recycling of waste, use of resources, building design aspects and landscape integration. This requires participatory planning by integrating end- users such as faculty, staff and students. It also includes life- cycle costing.

Principle two | Campus- wide planning and target settings.

To ensure long- term sustainable campus development, campus- wide master planning and target-setting should include environmental and social goals. (ISCN- GULF, 2017).

This principle focuses on the campus as a whole, where all buildings are included. Comprehensive master planning is important, where goals are for impact management, like limiting the use of land and natural resources, protecting eco- systems and setting goals for reducing greenhouse gas emissions. Creating indoor and outdoor spaces promotes social integration by giving people inviting areas to socialize.

Principle three | Integration of research, teaching, facilities and outreach.

To align the organization's core mission with sustainable development, facilities, research and education should be linked to create a "living laboratory" for sustainability. (ISCN- GULF, 2017).

This principle focuses on a "living laboratory", where the built environment, operational systems, research and education are linked together. The users (students, staff and faculty) have access to information and opportunities regarding environmental, social and economic issues, which lets a university collaborate with external partners, such as industry and government. The principle seeks to explore a sustainable future in general, by linking together the academic institution with the industry to reach a common goal, sustainability.

2.2. Hokkaido University, Japan

A part of the work with this report was to travel to Sapporo, for a two-month long stay at Hokkaido University. The purpose was to investigate how the University defines a sustainable campus and what they do to achieve their goals. Hokkaido University is a comprehensive university located on Hokkaido Island in Japan. It has 12 undergraduate schools, 18 graduate schools and 22 research centres, spread out on the campus' total land area of 1776249 m^2. As of May 1st, 2016, the University had a total of 22.083 students and staff.

Office for a Sustainable Campus (OSC) | The OSC at Hokkaido University has existed since November 1st, 2010, with the goal to create an environmentally conscious campus, a "sustainable campus", to contribute to the development of a sustainable society. The main goals of this office are to achieve zero- emissions for the entire University through energy saving and the use of renewable energy. It also aims towards the development and implementation of a sustainable social model using the campus as a demonstration field, with knowledge and human resources that meet the needs of society. The background of the establishment of the office is that the country wishes to reduce the total energy consumption. Another reason is the Great East- Japan Earthquake and the followed reactor's accident in Fukushima on March 11th, 2011, where the Japanese recognized the importance of sustainability and energy saving.

To achieve the goals, Hokkaido University formulated the "Action Plan 2012 for a Sustainable Campus", as the first university in Japan. The plan is based on the Sapporo Sustainability Declaration (SSD) adopted at the G8 Summit in Sapporo 2008. The outcome of the G8 Summit are three main points. The first point is to solve problems through research to leave future generations with a sustainable world. The second point is to educate the coming generations about sustainability. The third point is that Hokkaido University serves as a role model for a sustainable society, by becoming a sustainable campus. This meeting was the driving force to establish the OSC. There is no official definition of what a sustainable campus is, and the concept is still vague. Therefore, the OSC developed its own concept, described in the following subchapter. The Japanese Ministry of Education and Science has announced that Japanese universities must reduce energy consumption by at least by 1 % every year. The OSC follows a cycle of operations; the Plan, Do, Check and Act (PDCA) cycle, shown in figure 2.2.1, provided by Associate Professor and Project Manager of OSC, Takashi Yokoyama.

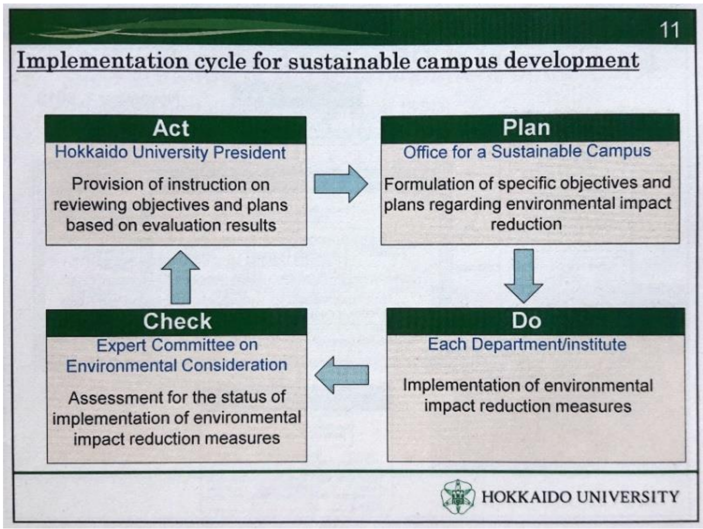


Figure 2.2.1. The PDCA cycle.

Sustainable Campus Concept of OSC | Figure 2.2.2 shows the concept developed and provided by Maki Ikegami, the coordinator of the OSC. The information about this chart was provided orally. The first step is the core functionality of Hokkaido University, represented by "Education and Research". From there, it branches out to the pink circle, and further out to the purple part, which concentrates in three main areas as seen in the figure.

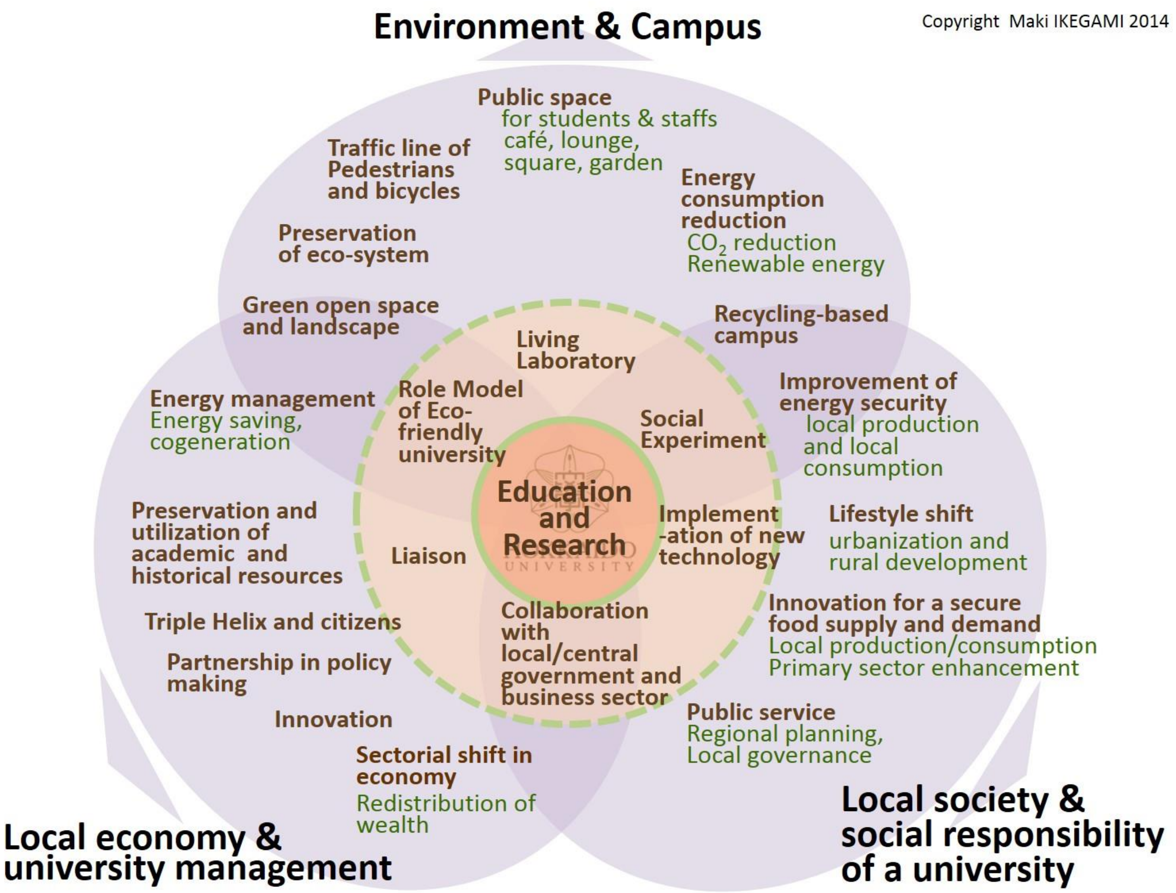


Figure 2.2.2. Concept chart of Hokkaido University as sustainable campus © Hokkaido University.

Step one | The core purpose of Hokkaido University is to educate people and do research on a wide range of study areas.

Step two | The pink circle creates the link between university and the outside society. The University strives to reach out to society to share knowledge and ideas, for everyone to reach a common goal, which is a sustainable community. The "Living laboratory" is about to letting students and researchers come together with people and companies from the industry, to achieve common goals and diminish the distance between an academic institution and the outside industry. "Role model of eco- friendly university" is the University's goal of setting an example for the outside society on how to achieve sustainability. "Implementation of new technology" is the idea to share and use new technology to become a sustainable campus. "Social experiment" is the concept of being a role- model for the outside society. "Liaison" is the labour needed for service, to install new technology, deal with logistics and to physically execute the ideas and implement them in the society and University. "Collaboration with local/ central government and business sector" is the University working together with the society to achieve common goals or help the other to achieve their goals. All the points from step two are means to create a collaboration between the society and Hokkaido University, to erase the line between the academic institution and the local industry and society, to make it easier to educate each other in how to achieve sustainability.

Step three | There are three main points in this last step: "Environment & campus", "Local economy & university management", and "Local society & social responsibility" of a university. The subsections of these points are fluid- like; they fit under several of the main points and are not "connected" to a certain main point, even if they are placed that way on the chart. Step three is striving for an interactive atmosphere. Each faculty at Hokkaido University is autonomous and the concept of a sustainable campus searches for an interactive atmosphere between the faculties, so that all faculties contribute to making the Hokkaido University sustainable. This might set an example for the outside society. An explanation of the subsections of the third step follows.

Public space | A sustainable campus is not only about reducing the energy consumption and minimizing the environmental footprint. It is also about creating a campus with a social role. One of those roles can be to create open and inviting areas outside and inside. By making the areas inviting for everyone, the border between society and the university can slowly become less apparent, although students and staff will mostly use the areas. Open and public spaces can be cafés, lounges, squares and gardens.

Traffic line of pedestrians and bicycles | Hokkaido University has a challenge with too many people riding bikes on campus. Students need to move quickly between classes located at different faculties, making it difficult to prevent the students from biking. A solution can be to put a course's classes closer, in faculties that are located close to each other. This requires restructuring a big part of the University's educational plan.

Preservation of eco- system | Hokkaido University strives to reduce the environmental footprint. One of the solutions is to preserve local eco- systems on campus, by taking into account the eco- systems when planning the outside campus areas and faculty placement.

Green open space and landscape | By creating green open spaces and landscapes, and witnessing the positive impact it has on the people and animals on campus, it is a role model for the outside society. The spaces are inviting people to come together.

Energy management | This is about energy saving and the use of renewable energy sources to heat up buildings on campus. Hokkaido University has four geothermal heat pump systems, which heat up the same building where the heat pump is located.

Preservation and utilization of academic and historical resources | These are elements of a sustainable campus.

Triple helix and citizens | The triple helix consist of three parts: industry, academic institution and the government. Companies raise their technological level and they engage in higher levels of knowledge sharing and training. The government acts as the public entrepreneur and venture capitalist for new companies. The universities develop links as they combine discrete pieces of intellectual property and exploit them jointly. The university can provide students with new ideas, skills and entrepreneurial talent. Students is the new generation of professionals in various scientific disciplines, who can also be trained and encouraged to become entrepreneurs, and contribute to economic growth and create jobs. The last piece is the citizens, who benefit from the triple helix, by making up the consumers and the liaison. (Triple Helix Research Group, 2017).

Partnership in policymaking | Providing analysis done at the University to policy- makers, will aid them when making policies that can better set goals towards obtaining sustainability.

Innovation: Hokkaido University wishes to collaborate with the outside society, create new ideas, and improve already existing businesses, to create jobs and make both university and society more eco-friendly and sustainable.

Sectorial shift in economy | A redistribution of wealth from the government is necessary for the University to afford to realize innovative ideas and make actions to reach the goal of becoming a sustainable campus.

Public service | Through research and teaching, and by turning research into action, it is possible to model an institutional pathway to a more sustainable future.

Innovation for a secure food supply and demand | Local production and consumption of food is the primary sector enhancement at Hokkaido University, and they produce local food, such as vegetables and milk products.

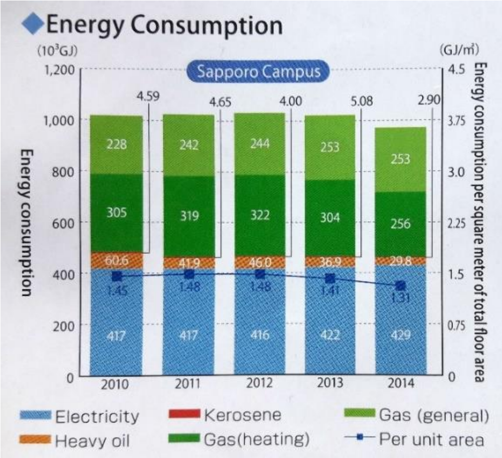
Lifestyle shift | This represents the dissemination or implementation of sustainability research and education in the real society.

Improvement of energy security | As mentioned earlier, Hokkaido University has four geothermal heat pump systems. The University has a goal to reduce the environmental footprint, and local energy production and local consumption is a "green" way to achieve this.

Recycling- based campus | Hokkaido University does what it can to recycle as much of the waste and electronics as possible. This has a positive impact on the environmental footprint.

Energy consumption | A reduction in the energy consumption includes reducing the CO_2 emissions and to use renewable energy as the source of energy.

Sustainability Reports | Hokkaido University has two campuses, Sapporo campus and Hakodate campus. The thesis focuses only on Sapporo campus. The campus receives electricity from Hokkaido Electric Power Company, the monopoly electric company of Hokkaido. The total energy consumption of 2014 was 1MWh/m^2. The University has set the upper limit of power consumption at 19000 kW, 10 % lower than the summer of 2010, in terms of maximum power consumption rate (kW/ m^2). The average maximum power consumption increased by 183 kW (0, 9 %) on day when the power consumption exceeded the upper limit, compared to 2013. On the same days, the average minimum power consumption increased by 112 kW (1 %). Figure 2.2.3 to 2.2.6 shows the demands and differences between 2013 and 2014. Hokkaido University strives to reduce and minimize its environmental impact. By the use of natural and renewable energy sources, the University is aiming for zero emissions. The medium- term goal of the University, in the period academic 2010- 2015, was to reduce the annual greenhouse gas (GHG) emissions by 2 % from the amount recorded in academic 2005, which was 91270 tons. The medium- and long- term goals involve reducing the emissions by 20 % by 2020, and 35 % by 2030.



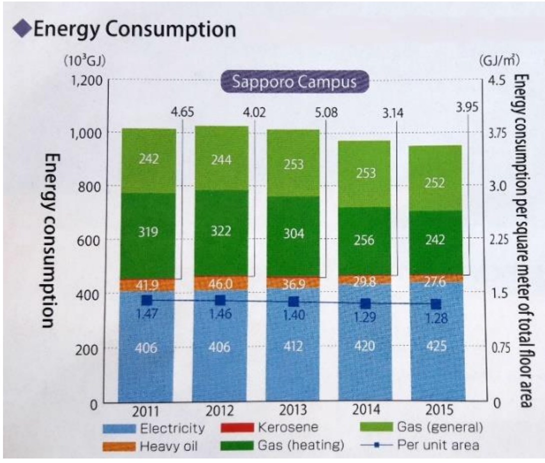
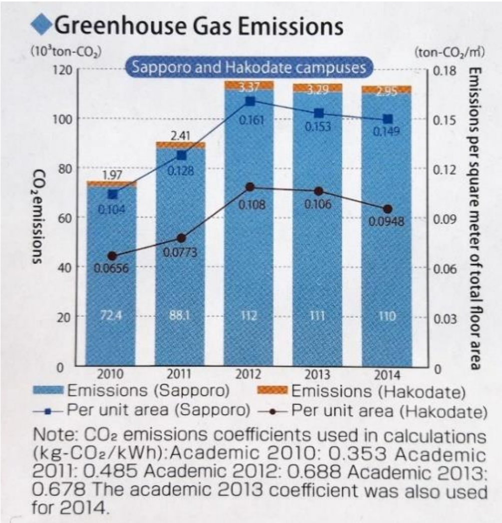


Figure 2.2.3. Energy consumption 2015. Figure 2.2.4. Energy concumption 2016.



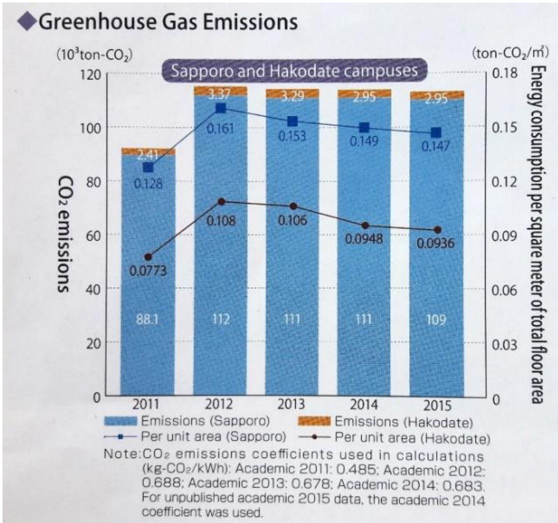


Figure 2.2.5. Greenhouse gas emissions 2015. Figure 2.2.6. Greenhouse gas emissions 2016.

Energy consumption | Hokkaido University has constructed new buildings on Sapporo campus, renovated existing structures, replaced and upgraded equipment from academic 2010 to 2014. It resulted in a floor increase of 5,8 %, to 39662 m^2. Individual gas- and electricity powered air-conditioning replaced the building air- conditioning from central heating based on boilers in the power centre. The power centre is the place where steam boilers for central heating are concentrated. This is the "district heating" on campus. These instalments also have cooling functions. This resulted in a significant increase in the consumption of electricity and gas for general purposes. At the same time, the consumption of gas for heating purposes at the power centre decreased. The overall energy consumption decreased from academic 2010 to 2014, thanks to the changes described. A Proton Beam Therapy Centre and a new outpatient building was introduced to the University in 2013, resulting in an increase of power usage. These buildings are medical facilities with large basic units of power consumption.

Greenhouse gas (GHG) emissions | The GHG emissions decreased with 18,5 % from academic 2005 to 2010, exceeding the reduction target. However, the figure has been above that on 2005 since the Great East Japan Earthquake of 2011. The rise was because of a significant increase in CO_2 emissions from the use of electricity in association with the shutdown of the nuclear power plant in Hokkaido. Hokkaido University depends on electricity for more than 40 % of its energy needs. Accordingly, new GHG emission reduction measures are needed. The GHG emission goal until 2015 was to reduce by 11% in 2015 compared to 2005. The university failed to meet this target due to the raise of carbon emission from use of electricity after the nuclear power plants shut down in 2011. The new target only focuses the energy consumption per area on campus: to reduce by 1.5% every year compared to 2015 until 560 kWh/m^2/year in 2021.

The sustainability report from 2016 states the same goals as from 2015. There are some additions, such as the campus' increase in total floor area, by 6,4 % to 44578 m^2, compared to the total floor area in May 2011. The report from 2016 states that the energy consumption rate has decreased by 8,7 % since 2011, thanks to the new and relatively more efficient air- conditioning units. Improved heat insulation performance of new buildings and the introduction of more efficient devices have contributed to the reduction in energy use. However, the electricity use has increased due to new experiment facilities with higher electricity consumption rates.

2.3. Harvard University, USA

Harvard University has recognized the responsibility of confronting challenges on climate change and environmental sustainability, and has taken on an obligation to do something about these challenges. The network of campuses on the University includes 12 Schools, administrative and operational groups, tens of thousands of faculty, students, and staff, and a broad range of building types and land uses. The University aims to transform into a sustainable community that contributes positive social, economic, and environmental benefits, by translating research and teaching into practice. That makes it possible to use the campus to pilot innovative solutions for replication in society. In the effort of making a change, each member of the community needs to participate. By working together across disciplines, new ideas can occur and spur exciting innovations. The greatest goal is to reduce greenhouse gas emissions. Climate change and the environmental degradation is global and requires a clear response from both organizations, governments, and businesses. Harvard University is committed to confront the challenges through research and teaching, by modelling an institutional pathway to a more sustainable campus. The drive behind the commitment are the Sustainability Principles (Harvard University Sustainability Plan, 2017), adopted in 2004, shown in figure 2.3.1. In 2008, the University began the sustainability commitment to reduce its greenhouse gas emissions by a maximum practicable rate. There was also a short- term goal to reduce greenhouse gas emissions 30 % by 2016 from a 2006 baseline, which also included growth.

Figure 2.3.1. Sustainability Principles of Harvard University © Harvard University.

The Harvard Sustainability Plan from 2012 to 2015 deals with five core topics: emissions and energy, campus operations, nature and ecosystems, health and well-being, and culture and learning. Each topic includes areas of focus with specific actions:

1. Goal | Resource reduction goals with a specific target within a set timeframe.
2. Standard | Operational standards to facilitate alignment across the University, ensuring implementation of a consistent approach. Standards designed to allow flexibility for implementation by individual Schools and administrative departments.
3. Commitment | A statement of commitment or recommendation for future research in areas without enough information to set a specific numeric goal or standard.
Figure 2.3.2 shows an overview of the five core topics (Harvard University Sustainability Plan, 2017).

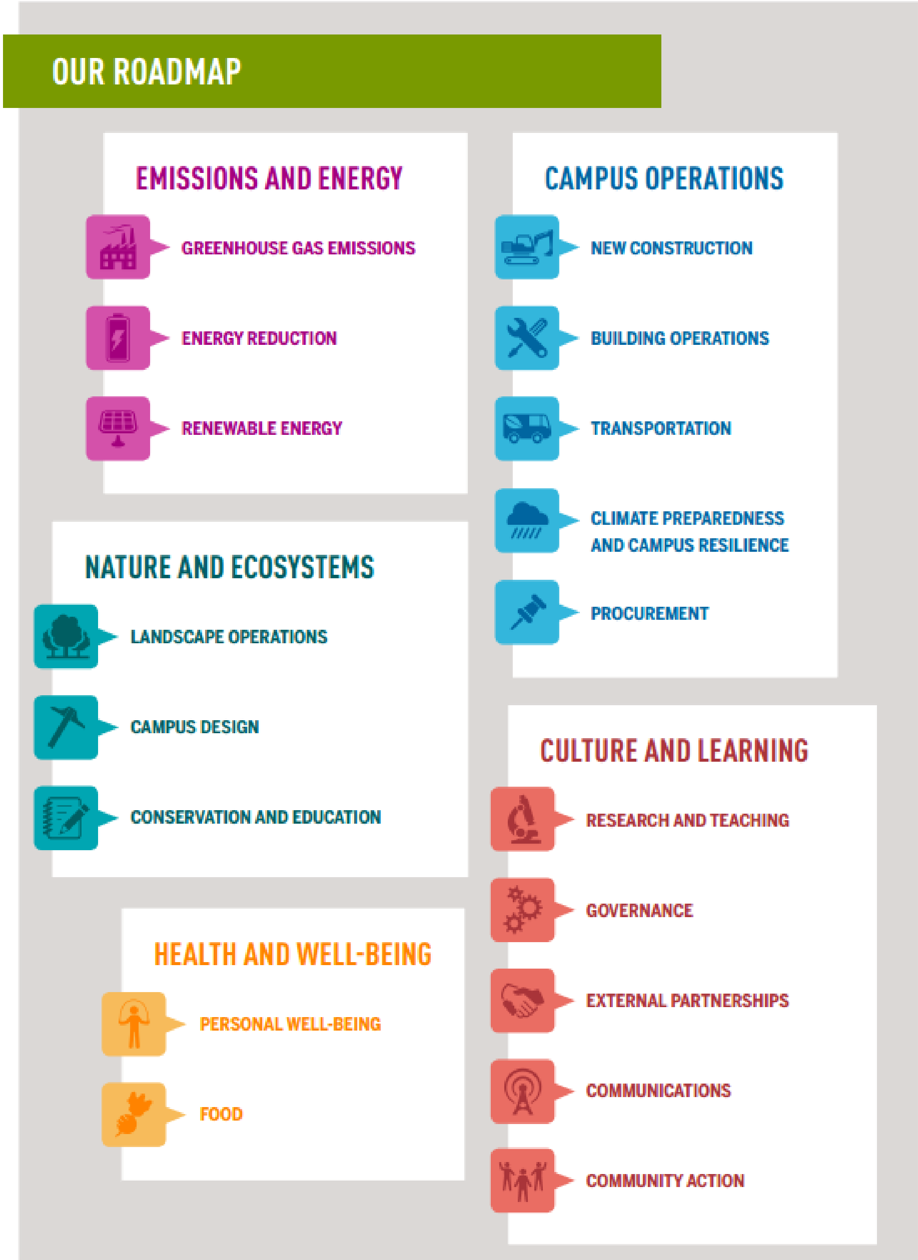


Figure 2.3.2. Harvard Sustainability Plan © Harvard University.

Emissions and energy | Reducing energy the use and emissions by a maximum practicable rate are the University's top priorities. Harvard University strives to meet the challenge through best-in-class innovations in energy efficiency, energy management, and renewable energy.

Greenhouse gas emissions decreased by 20 % since 2008, despite a 15 % growth in square footage and increased energy intensity of existing space. Excluding growth, emissions decreased by 31 %. Energy efficient measures decreased the energy consumption by 2 %, after according for a 15 % growth in square footage and energy- intensive space. Excluding growth, energy usage decreased by 16 %. 60 % of emission reductions are from actions taken on campus, while the remaining 40 % is the electric grid in the region becoming less carbon intensive. The University entered into a long- term agreement in 2009, for 12 MW of energy from a wind farm in Maine. In addition, the campus has installed over one MW of solar power.

Campus operations | Harvard University aims to have a restorative impact on the surrounding environment and the community of students, faculty and staff, by conserving resources, reduce pollution and further enhance the personal well- being at the campuses.

Nature and ecosystems | Campuses at Harvard University are part of an interconnected ecosystem. Actions taken could have ripple effects through the natural environment, thus the University strives to protect and enhance ecosystems and green spaces on campus, and manage or influence to enhance regional biodiversity.

Health and well-being | The vitality of Harvard University depends on people's health. The University strives to enhance health, productivity and quality of life of the students, faculty and staff, through design and maintenance of the campus environment, and development and implementation of programs that contribute to well- being.

Culture and learning | Powerful solutions to problems come from harnessing the power of collaboration and integrating knowledge across disciplines. The campus is a "living laboratory" where it develops the next generation of sustainability solutions, which strengthens the "One Harvard" culture across the Schools and Departments that embraces the environmental sustainability at Harvard University.

The five topics just described did not have any complementary information on what Harvard University has done to improve and reach their goals. Figure 2.3.3 and 2.3.4 shows the overview of the University's sustainability plan (Harvard University Sustainability Plan, 2017). The sustainability plan shows the goals, standards and commitments of the University, but does not go into detail on direct measures to achieve the objectives. However, it is still an inspiration for the future concept of UiT Narvik.

SUSTAINABILITY PLAN AT A GLANCE

GOALS

- Reduce University-wide greenhouse gas emissions 30% by 2016 from a 2006 baseline, including growth. (Adopted in 2008)
- Reduce waste per capita 50% by 2020 from a 2006 baseline, with the aspirational goal of becoming a zero-waste campus.
- Reduce University-wide water use 30% by 2020 from a 2006 baseline, including process, irrigation, and potable water usage.
- Maintain at least 75% of the University's landscaped areas with an organic landscaping program by 2020.

STANDARDS

- Maintain University-wide compliance with the Harvard University Green Building Standards, reviewed annually and revised every four years.
- Achieve University-wide compliance with the Harvard University Green Cleaning Standards by 2020.
- Achieve University-wide compliance with the Harvard University Sustainable IT Standards by 2017.
- Develop standards for climate preparedness and campus resilience that apply to new and existing building design and critical infrastructure by 2016.
- Develop a University-wide Climate Preparedness and Campus Resilience Plan by 2020.
- Develop University-wide standards for targeted environmentally preferred products by 2018.
- Achieve University-wide compliance with the Harvard University Sustainable Landscaping Standards by 2020.
- Develop Sustainable and Healthful Food Standards that include Green Restaurant Association certification, and achieve University-wide compliance by 2020.

COMMITMENTS

- Maintain a long-term commitment to reduce greenhouse gas emissions by the maximum practicable rate, aligned with the United Nations Intergovernmental Panel on Climate Change's recommendations to reduce emissions 80% by 2050. (Adopted in 2008)
- Track Scope 3 greenhouse gas emissions.
- Identify and implement net present value positive energy conservation measures in our buildings as part of the five-year capital planning process.
- Assess energy use by building and space type to inform goal setting by the 2016 Greenhouse Gas Reduction Goal Review Task Force.
- Conduct a University-wide on-site renewable energy study to inform goal setting by the 2016 Greenhouse Gas Reduction Goal Review Task Force.
- Recommend that the 2016 Greenhouse Gas Reduction Goal Review Task Force consider setting a renewable energy purchasing goal.
- Recycle or dispose of hazardous and electronic materials in a responsible and ethical manner, with a priority to minimize the use of hazardous materials, as appropriate.
- Develop a best practices guide for managing and operating buildings in a sustainable and energy-efficient manner in order to assist facilities teams in meeting sustainability-related goals, standards, and commitments.
- Develop a University-wide plan by 2016 for reducing campus fleet and shuttle emissions.
- Maintain and continuously improve sustainable transportation opportunities, programs, and incentives for Harvard affiliates.
- Increase the bikeability and safety of the streets in and around Harvard's campuses, and seek to achieve gold-level Bicycle Friendly University status from the League of American Bicyclists by 2020.

Figure 2.3.3. Harvard sustainability plan, part one © Harvard University.

Require all major vendors to report on progress in meeting Harvard standards and specified third-party environmental certifications, and demonstrate their commitment to sustainability through corporate responsibility reporting, by 2016.

Require all vendors, as appropriate, to comply with applicable Harvard sustainability goals and standards by 2020, and encourage vendors to align their practices with all sustainability commitments.

Reduce the amount of electronic waste generated per capita by 2020.

Continue to incorporate sustainability goals into facility, district, and campus planning.

Design landscapes and choose plant species that are likely to be robust to future environmental change, ensure appropriate levels of biodiversity and green or open space, and support stormwater reduction and passive stormwater filtration.

Continue to prioritize conservation, research, and education at Harvard-owned green spaces including the Harvard Forest and the Arnold Arboretum.

Reduce the Harvard community's exposure to toxic chemicals with a special focus on the natural and built environment, indoor air quality, furnishings, and cleaning products.

Identify and track high-risk chemicals in targeted building materials used on campus, informed by the latest research and LEED v.4 standards, through the Harvard Green Building Standards.

Identify and target at least two significant chemicals of concern for which viable alternatives exist, and develop a plan for eliminating exposure to those chemicals on campus.

Increase participation in, and access to, wellness programs through the Healthy Harvard Initiative by 2020.

Continue to develop and implement tobacco-free campus policies.

Translate research and teaching into practice on Harvard's campuses by facilitating collaborations to pilot and launch innovative solutions to sustainability challenges.

Foster a new generation of environmental leaders by providing mentoring, networking, and professional development opportunities that prepare undergraduate and graduate students with the insight and foresight to safeguard our environment in the years and decades to come.

Support the creation of new sustainability-related curricula, programming, and cross-disciplinary opportunities by fostering collaboration with the Harvard University Center for the Environment, Center for Global Health and the Environment, and other environmental initiatives on campus.

Facilitate strong governance structures to ensure integration of sustainability into business practices at all levels of the University.

Cultivate and lead external partnerships, in higher education and beyond, that help inform Harvard's efforts and amplify our local and global impact.

Communicate the "One Harvard" sustainability story to educate, engage, and motivate the Harvard community.

Engage senior leaders to communicate to their community of students, faculty, and staff on an annual basis about Harvard's commitment to sustainability.

Develop an alumni engagement strategy by 2016 to strengthen involvement of alumni in sustainability efforts at Harvard.

Increase staff participation in the Harvard Green Office Program by at least 30% by 2020 from a 2014 baseline.

Maintain and continuously improve programs and resources that drive sustainability action among students, faculty, staff, and alumni.

Recognize and reward sustainability accomplishments University-wide and at all Schools annually, including at the Harvard Heroes ceremony and the Harvard Green Carpet Awards.

Figure 2.3.4. Harvard sustainability plan, part two © Harvard University.

2.4. NTNU, Norway

The Norwegian University of Science and Technology (NTNU) has approximately 23000 students and 5000 person-years, where 3000 are in academic or scientific positions. The university has 48 departments and seven faculties that focuses on technology and natural sciences. NTNU is Norway's primary institution for educating MSc-level engineers and scientists, and has comprehensive programs in numerous fields.

Since 2012, NTNU has had an environmental ambition to be a frontrunner, and use knowledge from its own research to ensure a high standard for internal environmental management. NTNU has 15 goals for 2020 covering energy saving, waste handling, transport, procurement, biodiversity and student knowledge. In addition, NTNU has targets on equality and physical planning to ensure equal possibilities for all staff and students, irrespective of sex, ethnicity, beliefs or disabilities.

ISCN – principle one | *To demonstrate respect for nature and society, sustainability considerations should be an integral part of planning, construction, renovation, and operation of buildings on campus.* (ISCN- GULF, 2017).

NTNU is currently actively reducing the energy consumption. In this regard, the focus is on heat recovery and increased efficiency of the district heating system at Gløshaugen campus. The total energy consumption in 2014 was 120 245 915 kWh. That is a 14.3 % reduction from the baseline year 2010. In this period, the number of employees and students have increased by 9 %, from 25999 to 28527. Table 2.4.1 shows an overview of NTNU's principle one goals.

Goals and initiatives	Performance 2013	Performance 2014
Energy use		
NTNU will reduce energy consumption with 20% compared to 2010 levels by 2020.	126 923 478 kWh	120 245 915 kWh
Waste		
NTNU will reduce the quantities of waste by 15% compared to 2011 levels.	1 821,8 tons	1 889.0 tons
NTNU will increase the recycling rate to 85% by 2020	-	52.3%
NTNU will reduce the use of hazardous chemicals by raising awareness on the environmental impacts caused by the chemicals and potential substitutions.		All units are requested to substitute chemicals included (in annex XIV in REACH).
Procurement		
NTNU will reduce its climate footprint from procurement by reducing procurement quantity, raise environmental requirements in all procurement and give environmental requirements a minimum weight of 20% whenever relevant. For scientific equipment, a minimum weight should be 10%.		Total procurement on 1.8 billion NOK. Environmental criteria weighted 10-20% when included. All contracts from November 1 2014 have terms on environmental and ethical subjects.
NTNU will require environmental documentation for products and services in order to take environmental impact throughout the products life cycles into account, and ask for quantified targets for improvements of environmental performance in all procurement contracts.		From November 1 2014, all contracts have terms on compliance with ILO-conventions, anti- corruption and environmental standards.
By 2020, environmentally certified suppliers should deliver 80% of purchases and 50% of products should have an eco-label, 100% for products groups where eco-labelled products are well available.		There is no complete list. Among the 100 largest suppliers, approximately 50% have some kind of environmental certificate.

By 2020, all catering and fruit purchased should be ecological produced.		100% on cakes, approximately 50% on catering. Fruit is gradually introduced.
*Water**		
Total water consumption	198 638 m^3	187 148 m^3
*Universal design**		
NTNU has an ambition that all buildings and outdoor areas should be accessible for all.		Universal design is a topic in all building and renovation projects
*) No explicit targets set in the environmental ambition.		

Table 2.4.1. NTNU's goals from principle one.

ISCN – principle two | *To ensure long-term sustainable campus development, campus-wide master planning and target-setting should include environmental and social goals.* (ISCN- GULF, 2017).

Energy and transport are examples on how to reduce greenhouse gas emissions, but NTNU does not have an explicit target on which areas to target yet. The University is currently assessing the total greenhouse gas emissions from all University activities. The reporting excludes transport of students and employees to and from the University. NTNU is working on a strategy to achieve a climate neutral policy, which includes reduced traveling, environmental friendly transportation and compensation for necessary travels. NTNU introduced parking fees in 2014 to make people bike more. Better facilities for people who chose to bike were established. The University built more shower and changing rooms, and more areas for parking the bike safely under roof. All employees have access to electric cars on campus, for necessary travels. Table 2.4.2 shows the effect the measures has had on people's travel method to campus. The numbers are from questionnaires who took the survey at the end of April 2013 and 2015. The habits will likely be different during the winter, since the winter conditions in the city of Trondheim makes it difficult to travel by bike. Table 2.4.3 shows an overview of NTNU's principle two goals. Figure 2.4.1 shows the distribution of generated greenhouse gas emissions at NTNU in 2014.

Travel mode	2013	2015
Car driver	36 %	22 %
By bike	24 %	33 %
Walking	15 %	16 %
Public transport	18 %	16 %
Other*	7 %	13 %
*) Also includes combined travels, e.g. public transport combined with biking or driving to station, and passenger in private car.		

Table 2.4.2. Effect of measures on people's travel method to campus.

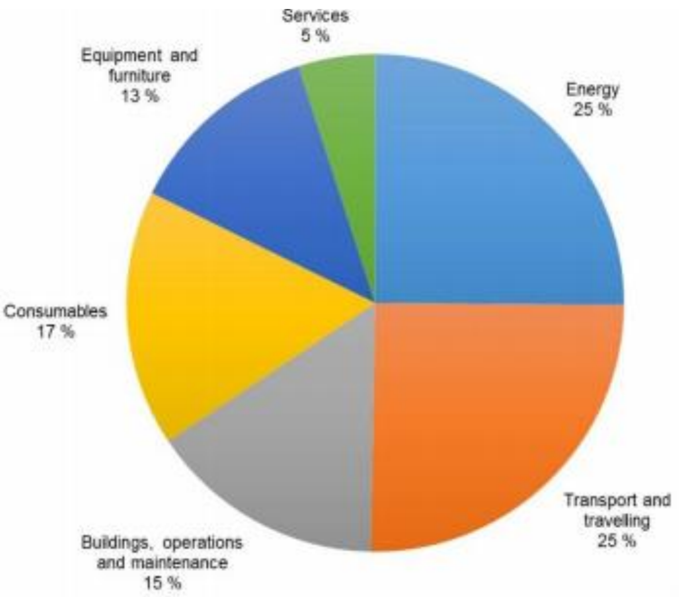


Figure 2.4.1. Generated greenhouse gas emissions at NTNU, 2014.

Goals and initiatives	Performance 2013	Performance 2014
Energy use		
By 2020, 5% of the buildings have energy label class A.		1 building, constituting 1.4 % of the total area, satisfy the requirement for label A.
Transport		
NTNU should have a climate neutral travel policy.	12 098 flights[1] 866 168 km car[2]	13 249 flights[1] 825 692 km car[2] Specification on how to achieve the target is currently under development.
NTNU will increase the use of video conferences and be a driving force among employees and partners to increase the use.	527.5 hours[3]	744 hours[3]
NTNU make it easier for employees and student to choose environmental friendly transport on everyday travels to campus.		NTNU has increased area for parking bicycles and improved changing rooms and showers on most campuses. Possibilities for charging electric cars installed on all campuses, and a fleet of available electric cars for employees makes it less necessary to bring own car.
NTNU should develop an environmental policy for internal transport.		Under development.
Biodiversity		
By 2016 NTNU should have a plan on how biodiversity on campus can be managed		Under development as an integrated part of the outdoor plan
*Greenhouse gas emissions**		
Total GHG-emissions from tier 1, 2 and 3	99 522 tCO_2eq4	
*Gender equality**		
Number and percentage female PhD defences.	141/ 38.1 %	161/ 44.0 %
Percentage female professors	21.9 %	23.1 %
1) Includes only flights booked through the travel agency. Total number of flights might be higher. 2) Includes use of private cars for work related travel, does not include use of NTNUs cars. 3) Includes use of equipment on Multimedia Centre at NTNU, does not include use of meeting facilities at units and programs on personal computers such as Skype. 4) A full GHG assessment is not performed annually. *) No explicit targets set in the environmental ambition.		

Table 2.4.3. NTNU's goals from principle two.

ISCN – principle three | *To align the organization's core mission with sustainable development, facilities, research, and education should be linked to create a "living laboratory" for sustainability.* (ISCN- GULF, 2017).

The main initiative at NTNU is planning a new campus to make it easier to integrate activities with the city of Trondheim. Sustainability is the core issue in the planning, still in an early phase.

- NTNU should be a model for a holistic sustainable campus, based on knowledge from NTNU's research.
- The campus should be a relevant case for research, teaching and demonstration, after the construction phase is completed.
- Basic knowledge on sustainable development should be implemented in all studies at NTNU.
- NTNU should use its knowledge on environmental systems analysis and collaborate with other Norwegian universities to compare environmental performance reporting systems.

NTNU identified since 2014 four strategic research areas: energy, health, oceans, and sustainability.

Energy | The aim of the research area "Energy" is to contribute to research across disciplines to find a coherent solution to energy challenges, and at the same time ensure better fulfilment of NTNU's responsibility to the society.

- Continuously develop improved technological solutions for renewable energy such as solar power, bioenergy, offshore wind power and wave power, to achieve substantial increase in green energy.
- Energy efficient buildings with better energy systems. Future buildings will produce energy, and a prerequisite is the combination of energy efficiency.
- Exploitation of fossil resources demands better methods of carbon capture, storage and transport.
- Safe and effective recovery of oil and gas from existing fields in the North Sea.
- Continuously innovate to promote a sustainable change in the Norwegian energy system. This includes a design of effective strategies on a political level, expanding the knowledge base for innovation, knowledge transfer from research to business, involvement of the public society and commercialization in enterprises.
- Integration of renewable energy sources and exploitation of the existing grid require better digital communication and smart control help from smart grids, to improve flexibility and reliability.

Health | The strategic areas of "Health" are three main research topics.

- Health promotion, prevention and empowerment including topics such as preventive medicine, residential environment and housing, geographical, social and ethnic differences in health and welfare.
- Diagnostics and therapy, including topics such as neuroscience, bio-nanotechnology, biotechnology, regenerative medicine, medical imaging, inflammation, palliative medicine, age and lifestyle related diseases.
- ICT-systems (Information and Communications Technology), welfare technology and organization of health services, including topics such as ICT in health services, electronic patient records, welfare technology, search engine and database technology, health management and leadership, health policy and health service organization.

Oceans | The strategic research area "Oceans" has the ambition to contribute to the knowledge base in the maritime: oil, gas and aquaculture industry. In addition, to identify and develop future knowledge needs in shipping, seafood production, deep ocean -and artic exploration, marine resources and energy, through research and joint projects with the industry. The goal is to combine research efforts in marine engineering, natural science, humanities and social sciences, to create solutions across disciplines supporting a sustainable production of marine resources.

Sustainability | The strategic area "Sustainability" emerged from the acknowledgement that sustainability is a global challenge, which is twofold. Poverty and injustice demand measures, and local and global environment needs preserving for present and future generations.

2.5. Summary all universities

Hokkaido University's main goal is to achieve zero emissions for the entire University through energy saving and the use of renewable energy. The University strives towards the development and implementation of a sustainable social model using the campuses as a demonstration field, with knowledge and human resources that meet the needs of society. A close collaboration with the society and business world outside the University, with emphasis on the "living laboratory" is in focus. It seems that one of the main concerns of this university is to educate students and society on sustainability. The University has a wide- spread concept that considers many areas as seen in Maki Ikegami's diagram, where only six of 22 areas focus on the direct environmental impact and footprint. In addition, becoming a zero emission university will most likely need more than saving energy and using renewable energy. Hokkaido University's plan still seem vague and undefined.

Harvard University's greatest goal is to reduce energy usage and greenhouse gas emissions by a maximum practicable rate, through best- in- class- innovations in energy efficiency, energy management and renewable energy. The University also aims to have a restorative impact on the surrounding environment and the community of students and employees, by conserving resources and reducing pollution. Although the University has a greater focus on the direct environmental footprint than Hokkaido University, Harvard University does not yet seem to have a clear plan on exactly how to address the problem areas they have pointed out. Their concept is also still vague in that regard.

NTNU has an ambition to be the frontrunner and use knowledge from its own research to ensure a high standard for internal environmental management. The University has a greater focus on reducing the energy use, energy efficiency and climate neutral travel policy than Hokkaido University and Hokkaido University. The difference between NTNU and the other two universities is that NTNU has a plan on exactly *how* they want to address the problem areas, with exact measures. NTNU also has set down exact numbers to work with and improve during a specific period. For this reason, from the three universities described, NTNU has the concept that seems the most compelling to work with and be inspired from for the concept at UiT Narvik. Another reason is that this university is the only one that has made a concept directly based on the principles of ISCN, making it simpler to categorize the measures in the concept for UiT Narvik.

3. Building regulations

The theoretical basis of this chapter is based on a literature study of the Norwegian building technical regulations (TEK 10, from 2010), as well as Norwegian Standards, which describe in detail how to achieve low- energy standard on commercial buildings. This will form the basis for the measures to execute at UiT Narvik to reach some of the goals in the concept. Energy efficient buildings is an inevitable point to consider for the concept of a sustainable campus. The problem description of this report stated an in-depth study of the building of UiT Narvik, on how to reduce the energy need and energy consumption of the building, without going into detail on the building engineering construction technology of building parts.

The Norwegian Law on Planning and Construction Processing governs the building technical regulations, currently TEK 10. All buildings constructed must comply with this law and thus the latest updated TEK 10. A subcategory of the TEK 10 is the Norwegian Standards (NS), that go into detail about the requirements that applies to the individual building type and standard, for example a commercial low- energy building. Descriptions of the buildings' technical details are in the building details manuals. Only the latest publications are used in the report.

3.1. Building technical regulations

The building technical regulations (TEK 10) demand a certain energy efficiency in buildings. The building's total net energy need must not exceed an upper limit of the energy budget. The energy budget method is applicable to all building categories. Requirements for energy performance of buildings are fulfilled if it is proved that the net energy need does not exceed a specified energy budget in NS 3031:2014, for the relevant building category. Control calculations are performed based on standard values for the operating conditions and environment, and therefore do not necessarily represent the building's actual anticipated energy use. Table 3.1.1 shows the energy budget for total net energy need in 13 defined building categories.

Building category	Total net energy need [kWh/m^2]
Residential building[2], holiday residence, ≥ 150 m^2 heated BRA	100 + 1600 / heated BRA
Apartment building	95
Kinder garden	135
Office building	115
School building	110
University/ university college	125
Hospital	225 (265)[3]
Nursing home	195 (230)[3]
Hotel building	170
Sports building	145
Business building	180
Culture building	130
Light industry/ workshop	140 (160)[3]

1) The requirements do not apply to:
- Buildings that keep low indoor temperature (15 ℃), and arranged so that the energy requirements are at a reasonable level.
- Holiday residence ≤ 150 m^2 heated BRA.
- Residential buildings and holiday residence with timbered exterior walls.

2) Residential buildings include detached, linked and terraced (up to three floors)

3) Numbers in parentheses refer to areas where ventilation heat recovery involve risk of spreading contamination or infection.

Table 3.1.1. Energy budget for total net energy need in different buildings.

Documentation of energy efficiency in accordance with total net energy provides freedom of choice of solutions for building structure and equipment. The minimum requirements of table 3.1.2 must be satisfied, setting the limits of freedom. Energy limits given in table 3.2.1 increase by up to 10 kWh/m^2, if it can be produced at least 20 kWh renewable electricity per square meter heated BRA annually, on the property, for the current building. Any electricity intended for export to the main grid is not included in the 20 kWh. The minimum requirements must be satisfied regardless of building energy efficiency or energy budget. Requirements for of energy supply are in table 3.1.3.

Minimum requirements for energy efficiency[1]. The requirements also apply buildings that have ≤ 70 m^2 heated BRA	
Thermal transmittance value, exterior wall[2]	Max 0,22 W/m^2K
Thermal transmittance value, roof[2]	Max 0,18 W/m^2K
Thermal transmittance value, ground and open air[2]	Max 0,18 W/m^2K
Thermal transmittance value, glass, windows, doors[2]	Max 1,2 W/m^2K
Leakage number	Max 1.5 air changes per hour at 50 Pa pressure difference
Insulation of pipes, equipment and ducting connected to the building's heating and distribution system including heaters.	Insulated to prevent unnecessary heat loss. Insulation thickness optimal economically.
1) The requirements do not apply to: - Buildings that keep low indoor temperature (15 ℃), and arranged so that the energy requirements are at a reasonable level. - Holiday residence ≤ 70 m^2 heated BRA. - Residential buildings and holiday residence with timbered exterior walls. Other minimum requirements apply to such buildings. 2) Thermal transmittance values are mean of the building part. Glass/ window/ door has the sill and frame included.	

Table 3.1.2. Minimum requirements for energy efficiency.

Building/ housing unit	Requirements for energy supply to meet the heat demand for heating and tap water
All[1]	One cannot install heating systems for fossil fuels.
Building of > 1000 m^2 heated BRA, except residential buildings[2]	The building should: - have flexible energy heating systems. - be adapted for use of low-temperature heating solutions.
Housing unit in residential buildings[2]	Housing unit must have a chimney.
Exception for housing units in residential buildings[2]	If the housing unit has central heating system with water or that the residential unit annual net energy for heating does not exceed the requirements for a passive house, there is no requirement for a chimney.
1) The requirement applies to all buildings that are heated. The exception are holiday residences ≤ 70 m^2 heated BRA. 2) Residential buildings include detached, linked and terraced (up to three floors) 3) Energy need for heating comprises heating and ventilation heat.	

Table 3.1.3. Requirements for energy supply.

The ban on heating installations for fossil fuels apply to all heated buildings, and includes both room heating, ventilation heating and heating of domestic hot water. Energy flexible heating systems and low temperature heating solutions in larger buildings will provide the opportunity to replace the heat source, but it is not necessary to install several heat sources simultaneously. Energy flexible systems may include room heating, ventilation heating and/ or domestic hot water. For the future exchange of heat sources to be possible, the heating central needs adequate space, room height and accessibility.

TEK 10 states in NS 3031:2014, that new buildings with an (BRA) area greater than 1000 m^2 must have energy flexible heating systems facilitated for low temperature solutions. The systems must also cover a minimum of 60 % of nominal net heat demand. (Lavenergiprogrammet, 2017).

Energy-flexible heating systems" means that the exchange of energy sources can happen without making any changes to the building itself, and is exclusively within the technical room (without significant rebuilding). This means that an internal heat distribution network (water or airborne) must *be used, which is supplied with heat from a heating system in the building.* (Direktoratet for byggkvalitet, 2017)

3.2. Requirements for low- energy buildings

A low- energy building is a building that consumes typically in the area of 30 kWh/m^{2}year -120 kWh/m^{2}year for room heating. It is suitable for all types of buildings, and often achieved with measures on technical components and minor measures on external surfaces. New buildings are built according to TEK 10, which impose strict requirements on energy consumption. The energy consumption of buildings is calculated according to Norwegian Standard NS 3031:2014. Various measures such as insulation, good windows and heat recovery of the ventilation system are used to meet the requirements.

NS 3701:2012 specifies requirements for passive house standard and low- energy standard for commercial buildings. The standard sets overarching criteria and minimum requirements for building components and technical systems in a building. All energy calculations are in accordance with NS 3031:2014 and TEK 10. NS 3031:2014 contains guidelines for calculation of energy performance of buildings. An overview of the areas of the total net energy as is contained in some of the requirements in NS 3701:2012 and TEK 10 is in figure 3.2.1.

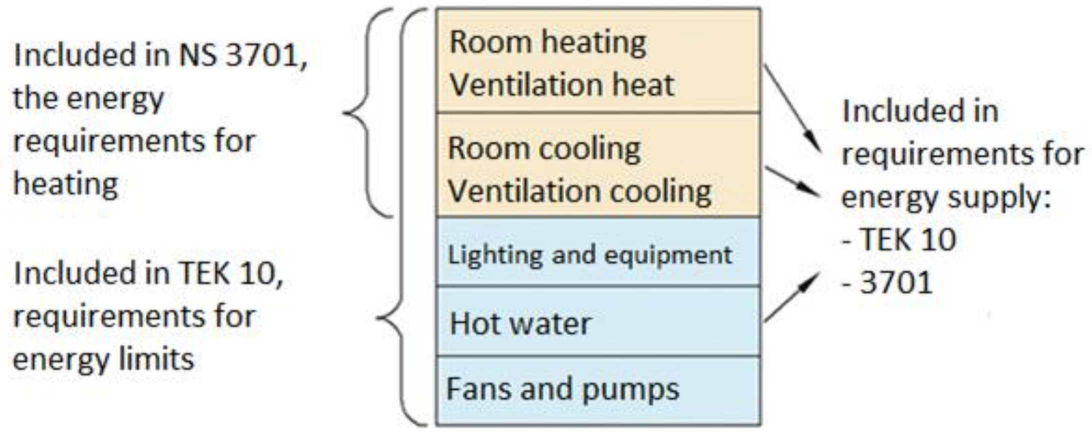


Figure 3.2.1. Overview of areas for total net energy (Building Details Manual 473.015).

The heat demand consist of both outdoor temperature *dependent* and outdoor temperature *independent* energy requirements, shown in figure 3.2.2. This means that the geographic location is important for heat demand size, and require calculation. When calculating the *energy need* of a building, only room heating and ventilation heat is considered. Calculating the *energy consumption* includes all instances that needs energy in the building, as described in NS 3701:2012.

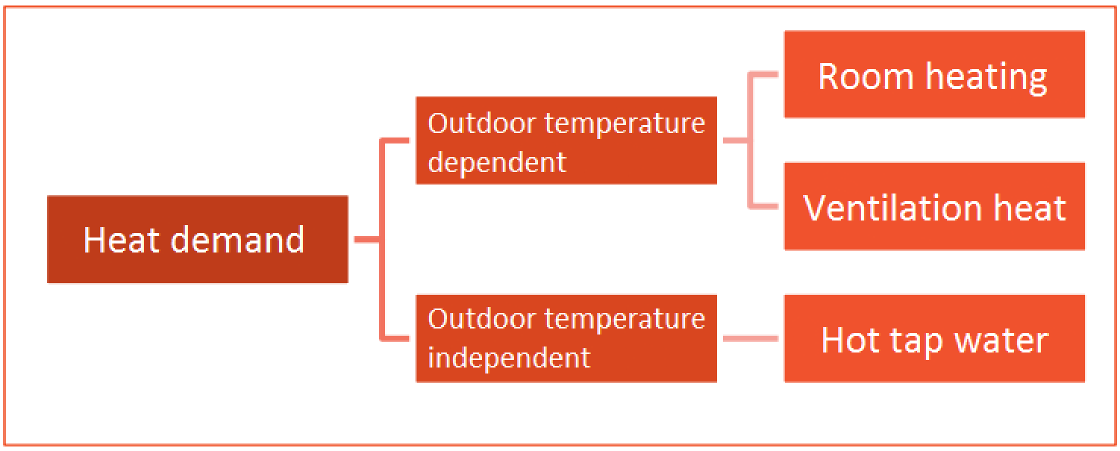


Figure 3.2.2. Heat demand.

The required heating demand comprises the energy demand for space heating and ventilation heat (heating coils). Heating of hot water is not included. Heating demand applies per heated part of the floor area (BRA). Allowable heating needs for commercial buildings depends on building category. The limit values are corrected for the heated part of the floor space (BRA), below 1 000 m^2 and annual temperature below 6,3 ̊C. For sites with design summer temperature (DUT_s) equal to or lower than 20 °C, cooling is not allowed. For places with DUT_s over 20 °C, cooling requirements depends on DUT_s on site and building category.

Commercial buildings according to NS 3701:2012 have the same requirements for energy supply as in TEK 10, i.e. there are limitations in the permitted amount of direct- acting electricity and fossil fuels. Low- energy buildings have minimum requirements for building parts, components and leakage numbers. If the building meets all minimum requirements, it does not necessarily imply that all other requirements are satisfactory. Characteristics that has minimum requirements must be met in NS 3701:2012. Table 3.2.1 shows an overview of the minimum requirements for low- energy buildings. Renovation projects may not always meet the requirements for normalized thermal bridge values. In that case, documentation must prove that thermal bridges do not cause problems for the indoor climate. Energy need for low- energy buildings is based on local climate data. Measures to reduce the heating demand is in table 3.2.2. Measures to reduce the cooling demand are in table 3.2.3.

All building categories	Low- energy building[2]
Thermal transmittance value doors and windows	≤ 1,2 W/m^2K
Normalized thermal bridge	≤ 0,05 W/m^2K
Annual average temperature efficiency of the heat recovery system	≥ 70 %
SFP- factor (Specific Fan Power) for ventilation system	≤ 2,0 $kW/(m^3/s)$
Leakage number at 50 Pa pressure difference	≤ 1,5 h^{-1}
Only commercial buildings	
Demand- controlled lighting for daylight	At least 60 % of the power of lighting is demand- controlled
Demand- controlled lighting for presence	At least one control zone per room, or per 30 m^2 in larger rooms
1) For buildings where heat recovery entails a risk of spread of contamination or infection, the minimum requirement is 70%.	

Table 3.2.1. Minimum requirement according to NS 3701.

Point	*Comment*
Reduce heat loss number	
Reduce heating requirements for ventilation air	Less airflow in ventilation[1] requires: - Greater degree of demand control - Divide into zones with regard to ventilation - Less emission from materials - Efficient heat recovery
Increase energy subsidies in heating periods	Reduce permanent shielding; increase the glass' sun protection factor.
Increase heat capacity	More surfaces of heavy materials directly exposed to the indoor air.
1) NS 3701 provide guidelines for the basis calculation for dimensioning airflow, which might make the calculated airflow deviate from the actual airflow. For an actual building, these measures are effective.	

Table 3.2.2. Points for optimization of heating demand.

Point	*Comment*
Increase shading	Effective shading, with lowest possible SPF. Consider permanent shading (considered in relation to heating demand and daylight). Sun shading on multiple windows.
Less windows facing south	Some heat from the sun comes through the windows, even with shading. By reducing the window area or moving windows to other facades, one can reduce the cooling load.

Increase heat capacity	Achieved by directly exposing several surfaces of heavy materials to the indoor air. Especially in rooms with large heating subsidies and thus large cooling requirements.
Night cooling	Obtained by utilizing low ambient temperatures to cool the structures at night. Heating coils must be switched off. This measure is most effective when the building has a high heat capacity.

Table 3.2.3. Points for optimization of cooling demand.

As the low- energy buildings have less heating and cooling needs than buildings that barely meet the energy requirement in TEK 10, they may be suitable for other energy solutions. A number of factors influence the choice of the type of energy supply, explained in building details manual 473.010. Selection and sizing of the energy supply must be based on detailed energy and power calculations with real operating conditions and local climate data. When performing the energy calculation, energy supply must be specified. It is usually a base load and peak load for heating. The base load is the minimum demand on an energy supply system over a period. The peak load is the source of power that activates during times of exceptionally high demand of energy.

The requirement for the highest calculated net specific energy requirements for lighting and the average power requirement during the operating time is 4,5 W/m^2 in a low- energy building. Energy efficient lighting and extensive demand control is necessary to meet the requirements for maximum limits. It might be necessary to:
- Increase demand control (with respect to the presence, constant light and/ or daylight).
- Choose lighting with lower power consumption.
- Ensure more efficient placement of lighting.
- Ensure more effective placement of windows (if daylight control).

Table 3.2.4 shows an overview of factors for a checklist of final energy calculation.

Assumptions for calculations
The proper building category selected.
Type of energy supply is as planned. Efficiencies in accordance with NS 3031:2014 or documented.
All areas are according to current drawings (BRA, door, window, facades, roofs, floors, separate to unheated zone, etc.).
Any zoning is in accordance with NS 3031:2014.
Any unheated areas excluded from the BRA.
Shielding from the environment taken into account.
Thermal transmittance value for all parts of the building exterior is as planned (windows, doors, gates, exterior wall, ceiling, floor, bulkhead and floors towards unheated rooms).
Input for ventilation in accordance with current projected values, with conditions in accordance with NS 3701:2012 for commercial buildings.
Heat capacity is as planned (type of surfaces).
Indoor air simulations with real conditions performed, and the input of any mechanical cooling is accordingly.
The type and possible control of shading in accordance with conditions in the indoor climate simulations.
Normalized thermal bridge is in accordance with thermal bridge calculations.
Leakage numbers are in accordance with measured value.
Sufficient power for heating and cooling provided.
Results
Heat loss numbers are within maximum allowed value.
Minimum requirements are within the maximum permissible values.
Airflow is within minimum.
Heating requirement is within the maximum allowed value.
Cooling requirement is within the maximum allowed value.
Energy supply is in accordance with requirements.

Table 3.2.4. Factors for checklist of final energy calculation according to NS 3701:2012.

3.3. Certification methods

There are different types of environmental certifications. Frequently used ones in Norway are Building Research Establishment Environmental Assessment Method (BREEAM), EnergyStar, Environmental Lighthouse and the Swan Label. The Leadership in energy and Environmental Design (LEED) is the most widely used certification method on world basis. Common for all instances is that they look into the life cycle of buildings or products and materials to ensure that the environmental impact is minimal. The terms “environmental certification” and “eco- labelling” are slightly different. Environmental certification (BREEAM, LEED and Environmental Lighthouse) means that the business itself is certified. Eco- labelling (EnergyStar and Swan Label) implies that certain products and services are eco- labelled. A brief explanation of the environmental certifications follows.

LEED | This is the most widely used green building rating system in the world. The LEED certification provides an independent verification of the building’s “green” features. The LEED certification means reduced stress on the environment by encouraging energy and resource- efficient buildings. LEED works for all types of buildings at all phases of development. Buildings that pursue a LEED certification earn points across nine basic areas that address sustainability issues, such as integrative process, location and transportation, sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, innovation and regional priority. (LEED, 2017) The report will not look into each area in detail. Based on the score the building(s) receive a LEED rating level: certified, silver, gold and platinum. Having the LEED plaque on a building is a mark of quality and achievement in a green building.

LEED projects are responsible for diverting over 80 million tons of waste from landfills. Compared to the average commercial building, LEED Gold buildings in the General Services Administration’s portfolio consume a quarter less energy and generate 34 % lower greenhouse gas emissions. (LEED USA, 2017).

LEED also includes certification multiple buildings. The LEED campus certification is for multiple buildings on a site and offers a number of options to help project owners to find the best way to reach their goals. A campus can be any shared site. That means it does not have to be a traditional university or corporate campus. The LEED campus certification is for two or more buildings located on a single site, controlled by a single entity. It will be a benefit if projects are able to share LEED credits and strategies with one another. The certification method should be considered if the buildings on site are very similar or follow the same policies.

BREEAM | BREEAM is the world's oldest (1990) and Europe’s leading environmental certification tool for buildings. BREEAM- NOR is the Norwegian adaptation of BREEAM and the industry's own tool for measuring environmental performance developed by the Norwegian Green Building Council (NGBC) in close collaboration with the construction and property industry in Norway. The purpose is to motivate sustainable design and construction throughout the entire construction project, from early stage to demolition of the building. BREEAM- NOR has proven to be an effective tool for coordinating the various players in a construction project and integrating sustainable thinking at all stages. A BREEAM- NOR certificate is issued in five levels; pass, good, very good, excellent and outstanding. The certification is based on documented environmental performances in nine categories - management, health and environment, energy, transport, water, materials, waste, land use and ecology as well as pollution. The report will not look into each area in detail. BREEAM works to raise awareness amongst owners, occupants, designers and operators of the benefits of taking a life cycle approach to sustainability. BREEAM also helps with adopting solutions, and facilitating market recognition of people’s achievements. Planning, design, construction and operation in accordance to sustainability principles are common for buildings with a BREEAM certificate. The aims of BREEAM are to mitigate the life cycle impact of buildings on the environment, and enable buildings to be recognized according to environmental benefits. BREEAM also wants to ensure best environmental practice incorporated in planning, design, construction and operation of buildings and the wider built environment.

Environmental Lighthouse | The Environmental Lighthouse is Norway's most widely used certificate for businesses that wish to document their environmental efforts and show corporate social responsibility. The environmental lighthouse is a tool for environmental management in most industries. Being an Environmental Lighthouse involves systematic work on environmental measures in everyday life, and meeting the criteria and implement measures for a more environmentally friendly operation and a good working environment. The Environmental Lighthouse has adapted criteria for different industries and a certificate is awarded after an independent assessment, meaning that the environmental certification implies that a company carries out an environmental survey and sets up an action plan to meet the criteria in a particular certification scheme. An annual climate and environmental report needs to be delivered and the business is recertified every three years. Becoming an Environmental Lighthouse takes four steps:

1. Once the business has decided to become an Environmental Lighthouse, contact an approved Environmental Lighthouse consultant to help meet criteria in the following areas: systems, working environment, energy, waste, transportation and purchasing.

2. The next step in the process is to conduct an environmental survey of the business, with the help of said consultant. Thereafter, various measures are taken to fulfill certain basic common criteria in addition to certain specific industry criteria. The criteria will not be specified here.

3. When the business and the consultant agree that the criteria are met, an independent certifier will approve the buildings as a valid Environmental Lighthouse. After approval, the building will receive a certificate that is valid for three years. Re-certification is necessary.

4. By April 1, each year, the company will prepare the status of its environmental performance. By filling out the annual climate and the environmental report, one can measure the impact of environmental measures, set new goals and add action plans to improve performance. The report is useful to sensitize management and employees about the company's environmental impact. (Miljøfyrtårn, 2017).

EnergyStar | Saving energy reduces electricity demand and pollution. A way to help is to use energy wisely. The Environmental Protection Agency (EPA)'s EnergyStar Program was created to help identify the best ways to save energy. The label of EnergyStar says that the labelled product, residence, building or factory is doing the right things to save energy. A third party of experts analyze and test products, and go through a certification process to make sure anything that earns the label meets the highest standards of energy saving. Examples on products that earned the label are various appliances, building products, electronics, lighting, office equipment and water heaters. (EnergyStar, 2017).

Swan Label | The Swan Label is the official Nordic Ecolabel. The Swan Label considers the best environmental choice. It looks at the entire product's journey, from resource production to instalment, and all the environmental issues that arise along the way. The Swan Label sets strict requirements for the management of raw materials, the use of energy and chemicals, safety and quality during use, and good biodegradability of the waste. A Swan-labelled product has had the most eco-friendly journey. (Svanemerket, 2017).

4. Results

This chapter is based on the previous literature studies in chapter three and four. The chapter describes the concept created for UiT Narvik before looking into the state of UiT Narvik in 2012. Afterwards comes a detailed explanation on how the University reaches the standard of a low- energy building. The end of this chapter describes the concept of a "sustainability label", an idea that came up during the simulations.

The concept "sustainable campus" that applies to UiT Narvik is one that will focus on energy efficiency, renewable energy and reducing greenhouse gas emissions, areas decided by the author. The previous universities base their concept on ISCN's three principles. As there is no clear definition of a sustainable campus, a university is free to interpret and tailor a concept on its own, based on the principles. That means every university can make its own version of sustainability, and create their own goals. After the stay at Hokkaido University, it became clear that the information provided was insufficient. More information was required to have a big enough knowledge base as a foundation before creating a concept for UiT Narvik. Thus, Harvard University and NTNU were included. The concept for UiT Narvik will base itself on the principles as well to some extent, and follow NTNU's way of thinking. However, even if the concept is based on ISCN's principles, it will not be made to be approved by ISCN, for UiT Narvik to become part of the network.

Hokkaido University and Harvard University puts emphasis on a living laboratory, and creating surroundings that are supposed to be healthy and inviting for people to thrive at campus. These points are important, but not necessarily part of the definition "sustainable campus". NTNU has a greater focus on reducing the energy use than the previous universities. The way NTNU made their concept is more defined and clear, and each principle approached directly with detailed explanation on *how* to approach the goals and challenges. Hokkaido University and Harvard University seem more on the planning- stage compared to NTNU. This statement is purely an opinion after studying the universities. Upon hearing the word "sustainable", the first thoughts that comes up are "less energy", "renewable energy" and "less pollution". Creating an inviting, healthy atmosphere and a "living laboratory", as described in the third principle, should be the goal of any university, regardless of striving for sustainability or not. This report will look into a concept with measures that can have a direct impact on the environmental footprint, such as improving the building's energy efficiency, phasing out oil-based heating systems and replacing equipment with more energy efficient equipment. The focus on the environmental footprint is partly because of the author's educational background in Renewable Energy Engineering, but also because a university has an example function and is meant to inspire students for their future path. Students staying at the university campus can see for themselves how a sustainable campus works. They can be inspired to share their experiences and knowledge about the campus, in their future workplace. The concept "sustainable campus" can attract more students and staff to the relevant university. The image of a university with a sustainable campus will be that of a positive one. Long-term thinking and focus on taking care of nature and environment will likely attract and inspire people, and could have an impact on applicants of both students and staff to study and work there, and further help the development of a sustainable society.

4.1. The concept of a sustainable campus at UiT Narvik

The Arctic University of Norway (UiT) is Norway's third largest university and has campuses spread out on eight different locations in Northern Norway. The main campus is in Tromsø. Narvik University College merged with UiT on January 1, 2016 and thus became UiT Narvik. UiT Narvik has approximately 2000 students and teaches mainly in Engineering up to doctorate level, but also has Nursing and Business Administration studies. UiT is not a member of the ISCN like the previous universities that are already mentioned, and therefore currently has no plan on how to address challenges like reducing energy use, energy need and greenhouse gas emissions. Creating goals that cover energy saving, waste handling, transport, procurement, emissions and other areas that affect the environmental footprint, is crucial when wanting to achieve the status of a sustainable campus. Still, the report will make a concept of a sustainable campus based roughly on ISCN's principles.

Norway is almost at the top in the world when it comes to use of electrical power. Norway's peak power consumption per person in Europe is due to relatively low electricity prices, well-developed power grids, and thus use electricity for heating and other energy needs. Norway's many mountains and waterfalls have provided a natural basis for renewable hydropower. Norway is also a major oil and gas producer, but exports most of the oil and gas (SSB, 2017). It is possible to achieve lower energy need in a building, but reducing the energy consumption is also critical, since energy consumption is the power delivered to the building to cover all needs, not only room heating. A change in mentality is necessary. If people are aware of the benefits of lower energy use, and how to spend less energy, the energy consumption will reduce. As mentioned above, Norway produce much energy, to the extent that people do not have to worry about electrical power to "run out". That does not mean it is a good idea to waste the energy. As an example, it is more common for people in the Netherlands to turn off the light in rooms that are not in use. In Norway, people often leave some lights on day and night. This statement is purely an observation, but it could show that people in Norway, in general, could change their habits in how they use energy.

ISCN – principle one | *To demonstrate respect for nature and society, sustainability considerations should be an integral part of planning, construction, renovation, and operation of buildings on campus.* (ISCN- GULF, 2017).

UiT Narvik does not have any ongoing activity to reduce the energy consumption. As explained before, NTNU has the goal to use proprietary technology and knowledge to become a sustainable campus. This idea is not important for UiT Narvik, as the University still need to abide by the requirements in the concept to become a sustainable campus. It is more important to use the latest technology to keep up with the development of sustainability and stricter building- and energy efficiency regulations, set by the Norwegian Government. Energy is not the only main point in the first principle. Making sure that products and materials for the university are eco- friendly with as little environmental impact as possible, is of great importance. There are several labels to look for when buying products and materials, such as the Swan Label and EPA's EnergyStar. Table 4.1.1 shows the goals and initiatives for principle one at UiT Narvik.

Goals and initiatives
Energy use
A sustainable campus only has certificated low- energy buildings on the campus.
Conduct a University- wide on- site study to inform the school board on which measures to make to implement renewable energy.
Buy power from a power supplier that guarantees green production, such as a wind park or hydro power plant, to cover 20 % of the energy need.
Waste
UiT Narvik must get an overview of the amount of waste produced on campus by looking into invoices for garbage collection from campus. This includes looking at the recycling rate and the amount of hazardous chemical waste produced. Reduce the amount of waste at the highest applicable rate as possible.
Recycle or dispose of hazardous and electronic materials in a responsible and ethical manner, with a priority to minimize the use of hazardous materials, as appropriate.
Procurement
Use materials, structures, processes and routines that are eco- friendly and resource- conserving during the building's lifetime, from design, construction, operation, maintenance, renovation and demolition.
Reduce the environmental footprint by reducing procurement quantity.
Create environmental documentation for products and services.
Environmentally certified suppliers should deliver the material purchases. All products should have an eco-label, such as the Swan Label, EnergyStar Label or other label that proved that the product is environmentally friendly. The Energy Label of light bulbs should be within a limit that allows the building to stay within the low-energy standard.

All catering and food must be of ecological origin.

Table 4.1.1. Goals and initiatives for principle one at UiT Narvik.

ISCN – principle two | *To ensure long-term sustainable campus development, campus-wide master planning and target-setting should include environmental and social goals.* (ISCN- GULF, 2017).

Energy use, energy need and transport are examples on how to reduce greenhouse gas emissions. The University should conduct an evaluation of the total greenhouse gas emissions before setting a goal on reduction. A way of doing that is for example to look into the invoices for garbage collection from the campus from previous years, to get an idea of the garbage quantity produced, and thus know the amount of emission from the garbage once combusted, decomposed or stored. The source of the electrical power is difficult to know as it comes from the main grid. By following principle one, it is possible to make sure a part of the electricity comes from a renewable energy source, by buying electricity from a production plant that can guarantee the electrical power's origin. Emissions from transportation must also be included. That includes transport to and from campus, either by personal vehicle or by public transport. Long- distance travel by plane and other means of travel is also included. By counting the amount of cars that park on campus over time, it is possible to make an estimation on the emissions during a year. Surveys by students and staff can tell how far they have to travel to and from campus, and thus give a more exact number on emissions from transport. From this, it is possible to create a strategy on how to achieve lower emissions. Table 4.1.2 shows the goals and initiatives for principle two at UiT Narvik.

Goals and initiatives
Energy use
The campus must strive for a minimum of energy label class B yellow, and there should be follow- ups on this label every five years to ensure that the University continues to improve its standard, despite changes and replacement of equipment. Energy efficiency is cost effective when it comes to reducing energy consumption and preserving of the environment.
Develop a best practices guide for managing and operating buildings in a sustainable and energy- efficient manner, in order to assist facilities teams in meeting sustainability- related goals, standards and commitments.
Involve BREEAM in future building processes and already existing buildings, if there is only one building on campus. If there are more buildings in the future, LEED could be appropriate. Get, as high as possible score on the BREEAM (or LEED) certificate, where "pass" is the absolute minimum requirement. Ensure that the certification method is considered throughout the building's entire life span.
Transport
Increase the use of video conferences among employees and partners, due to the campus' remote location.
Make it easier to choose environmentally friendly transport to campus. Measures can be more bicycle parking areas, with roofing and key card locks, as well as better access to shower areas that are free of charge.
Create green roads to make vehicles use less energy (flatter and easier for vehicles and cyclists), for new campuses, as a part of the architectural planning.
Greenhouse gas emissions
Total GHG emissions should be registered and monitored. This includes travels, private cars, equipment on campus as well as the energy use.

Table 4.1.2. Goals and initiatives for principle two at UiT Narvik.

ISCN – principle three | *To align the organization's core mission with sustainable development, facilities, research, and education should be linked to create a "living laboratory" for sustainability.* (ISCN- GULF, 2017).

UiT Narvik should aim to educate environmental leaders by providing mentoring, networking and professional development opportunities for undergraduate and graduate students, to have the insight and foresight to safeguard the environment when they enter the business sector after graduation. If students have sufficient knowledge in sustainability in their own field, they can contribute to making their work place more sustainable and environmentally friendly. The campus itself can be an inspiration for the society, by showing the outside world that the University takes responsibility and become more environmentally friendly. One way to show that is to become an Environmental Lighthouse.

Energy | The aim of "energy" is to contribute to interdisciplinary research as well as an integrated and coherent solution to energy challenges while ensuring better fulfilment of UiT Narvik's responsibility to society, as the University educates the next generation of work force. UiT Narvik has great focus on engineering studies and has the opportunity to make a great change, since engineers strive to find new and better solutions to problems in many fields, such as for example energy efficiency in buildings. The development of technology for renewable energy is important for a substantial increase in eco-friendly energy. Finding technological solutions for renewable energy, like solar energy, bioenergy, district heating, fuel cells and wind power is important for solid future energy sources in Norway. Energy efficiency and restructuring of energy systems in buildings in arctic regions should be in focus, since the campus, along with several other campuses of UiT are located in arctic regions, giving the opportunity to do research on the production of renewable energy and achieving energy efficient buildings in this region's climatic conditions. A prerequisite for sustainability will be the combination of greater energy efficiency combined with locally produced renewable energy. Integration of renewable energy sources and exploitation of the existing grid require smart solutions, to improve flexibility and reliability of power supply. Creating a "living laboratory" with knowledge transfer from research to business, and involvement of the public, will educate more people than just the students, encouraging a shift in the attitude towards sustainability. If students had contact with companies related to their studies while studying, it would be easier to share knowledge across border between the academic institution and the business sector.

4.2. Former simulations of UiT Narvik

The information about the University building is from a simulation done by COWI AS in 2012. The software used for the simulations is SIMIEN, developed by ProgramByggerne. The software is for calculations of energy use and indoor climate in buildings. The access to the simulation file used by COWI AS and results from that simulation was given from Statsbygg, the owner of the building, for the purpose of this report. Further simulations are based on those results. The University has an energy label as well, from the simulation done in 2012, as shown in the next subchapter. This chapter will look at the state of the university building in 2012, including the energy label, before looking into the measures for achieving low- energy standard and an improved energy label.

Data for this chapter is from the Energy Efficiency Report from 2012 for HiN - Narvik University College, with technical data from 2011, before the college merged with UiT in 2015. UiT Narvik has a floor area of 24900 m^2 and is a complex of buildings. The oldest building is from 1969, and covers an area of 11700 m^2. The building was expanded in 1997, a part that has a floor area of 13200 m^2, and consists of four blocks and an atrium linking the new and old buildings together. Its main use is undergraduate education, with associated features such as laboratories, open-access areas and canteen/ catering. Façade drawings are attached in appendix A. UiT Narvik's energy consumption was above the normal range for similar buildings in the same building category, according to COWI AS' measurements from 2012. Norm figures for the part from 1969 is 198 kWh/ m^2, while the norm for the part from 1997 is 156 kWh/ m^2. Average specific energy consumption for UiT Narvik for the last three years was 235 kWh/ m^2. Statistics from Enova for university and university college buildings, shows that the average temperature and place- corrected specific energy consumption is 227 kWh/ m^2. Table 4.2.1 shows the energy consumption between 2009 and 2011.

Energy bearer	Consumption
Electricity, measured	2 916 433 kWh
Thermal heat, measured and climate corrected	2 924 558 kWh
Total measured energy consumption	5 840 991 kWh
Specific energy use	235 kWh/m^2year

Table 4.2.1. Energy consumption, 2009-2011.

Temperature corrected consumption is the energy consumption for heating after total consumption is adjusted according to the outside temperature. This correction takes into account the average climate for each of the respective periods, and "normalizes" the actual energy use. The table below shows the measures considered for Energy Efficiency Report from 2012. The highlighted measures in thick font listed in table 4.2.2 are either done, such as 8.6 and 8.7, carried out during 2017, such as 7.1 or planned for 2018/ 2019, such as 2.1 and 2.11.

Measure description	
1.3	Individual heat measurements/ EMS (Energy Monitoring System)
2.1	**Insulation of external wall**
2.11	**Replacing windows**
4.1	Heat recovery in ventilation systems
4.3	Demand control of ventilation (DCV)
4.5	Adjusting the airflows
7.1	**Balancing heating installation**
7.3	Rebuilding into quantity regulated system
7.10	Replace oil boilers with heat pump
8.5	Balancing cooling installation
8.6	**Rebuilding into quantity regulated cooling system**
8.7	**Replacement of pumps in cooling system**

Table 4.2.2. Overview of on- going measures.

4.3. Energy label

The energy label identifies the energy standard of the building. The label consists of an energy grade and heating grade. The energy grade indicates the energy efficiency of the building, including the heating system, calculated from the typical energy consumption of the specific building type. In this case, a university building. The calculations are based on normal use in a mean climate. The building's energy standard determines the energy grade. Grade A means that the building is highly energy efficient, grade G means the building is not very energy efficient. The heating grade tells how much of the heating demand (heating and hot water) that is covered by electricity, oil or gas. Green color means low share, red color means high share. All buildings over 1000 m^2 must always have an energy certificate. It is the owner or the seller who is responsible for the building having an energy label. The energy certificate must be visible in a central location in the building. The certificate is valid for ten years. (NVE, 2017).

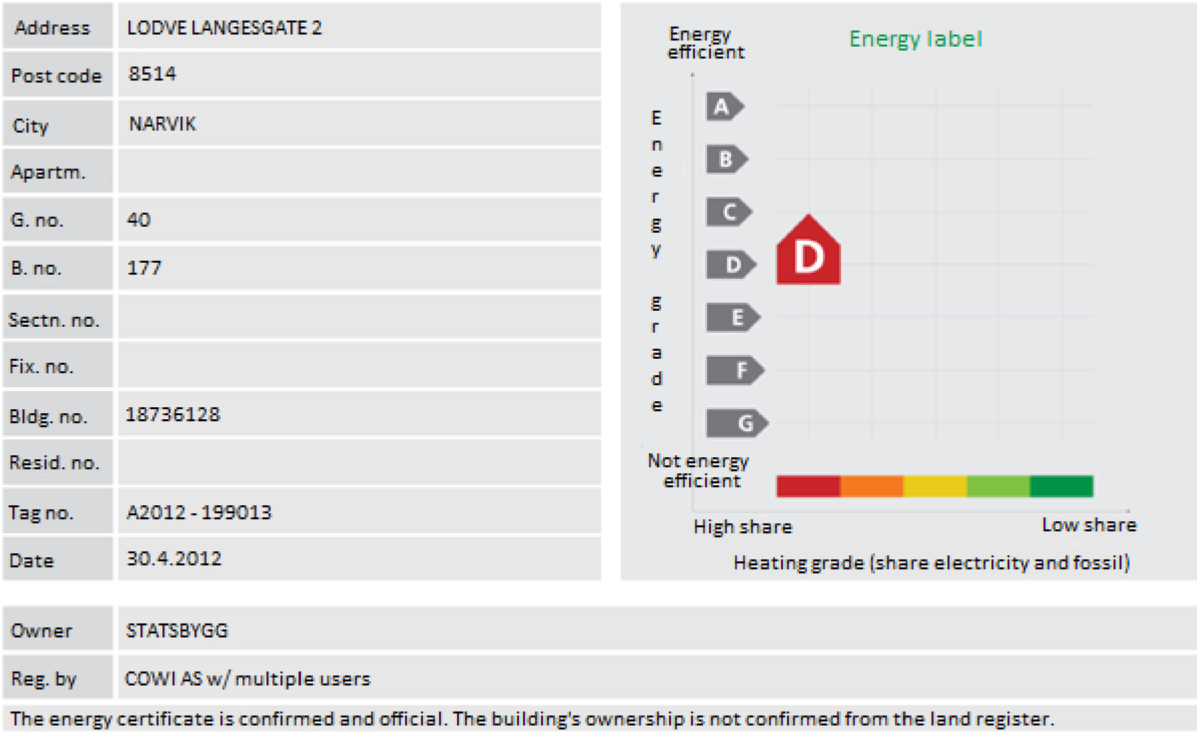
Examples of energy grades:

A – B: Low energy buildings, passive houses and the like. These buildings normally meet stricter requirements than those specified in the building regulations, and/ or have an effective heating system.
C – D: Buildings after building regulations from 2010, TEK 10.
E – G: Most of the existing homes built according to older and less stringent technical regulations.

Examples of heating grades:

Green: waterborne heating based on biofuel boiler, with electricity as a peak load.
Light green: district heating.
Yellow: air-to-air heat pump and closed wood stove, combined with direct electric heating.
Red: only electric or oil heating.

The energy demand is affected by how the building is used, and may explain the discrepancy between the estimated energy and the measured energy. Good energy habits contribute to reduced energy demand. The energy demand reduces if parts of the building are not in use, fewer people use the building or that it is used less than 365 days a year. Changes in the building's energy requirements will not affect the building's energy label. The energy label can improve only through physical changes to the building. Figure 4.3.1 shows the UiT Narvik’s current Energy Label, and table 4.3.1 is an overview of the provided information, for which the building owner is responsible. Where information is not available, typical standard values for the relevant building type are used.



Address	LODVE LANGESGATE 2
Post code	8514
City	NARVIK
Apartm.	
G. no.	40
B. no.	177
Sectn. no.	
Fix. no.	
Bldg. no.	18736128
Resid. no.	
Tag no.	A2012 - 199013
Date	30.4.2012
Owner	STATSBYGG
Reg. by	COWI AS w/ multiple users

The energy certificate is confirmed and official. The building's ownership is not confirmed from the land register.

Figure 4.3.1. Energy certificate with energy label from COWI AS.

Unit	Input value
Building category	University/ university college
Building type	Educational building
Year of construction	1969, expanded in 1997
BRA (gross area)	23446 m^2
Heated BRA	23446 m^2
Area exterior walls	4278 m^2
Area roof	8601 m^2
Areal floor	9948 m^2
Area glass/ windows/ doors	2643 m^2
Area percentage glass/ windows/ doors	11,3 %

Table 4.3.1. Building data.

Table 4.3.2 shows the values of some energy posts of the UiT Narvik in 2012, compared to values of a low- energy building from NS 3701:2012. A new simulation was made with no changes in numbers from 2012, and still the numbers are slightly different from COWI AS' result file from 2012. The numbers from COWI AS were based on calculations carried out by version 5.009 of SIMIEN. There can be several reasons for the difference in numbers, such as an update in SIMIEN where it uses slightly different standard input numbers. For the sake of clarity, the report will use numbers from current simulations, by version 6.005 of SIMIEN.

Energy post	Today's values (2012)	Low- energy building
Specific energy need (room heating, ventilation heat)	91,8 kWh/m^2 year	46,8 kWh/m^2 year
Specific net supplied energy	178,2 kWh/m^2 year	-
Thermal transmittance value, exterior wall	0,27 W/(m^2K)	0,16 W/(m^2K)
Thermal transmittance value, roof	0,20 W/(m^2K)	0,12 W/(m^2K)
Thermal transmittance value, floor	0,11 W/(m^2K)	0,12 W/(m^2K)

Thermal transmittance value, glass, windows, doors	1,65 W/(m²K)	1,2 W/(m²K)
Normalized thermal bridge	0,12 W/(m²K)	< 0,05 W/(m²K)
Leakage number	1,5 h^{-1}	1,5 h^{-1}
Temperature efficiency heat recovery	60 %	70 %
SFP- factor during operating time	2,87 kW/(m³/s)	< 2,0 kW/(m³/s)
SFP- factor outside operating time	0,30 kW/(m³/s)	-
Temperature during operating time	21,0℃	-
Temperature outside operating time	19℃	-
Power requirement for lighting during operating hours	8 W/m²	4,5 W/m²
Heat supplement from equipment during operating hours	11 W/m²	5 W/m²
Heat supplement from people during operating hours	6 W/m²	6 W/m²

Table 4.3.2. Energy posts.

Table 4.3.2 shows that the energy need in 2012 (with current simulations) for room heating and ventilation heat was 91,8 kWh/m² year. For a low- energy building it should be around half of that, 46,8 kWh/m² year. The calculations are in appendix B. The energy consumption for the University is in table 4.3.3.

Total energy consumption	4 803 197 kWh	100 %
Electricity	3 708 942 kWh	77,2 %
Oil (fossil)	1 094 255 kWh	22,8 %

Table 4.3.3. Total energy consumption.

Table 6 in NS 3701:2012 says that if DUT (Dimensioned Outdoor Temperature) is lower than 20℃, there is no net specific energy need for cooling the building. The DUT in Narvik is -27℃, so there is no need for cooling (VariantVVS, 2017).

4.4. Simulations

The measures taken in this subchapter do not consider the measures by COWI AS, that are already carried out or planned for the building. The Energy Efficiency Report from 2012, says nothing about necessary actions for the University to qualify as a low- energy building. It is rather a report that states the current (2012) state of the building. COWI AS has not attempted to achieve a low- energy standard by their measures. This thesis has independent simulations, results and arguments for improvements. The following measures have been attempted simulated within the requirements of NS 3701:2012, as close to the requirements as possible, to minimize the extent of the measures, in addition to being realistic and feasible. The gym is part of the University and connected to a part of the University building complex. The gym required a separate simulation, carried out by COWI, but for the sake of this report, the gym is not included.

Simulation 1

Replace lightbulbs with energy saving bulbs | Since it is difficult to know the effect in watts of lightbulbs in the entire building, an average number of the bulbs' effect during operating hours is set. To find out which bulbs to use, one needs to know the power requirement of every single lightbulb, and replace them with low- energy bulbs such as for example LED, add all bulbs' power requirements together and divide this number on the total BRA of the building. It was not possible to do this practicality when writing the report, so this is rather a suggestion on how to approach the matter. According to NS 3701:2012, the requirements for highest calculated net specific energy requirements for lighting in a university building is 4,5 W/m² during operating hours. The power requirement for lighting is set equal to heat supplements, i.e. it is assumed that all energy use for lighting becomes a heat supplement to the building. Table 4.4.1 shows the results from simulation 1.

	Before measures	After measures	Low- energy building
Power requirement for lighting during operating hours	8,0 W/m²	4,5 W/m²	4,5 W/m²

Specific energy need (room heating, ventilation heat)	91,8 kWh/m^2 year	97,7 kWh/m^2 year	46,8 kWh/m^2 year
Specific delivered energy	178,2 kWh/m^{2}year	176,6 kWh/m^{2}year	-
Specific CO_2 emission	65,0 kg/m^{2}year	64,2 kg/m^{2}year	-

Table 4.4.1. Results from simulation 1.

After measures, the goal of 4,5 W/m^2 for lighting is reached. The specific energy need for room heating, ventilation heat and hot water has increased due the low heat supplement from the bulbs low energy use. The specific delivered energy has decreased due to a lower energy demand. The reduction in CO_2 emissions is minimal from this measure.

Simulation 2

Reduce indoor temperature and adjust the internal heat contribution | This simulation focuses on reducing other internal heat supplements than lighting, in addition to a small adjustment in the indoor temperature during -and outside operating hours. The temperature during operating hours reduced from 21℃ to 20℃. Outside operating hours it reduced from 19℃ to 18℃. Energy efficient equipment management with low internal heat supplements is required in low- energy buildings, as a measure to reach a low enough energy consumption. The internal heat supplement from equipment is decided by NS 3701:2012 and set to 5,0 W/m^2. For people it was already set to 6,0 W/m^2 in SIMIEN, leaving this number as it is. Table 4.4.2 shows the result from this simulation.

	Before measures	After measures	Low- energy building
Temperature during operating time	21℃	20℃	-
Temperature outside operating time	19℃	18℃	-
Heat supplement from equipment	11 W/m^2	5 W/m^2	5 W/m^2
Heat supplement from people	6 W/m^2	6 W/m^2	6 W/m^2
Specific energy need (room heating, ventilation heat)	91,8 kWh/m^{2}year	93 kWh/m^2 year	46,8 kWh/m^2 year
Specific delivered energy	178,2 kWh/m^{2}year	167,9 kWh/m^{2}year	-
Specific CO_2 emission	65,0 kg/m^{2}year	60,8 kg/m^{2}year	-

Table 4.4.2. Results from simulation 2.

The simulation shows that the specific energy need for room heating, ventilation heat and hot water has increased slightly. The reason is that energy efficient equipment emit less heat. NS 3701:2012 assumes that all energy spent by equipment becomes heat supplement to the building, thus less energy spent means less heat. The specific delivered energy reduced 6 %, since the energy efficient equipment uses less energy. The measures reduced the CO_2 emissions by 6,5 %. The numbers were calculated using simple percentage calculation.

Simulation 3

Improved heat recovery from ventilation | Table 9 in NS 3701:2012 states that the annual average temperature efficiency of the heat recovery system in low- energy buildings must be 70 % or above. The SFP (Specific Fan Power) factor, from the same table, is set to maximum 2,0 kW/(m^3/s). The university building only has CAV, (Constant Air Volume) balanced ventilation systems. The SFP factor during operation time varies greatly, from 1,59 kW/(m^3/s) to 6,77 kW/(m^3/s). Outside operation time it also varies, from 0,71 to 6,77 kW/(m^3/s). The temperature efficiency of the heat recovery spans from 34 % to 82 %. During simulation, the SFP factor is set to maximum 2,0 kW/(m^3/s) during operating time, and 1,0 kW/(m^3/s) outside operating time. The temperature efficiency of heat recovery is set to 70 % in SIMIEN. Values that are within the limits remain as they are. The exceptions are the technical room and the kitchen in the cafeteria due to a greater need in these rooms. In the technical room the SFP factor is 4 kW/(m^3/s) during operating time and 2 kW/(m^3/s) outside operating time. In the kitchen, the SFP factor is 3 kW/(m^3/s) during operating time and 1 kW/(m^3/s) outside operating time. Table 4.4.3 shows the result from the simulation.

	Before measures	After measures	Low- energy building
Annual average temperature efficiency of the heat recovery system	60 %	72 %	≥ 70 %
Specific Fan Power (SFP)	2,87 kW/(m^3/s)	1,99 kW/(m^3/s)	≤ 2,0 kW/(m^3/s)
Specific energy need (room heating, ventilation heat)	91,8 kWh/m^2 year	72,6 kWh/m^2 year	46,8 kWh/m^2 year
Specific delivered energy	178,2 kWh/m^{2}year	147,5 kWh/m^2 year	-
Specific CO_2 emission	65,0 kg/m^{2}year	54,3 kg/m^{2}year	-
Annual energy budget ventilation heat	34,8 %	27,4 %	-
Heat loss from ventilation	48 %	39,4 %	-

Table 4.4.3. Results from simulation 3.

Improved heat recovery from the ventilation system has a great impact on the points mentioned in the table above. The annual average temperature efficiency of the heat recovery system increased from 60 % to 72 % after simulation, even though the number was simulated with 70 %. This is within the limits of the requirements of a low- energy building. The specific energy need and energy consumption reduced by 20,9 % and 17,2 %, respectively. The specific CO_2 emission has reduced with 16,5 %. The annual energy budget for ventilation heat reduced from 34,8 % to 27,4 %, and the building now has 39,4 % heat loss from the ventilation. This measure is of great importance when striving for a “green” campus, since wasting less energy is a key to achieve the goal of reduced energy use.

Simulation 4

Replace oil used for peak load, with bio fuel (pellets) | The source for electrical power is the grid, which makes it difficult to know where the power comes from and how it is produced. The requirement for energy supply is in building details manual 473.101. It states that one cannot install heat production run on fossil fuels, no matter what type of building. This includes room heating, ventilation heat and hot water production. It is important that the heat central has sufficient area, height and accessibility, when switching to bio fuel such as for example pellets. The University building uses water borne heating. The hot water is currently made by electrical boilers for the base load and with oil for the peak load in the boiler room. The differences in oil and bio fuel are in table 4.4.4. These numbers are pre-set in SIMIEN.

	Oil	Bio fuel (pellets)
System efficiency room heating	0,77	0,73
System efficiency hot water	0,77	0,73
System efficiency heating coils	0,77	0,73
CO_2 emissions	284 g/kWh	14 g/kWh
Energy prize	0,85 NOK/kWh	0,65 NOK/kWh

Table 4.4.4. Difference in oil and bio fuel (pellets).

Changing from oil to bio fuel of pellets will require replacing equipment that can handle the new type of fuel. As shown in the table, CO_2 emissions reduce from 284 g/kWh to 14 g/kWh. That is a 95 % reduction in emissions per kWh of fuel. The energy prize is lower for bio fuel, but the efficiency is lower as well. One kilogram of solid biofuel contains less energy than one kilogram of fossil oil or natural gas. Therefore, biofuel requires larger storage space and higher transport costs than oil or natural gas. The solid biofuel pellets has the highest degree of processing of biofuel. The effective burn value for pellets is 4,8 kWh/ kg (Fornybar, 2017). The real value of pellets is 0,83 NOK/kWh, while for oil its 1 NOK/kWh, when considering the efficiency of the fuel types. Calculations are in appendix C. The calculations do not consider delivery of the fuel. Table 4.4.5 shows that the specific delivered energy to the building increased. Solid biofuel has lower energy density than fossil oil and gas. The specific energy need is approximately the same, which is also natural, since the building needs the same amount of energy to cover all energy use and energy needs, regardless of energy source.

	Before measures	After measures	Low- energy building
Specific energy need (room heating, ventilation heat)	91,8 kWh/m^2 year	91,8 kWh/m^2 year	46,8 kWh/m^2 year
Specific delivered energy	178,2 kWh/m^2year	180,8 kWh/m^2 year	-
Specific CO_2 emission	65,0 kg/m^2year	52,1 kg/m^2year	-

Table 4.4.5. Results from simulation 4.

Table 4.4.5 shows that the specific energy need for room heating and ventilation heat stays the same. Specific delivered energy increased from 178,2 kWh/m^2 year to 180,8 kWh/m^2 year, because of lower efficiency of the bio fuel. More energy in form of pellets needs burning for the building to keep up with the energy demand. Specific CO_2 emission reduced from 65,0 kg/m^2 to 52,1 kg/m^2. That is a 20 % reduction in emissions. Even though the reduction in emissions is relatively close to that of oil, the use of biomass for energy purposes is CO_2-neutral in the sense that the CO_2 released upon combustion of a tree corresponds to the amount of CO_2 the tree retrieved from the surroundings and bound up during growth. In order for the use of bioenergy to be sustainable, it is important that the biomass harvest does not exceed the growth of new trees.

Simulation 5

Short- term measures combined | Improved energy efficiency in lightbulbs, adjustment of indoor temperature and internal heat contribution, improved heat recovery and replacement of oil used for peak load with bio fuel run on pellets, are relatively easy measures since they do not require changes in the building structure itself. The measures only require replacement of equipment, and it should not take long to carry them out. Table 4.4.6 shows the impact the previous measures combined has on the building's performance, compared to the current condition of the building.

	Before measures	After measures	Low- energy building
Specific energy need for room heating, ventilation heat, hot water	91,8 kWh/m^2 year	79,5 kWh/m^2 year	46,8 kWh/m^2 year
Specific delivered energy	178,2 kWh/m^2year	140,0 kWh/m^2 year	-
Specific CO_2 emission	65,0 kg/m^2year	39,4 kg/m^2year	-

Table 4.4.6. Results from simulation 5.

The measures reduced the specific energy need for room heating and ventilation heat with 13,4 %. For the building to reach the requirement of a low- energy building, this number needs to be reduced from 91,8 kWh/m^2 year to 46,8 kWh/m^2 year, a 49 % reduction. A 13,4 % reduction is well on the way toward that goal, by carrying out three relatively simple measures. The measures also had great impact on the CO_2 emissions. The emission reduced by 39,4 %.

Simulation 6

Replace windows, doors, gates and frames | The previous simulations were short- term measures that do not require any change in the building structure. The next two simulations are long- term measures that *will* require making changes in the building structure. Today the University building has standard windows installed, with an average thermal transmittance value (U- value) of 1,65 W/m^2K. According to table 4.4.7, a low- energy building has a maximum value of 1,2 W/m^2K. The current windows are standard windows, which will be replaced with three- layered glass ones, with one low emissivity coating and argon gas. The current frames are standard as well, and replaced with wooden, super insulated frames with super spacers, and the whole window construction has a total thermal transmittance value of 0,93 W/m^2K. An identical current standard window with a standard frame would have a total thermal transmittance value of 1,73 W/m^2K, all according to SIMIEN's calculations. The transmittance value changes depending on how big the windows are and how much percentage the window frames makes out of the total area of the window construction. The current front doors are made of glass and replaced with glass doors of the same characteristics as the energy efficient windows. The façade facing west (from 1969) has gates with a thermal transmittance value of 3,0 W/m^2K. Since the characteristics or the gates are unknown, the thermal transmittance value is customized. Simulated value after measures is reduced to 2,0 W/m^{2}K. Façade north from 1969 is made of glass with a customized value of 3,0 W/m^{2}K. The value is reduced to 2,0 W/m^{2}K. The façade facing north (from 1997) has an uninsulated front door with thermal transmittance value 2,4 W/m^{2}K. The door is switched out with a well insulated door with thermal transmittance value 1,2 W/m^{2}K. The façade facing east (from 1997) has gates with a thermal transmittance value of 3,0 W/m^{2}K. New gates has a value of 2,0 W/m^{2}K. The reduction from 3,0 W/m^{2}K to 2,0 W/m^{2}K are based on personal judgement and comparison to the thermal transmittance value of windows and doors. Gates are large compared to doors and are a source of heat loss, thus they need much insulation. The upper limit is an average of 1,2 W/m^{2}K, therefore a reduction to 2,0 W/m^{2}K for the gates seemed reasonable. The result from this simulation is in table 4.4.7.

	Before measures	After measures	Low- energy building
Thermal transmittance value windows, front doors, gates	1,65 W/(m^{2}K)	0,91 W/(m^{2}K)	1,2 W/(m^{2}K)
Specific energy need (room heating, ventilation heat)	91,8 kWh/m^2 year	81,7 kWh/m^{2}year	46,8 kWh/m^2 year
Specific delivered energy	178,2 kWh/m^{2}year	166,5 kWh/m^{2}year	-
Specific CO_2 emission	65,0 kg/m^{2}year	60,8 kg/m^{2}year	-

Table 4.4.7. Results from simulation 6.

By replacing windows, front doors, gates and frames, the specific energy need for room heating and ventilation reduced with 11 %. The specific delivered energy to the building reduced with 6,6 %. The CO_2 emissions reduced by 6,5 %. A thermal transmittance value of 0,91 W/(m^{2}K) might seem excessive when the requirement is 1,2 W/(m^{2}K). Other alternatives in SIMIEN had either much higher or much lower numbers. The choices in this measure were as close to the requirement as possible.

Simulation 7

Increase insulation and improve normalized thermal bridges | The University will be simulated with 150 mm extra insulation in the entire building's walls and roofs. The walls today have 150 mm insulation in all building parts, both from 1969 and 1997. After measures, all walls will have 300 mm insulation. The roofs currently have 200 mm insulation, and after measures, all roofs will have 350 mm insulation. The connecting wall between the university and the gym remains untouched. As mentioned before, the gym itself is not included in the simulation or thesis. During the simulation, the wall towards the gym was set to be a wall facing a "heated zone" in SIMIEN. The impact of changes in that specific wall was considered negligible. Table 4.4.8 shows the thermal transmittance value of the different building parts before and after measures, including the value of the floor.

Building part	Current value	After measures	Low- energy building
Thermal transmittance value exterior walls	0,28 W/m^{2}K	0,16 W/m^{2}K	0,16
Thermal transmittance value roof	0,20 W/m^{2}K	0,12 W/m^{2}K	0,12
Thermal transmittance value floor	0,11 W/m^{2}K	-	0,11
Normalized thermal bridge	0,12 W/m^{2}K	0,05 W/m^{2}K	$\leq$ 0,05 W/m^{2}K

Table 4.4.8. Thermal transmittance value of building parts.

The measures with 150 mm extra insulation made the building parts fulfil the requirements of a low-energy building. The normalized thermal bridge is also within the limits. Table 4.4.9 shows the impact of the measures.

	Before measures	After measures	Low- energy building
Specific energy need (room heating, ventilation heat)	91,8 kWh/m^2 year	77,4 kWh/m^2 year	46,8 kWh/m^2 year
Specific delivered energy	178,2 kWh/m^{2}year	161,4 kWh/m^2 year	-
Specific CO_2 emission	65,0 kg/m^{2}year	59,0 kg/m^{2}year	-

Table 4.4.9. Results from simulation 7.

The specific energy need reduced with 15,7 % and the specific delivered energy reduced with 9,4 %. Specific CO_2 emissions reduced with 9 %. The normalized thermal bridge was lowered from 0,12 W/m^{2}K to 0,05 W/m^{2}K, as is the requirement. This shows that a significant increase in insulation and improved thermal bridges have impact on the overall energy need and consumption. These measures make sure less heat escapes from the building. The thermal transmittance value of the floor was already within the limits of 0,11 W/m^{2}K, according to table 4.3.2.

Simulation 8

All measures combined | The last simulation is a combination of all previous measures; replace lightbulbs, increased heat recovery from ventilation, bio fuel as peak load, better windows, doors, gates and associated frames, increased insulation in walls and roof and improved normalized thermal bridges. After fulfilling all the requirements in NS 3701:2012 for equipment and construction parts in a low- energy building, UiT Narvik still had greater specific energy need than the maximum calculated value of 46,8 kWh/m^2 year. After simulation the value was 54,3 kWh/m^2 year. Finding a way of lowering the specific energy need required the method of trial and error. The only instance that seemed natural to improve was the temperature efficiency on heat recovery, although this value was already within limits, at 72 %. Several simulations were executed, all with slightly improved heat recovery until satisfactory. The new temperature efficiency became 79 %, reducing the specific energy need to 46,4 kWh/m^2 year. This means the building now has fulfilled every requirement of becoming a low- energy building, and the checklist of assumptions for calculations in Table 3.1.4, is acceptable on every instance. The final results are in table 4.4.10 and 4.4.11.

Description	Value before	Value after	Low- energy building
Thermal transmittance value exterior walls	0,27 W/m^{2}K	0,16 W/m^{2}K	0,16 W/m^{2}K
Thermal transmittance value roof	0,20 W/m^{2}K	0,12 W/m^{2}K	0,12 W/m^{2}K
Thermal transmittance value floor	0,11 W/m^{2}K	0,11 W/m^{2}K	0,11 W/m^{2}K
Thermal transmittance value windows and doors	1,65 W/m^{2}K	0,91 W/m^{2}K	1,2 W/m^{2}K
Normalized thermal bridge	0,12 W/m^{2}K	0,05 W/m^{2}K	$\leq$ 0,05 W/m^{2}K
Leakage figure	1,50 h^{-1}	1,5 h^{-1}	1,5 h^{-1}
Temperature efficiency on heat recovery	60 %	79 %	$\geq$ 70 %
SFP factor	2,87 kW/(m^3/s)	1,99 kW/(m^3/s)	$\leq$ 2 kW/(m^3/s)
Power requirement for lighting during operating hours	8 W/m^2	4,5 W/m^2	4,5 W/m^2
Heat supplement from equipment during operating hours	11 W/m^2	5 W/m^2	5 W/m^2
Heat supplement from people during operating hours	6 W/m^2	6 W/m^2	6 W/m^2

Table 4.4.10. Key input from SIMIEN.

	Before measures	After measures	Low- energy building
Specific energy need (room heating, ventilation heat)	91,8 kWh/m^2 year	46,4 kWh/m^2 year	46,8 kWh/m^2 year
Specific delivered energy	178,2 kWh/m^{2}year	97,9 kWh/m^2 year	-
Specific CO_2 emission	65,0 kg/m^{2}year	28,7 kg/m^{2}year	-

Table 4.4.11. Results before and after simulating.

The specific energy need for room heating reduced by 49,5 % after measures, as required. The specific delivered energy to the University building reduced by 45 % and the specific CO_2 emissions reduced by 56 %. The new numbers have halved compared to the initial numbers. All requirements are met, also showing that the measures are sufficient for the building to achieve the low- energy standard. There are no major changes in the building itself other than inserting more insulation and new windows, doors, gates and associated frames. The change is the thickness of the walls due to more insulation. The size of windows, doors and gates are the same. The same is the size ratio of glass and frame. This gives the same amount of daylight so there is no need for more lighting than what already exists. A summary of all numbers and information before and after measures from the simulations are in appendix D.

4.5. New energy Label

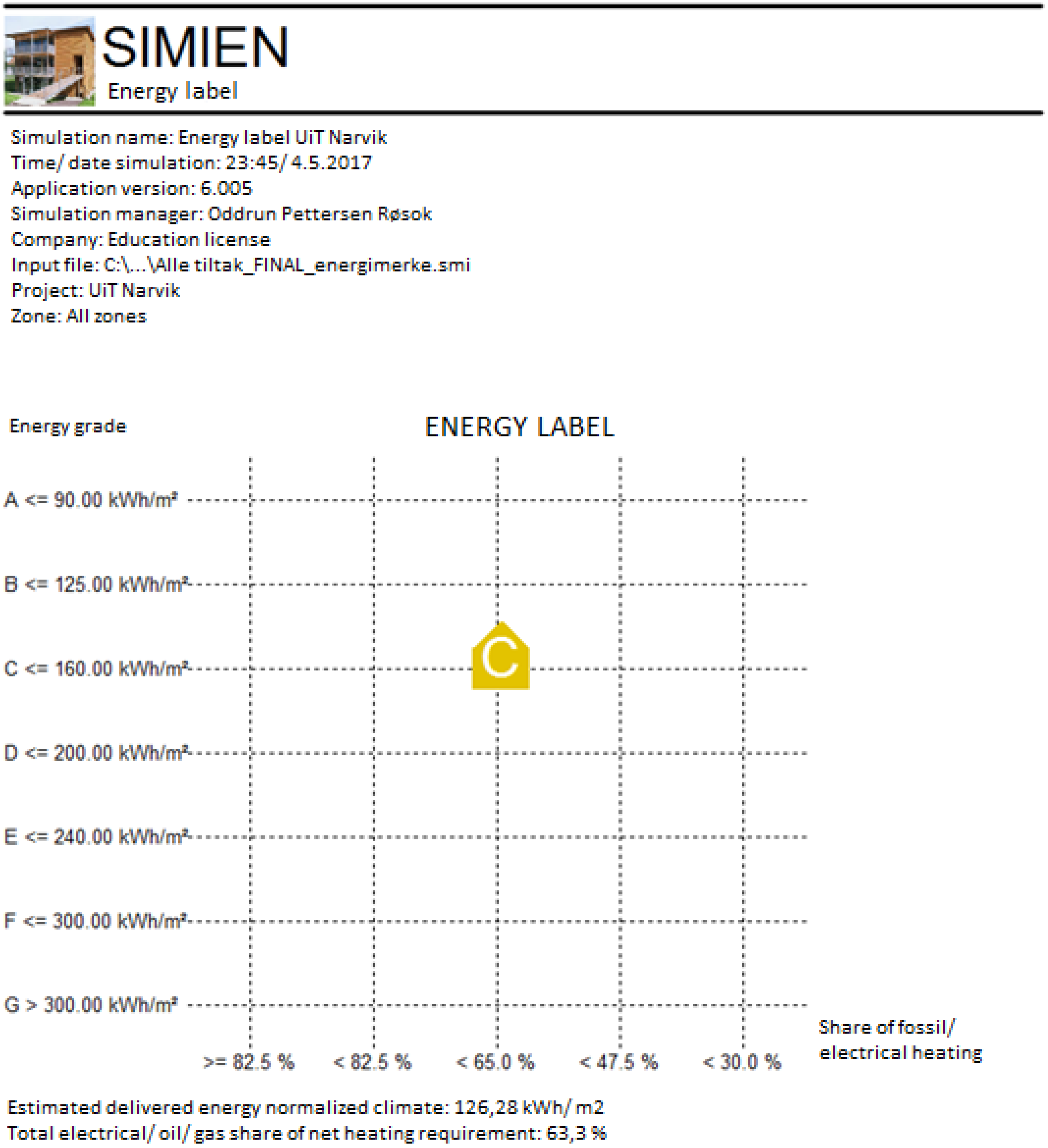


Figure 4.9.1. New energy label for UiT Narvik.

As mentioned before, the energy labels consists of an energy grade and heating grade. The energy grade indicates the energy efficiency of the building, including the heating system, calculated from the typical energy consumption of the specific building type. The building's energy standard determines the energy grade. Grade A means that the building is energy efficient, grade G means the building is not very energy efficient. The heating grade tells how much of the heating demand (heating and hot water) that is covered by electricity, oil or gas. Green color means low share, red color means high share. Figure 4.9.1 shows the new energy label for UiT Narvik after achieving the standard of a low-energy building. According to table 4.1.2 from principle two in the concept for UiT Narvik, the building must strive for a grade of minimum yellow B, which a low- energy building would normally get, as explained previously in the thesis. Even if UiT Narvik reached all requirements for a low- energy building it could not achieve higher than energy grade C, almost reaching the minimum requirement.

The reason for the yellow colour is that the building uses electricity as the base load for heating and pellets as peak load. A high amount of electricity or fossil fuel use gives a bad colour (closer to red), while renewable energy sources give a better colour (closer to green). Thus, for the colour to be better than yellow, more energy needs to come from a renewable source and less from an electrical source. The building is a complex of buildings connected together. A part of the building is from 1969 and the new part is from 1997. The first Building Technical Regulations (TEK) came in 1997, as TEK 97, so the building from 1997 had to follow those regulations. The building from 1969 followed building codes from 1969. This means that the regulations were different for each part of the building. The building technical regulations improve all the time, so it is reasonable to assume that the regulations from TEK 97 were stricter than regulations from the building code in 1969. When simulating the building to become a low- energy building it is a challenge to get the part of the complex from 1969 to become as energy efficient as the part from 1997, by making similar measures in all building parts according to NS 3701:2012. The part from 1969 will be less energy efficient and thus give a lower total energy grade for the entire building complex. A solution to achieve a better grade than C could be to carry out stricter measures on the building parts from 1969. Due to lack of time for this report, it was not possible to compare building parts from 1969 and 1997 and achieve those measures.

4.6. Sustainability label

After working on the concept of a sustainable campus, nothing was found on *when* a campus can label itself “sustainable”. The ISCN has principles to follow to achieve the status of a sustainable campus, but it says nothing on how much that has to be achieved before the relevant university gets that status. From there, the idea of a label came up. Just as buildings have an energy label, a labelling system for sustainability can be made, a so- called “sustainability label”. Since the thesis is about making UiT Narvik a sustainable campus based on own definitions, with emphasis on energy efficiency in the building, this new labelling system will get an explanation for a general idea that requires considerable review. Thus, this concept will be part of possible future work after this thesis. A grade system for sustainability requires continuous processing and collection of information before it can be used in real life as a realistic grading system for sustainability. This new concept came up at the end of the writing period, so there was limited amount of time to work on it.

The definition of a sustainable campus will remain the same for any university or campus that decide to use UiT Narvik’s concept. The difference is the degree of implementation of the concept. The idea is that all measures from UiT Narvik’s concept need fulfilling as part of achieving the highest grade of the sustainability label. The labelling system should further have three main areas for the University to consider; current state, future development and maintenance.

The *current state* is about the condition the building has today, compared to all areas mentioned in the concept for UiT Narvik. *Future development* is about the building’s ability to develop over time to be able to keep up with the development of new and improved technology. Easy repairing or replacement of equipment is important, and it requires good planning from architect and engineers, preferably before constructing the building. The equipment can be anything from exterior walls, windows, heaters and insulation, to technological equipment used in teaching context. If some equipment is not easily replaced, it could require an individual certificate for the specific equipment, so that it can be installed for a longer period, even if there are new and improved products available. *Maintenance* is about how environmentally friendly the maintenance of the building is during its lifetime. Parts need replacing or repairing and the building needs a constant flow of procurement. The procurement must be accounted for and made sure has a label such as the EnergyStar, the Swan Label, or any other label that makes sure the products are eco- friendly and energy saving. Maintenance can also include energy sources, to make sure a certain part of the electrical energy is renewable and that the base load is at least partly covered by a renewable energy source. The sustainability label should have some “fluid” definitions, such as the low- energy standard. Anyone can achieve the low- energy standard, but the requirements for that standard will change depending on the climate (annual mean temperature) on the building’s location.

The Sustainability Label should also have a grade system, for example in the order: pass, good, very good, excellent, and outstanding. It should come with a description that states the areas the UiT Narvik is good or bad at, and the requirements needed to achieve every grade of the scale. The labelling of sustainability should be mandatory for every university in Norway, and the label should be accessible for any student or people who wish to apply at a Norwegian university. The label can show how determined the universities are in doing what they can to spare the environment. The more attention sustainability gets, the higher the focus on the topic. Making the label visible to anyone, both online and at the campus itself, could put more focus on sustainability.

For universities with more buildings than one on campus, LEED can serve as a target when developing the labelling system. It could be that universities with only one building can use BREEAM as certification method, and for universities with several buildings, LEED's campus certification method is more appropriate to determine the building's environmental impact. The Environmental Lighthouse has a four- step approach on how a building becomes an Environmental Lighthouse. Perhaps it is necessary to create an office or administration that works on certifying university buildings with the sustainability label, with a similar approach adopted from the Environmental Lighthouse.

5. Discussion

There are some elements, which seem inaccurate or need more research to be sure the results are reasonable and realistic. During the stay at Hokkaido University, it became evident that the information received there was insufficient. Much of the information, such as the concept from the coordinator Maki Ikegami, was explained orally during a meeting. The chance of misunderstanding and misconception of the information received is present and difficult to proofread. This could give the possibility of having the wrong impression of the concept at Hokkaido University. It was explained in the report what areas are the focus areas of their concept, which because of the oral explanation and lack of information about their concept, could be interpreted slightly wrong. In addition, the main focus was from the beginning on Hokkaido University's concept. It was after arriving back in Norway that it became clear more universities needed to be included. It means that less time could be spent on doing research on the concepts Harvard University and NTNU, due to a tight schedule.

The concept of UiT Narvik is not necessarily only for areas in Northern Norway. SIMIEN considers locations all over Norway, and the energy need of any building can be calculated by using the annual mean temperature and BRA of the building, according to NS 3701:2012. However, the concept was made with UiT Narvik as the base. The requirements were adjusted to the University's surroundings. If the surroundings of the building had flatter surroundings or more green areas, more emphasis could be put on preserving it. Since the building is located on the mountain side, there is a limit to how much people can be inspired to for example ride their bike to University, because of the steep and tiresome climb up the mountain. The surroundings and location of the University building also makes it difficult to implement any renewable energy production on campus. Harvard University installed solar panels, and if it seemed easy to implement it, it would likely be included in the concept for UiT Narvik. In addition, the University could then use energy produced on- site to cover part of the base load, improving the energy grade, which in total would give a better energy label.

The simulations in this report are based on COWI AS 'SIMIEN file from 2012, with an earlier version of SIMIEN. Their simulations may have shortcomings and errors. It is uncertain how precise and thorough COWI AS had been with the simulation and how much of a deviation was allowed when it comes to measurements on the building structure and insertion of this information in SIMIEN. It was not possible to double check COWI AS 'simulation with information about the building, due to a limited time frame for the thesis. However, COWI AS' simulation can still be validated, as they put today's actual energy label, in addition to making the Energy Efficiency Report from 2012, which the University building currently follows. Another area to investigate is if COWI AS has simulated the building parts from 1969 with different characteristics than the buildings parts from 1997, and if that was the reason for the energy grade C.

It is unknown what types of gases are included in the greenhouse gas emissions from each university. CO_2 is not the only gas released from buildings, and details about the exact types of emissions were not found. Some gases have greater impact on the greenhouse effect than CO_2, such as methane. It is crucial to know every type of gas released from the university building at UiT Narvik before having a final overview of the greenhouse gas emissions. The simulations in SIMIEN only account for the CO_2 emissions. That makes it difficult to know if the numbers for the CO_2 emissions are realistic. Perhaps the real number is much greater because of other gases with a stronger impact on the greenhouse effect. When it comes to isolated numbers for CO_2, the numbers from the simulations can still be realistic.

6. Topics for further research

Financial aspect | The research presented in this thesis have opened for more questions. There are several lines of research arising from this work, which could be pursued. Firstly, the total financial aspect of making UiT Narvik sustainable, be it the already existing building, or a future new building on campus. Also, calculate the cost to do the measures stated in the sustainability concept. Furthermore, make calculations on how much money will be saved over time, during the building's lifetime as a sustainable campus compared to not doing the measures. It could be necessary to do a study on the life- span of the University as a sustainable campus compared to the current campus, to find out if the concept is worth spending money on, from start to end of the campus' life cycle.

Further study of the sustainability label | An in- depth study of the sustainability label has been left for the future due to lack of time (i.e. the thesis' main goal has been to create a concept of a sustainable campus and the idea of a sustainability label emerged at the end of the writing). Future work concerns deeper analysis of what to include in the labelling system. A study needs to be done to be able to specify the exact requirements for each grade of sustainability. There needs to be exact numbers and definitions, so that there is no doubt of what is required.

Lifespan | A study can be performed to find out how long it takes before the requirements in the sustainable campus concept is outdated. One of the requirements for the concept is to achieve low-energy standard on the University building, but the requirements have only become stricter and will most likely keep on becoming stricter in the future. A study on the follow- up of the concept might be necessary, to ensure that the campus is always able to stay within new limitations and requirements.

Extension of the concept | In the future, if the concept of a sustainable campus at UiT Narvik has gained foothold, the process of expanding could be interesting. As mentioned, UiT has eight campuses spread out on the Northern part of Norway. One could look into the possibility to apply the concept of a sustainable campus to every campus that belong to UiT so that the university as a whole can label itself as a sustainable university. To achieve a sustainable university, one can look into LEED's way of certificating and investigate if the newly made concept for UiT Narvik can somehow merge with LEED's certification method, or if BREEAM's method is better suited.

7. Conclusion

This thesis was about creating a concept of a sustainable campus tailored for UiT Narvik. The concept is based on three universities around the world, Hokkaido University in Japan, Harvard University in USA, and NTNU in Norway. All three universities are members of the International Sustainable Campus Network (ISCN). The university members follow three principles on how to become a sustainable campus, made by the ISCN, although the ISCN does not yet have a clearly defined concept of a sustainable campus.

The thesis included a two month- long stay in Japan at Hokkaido University to study this university's solution to become a sustainable campus, in addition to find inspiration for the concept to create for UiT Narvik. The stay in Japan revealed that the thesis needed more information about a sustainable campus than Hokkaido University could provide, so in consultation with the supervisor it was decided to include the other two more universities. After looking through the list of members of ISCN and the homepages of the universities, it became clear that Harvard University and NTNU had a well-developed idea of a concept.

A concept was created for UiT Narvik, based on the concepts of all three universities. NTNU has a greater focus on reducing the energy use than Harvard University and Hokkaido University, making NTNU's concept the main foundation. NTNU's concept is more defined and clear than the concepts of Hokkaido University and Harvard University. Each principle is approached directly with detailed explanation on how to reach the goals and tackle challenges. It was up to the author of the report to set the rules and decide what the concept should include, thus it was decided that the focus should be on the environmental footprint in form of reducing the energy consumption and greenhouse gas emissions from the building. One of the requirements decided for the concept was to transform the current university building at UiT Narvik, into a low- energy building. Eight simulations were carried out separately, of which six are individual measures determined by the requirements of a low- energy building. Four of the simulations were short- term measures, which can be performed without making any changes in the building structure itself, followed by a simulation that included all four measures combined. Two new simulations were performed with measures where changes in the building structure itself is necessary. The final simulation was a combination of all measures that in the end needed some tweaking to fulfill all requirements of a low- energy building, even though all previous simulations were within the limits. UiT Narvik obtained the requirements of a low- energy building, as well as a new and improved energy label.

Finally, a new contribution based on the concept itself emerged. The idea of a sustainability label came up, similar to an energy label, as a tool to determine the degree of sustainability on campus. This sustainability label was explained briefly to give an idea of how one could proceed on developing the idea.

8. Bibliography

ISCN, 2017, 31 State Street, 10th Floor, Boston, MA 02109 USA, http://www.international-sustainable-campus-network.org/ (1.2.2017).

ISCN-GULF, 2017, 31 State Street, 10th Floor, Boston, MA 02109 USA, http://www.international-sustainable-campus-network.org/downloads/charter-and-guidelines/443-iscn-gulf-charter-guidelines/file (2.2.2017)

ISCN- Charter and Guidelines, 2017, 31 State Street, 10th Floor, Boston, MA 02109 USA, http://www.international-sustainable-campus-network.org/charter-and-guidelines (2.2.2017)

Hokkaido University Guidebook 2016- 2017, Sapporo Japan

Hokkaido University, 2017, Connection and Working toward the Future, Sustainability Report 2015, Sapporo Japan

Triple Helix Research Group, 2017, Stanford University, 450 Serra Mall, Stanford, CA 94305-2004, https://triplehelix.stanford.edu/3helix_concept (10.2.2017)

Hokkaido University, 2017, What is a Good Campus? Sustainability Report 2016, Toward a Sustainable Campus, Sapporo Japan

Harvard University Sustainability Plan, 2017, Massachusetts Hall, Cambridge, MA 02138 USA, https://green.harvard.edu/sites/green.harvard.edu/files/Harvard%20Sustainability%20Plan-Web.pdf (15.3.2017)

Sustainability Report, 2017, Massachusetts Hall, Cambridge, MA 02138 USA, http://report.green.harvard.edu/ (16.3.2017)

ISCN-GULF Sustainable Campus Charter Report 2014, 2017, NTNU 7491 Trondheim Norway, https://www.ntnu.no/documents/10137/1262279573/NTNU_ISCN+report+2014.pdf/2273fe9c-9051-4899-8c40-166b73512f07 (20.3.2017)

Why Renewable Energy, 2017, Professor Brochs gate 2, 7030 Trondheim, post boks 5700 Sluppen, Norway, http://www.fornybar.no/energipolitikk (1.4.2017)

Plan- og bygningsloven, 2017, Lovdata Postboks 2016 Vika, 0125 Oslo Norway, https://lovdata.no/dokument/NL/lov/2008-06-27-71 (6.5.2017)

Building Details Manual 473.015, Documentation of passive houses and low energy buildings according to NS 3700 and NS 3701, Building Research Series

Norwegian Standard NS 3701:2012, Criteria for passive houses and low energy buildings, non-residential buildings, ICS 91.040.01; 91.120.10, Standard Norway

Norwegian Standard NS 3031:2014, Calculation of energy performance of buildings – Method and data, Standard Norway

Building Technical Regulations from 2010 TEK10, Building Quality Directorate

Building Details Manual 473.102, Energy requirements for buildings. Energy budgets, Building Research Series

Building Details Manual 473.101, Energy requirements for buildings. Overview, Building Research Series

NVE, 2017, Middelthuns gate 29, 0368 Oslo Norway, https://www.energimerking.no/download?objectPath=/upload_images%2FD6C27F0DE6F54ED580C2170275959ADF.pdf (5.5.2017)

LEED 2017, 2101 L Street NW, suite 500 Washington, DC 20037 USA, http://www.usgbc.org/leed-v4 (6.5.2017)

LEED USA, 2017, 2101 L Street NW, suite 500 Washington, DC 20037 USA, http://leed.usgbc.org/leed.html (6.5.2017)

LEED campus, 2017, 2101 L Street NW, suite 500 Washington, DC 20037 USA, http://www.usgbc.org/articles/certify-multiple-buildings-leed (6.5.2017)

BREEAM, 2017, Kongens gate 1, 0153 Oslo Norway, http://ngbc.no/breeam-nor/ (24.4.2017)

Environmental Lighthouse, 2017, Grønt senter, Odderøyveien 5, 4610 Kristiansand Norway, http://www.miljofyrtarn.no/dette-er-milj%C3%B8fyrt%C3%A5rn/2015-11-18-23-59-53 (24.4.2017)

Miljøfyrtårn, 2017, Grønt senter, Odderøyveien 5, 4610 Kristiansand Norway, http://www.miljofyrtarn.no/slikblirdu (25.4.2017)

EnergyStar, 2017, 1200 Pennsylvania Ave NW Washington, DC 20460 USA, https://www.energystar.gov/about/why_energy_star (27.4.2017)

Svanemerket, 2017, Henrik Ibsens gate 20, 0255 Oslo Norway, http://www.svanemerket.no/om-svanemerket/livslopet/svanemerket/ (25.4.2017)

SSB, 2017, Akersveien 26, 0177 Oslo Norway, https://www.ssb.no/energi-og-industri/artikler-og-publikasjoner/pa-verdenstoppen-i-bruk-av-strom (20.4.2017)

COWI AS, 2017, Energy Efficiency Report HiN 2012

COWI AS, 2017, Energy Certificate HiN 2012, Norwegian Water Resources and Energy Directorate NVE

VariantVVS, 2017, Barkåker Næringspark, Wirgenes vei 8B, 3157 Barkåker Norway, http://byggebolig.no/imageoriginals/8215a2bc48464754ae96d2c463616a93.pdf (27.4.2017)

Fornybar, 2017, Professor Brochs gate 2, 7030 Trondheim, post boks 5700 Sluppen, Norway, http://www.fornybar.no/bioenergi/ressursgrunnlag (5.5.2017)

Lavenergiprogrammet, 2017, Middelthunsgate 27 Majorstuen, 0307 Oslo Norway, http://lavenergiprogrammet.no/artikkel/nye-energikrav-i-byggteknisk-forskrift/ (3.4.2017)

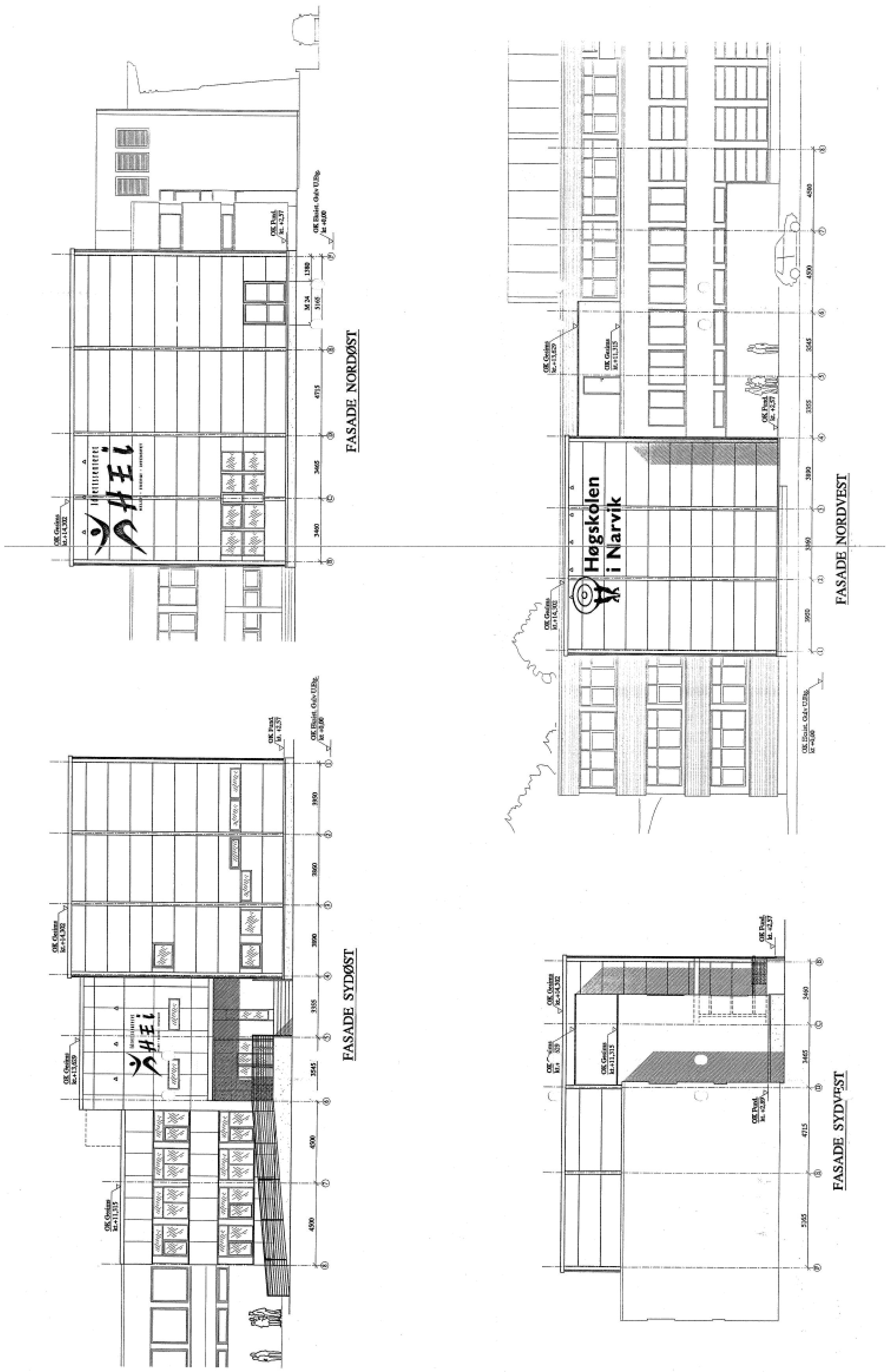
Direktoratet for byggkvalitet, 2017, Mariboes gate 13, 0183 Oslo Norway, https://dibk.no/globalassets/energi/energifleksibilitet-i-bygg---en-studie-av-konsekvenser-av-preaksepterte-losninger_asplan-viak_juni_2016.pdf (13.4.2017)

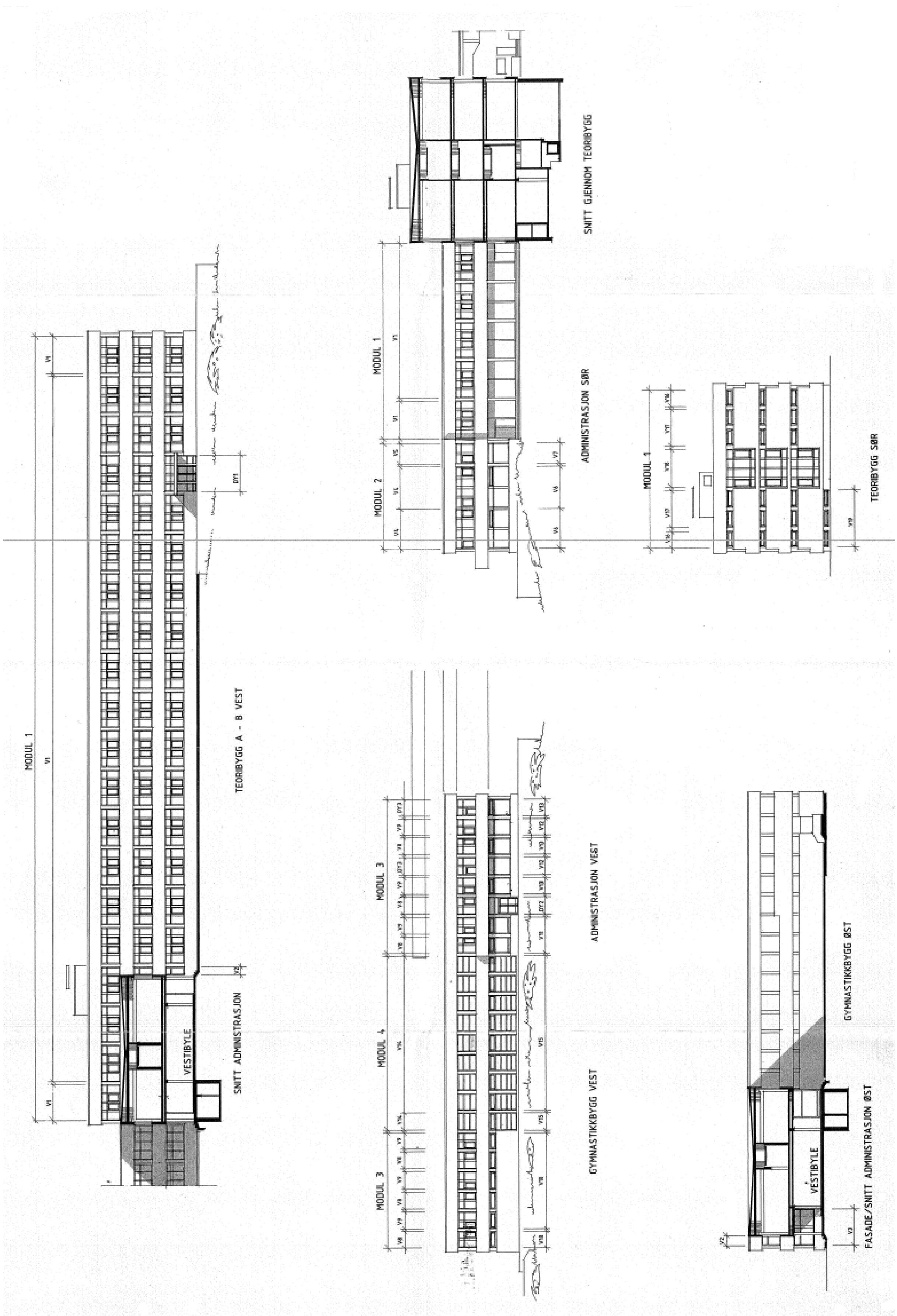
Software:

SIMIEN v. 6005, 2017, ProgramByggerne ANS Rajeveien 93, 3618 Skollenborg, http://www.programbyggerne.no/ (31.3.2017)

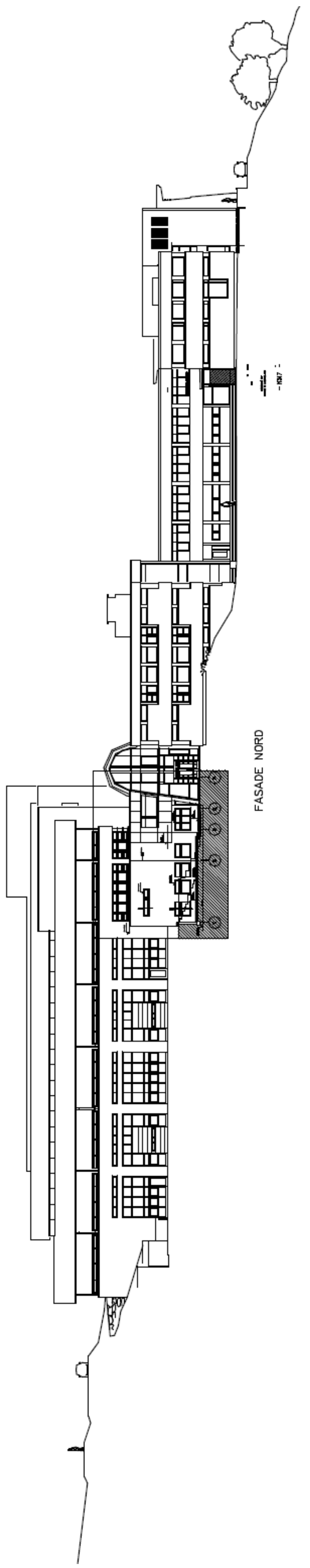
9. Appendix

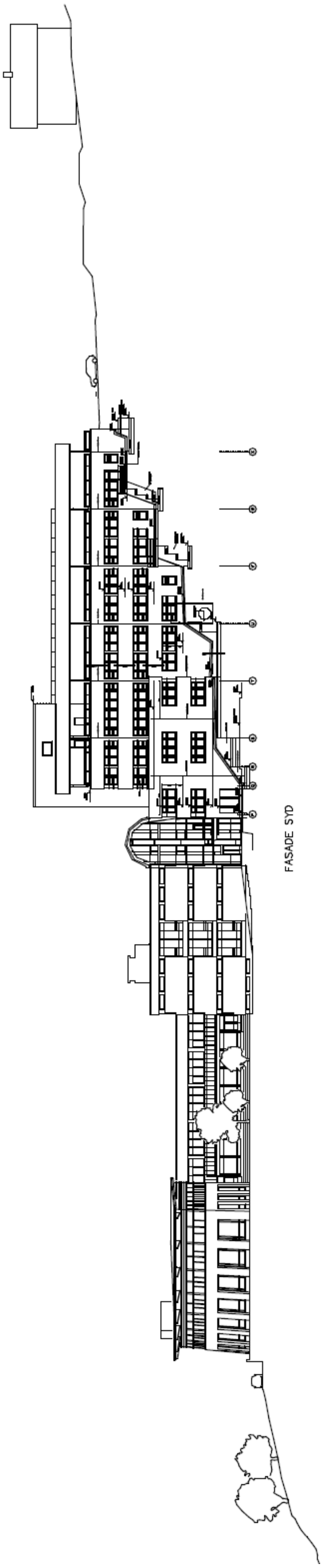
Appendix A. Façade drawings



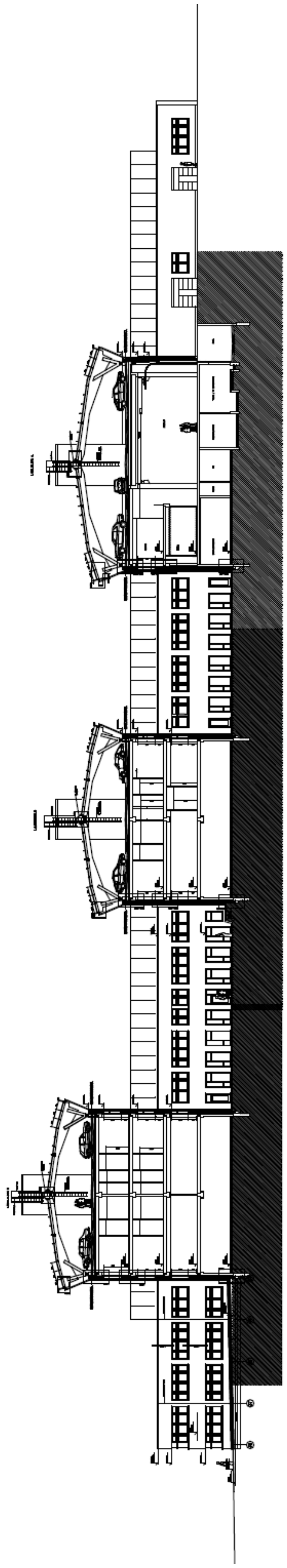

MODUL 1
TEORIBYGG A - B VEST
SNITT ADMINISTRASJON
VESTIBYLE
SNITT GJENNOM TEORIBYGG
MODUL 2
ADMINISTRASJON SØR
TEORIBYGG SØR
MODUL 3
MODUL 4
ADMINISTRASJON VEST
GYMNASTIKKBYGG VEST
GYMNASTIKKBYGG ØST
FASADE/SNITT ADMINISTRASJON ØST

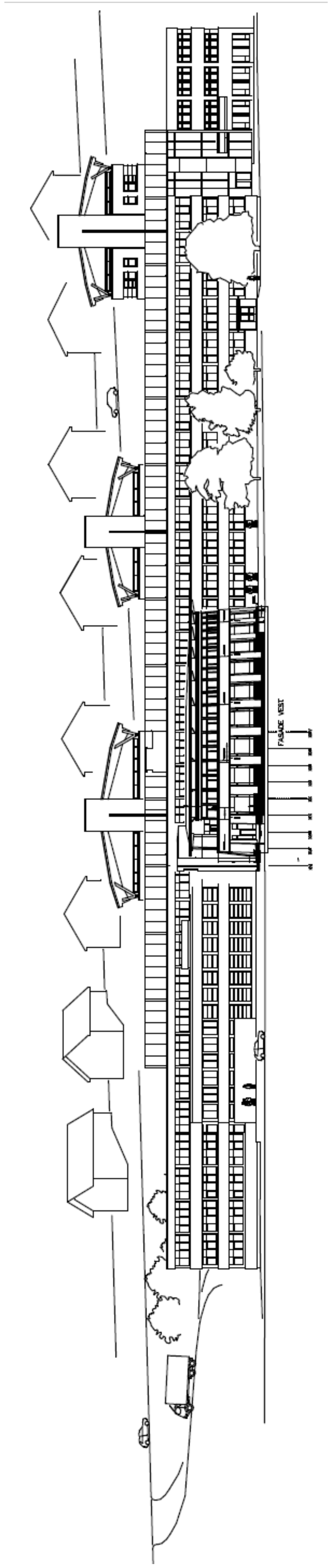
Façades facing North and South





Façades facing East and West





Appendix B. Calculated energy need at UiT Narvik

Calculation for energy need, university building

From NS 3701:2012

4.2, table 4 - Heating demand

Annual mean temperature Narvik: 3, 8 ̊C < 6, 3 ̊C (From Simien)

BRA (gross area): 23.446 m^2 > 1.000 m^2

$EP_{H,0} + K_1 * (6{,}3 - \theta_{ym})$

From table 5, university building:

$EP_{H.0}$ = 35

K_1 = 47

$35 + 4{,}7 * (6{,}3 - 3{,}8) = 46{,}8\ kWh/m^2 year$

Appendix C. Real value of pellets and oil

Pellets

System efficiency: 0,73

Energy prize: 0,65 NOK/kWh

Real value per kWh:

$$0{,}65\frac{NOK}{kWh} * 1 + (1 - 0{,}73) = 0{,}65\frac{NOK}{kWh} * 1{,}27 = 0{,}83\frac{NOK}{kWh}$$

Oil

System efficiency: 0,77

Energy prize: 0,85 nok/kWh

Real value per kWh:

$$0{,}85\frac{nok}{kWh} * 1 + (1 - 0{,}77) = 0{,}85\frac{nok}{kWh} * 1{,}23 \approx 1{,}00\frac{nok}{kWh}$$

Appendix D.1. Results from SIMIEN, before measures

SIMIEN

Resultater årssimulering

Simuleringsnavn: Årssimulering_før tiltak
Tid/dato simulering: 17:30 3/5-2017
Programversjon: 6.005
Simuleringsansvarlig: Oddrun Pettersen Røsok
Firma: Undervisningslisens
Inndatafil: C:\...\Før tiltak_utgangspunkt.smi
Prosjekt: UiT Narvik
Sone: Alle soner

Energibudsjett		
Energipost	Energibehov	Spesifikt energibehov
1a Romoppvarming	840909 kWh	35,9 kWh/m²
1b Ventilasjonsvarme (varmebatterier)	1310528 kWh	55,9 kWh/m²
2 Varmtvann (tappevann)	99034 kWh	4,2 kWh/m²
3a Vifter	531147 kWh	22,7 kWh/m²
3b Pumper	14868 kWh	0,6 kWh/m²
4 Belysning	453948 kWh	19,4 kWh/m²
5 Teknisk utstyr	510658 kWh	21,8 kWh/m²
6a Romkjøling	0 kWh	0,0 kWh/m²
6b Ventilasjonskjøling (kjølebatterier)	8560 kWh	0,4 kWh/m²
Totalt netto energibehov, sum 1-6	3769651 kWh	160,8 kWh/m²

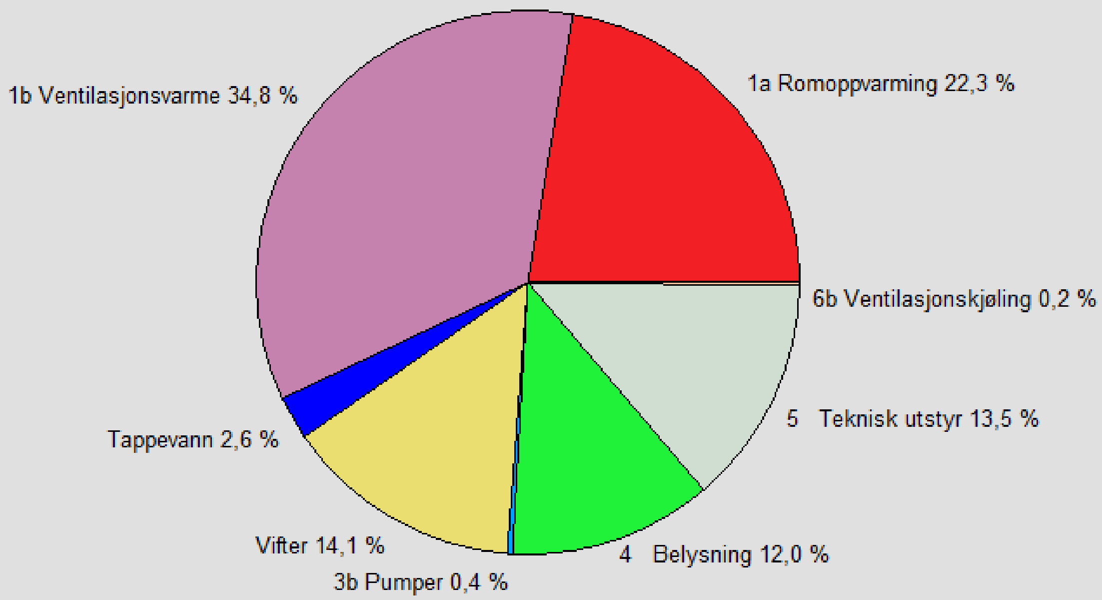
Levert energi til bygningen (beregnet)		
Energivare	Levert energi	Spesifikk levert energi
1a Direkte el.	3052910 kWh	130,2 kWh/m²
1b El. til varmepumpesystem	0 kWh	0,0 kWh/m²
1c El. til solfangersystem	0 kWh	0,0 kWh/m²
2 Olje	1124015 kWh	47,9 kWh/m²
3 Gass	0 kWh	0,0 kWh/m²
4 Fjernvarme	0 kWh	0,0 kWh/m²
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	4176925 kWh	178,2 kWh/m²
Solstrøm til eksport	-0 kWh	-0,0 kWh/m²
Netto levert energi	4176925 kWh	178,2 kWh/m²

Dekning av energibudsjett fordelt på energikilder						
Energikilder	Romoppv.	Varmebatterier	Varmtvann	Kjølebatterier	Romkjøling	El. spesifikt
El.	26,9 kWh/m²	27,9 kWh/m²	4,2 kWh/m²	0,4 kWh/m²	0,0 kWh/m²	64,4 kWh/m²
Olje	9,0 kWh/m²	27,9 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	0,0 kWh/m²	0,0 kWh/m²	0,0 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	35,9 kWh/m²	55,9 kWh/m²	4,2 kWh/m²	0,4 kWh/m²	0,0 kWh/m²	64,4 kWh/m²

Årlige utslipp av CO2		
Energivare	Utslipp	Spesifikt utslipp
1a Direkte el.	1205900 kg	51,4 kg/m²
1b El. til varmepumpesystem	0 kg	0,0 kg/m²
1c El. til solfangersystem	0 kg	0,0 kg/m²
2 Olje	319220 kg	13,6 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	1525120 kg	65,0 kg/m²
Solstrøm til eksport	-0 kg	-0,0 kg/m²
Netto CO2-utslipp	1525120 kg	65,0 kg/m²

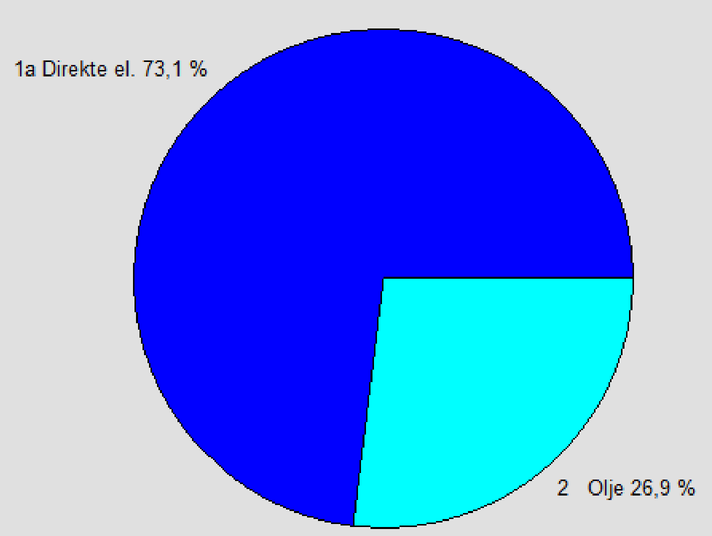
Kostnad kjøpt energi		
Energivare	Energikostnad	Spesifikk energikostnad
1a Direkte el.	2442328 kr	104,2 kr/m²
1b El. til varmepumpesystem	0 kr	0,0 kr/m²
1c El. til solfangersystem	0 kr	0,0 kr/m²
2 Olje	955413 kr	40,7 kr/m²
3 Gass	0 kr	0,0 kr/m²
4 Fjernvarme	0 kr	0,0 kr/m²
5 Biobrensel	0 kr	0,0 kr/m²
6. Annen energikilde	0 kr	0,0 kr/m²
7. Solstrøm til egenbruk	-0 kr	-0,0 kr/m²
Årlige energikostnader, sum 1-7	3397741 kr	144,9 kr/m²
Solstrøm til eksport	0 kr	0,0 kr/m²
Netto energikostnad	3397741 kr	144,9 kr/m²

Årlig energibudsjett

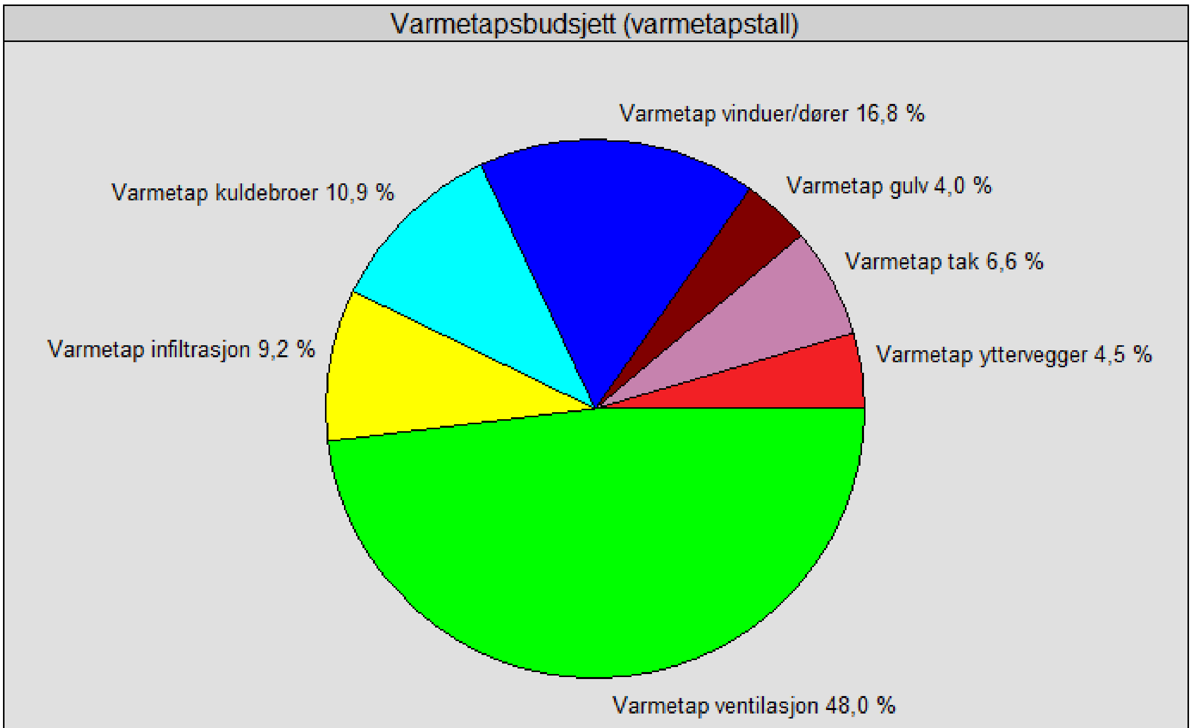


1a Romoppvarming	840909 kWh
1b Ventilasjonsvarme (varmebatterier)	1310528 kWh
2 Varmtvann (tappevann)	99034 kWh
3a Vifter	531147 kWh
3b Pumper	14868 kWh
4 Belysning	453948 kWh
5 Teknisk utstyr	510658 kWh
6a Romkjøling	0 kWh
6b Ventilasjonskjøling (kjølebatterier)	8560 kWh
Totalt netto energibehov, sum 1-6	3769651 kWh

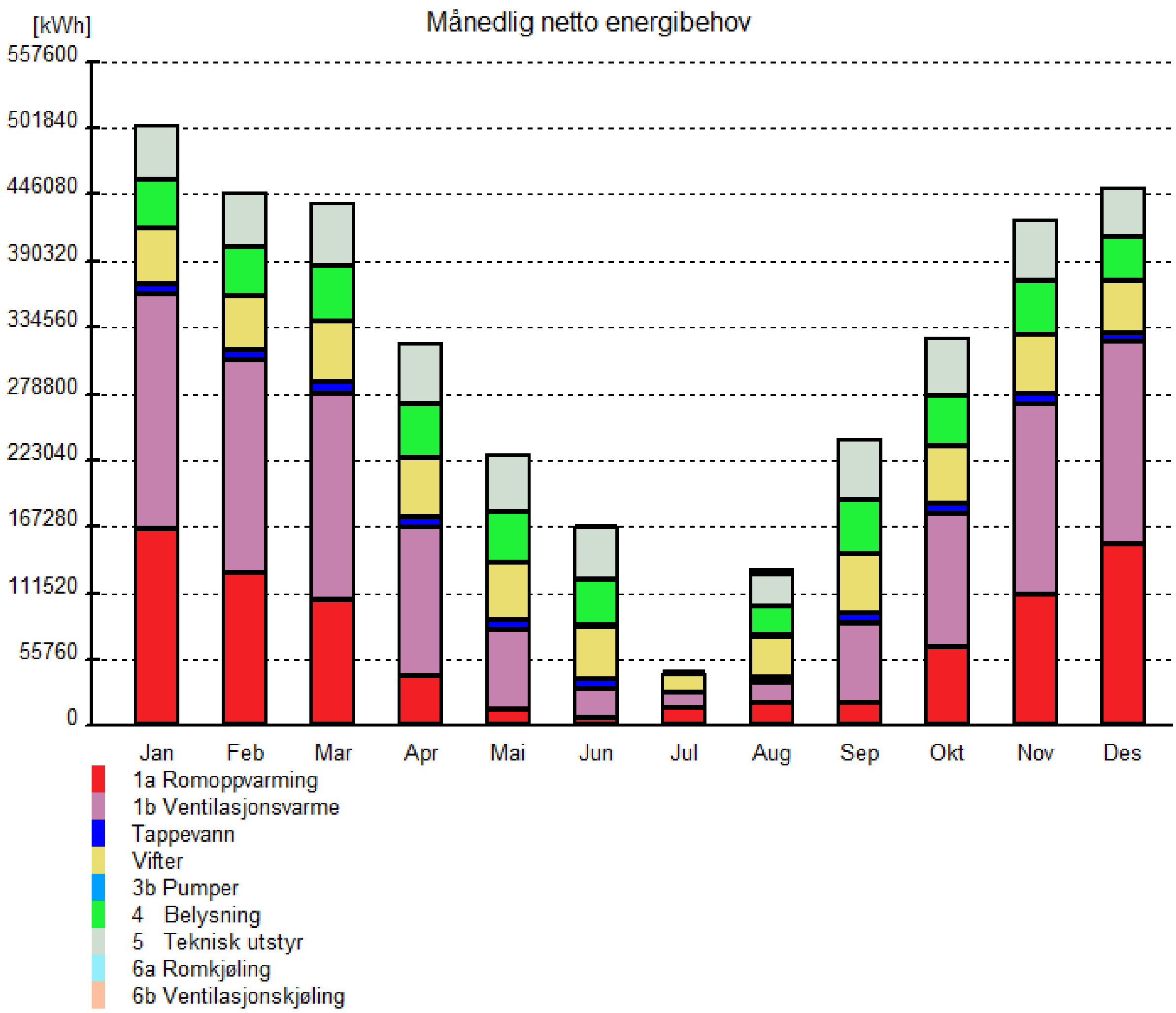
Levert energi til bygningen (beregnet)

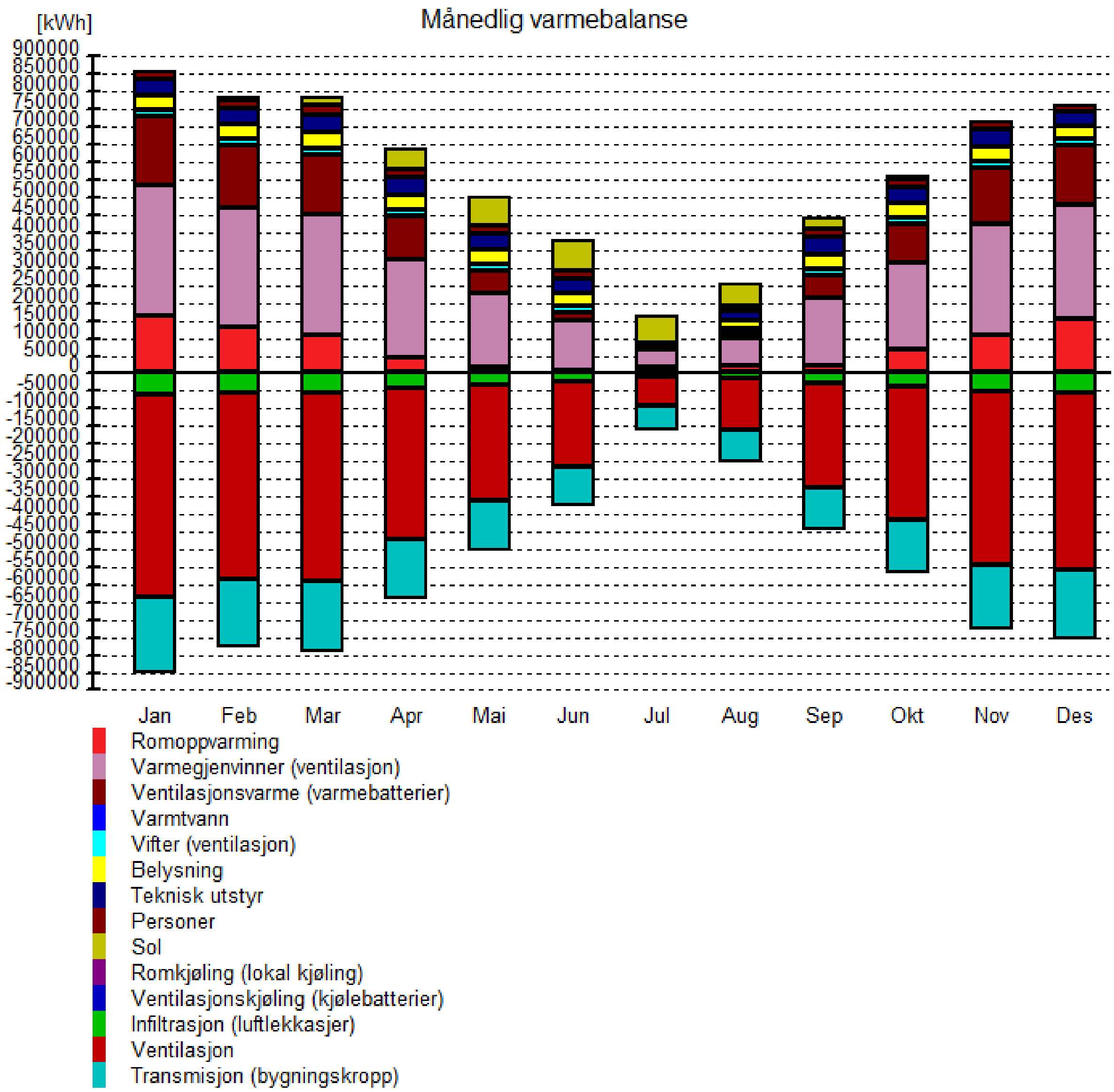


1a Direkte el.	3052910 kWh
1b El. til varmepumpesystem	0 kWh
1c El. til solfangersystem	0 kWh
2 Olje	1124015 kWh
3 Gass	0 kWh
4 Fjernvarme	0 kWh
5 Biobrensel	0 kWh
6. Annen energikilde	0 kWh
Totalt levert energi, sum 1-7	4176925 kWh

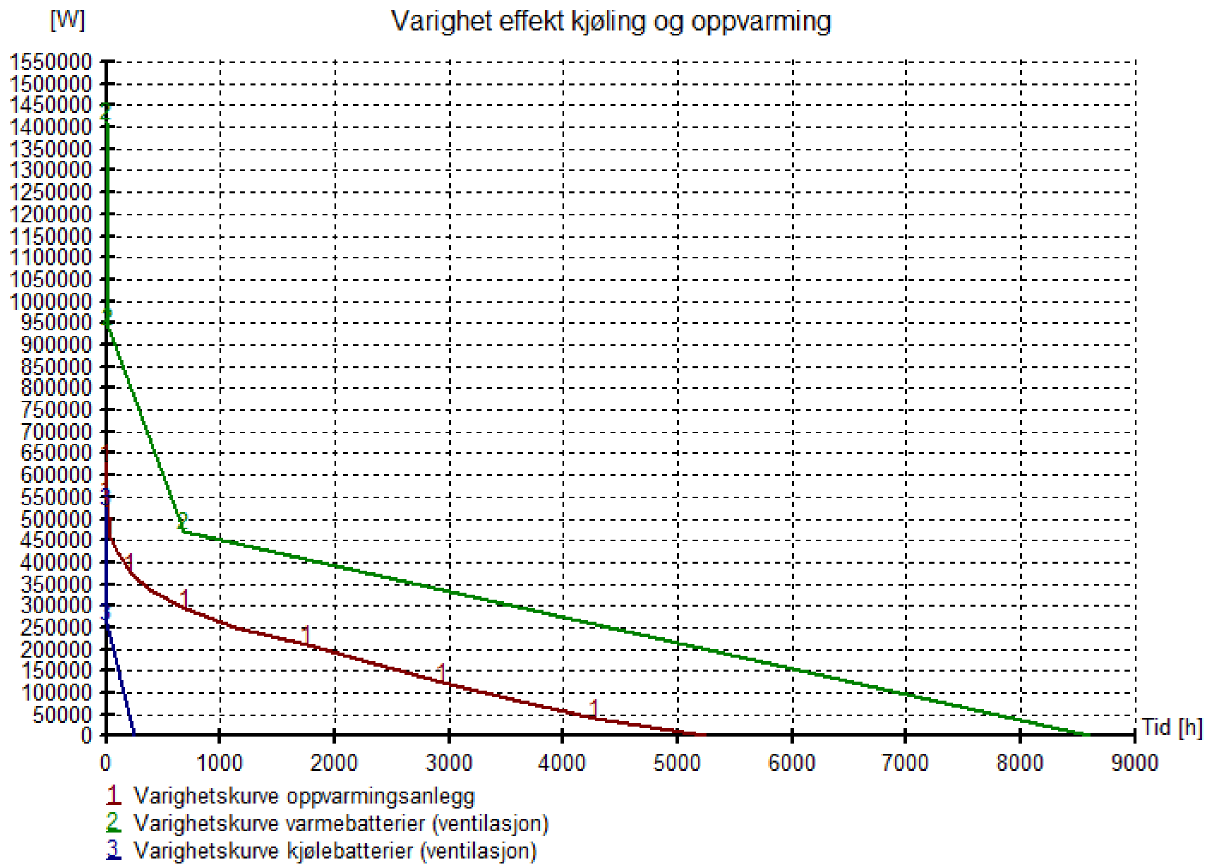


Varmetapstall yttervegger	0,05 W/m²K
Varmetapstall tak	0,07 W/m²K
Varmetapstall gulv på grunn/mot det fri	0,04 W/m²K
Varmetapstall glass/vinduer/dører	0,19 W/m²K
Varmetapstall kuldebroer	0,12 W/m²K
Varmetapstall infiltrasjon	0,10 W/m²K
Varmetapstall ventilasjon	0,53 W/m²K
Totalt varmetapstall	1,10 W/m²K


[kWh]
Månedlig netto energibehov
557600
501840
446080
390320
334560
278800
223040
167280
111520
55760
0
Jan
Feb
Mar
Apr
Mai
Jun
Jul
Aug
Sep
Okt
Nov
Des
1a Romoppvarming
1b Ventilasjonsvarme
Tappevann
Vifter
3b Pumper
4 Belysning
5 Teknisk utstyr
6a Romkjøling
6b Ventilasjonskjøling



Månedlige temperaturdata (lufttemperatur)					
Måned	Midlere ute	Maks. ute	Min. ute	Maks. sone	Min. sone
Jan	-4,3 °C	5,8 °C	-14,7 °C	22,0 °C (Byggetrinn 1997)	19,0 °C (Byggetrinn 1969)
Feb	-4,0 °C	6,3 °C	-14,6 °C	22,6 °C (Byggetrinn 1969)	19,0 °C (Byggetrinn 1969)
Mar	-1,7 °C	7,8 °C	-11,6 °C	24,3 °C (Byggetrinn 1969)	19,0 °C (Byggetrinn 1969)
Apr	2,1 °C	12,0 °C	-6,2 °C	25,4 °C (Byggetrinn 1969)	19,0 °C (Byggetrinn 1969)
Mai	7,2 °C	17,6 °C	-0,5 °C	27,2 °C (Byggetrinn 1969)	19,0 °C (Byggetrinn 1969)
Jun	10,8 °C	24,4 °C	2,6 °C	29,1 °C (Byggetrinn 1969)	19,0 °C (Byggetrinn 1969)
Jul	13,5 °C	26,7 °C	6,0 °C	26,2 °C (Byggetrinn 1969)	19,0 °C (Byggetrinn 1969)
Aug	12,4 °C	22,3 °C	4,6 °C	27,6 °C (Byggetrinn 1969)	19,0 °C (Byggetrinn 1969)
Sep	8,2 °C	17,2 °C	-0,6 °C	26,9 °C (Byggetrinn 1969)	19,0 °C (Byggetrinn 1969)
Okt	3,9 °C	12,5 °C	-4,6 °C	23,0 °C (Byggetrinn 1969)	19,0 °C (Byggetrinn 1969)
Nov	-0,5 °C	8,8 °C	-8,8 °C	22,3 °C (Byggetrinn 1997)	19,0 °C (Byggetrinn 1969)
Des	-2,7 °C	6,2 °C	-13,3 °C	22,1 °C (Byggetrinn 1997)	19,0 °C (Byggetrinn 1969)


[W]
Varighet effekt kjøling og oppvarming
1550000
1500000
1450000
1400000
1350000
1300000
1250000
1200000
1150000
1100000
1050000
1000000
950000
900000
850000
800000
750000
700000
650000
600000
550000
500000
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
Tid [h]
1 Varighetskurve oppvarmingsanlegg
2 Varighetskurve varmebatterier (ventilasjon)
3 Varighetskurve kjølebatterier (ventilasjon)

Dekningsgrad effekt/energi oppvarming	
Effekt (dekning)	Dekningsgrad energibruk
1263 kW (90 %)	100 %
1123 kW (80 %)	100 %
982 kW (70 %)	99 %
842 kW (60 %)	98 %
702 kW (50 %)	96 %
561 kW (40 %)	92 %
421 kW (30 %)	84 %
281 kW (20 %)	69 %
140 kW (10 %)	42 %
Nødvendig effekt til oppvarming av tappevann er ikke inkludert	-

Dokumentasjon av sentrale inndata (1)		
Beskrivelse	Verdi	Dokumentasjon
Areal yttervegger [m²]:	4278	
Areal tak [m²]:	8601	
Areal gulv [m²]:	9948	
Areal vinduer og ytterdører [m²]:	2643	
Oppvarmet bruksareal (BRA) [m²]:	23446	
Oppvarmet luftvolum [m³]:	86816	
U-verdi yttervegger [W/m²K]	0,27	
U-verdi tak [W/m²K]	0,20	
U-verdi gulv [W/m²K]	0,11	
U-verdi vinduer og ytterdører [W/m²K]	1,65	
Areal vinduer og dører delt på bruksareal [%]	11,3	
Normalisert kuldebroverdi [W/m²K]:	0,12	
Normalisert varmekapasitet [Wh/m²K]	53	
Lekkasjetall (n50) [1/h]:	1,50	
Temperaturvirkningsgr. varmegjenvinner [%]:	60	

Dokumentasjon av sentrale inndata (2)		
Beskrivelse	Verdi	Dokumentasjon
Estimert virkningsgrad gjenvinner justert for frostsikring [%]:	59,8	
Spesifikk vifteeffekt (SFP) [kW/m³/s]:	2,87	
Luftmengde i driftstiden [m³/hm²]	11,73	
Luftmengde utenfor driftstiden [m³/hm²]	2,08	
Systemvirkningsgrad oppvarmingsanlegg:	0,85	
Installert effekt romoppv. og varmebatt. [W/m²]:	424	
Settpunkttemperatur for romoppvarming [°C]	19,8	
Systemeffektfaktor kjøling:	2,50	
Settpunkttemperatur for romkjøling [°C]	0,0	
Installert effekt romkjøling og kjølebatt. [W/m²]:	209	
Spesifikk pumpeeffekt romoppvarming [kW/(l/s)]:	0,00	
Spesifikk pumpeeffekt romkjøling [kW/(l/s)]:	0,00	
Spesifikk pumpeeffekt varmebatteri [kW/(l/s)]:	0,50	
Spesifikk pumpeeffekt kjølebatteri [kW/(l/s)]:	0,60	
Driftstid oppvarming (timer)	11,0	

Dokumentasjon av sentrale inndata (3)		
Beskrivelse	Verdi	Dokumentasjon
Driftstid kjøling (timer)	0,0	
Driftstid ventilasjon (timer)	13,0	
Driftstid belysning (timer)	11,0	
Driftstid utstyr (timer)	9,0	
Oppholdstid personer (timer)	9,0	
Effektbehov belysning i driftstiden [W/m²]	8,00	
Varmetilskudd belysning i driftstiden [W/m²]	8,00	
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]	6,00	
Total solfaktor for vindu og solskjerming:	0,34	
Gjennomsnittlig karmfaktor vinduer:	0,33	
Solskjermingsfaktor horisont/utspring (N/Ø/S/V):	1,00/1,00/1,00/1,00	

Inndata bygning	
Beskrivelse	Verdi
Bygningskategori	Universitets- og høgskolebygg
Simuleringsansvarlig	Oddrun Pettersen Røsok
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

Inndata energiforsyning	
Beskrivelse	Verdi
1a Direkte el.	Systemvirkningsgrad romoppv,: 0,90 Systemvirkningsgrad varmtvann: 0,90 Systemvirkningsgrad varmebatterier: 0,90 Kjølefaktor romkjøling: 2,50 Kjølefaktor kjølebatterier: 2,50 Energipris: 0,80 kr/kWh CO2-utslipp: 395 g/kWh Andel romoppvarming: 75,0% Andel oppv, tappevann: 100,0% Andel varmebatteri: 50,0 % Andel kjølebatteri: 100,0 % Andel romkjøling: 100,0 % Andel el, spesifikt: 100,0 %
2 Olje	Systemvirkningsgrad romoppv,: 0,77 Systemvirkningsgrad varmtvann: 0,77 Systemvirkningsgrad varmebatterier: 0,77 Kjølefaktor romkjøling: 2,50 Kjølefaktor kjølebatterier: 2,50 Energipris: 0,85 kr/kWh CO2-utslipp: 284 g/kWh Andel romoppvarming: 25,0% Andel oppv, tappevann: 0,0% Andel varmebatteri: 50,0 % Andel kjølebatteri: 0,0 % Andel romkjøling: 0,0 % Andel el, spesifikt: 0,0 %

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

Appendix D.2. Results from SIMIEN, after measures

SIMIEN
Resultater årssimulering

Simuleringsnavn: Årssimulering_alle tiltak
Tid/dato simulering: 20:27 4/5-2017
Programversjon: 6.005
Simuleringsansvarlig: Oddrun Pettersen Røsok
Firma: Undervisningslisens
Inndatafil: C:\...\Alle tiltak.smi
Prosjekt: UiT Narvik
Sone: Alle soner

Energibudsjett		
Energipost	Energibehov	Spesifikt energibehov
1a Romoppvarming	391859 kWh	16,7 kWh/m²
1b Ventilasjonsvarme (varmebatterier)	697356 kWh	29,7 kWh/m²
2 Varmtvann (tappevann)	99034 kWh	4,2 kWh/m²
3a Vifter	358783 kWh	15,3 kWh/m²
3b Pumper	9641 kWh	0,4 kWh/m²
4 Belysning	255320 kWh	10,9 kWh/m²
5 Teknisk utstyr	232104 kWh	9,9 kWh/m²
6a Romkjøling	0 kWh	0,0 kWh/m²
6b Ventilasjonskjøling (kjølebatterier)	7427 kWh	0,3 kWh/m²
Totalt netto energibehov, sum 1-6	2051525 kWh	87,5 kWh/m²

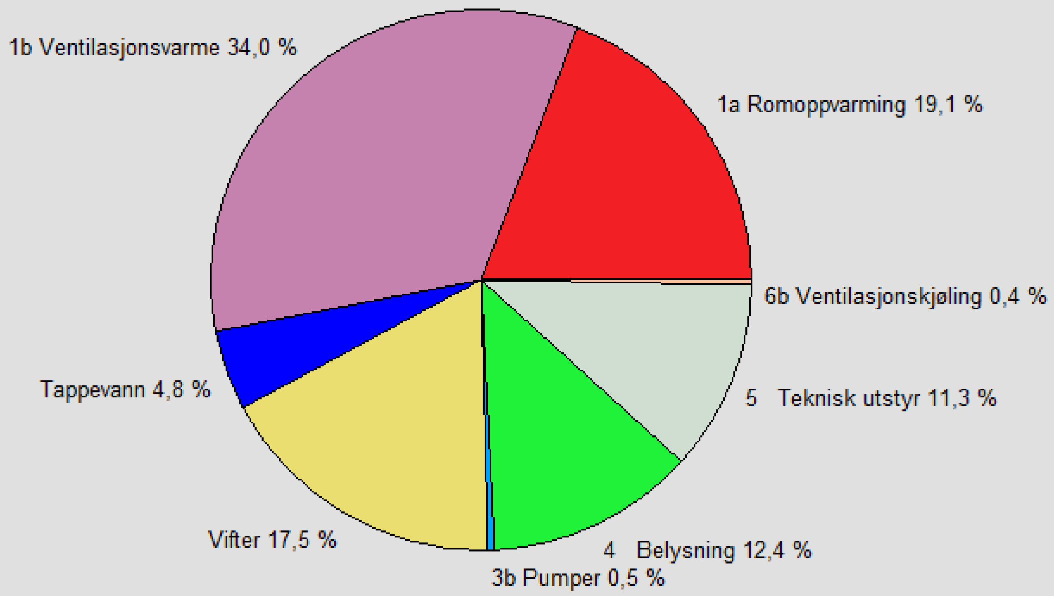
Levert energi til bygningen (beregnet)		
Energivare	Levert energi	Spesifikk levert energi
1a Direkte el.	1682826 kWh	71,8 kWh/m²
1b El. til varmepumpesystem	0 kWh	0,0 kWh/m²
1c El. til solfangersystem	0 kWh	0,0 kWh/m²
2 Olje	0 kWh	0,0 kWh/m²
3 Gass	0 kWh	0,0 kWh/m²
4 Fjernvarme	0 kWh	0,0 kWh/m²
5 Biobrensel	611840 kWh	26,1 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	2294666 kWh	97,9 kWh/m²
Solstrøm til eksport	-0 kWh	-0,0 kWh/m²
Netto levert energi	2294666 kWh	97,9 kWh/m²

Dekning av energibudsjett fordelt på energikilder						
Energikilder	Romoppv.	Varmebatterier	Varmtvann	Kjølebatterier	Romkjøling	El. spesifikt
El.	12,5 kWh/m²	14,9 kWh/m²	4,2 kWh/m²	0,3 kWh/m²	0,0 kWh/m²	36,5 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	4,2 kWh/m²	14,9 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Varmepumpe	0,0 kWh/m²	0,0 kWh/m²	0,0 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	16,7 kWh/m²	29,7 kWh/m²	4,2 kWh/m²	0,3 kWh/m²	0,0 kWh/m²	36,5 kWh/m²

Årlige utslipp av CO2		
Energivare	Utslipp	Spesifikt utslipp
1a Direkte el.	664716 kg	28,4 kg/m²
1b El. til varmepumpesystem	0 kg	0,0 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	8566 kg	0,4 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	673282 kg	28,7 kg/m²
Solstrøm til eksport	-0 kg	-0,0 kg/m²
Netto CO2-utslipp	673282 kg	28,7 kg/m²

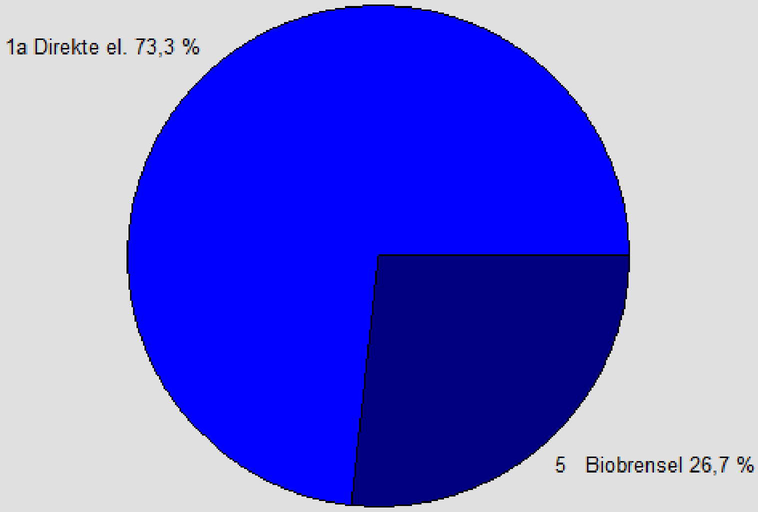
Kostnad kjøpt energi		
Energivare	Energikostnad	Spesifikk energikostnad
1a Direkte el.	1346261 kr	57,4 kr/m²
1b El. til varmepumpesystem	0 kr	0,0 kr/m²
1c El. til solfangersystem	0 kr	0,0 kr/m²
2 Olje	0 kr	0,0 kr/m²
3 Gass	0 kr	0,0 kr/m²
4 Fjernvarme	0 kr	0,0 kr/m²
5 Biobrensel	397696 kr	17,0 kr/m²
6. Annen energikilde	0 kr	0,0 kr/m²
7. Solstrøm til egenbruk	-0 kr	-0,0 kr/m²
Årlige energikostnader, sum 1-7	1743957 kr	74,4 kr/m²
Solstrøm til eksport	0 kr	0,0 kr/m²
Netto energikostnad	1743957 kr	74,4 kr/m²

Årlig energibudsjett



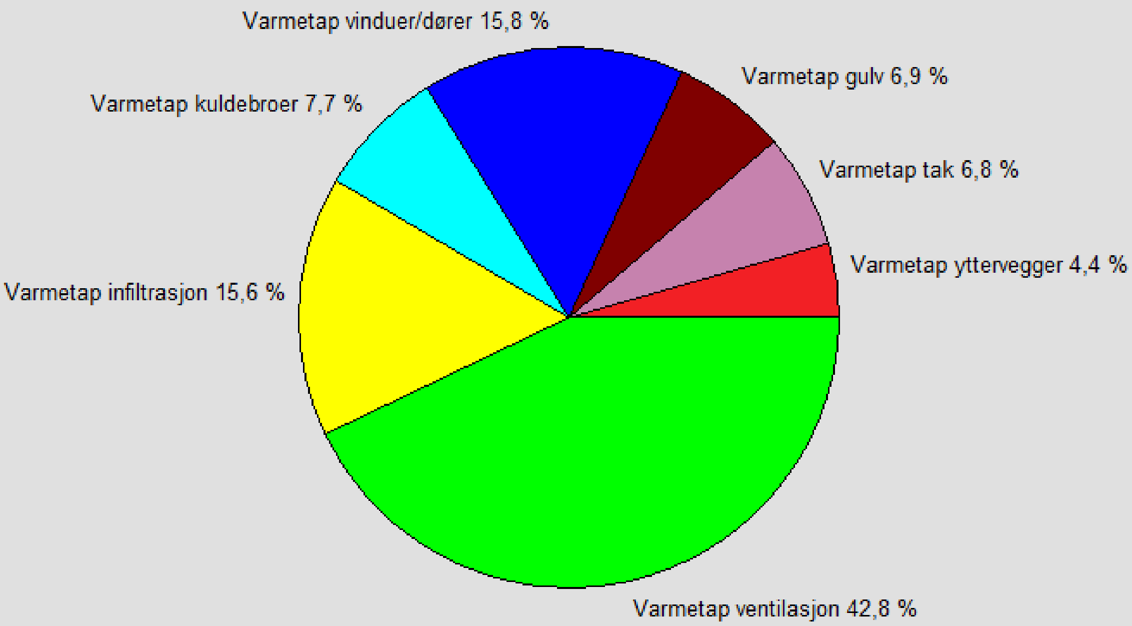
1a Romoppvarming	391859 kWh
1b Ventilasjonsvarme (varmebatterier)	697356 kWh
2 Varmtvann (tappevann)	99034 kWh
3a Vifter	358783 kWh
3b Pumper	9641 kWh
4 Belysning	255320 kWh
5 Teknisk utstyr	232104 kWh
6a Romkjøling	0 kWh
6b Ventilasjonskjøling (kjølebatterier)	7427 kWh
Totalt netto energibehov, sum 1-6	2051525 kWh

Levert energi til bygningen (beregnet)

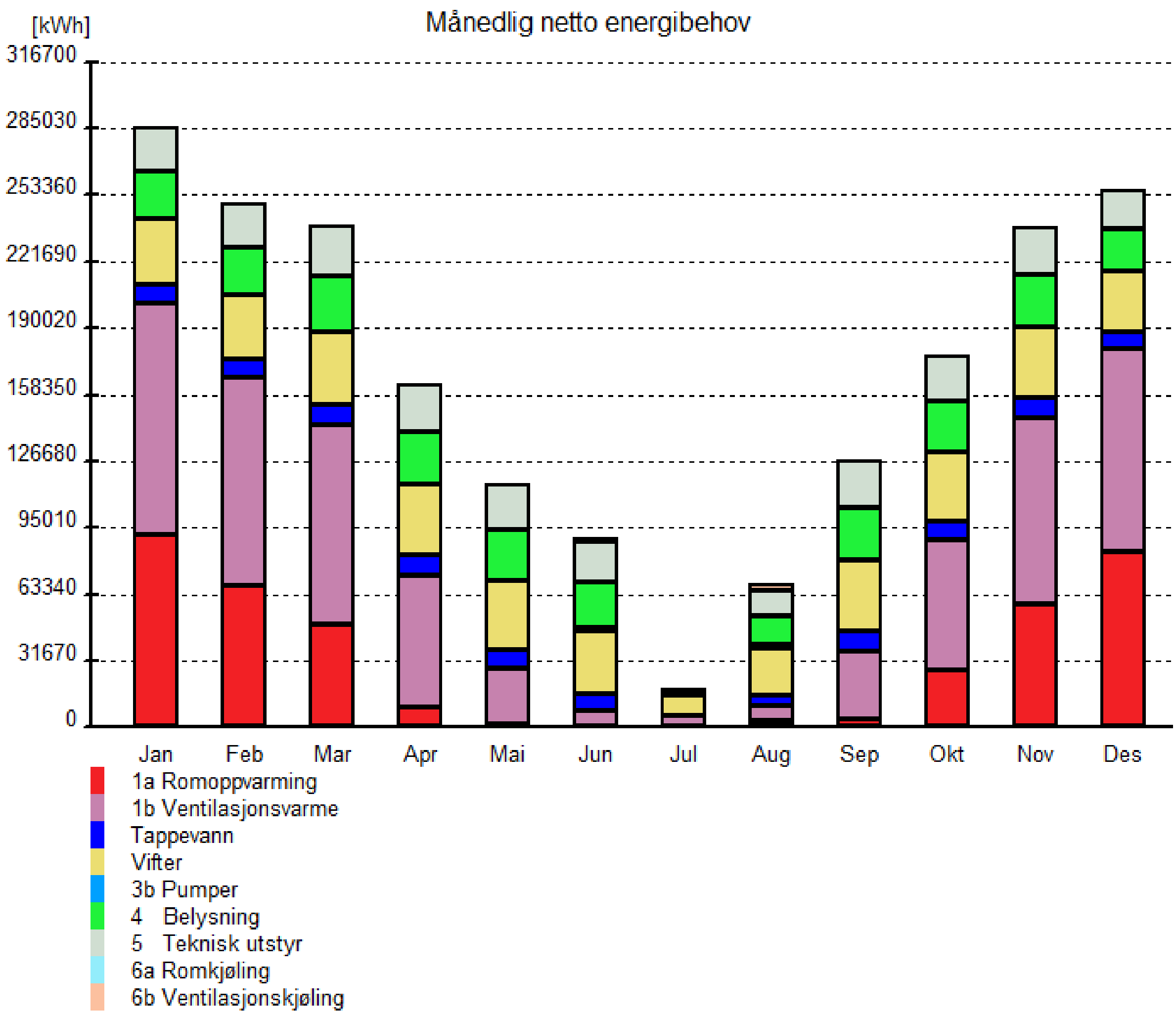


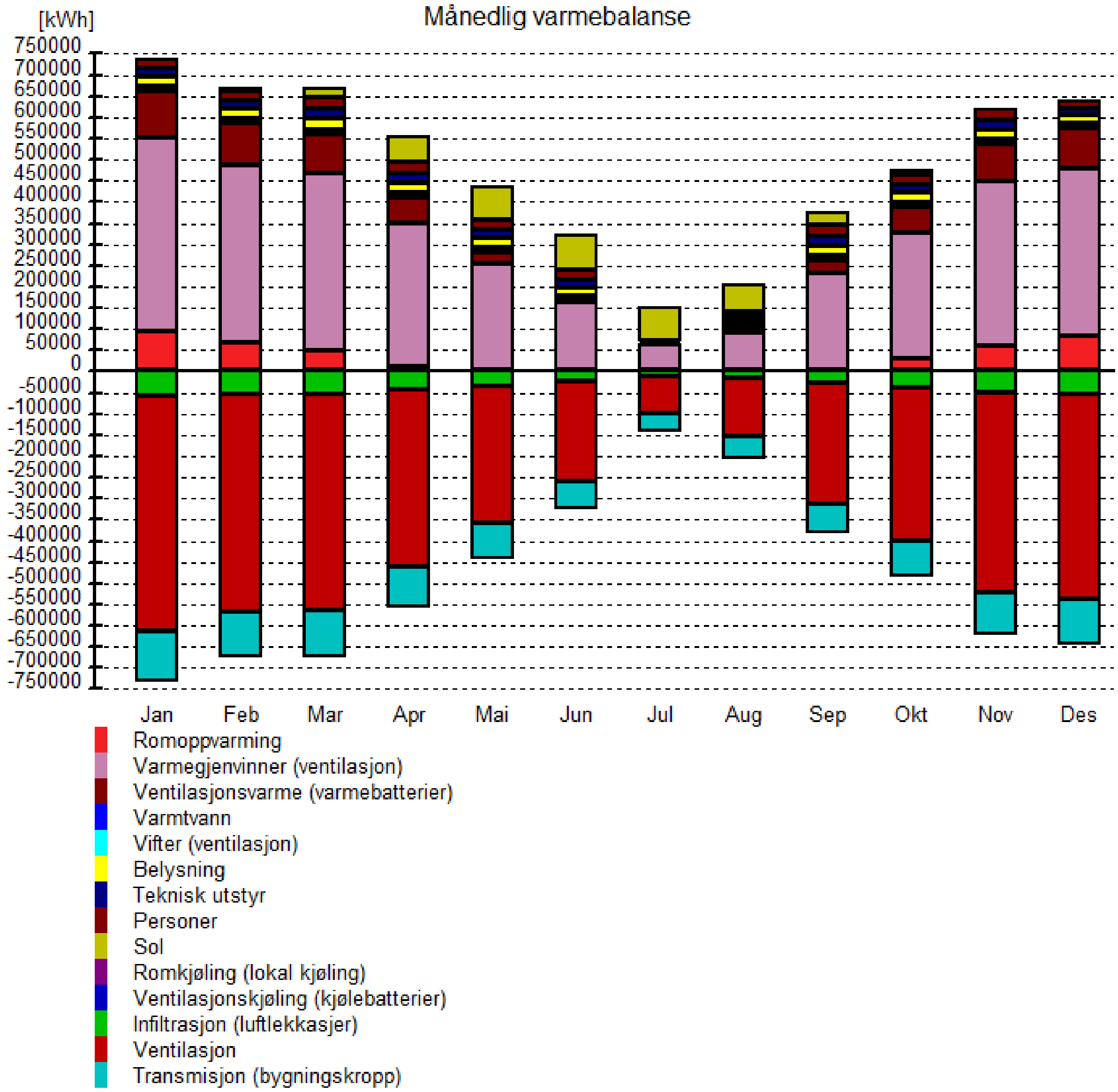
1a Direkte el.	1682826 kWh
1b El. til varmepumpesystem	0 kWh
1c El. til solfangersystem	0 kWh
2 Olje	0 kWh
3 Gass	0 kWh
4 Fjernvarme	0 kWh
5 Biobrensel	611840 kWh
6. Annen energikilde	0 kWh
Totalt levert energi, sum 1-7	2294666 kWh

Varmetapsbudsjett (varmetapstall)

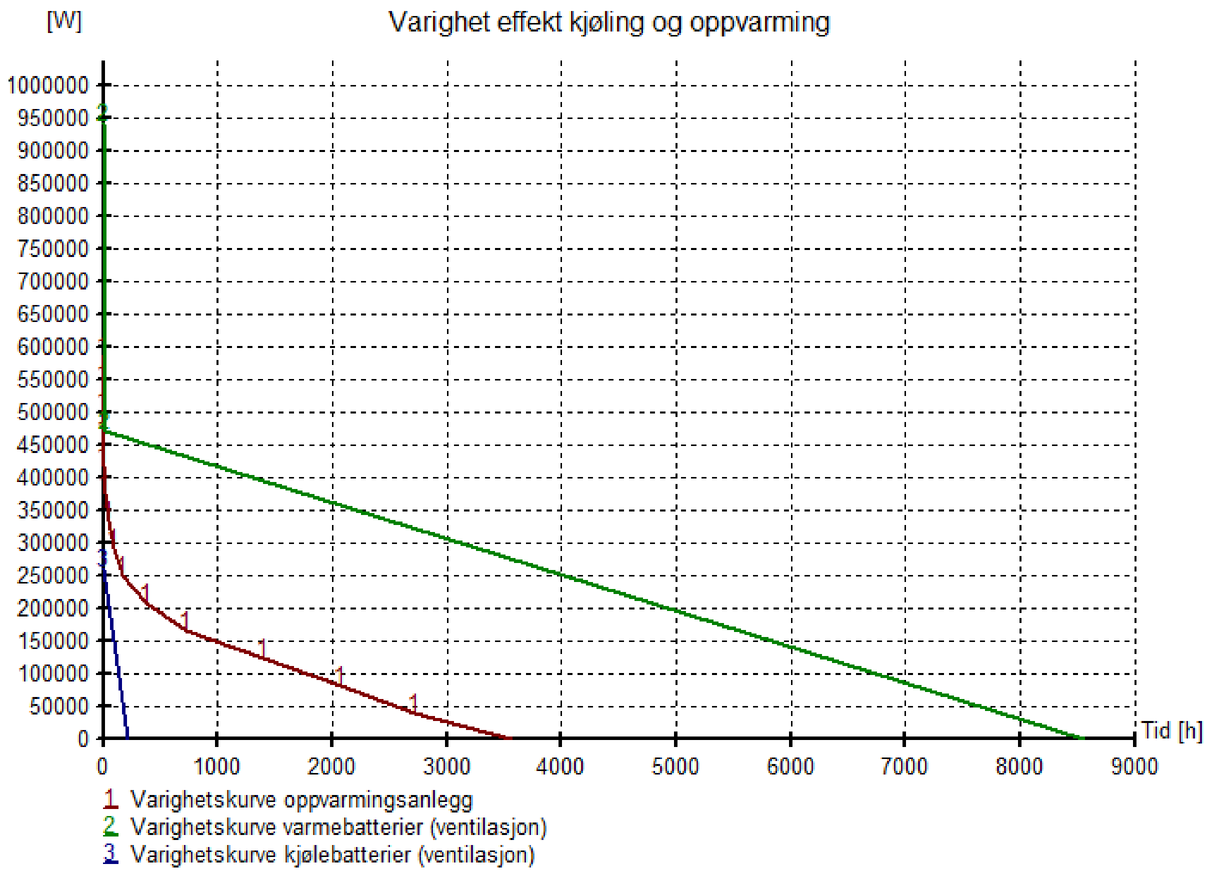


Varmetapstall yttervegger	0,03 W/m²K
Varmetapstall tak	0,04 W/m²K
Varmetapstall gulv på grunn/mot det fri	0,04 W/m²K
Varmetapstall glass/vinduer/dører	0,10 W/m²K
Varmetapstall kuldebroer	0,05 W/m²K
Varmetapstall infiltrasjon	0,10 W/m²K
Varmetapstall ventilasjon	0,28 W/m²K
Totalt varmetapstall	0,65 W/m²K


Månedlig netto energibehov
[kWh]
316700
285030
253360
221690
190020
158350
126680
95010
63340
31670
0
Jan
Feb
Mar
Apr
Mai
Jun
Jul
Aug
Sep
Okt
Nov
Des
1a Romoppvarming
1b Ventilasjonsvarme
Tappevann
Vifter
3b Pumper
4 Belysning
5 Teknisk utstyr
6a Romkjøling
6b Ventilasjonskjøling



Månedlige temperaturdata (lufttemperatur)					
Måned	Midlere ute	Maks. ute	Min. ute	Maks. sone	Min. sone
Jan	-4,3 °C	5,8 °C	-14,7 °C	20,7 °C (Byggetrinn 1997)	18,0 °C (Byggetrinn 1969)
Feb	-4,0 °C	6,3 °C	-14,6 °C	21,2 °C (Byggetrinn 1969)	18,0 °C (Byggetrinn 1969)
Mar	-1,7 °C	7,8 °C	-11,6 °C	22,9 °C (Byggetrinn 1969)	18,0 °C (Byggetrinn 1969)
Apr	2,1 °C	12,0 °C	-6,2 °C	25,4 °C (Byggetrinn 1969)	18,0 °C (Byggetrinn 1969)
Mai	7,2 °C	17,6 °C	-0,5 °C	27,4 °C (Byggetrinn 1969)	18,0 °C (Byggetrinn 1997)
Jun	10,8 °C	24,4 °C	2,6 °C	28,3 °C (Byggetrinn 1969)	18,1 °C (Byggetrinn 1997)
Jul	13,5 °C	26,7 °C	6,0 °C	27,6 °C (Byggetrinn 1969)	18,0 °C (Byggetrinn 1997)
Aug	12,4 °C	22,3 °C	4,6 °C	26,6 °C (Byggetrinn 1969)	18,0 °C (Byggetrinn 1997)
Sep	8,2 °C	17,2 °C	-0,6 °C	26,0 °C (Byggetrinn 1969)	18,0 °C (Byggetrinn 1969)
Okt	3,9 °C	12,5 °C	-4,6 °C	21,8 °C (Byggetrinn 1969)	18,0 °C (Byggetrinn 1969)
Nov	-0,5 °C	8,8 °C	-8,8 °C	21,1 °C (Byggetrinn 1997)	18,0 °C (Byggetrinn 1969)
Des	-2,7 °C	6,2 °C	-13,3 °C	20,9 °C (Byggetrinn 1997)	18,0 °C (Byggetrinn 1969)


[W]
Varighet effekt kjøling og oppvarming
1000000
950000
900000
850000
800000
750000
700000
650000
600000
550000
500000
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
Tid [h]
1 Varighetskurve oppvarmingsanlegg
2 Varighetskurve varmebatterier (ventilasjon)
3 Varighetskurve kjølebatterier (ventilasjon)

Dekningsgrad effekt/energi oppvarming	
Effekt (dekning)	Dekningsgrad energibruk
724 kW (90 %)	100 %
643 kW (80 %)	100 %
563 kW (70 %)	99 %
482 kW (60 %)	97 %
402 kW (50 %)	95 %
322 kW (40 %)	90 %
241 kW (30 %)	82 %
161 kW (20 %)	67 %
80 kW (10 %)	43 %
Nødvendig effekt til oppvarming av tappevann er ikke inkludert	-

Dokumentasjon av sentrale inndata (1)		
Beskrivelse	Verdi	Dokumentasjon
Areal yttervegger [m²]:	4278	
Areal tak [m²]:	8601	
Areal gulv [m²]:	9948	
Areal vinduer og ytterdører [m²]:	2643	
Oppvarmet bruksareal (BRA) [m²]:	23446	
Oppvarmet luftvolum [m³]:	86816	
U-verdi yttervegger [W/m²K]	0,16	
U-verdi tak [W/m²K]	0,12	
U-verdi gulv [W/m²K]	0,11	
U-verdi vinduer og ytterdører [W/m²K]	0,91	
Areal vinduer og dører delt på bruksareal [%]	11,3	
Normalisert kuldebroverdi [W/m²K]:	0,05	
Normalisert varmekapasitet [Wh/m²K]	53	
Lekkasjetall (n50) [1/h]:	1,50	
Temperaturvirkningsgr. varmegjenvinner [%]:	79	

Dokumentasjon av sentrale inndata (2)		
Beskrivelse	Verdi	Dokumentasjon
Estimert virkningsgrad gjenvinner justert for frostsikring [%]:	78,9	
Spesifikk vifteeffekt (SFP) [kW/m³/s]:	1,99	
Luftmengde i driftstiden [m³/hm²]	11,73	
Luftmengde utenfor driftstiden [m³/hm²]	2,08	
Systemvirkningsgrad oppvarmingsanlegg:	0,83	
Installert effekt romoppv. og varmebatt. [W/m²]:	424	
Settpunkttemperatur for romoppvarming [°C]	18,8	
Systemeffektfaktor kjøling:	2,50	
Settpunkttemperatur for romkjøling [°C]	0,0	
Installert effekt romkjøling og kjølebatt. [W/m²]:	209	
Spesifikk pumpeeffekt romoppvarming [kW/(l/s)]:	0,00	
Spesifikk pumpeeffekt romkjøling [kW/(l/s)]:	0,00	
Spesifikk pumpeeffekt varmebatteri [kW/(l/s)]:	0,50	
Spesifikk pumpeeffekt kjølebatteri [kW/(l/s)]:	0,60	
Driftstid oppvarming (timer)	11,0	

Dokumentasjon av sentrale inndata (3)		
Beskrivelse	Verdi	Dokumentasjon
Driftstid kjøling (timer)	0,0	
Driftstid ventilasjon (timer)	13,0	
Driftstid belysning (timer)	11,0	
Driftstid utstyr (timer)	9,0	
Oppholdstid personer (timer)	9,0	
Effektbehov belysning i driftstiden [W/m²]	4,50	
Varmetilskudd belysning i driftstiden [W/m²]	4,50	
Effektbehov utstyr i driftstiden [W/m²]	5,00	
Varmetilskudd utstyr i driftstiden [W/m²]	5,00	
Effektbehov varmtvann på driftsdager [W/m²]	0,80	
Varmetilskudd varmtvann i driftstiden [W/m²]	0,00	
Varmetilskudd personer i oppholdstiden [W/m²]	6,00	
Total solfaktor for vindu og solskjerming:	0,34	
Gjennomsnittlig karmfaktor vinduer:	0,33	
Solskjermingsfaktor horisont/utspring (N/Ø/S/V):	1,00/1,00/1,00/1,00	

Inndata bygning	
Beskrivelse	Verdi
Bygningskategori	Universitets- og høgskolebygg
Simuleringsansvarlig	Oddrun Pettersen Røsok
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

Inndata energiforsyning	
Beskrivelse	Verdi
1a Direkte el.	Systemvirkningsgrad romoppv,: 0,90 Systemvirkningsgrad varmtvann: 0,90 Systemvirkningsgrad varmebatterier: 0,90 Kjølefaktor romkjøling: 2,50 Kjølefaktor kjølebatterier: 2,50 Energipris: 0,80 kr/kWh CO2-utslipp: 395 g/kWh Andel romoppvarming: 75,0% Andel oppv, tappevann: 100,0% Andel varmebatteri: 50,0 % Andel kjølebatteri: 100,0 % Andel romkjøling: 100,0 % Andel el, spesifikt: 100,0 %
5 Biobrensel	Systemvirkningsgrad romoppv,: 0,73 Systemvirkningsgrad varmtvann: 0,73 Systemvirkningsgrad varmebatterier: 0,73 Kjølefaktor romkjøling: 2,50 Kjølefaktor kjølebatterier: 2,50 Energipris: 0,65 kr/kWh CO2-utslipp: 14 g/kWh Andel romoppvarming: 25,0% Andel oppv, tappevann: 0,0% Andel varmebatteri: 50,0 % Andel kjølebatteri: 0,0 % Andel romkjøling: 0,0 % Andel el, spesifikt: 0,0 %

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

Appendix E. Kilograms of pellets

1 kg pellets equals to 4,8 kWh/ kg

Net delivered energy of biofuel, from SIMIEN: 611840 kWh

Kilograms of pellets needed:

$$\frac{611840\ kWh}{4{,}8\ kWh/kg} = 127467\ kg$$

Faculty of Engineering Science and Technology

Sustainable University Buildings

Scientific article

—

Oddrun Pettersen Røsok

Master's thesis in Integrated Building Technology May 2017

Abstract

The concept of a sustainable campus is today still vague and not yet completely defined. The purpose of the master thesis was to determine the elements to include in a self- made concept for UiT Narvik as a sustainable campus, along with suggestions on how to achieve the goals in the concept. The concept was based on the study of three different universities that are already working towards becoming sustainable campuses. A part of working with this thesis was a trip to Japan to stay at Hokkaido University in Sapporo. The stay lasted two months to investigate the University's concept and find out if the University has applicable solutions to the concept of UiT Narvik. A concept was made for UiT Narvik, and a big part of the it is that UiT Narvik's building has to achieve a low- energy standard, with an associated satisfactory energy label. The rest of the requirements in the concept are solely focusing on reducing the environmental footprint of the University. The Norwegian Standard with criteria for commercial passive houses and low- energy buildings, made the basis for the measures with associated simulations in SIMIEN. Lastly, it became evident that the concept is still vague in the regard that it is difficult to know exactly when a campus can call itself sustainable, and from that, the idea of a "sustainability label" emerged.

1. Introduction

1.1. Background

Hokkaido University in Sapporo Japan, Harvard University in Massachusetts USA, and the Norwegian University of Science and Technology (NTNU) in Trondheim Norway are all members of the International Sustainable Campus Network (ISCN), a society that strives to guide universities in becoming sustainable campuses. The definition of a sustainable campus is different for each university, since they can "tailor" the concept as long as they follow ISCN's principles.

1.2. Sustainable campus

The concept "sustainable campus" is currently vague. There are no clear guidelines or objectives to fulfil in achieving said status. The only definition are ISCN's three principles that explain in a general way which areas the university needs to focus on. The principles focus on buildings and their sustainability impacts, campus- wide planning and target settings, and integration of research, teaching, facilities and outreach.

1.3. Problem description

A concept "sustainable campus" is to be tailored for UiT Narvik. It was supposed to be based solely on the already existing concept at Hokkaido University. The content of the problem description has changed over time. In consultation with the supervisor, it was decided to study two more universities to have a big enough knowledge base about sustainable campuses. The content of the concept of UiT Narvik is based on personal assessments. The author's background is from Renewable Energy Engineering, thus it seemed natural that the concept would have great emphasis on energy efficiency and environmental footprint, as these areas could have great impact on the environment.

2. Sustainable campus

2.1. International Sustainable Campus Network

The International Sustainable Campus Network (ISCN), a non- profit association, provides a global forum online to support leading universities, colleges and corporate campuses in exchanging information, ideas and practices to achieve sustainable campuses and integrate sustainability in research and teaching. ISCN has three main principles to follow:

Principle one: Buildings and their sustainability impacts. *To demonstrate respect for nature and society, sustainability considerations should be an integral part of planning, construction, renovation and operation of buildings on campus.*
Principle two: Campus- wide planning and target settings. *To ensure long- term sustainable campus development, campus- wide master planning and target- setting should include environmental and social goals.*
Principle three: Integration of research, teaching, facilities and outreach. *To align the organization's core mission with sustainable development, facilities, research and education should be linked to create a "living laboratory" for sustainability.*

2.2. Hokkaido University, Japan

Hokkaido University's main goal is to achieve zero emissions for the entire University through energy saving and the use of renewable energy. The University strives towards the development and implementation of a sustainable social model with heavy emphasis on using the campuses as a demonstration field. A close collaboration with the society and business world outside the University is in focus. The University has a wide- spread concept that considers 22 different areas divided in three main points: environment & campus, local economy & university management, and local society & social responsibility of a university. Only six out of the 22 areas focus on the direct environmental impact and footprint. Hokkaido University's plan still seem vague and undefined in the regard that they do not have a clear plan on *how* to achieve their goals.

2.3. Harvard University, USA

Harvard University's greatest goal is to reduce the greenhouse gas emissions by a maximum practicable rate, through best- in- class- innovations in energy efficiency, energy management and renewable energy. The University also aims to have a restorative impact on the surrounding environment and the community of students and employees, by conserving resources and reducing pollution. Their *goal* is to resource reduction goals with a specific target within a set timeframe. Their operational *standard* is to facilitate alignment across the University, ensuring implementation of a consistent approach. They have a *statement* of commitment or recommendation for future research in areas without enough information to set a specific numeric goal or standard. Harvard University also does not yet seem to have a clear plan on exactly *how* to address the problem areas they have pointed out.

2.4. NTNU, Norway

The Norwegian University of Science and Technology (NTNU) has an ambition to be the frontrunner and use knowledge from its own research to ensure a high standard for internal environmental management. The University has a greater focus on reducing the energy use, energy efficiency and climate neutral travel policy than Hokkaido University and Harvard University. The University has a clear focus on energy use, waste reduction, eco- friendly procurement, environmentally friendly transportation, biodiversity and greenhouse gas emissions, to mention some. In addition, a well-developed ambition on contributing to research within energy, health science, maritime technology and sustainability, on both national level and later global level. The difference between NTNU and the other two universities is that NTNU has a plan on exactly *how* they want to address the problem areas, with exact measures.

3. Building regulations

3.1. Building technical regulations

The Norwegian Law on Planning and Construction Processing governs the building technical regulations, currently TEK 10. All buildings constructed must comply with this law and thus the latest updated TEK 10. A subcategory of the TEK 10 are the Norwegian Standards (NS), that go into detail about the requirements that applies to the individual building type and standard. Descriptions of the buildings' technical details are in the building details manuals.

3.2. Certification methods

There are different types of environmental certifications. Frequently used ones in Norway are Building Research Establishment Environmental Assessment Method (BREEAM), EnergyStar, Environmental Lighthouse and the Swan Label. The Leadership in energy and Environmental Design (LEED) is the most widely used certification method on world basis. Common for all instances is that they look into the life cycle of buildings or products and materials to ensure that the environmental impact is minimal.

4. Results

4.1 The concept of a sustainable campus at UiT Narvik

The concept "sustainable campus" that applies to UiT Narvik is one that will focus on environmental footprint, in form of energy efficiency, renewable energy and reducing greenhouse gas emissions. As there is no clear definition of a sustainable campus, a university is free to interpret and tailor a concept on its own, based on ISCN's principles. After the stay at Hokkaido University, it became clear that the information provided was insufficient. More information was required to have a big enough knowledge base as a foundation before creating a concept for UiT Narvik. Thus, Harvard University and NTNU were included. The concept for UiT Narvik will base itself on the principles as well to some extent, and follow NTNU's way of thinking. However, even if the concept is based on ISCN's principles, it will not be made to be approved by ISCN.

Principle one | UiT Narvik does not have any ongoing activity to reduce the energy consumption. As explained before, NTNU has the goal to use proprietary technology and knowledge to become a sustainable campus. This idea is not important for UiT Narvik, as the University still need to become a sustainable campus and abide by the requirements in the concept. It is more important to use the latest technology to keep up with the development of sustainability and stricter building and energy efficiency regulations, set by the government. Energy is not the only main point in the first principle. It is of great importance to make sure that products, materials and procurement such as office equipment and food are eco- friendly with as little environmental impact as possible. There are several labels to look for when buying products and materials, such as the Swan Label and EPA's EnergyStar.

Principle two | Energy use, energy need and transport are examples on how to reduce greenhouse gas emissions. The University should conduct an evaluation of the total greenhouse gas emissions before setting a goal on reduction. A way of doing that is for example to look into the invoices for garbage collection from the campus from previous years, to get an idea of the garbage quantity produced, and thus know the amount of emission from the garbage once combusted, decomposed or stored. The source of the electrical power is difficult to know as it comes from the main grid. By following principle one, it is possible to make sure a part of the electricity comes from a renewable energy source, by buying electricity from a production plant that can guarantee the electrical power's origin. Emissions from transportation must also be included. That includes transport to and from campus, either by personal vehicle or by public transport. Long- distance travel by plane and other means of travel is also included.

Principle three | UiT Narvik should aim to educate environmental leaders by providing mentoring, networking and professional development opportunities for undergraduate and graduate students, to have the insight and foresight to safeguard the environment when they enter the business sector after graduation. If students have sufficient knowledge in sustainability in their own field, they can contribute to making their work place more sustainable and environmentally friendly. The campus itself can be an inspiration for the society, by showing the outside world that it takes responsibility and become more environmentally friendly. One way to show that is to become an Environmental Lighthouse. UiT should contribute to interdisciplinary research as well as an integrated and coherent solution to energy challenges while ensuring better fulfilment of UiT's responsibility to society, as UiT educates the next generation of work force. UiT Narvik has great focus on engineering studies and has the opportunity to make a great change, since engineers strive to find new and better solutions to problems in many fields, such as for example energy efficiency in buildings.

4.2 Former simulations of UiT Narvik

The company COWI AS did a simulation of UiT Narvik's building in 2012 as part of setting an energy label on the building and creating an Energy Efficiency Report. Access to the simulation file used by COWI AS and results from their simulation was given from Statsbygg, for the purpose of this report.

4.3 Energy label

The energy label identifies the energy standard of the building. The label consists of an energy grade and heating grade. The energy grade indicates the energy efficiency of the building, including the heating system, calculated from the typical energy consumption of the specific building type. The building's energy standard determines the energy grade. Grade A means that the building is highly energy efficient, grade G means the building is not very energy efficient. The heating grade tells how much of the heating demand (heating and hot water) that is covered by electricity, oil or gas. Green color means low share, red color means high share. In 2012 the University building achieved a red D, after COWI AS's simulation.

4.4 Simulations

The simulated measures do not consider the suggested measures in the Energy Efficiency Report from 2012. That report says nothing about necessary actions for the University to qualify as a low- energy building. The thesis has independent simulations, attempted simulated within the requirements of NS 3701:2012, as close to the requirements as possible to minimize the extent of the measures, in addition to being realistic and feasible. A final simulation combined all measures; replace lightbulbs, increased heat recovery from ventilation, bio fuel as peak load, better windows, doors, gates and frames, increased insulation in walls and roof and improved normalized thermal bridges. The simulation finally fulfilled all the requirements in NS 3701:2012 for equipment and construction parts in a low- energy building.

4.5 New energy label

Even if UiT Narvik reached all requirements for a low- energy building it could not achieve higher than energy grade C, which was the minimum requirement in UiT Narvik's concept. The reason for the yellow colour is that the building uses electricity as the base load for heating and pellets as peak load. A high amount of electricity or fossil fuel use gives a bad colour (closer to red), while renewable energy sources give a better colour (closer to green). The reason for the grade C is that it is difficult to get the part of the building complex from 1969 to become as energy efficient as the part from 1997, by making similar measures in all building parts, according to NS 3701:2012.

4.6 Sustainability label

After working on the concept of a sustainable campus, nothing was found on *when* a campus can label itself "sustainable". Just as buildings have an energy label, a labelling system for sustainability can be made. The idea is that all measures from UiT Narvik's concept needs to be fulfilled as a part of achieving the highest grade of the sustainability label. The labelling system should further have three main areas for the University to consider; current state, future development and maintenance. The label should also have a grade system, for example from: pass, good, very good, excellent, and outstanding.

5. Discussion

There are some elements, which seem inaccurate or need more research to be sure the results are reasonable and realistic. Much of the information from Hokkaido University, such as their concept, was explained orally during meetings. The chance of misunderstanding and misconception of the information received is present and difficult to proofread. This could give the possibility of having the wrong impression of the concept at Hokkaido University.

The simulations in this report are based on COWI AS 'SIMIEN file from 2012, with an earlier version of SIMIEN. Their simulations may have shortcomings and errors. It is uncertain how precise and thorough COWI AS have been with their simulation and how much of a deviation they allowed when it comes to measurements on the building and insertion of this information in SIMIEN. It was not possible to double check COWI AS 'simulation against information about the building, due to a limited time frame for this report.

It is unknown what types of gases are included in the greenhouse gas emissions from each university. CO_2 is not the only gas released from buildings, and details about the exact types of emissions were not found. It is crucial to know every type of gas released from the university building at UiT Narvik before having a final overview of the greenhouse gas emissions.

6. Topics for further research

Financial aspect | Look into the total financial aspect of making UiT Narvik sustainable, be it the already existing building, or a future new building on campus. Also, calculate the cost to do the measures stated in the sustainability concept.
Further study of the sustainability label | Future work concerns deeper analysis of what to include in the labelling system.
Lifespan | A study can be performed to find out how long it takes before the requirements in the sustainable campus concept is outdated.
Extension of the concept | In the future, it could be interesting to apply the concept of a sustainable campus to every campus that belong to UiT so that the university as a whole can label itself as a sustainable university.

7. Conclusion

This thesis was about creating a concept of a sustainable campus tailored for UiT Narvik, based on three universities, Hokkaido University in Japan, Harvard University in USA, and NTNU in Norway. All three universities are members of the International Sustainable Campus Network (ISCN). The university members follows ISCN's three principles of how to become a sustainable campus, although the ISCN does not yet have a clearly defined concept of a sustainable campus. The thesis included a two month- long stay in Japan at Hokkaido University to study this university's concept.

A concept was created for UiT Narvik. It was up to the author of the report to set the rules and decide what the concept should include, thus the focus was on the environmental footprint in form of reducing the energy consumption and greenhouse gas emissions from the building. One big requirement in the concept was to transform the current University building, into a low- energy building. Six individual simulations, each with a corresponding measure or measures, were carried out. UiT Narvik obtained the requirements of a low- energy building, as well as a new and improved energy label. Finally, a new contribution based on the concept itself emerged. The idea of a sustainability label came up, similar to an energy label, as a tool to determine the degree of sustainability on campus.

8. Bibliography

ISCN-GULF, 2017, 31 State Street, 10th Floor, Boston, MA 02109 USA, http://www.international-sustainable-campus-network.org/downloads/charter-and-guidelines/443-iscn-gulf-charter-guidelines/file (2.2.2017)

Sustainability Report, 2017, Massachusetts Hall, Cambridge, MA 02138 USA, http://report.green.harvard.edu/ (16.3.2017)

ISCN-GULF Sustainable Campus Charter Report 2014, 2017, NTNU 7491 Trondheim Norway, https://www.ntnu.no/documents/10137/1262279573/NTNU_ISCN+report+2014.pdf/2273fe9c-9051-4899-8c40-166b73512f07 (20.3.2017)

Plan- og bygningsloven, 2017, Lovdata Postboks 2016 Vika, 0125 Oslo Norway, https://lovdata.no/dokument/NL/lov/2008-06-27-71 (6.5.2017)

LEED campus, 2017, 2101 L Street NW, suite 500 Washington, DC 20037 USA, http://www.usgbc.org/articles/certify-multiple-buildings-leed (6.5.2017)

BREEAM, 2017, Kongens gate 1, 0153 Oslo Norway, http://ngbc.no/breeam-nor/ (24.4.2017)

Environmental Lighthouse, 2017, Grønt senter, Odderøyveien 5, 4610 Kristiansand Norway, http://www.miljofyrtarn.no/dette-er-milj%C3%B8fyrt%C3%A5rn/2015-11-18-23-59-53 (24.4.2017)

Miljøfyrtårn, 2017, Grønt senter, Odderøyveien 5, 4610 Kristiansand Norway, http://www.miljofyrtarn.no/slikblirdu (25.4.2017)

EnergyStar, 2017, 1200 Pennsylvania Ave NW Washington, DC 20460 USA, https://www.energystar.gov/about/why_energy_star (27.4.2017)

Svanemerket, 2017, Henrik Ibsens gate 20, 0255 Oslo Norway, http://www.svanemerket.no/om-svanemerket/livslopet/svanemerket/ (25.4.2017)

COWI AS, 2017, Energy Efficiency Report HiN 2012

COWI AS, 2017, Energy Certificate HiN 2012, Norwegian Water Resources and Energy Directorate NVE

SIMIEN v. 6005, 2017, ProgramByggerne ANS Rajeveien 93, 3618 Skollenborg, http://www.programbyggerne.no/ (31.3.2017)