ZEN

Research Centre on
ZERO EMISSION
NEIGHBOURHOODS
IN SMART CITIES

ANNUAL REPORT 2018

FME
CENTRE FOR ENVIRONMENT-FRIENDLY ENERGY RESEARCH
The Research Council of Norway

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«Sustainable neighbourhoods with zero greenhouse gas emissions»

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Photo: If not stated otherwise, all photographs and illustrations in the magazine are by NTNU, SINTEF or ZEN partners.

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DEFINING ZERO EMISSION NEIGHBOURHOODS

Summary of the research from 2018

Arild Gustavsen
Centre director and professor,
ZEN, NTNU

After two years of operation, the Research Centre on Zero Emission Neighbourhoods in Smart Cities (ZEN Centre) is beginning to find its form. PhDs, Postdocs, and researchers are collaborating across work package boundaries, and the number of activities associated with the pilot areas is increasing. Public and industry partners are seeing more opportunities to connect their ongoing activities to the ZEN Centre. Communication and innovation strategies are in place, ensuring a strong focus on important areas for the Centre. Scientifically, important results have been completed and disseminated. A selection is presented below and in English and Norwegian in the articles that follow.

We have a definition of a zero emission neighbourhood; it is defined as a group of interconnected buildings with associated infrastructure, located within a confined geographical area, aiming at reducing its direct and indirect greenhouse gas (GHG) emissions towards zero. Life cycle assessment (LCA) is used to estimate the potential environmental impacts of a product or service system throughout its life cycle. The methodology was initially developed and used for zero emission buildings. We have now expanded it to include zero emission neighbourhoods (ZENs).

Drivers and barriers to implementing ZEN concepts in Norway have been explored. Preliminary findings are that inflexible regulations and misunderstanding of the concept are important barriers. Best practice projects as well as enthusiasts in key positions are important drivers. We have also explored key drivers of success and failure regarding public private collaboration in a ZEN context. Five themes can contribute to successful collaboration: supportive public policy, stakeholder management, a common ground for understanding, knowledge sharing and learning, and uncertainty management.

An Excel-based energy profiles generator has been developed. The tool generates aggregated energy use profiles (split in electric and thermal). The tool may be used for any given neighbourhood, based on the floor area (m^2) of building types and statistically representative typical energy use profiles. The profiles are extracted from a database of well-monitored buildings.

eTransport is a PC-tool for optimization of operation and developing energy systems within confined areas. Through ZEN we have re-established the program and developed two new modules: A battery module and a district heating module. A case study in collaboration with the FutureBuilt project "Microenergy system Furuset" is underway.

We are currently developing an indicator method based on the Geographical Information System (GIS), to analyse spatial conditions essential to carbon emissions in neighbourhoods. The method is being tested by analyzing specific variables related to building morphology, building densities, and spatial properties of street networks in the pilot project Sluppen in Trondheim.

Work has started in nine pilot projects: Ydalir in Elverum, Furuset in Oslo, NTNU Campus and Sluppen in Trondheim, Zero Village Bergen, Lø in Steinkjer, Nyby

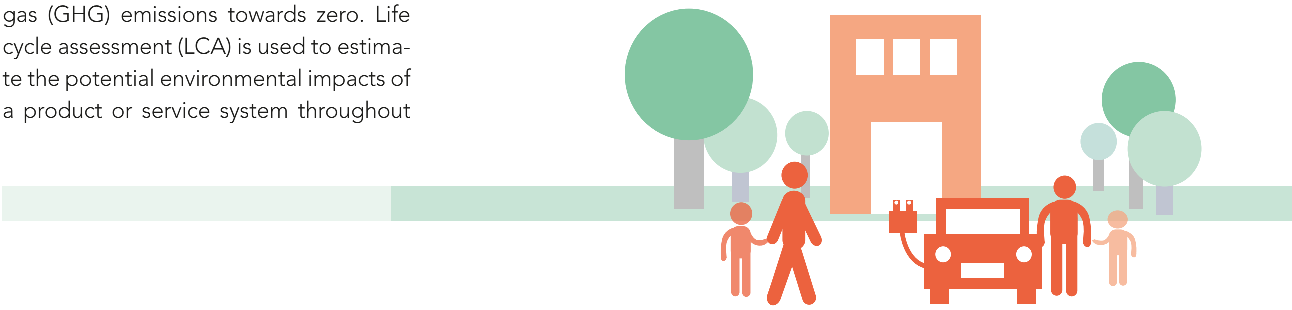

Photo: Thomas Klungland. The same photo is used on the cover illustration.

Bodø, Fornebu in Bærum, and Campus Evenstad in Hedmark. ZEN researchers are working with municipalities and other stakeholders to define goals and key performance indicators (KPIs). They offer advice, test and analyze solutions, and document the KPIs.

Two living labs have been organised in Evenstad and Steinkjer. Living labs reveal barriers against zero emission innovation that are often not visible before these innovations affect end-users and other stakeholders. In Steinkjer, we observed how future end-users organized political opposition to reusing a building, providing useful insight that can support start-up processes in other zero emission neighbourhoods.

The thermal performance of wood fiber and mineral-based insulation materials were studied in a laboratory experiment, investigating whether natural convection and varying moisture levels in the insulation influenced the thermal performance. Thermal conductivity was shown to be unaffected by moisture in the hygroscopic range. Natural convection increased the heat transmission by up to 10 percent in the 400 mm thick walls. The effect of these factors on total heating demand in two case buildings had a negligible impact.

In the research snapshots that follow, you can read more about our testing, development, design, collaboration and implementation. Much has been accomplished, and this year's results provide a strong foundation for working towards a low carbon society. We are on our way to making this happen!

THE FRAMEWORK IS IN PLACE – IT'S TIME TO DELIVER LOW CARBON SOLUTIONS AND CONCEPTS!

Rune Stene
Chairman of the Board ZEN, and Director of Skanska Technology

After two years where focus has been on setting up the Centre and employing people with expertise within the field, we are moving into the implementation phase. We now have a well-tuned and robust organisation, ready to support partner and pilot initiatives. However, we still need to get more of the industry and public partners actively involved, to increase the Centre's total volume of research and dissemination and expanding its expertise.

As the Centre moves into a period with greater focus on the delivery of results and partner engagement, the Board's agenda has been to facilitate Centre management and strengthen supporting structures. Our pilot projects are developing, and the industry partners are starting to position their expertise with regard to future deliveries, but we need to put more effort into establishing ZEN-cases. Results from cases will be very valuable and of high interest during the planning and development of the pilot projects.

Feedback from international institutions comparable to us, highlights that our research and innovations are unique, especially when it comes to the holistic approach to energy and emission from a neighborhood perspective. With the framework in place, the ZEN-definition and criteria will guide society and us into activities to reduce carbon emissions, but we have to expand the list of actual solutions. Again, the cases will play a major role, with public and industry initiative, insight, and ownership paired with researchers' in-depth knowledge and analytical approach. To welcome more partner initiatives the Board has increased the budget for case support.

The time has come for all partners to start contributing, and to share their competence and enthusiasm for developing a low carbon society. Many partner activities are going on, such as lunch lectures, seminars, and dialog meetings. To get even more involved in creating tomorrow's solutions for zero emission neighbourhoods, we recommend that you investigate your company's potential for case involvement. In my opinion, all partners should have had at least one case before the Centre wraps up its activities in 2024!

Centre Board

Tonje Frydenlund, Snøhetta
Partow P. Henriksen, SINTEF
Rakel Hunstad, Bodø municipality
Thomas Løkken, Hunton
Synnøve L. Sandberg, Statsbygg
Fredrik Shetelig, NTNU
Rune Stene, Skanska Norway

OVERALL GOALS AND RESEARCH PLAN

BACKGROUND

The buildings and construction sectors combined, account for 36% of total global final energy use and nearly 40% of total direct and indirect CO_2 emissions[1]. Improving the energy performance of the building stock is critical[2] and is more cost-effective and environment-friendly than extending capacity in the energy supply system[3]. Energy security in the IEA countries is improving with increased energy efficiency, and CO_2-emissions are reduced[4]. Flexibility in buildings' energy use is needed to accommodate the further integration of varying renewable power generation in Europe.

Focusing solely on individual buildings can lead to suboptimal solutions when aiming for a zero emission target due to high power peaks and fast load fluctuations, failing to achieve synergy effects between energy consumption and production. For some buildings it may not even be possible to achieve the zero energy or emissions targets, either because energy demand cannot be reduced sufficiently, such as in building renovation under architectural constraints, or due to a lack of access to renewable energy on-site or near-by. Additionally, to achieve high renewable energy shares in the generation mix, large-scale and centralized resources for generation and storage need to be supported by small-scale and distributed resources.

Energy distribution grids in Norway are designed and dimensioned to supply the bulk of demand. In many areas the grid is rather weak[5] and sensitive to bidirectional power flows (from distributed generation) and large step-changes in consumption (e.g. from fast-charging stations for electric vehicles). This makes development of well-functioning local solutions crucial. For electricity, distributed energy resources (DER) need to be locally optimized within the bottlenecks of the distribution grid. For thermal energy, local, smart thermal energy grids need to be developed concurrently with the renovation and densification of urban settlements[6,7].

OVERALL GOALS

The Research Centre on Zero Emission Neighbourhoods in Smart Cities (ZEN Centre) will enable the transition to a low carbon society by developing sustainable neighbourhoods with zero greenhouse gas emissions. The ZEN Centre will speed up de-carbonization of the building stock (existing and new), use more renewable energy sources, and create positive synergies among the building stock, energy, ICT and mobility systems, and citizens.

The zero emission neighbourhoods and communities should ensure optimal energy use and be good places for people to live and work. This requires continued and increased attention to reduction of GHG emissions, increased production of renewable energy, and energy efficiency and flexibility, while simultaneously developing the quality of the buildings and communities in which people spend their daily lives and empowering citizens and stakeholders by effective ICT services that provide real-time intelligence and understanding of energy, mobility, and people flows.

RESEARCH PLAN

The ZEN Centre delivers benefits for Norwegian and international society through it's new, strategic cooperation between the public partners, the building and energy sectors, and will advance the state of the art in six areas/work packages needed to speed up the transition to a low carbon society (Figure 1). Multidisciplinary collaboration between areas is key to addressing the overall goal.

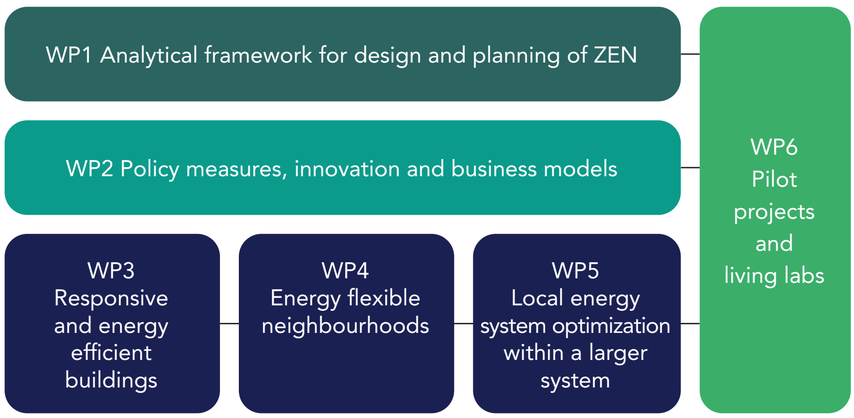

Figure 1: ZEN Centre's six work packages.

WORK PACKAGE 1 – ANALYTICAL FRAMEWORK FOR DESIGN AND PLANNING OF ZEN

Goal: Develop neighbourhood design and planning instruments, integrating science-based knowledge on greenhouse gas emissions.

- Establish a set of definitions and key performance indicators (KPI) for ZEN.
- Develop a data management plan to collect, structure, and analyze KPI data.
- Identify, evaluate, and develop modeling principles and methods for consistent use of LCA in ZEN.
- Develop a framework for ZEN scenario analysis with dynamic models linking demand, building stock, and flows of energy and GHG emissions for ZEN concepts to examine aggregated LCA effects when expanding from the building to the neighbourhood scale.
- Analyze which design and planning instruments (analogue, digital, or other) can support design of ZEN Living Labs in the best holistic manner.
- Investigate how 3D visualization can be used as a means to involve stakeholders in the design, planning, and management of ZEN Living Labs.

WORK PACKAGE 2 – POLICY MEASURES, INNOVATION, AND BUSINESS MODELS

Goal: Create new business models, roles, and services that address the lack of flexibility towards markets and catalyze the development of innovations for broader public use; this includes studies of political instruments and market design.

- Study markets, instruments, and other public incentives, including regulation, with an eye to ZEN relevance.
- Study how new markets and business models promote zero emission neighbourhoods and how they can be implemented in models.
- Map state-of-the-art literature on public-private collaboration and identify both successful and less successful cases of public-private cooperation in the area of sustainability and in particular initiatives geared towards zero-emission objectives.
- Map the state-of-the-art literature on possible systems for governance of public-private cooperation at different levels (national, regional, local), including incentive and market systems and sustainable business models (sharing rewards and risks).
- Contribute to the development of an innovation strategy for ZEN.

WORK PACKAGE 3 – RESPONSIVE AND ENERGY EFFICIENT BUILDINGS

Goal: Create cost effective, resource and energy efficient buildings by developing low carbon technologies and construction systems based on lifecycle design strategies.

- To investigate how LCA principles can be used in the design of buildings structures to reduce emissions and enhance flexibility.
- To investigate solutions for heating, ventilation, and cooling of building that have lower energy use than existing systems. The solutions should tolerate variations in thermal and/or electric energy supply, have low embodied energy in itself, and secure good indoor environment quality at reasonable costs.
- Analyze the potential of and criteria for use of ventilative heating and cooling in new buildings and for upgrading of existing buildings.
- Mapping and analysis of existing responsive and energy flexible buildings. Develop a definition of the concept "Responsive buildings".

WORK PACKAGE 4 – ENERGY FLEXIBLE NEIGHBOURHOODS

Develop technologies and solutions for design and operation of energy flexible neighbourhoods.

- Survey which pilot projects will develop or use thermal networks (in Norwegian "fjernvarme" or "nærvarme") for heating and cooling distribution, and what technologies are relevant.
- Survey options and costs for introducing hydronic heating (and cooling) in new and renovated buildings.
- Present the state-of-the-art for electric vehicle (EV) smart charging systems, including fast charging stations. Investigate the opportunities for interaction between photovoltaic (PV) and EV charging in buildings and neighbourhoods, including additional stationery batteries.
- Propose a definition of an "energy flexible neighbourhood" that shall be useful for the needs and purposes of the ZEN pilots.
- Collect existing and new data of thermal and electric hourly load profiles for different types of buildings (house, apartment, office, school, etc.), develop a methodology for defi-

ning statistically representative load profiles, and define a methodology for aggregation to the neighbourhood scale.

WORK PACKAGE 5 – LOCAL ENERGY SYSTEM OPTIMIZATION WITHIN A LARGER SYSTEM

Goal: Develop a decision-support tool for optimization of local energy systems and their interaction with the larger system.

- Update and make the software tool eTransport fully functional, with a new user-interface, and identify the first steps for further developments in light of needs within ZEN.
- Explore which existing software tools can be used for socio-economic optimal expansion planning of local energy systems.
- Develop a strategy for how to carry out power system analysis and assessment of environmental impacts within ZEN.

WORK PACKAGE 6 – PILOT PROJECTS AND LIVING LABS

Goal: Create and manage a series of neighbourhood-scale pilot projects and living labs which will act as innovation hubs and testing grounds for the solutions developed in the Centre. The pilot projects are Furuset in Oslo, Fornebu in Bærum, Campus NTNU and Sluppen in Trondheim, NRK-site in Steinkjer, Ydalir in Elverum, Campus Evenstad, NyBy Bodø, and Zero Village Bergen. All together, the pilot projects encompass an area of more than 1 million m^2 and more than 30 000 inhabitants.

- Description of ZEN pilot projects with respect to ambition levels, KPIs, definitions, and applied strategies, processes, tools, technologies, and lessons learned.
- Describe what should be the criteria for each of the pilot building projects (in cooperation with Work Package 1 and other WPs).
- Support planning and development of pilot projects. This activity includes participation in the planning, design, and evaluation of pilot building projects, to ensure the relations to the goals and other activities of the ZEN Centre.
- Map, compare, and analyze relevant existing urban living labs.
- Develop ideas for living lab activities that can contribute positively to the pilot projects and identify the most promising ones.
- Describe a realistic experimental design for the first two living labs.

ZEN leader group. Annika Bremvåg is not present due to maternity leave. Photo: NTNU

1 IEA (2019). Energy Efficiency: Buildings, The global exchange for energy efficiency policies, data and analysis. https://www.iea.org/topics/energyefficiency/buildings/.
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ORGANISATION OF THE ZEN RESEARCH CENTRE

The ZEN Research Centre is a centre for environmentally friendly energy and was established in 2017 by the Research Council of Norway. The Centre is hosted by the Norwegian University of Science and Technology, and jointly organised by NTNU/SINTEF.

The ZEN Research Centre has a General Assembly and an Executive Board. The Executive Board (EB) is responsible for the quality and progress of the research activities and for the allocation of funds to support the various activities. The user partners have the majority and the Chair of the EB. The General Assembly (GA) includes a representative from each of the partners. The GA gives guidance to the EB in their decision-making on major project management issues and approval of the semi-annual implementation plans.

The Centre also has a Scientific Committee (SC) with representatives from leading international institutes and universities to ensure international relevance and quality of the work performed. The SC consists of selected representatives from the Centre's international partners, who have been selected because their competence is relevant for the Centre's research activities.

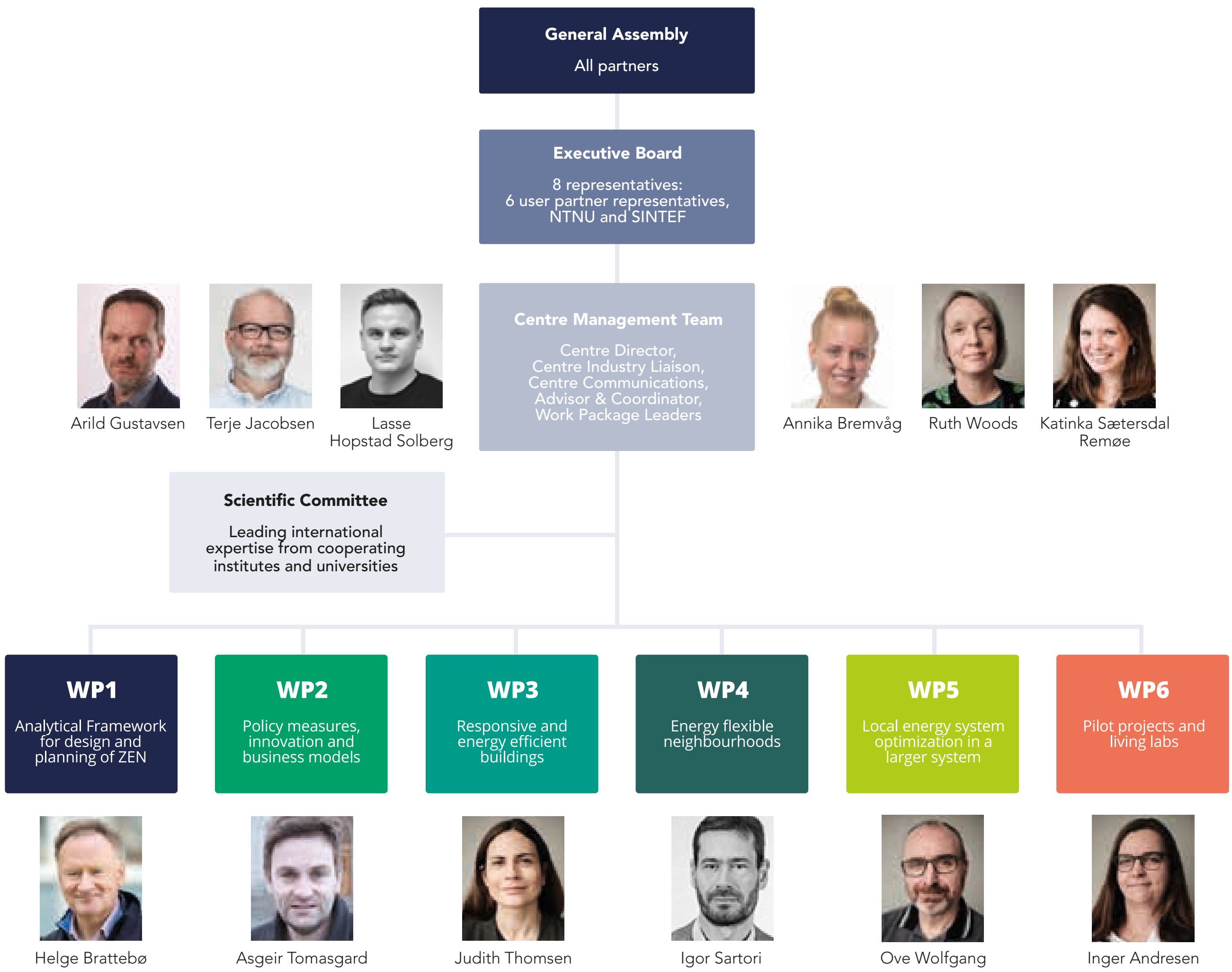

Figure 2: The ZEN Research Centre`s organisational structure.

OUR PARTNERS

The partners in the ZEN Research Centre hold central roles within the design and development of neighbourhoods and the energy system. This include representatives from municipal and regional governments, property owners, developers, consultants and architects, ICT companies, contractors, energy companies, manufacturers of materials and products, and governmental organisations.

The Norwegian University of Science and Technology (NTNU) is the host and leads the Centre together with SINTEF Building and Infrastructure and SINTEF Energy.

PRIVATE SECTOR

PUBLIC SECTOR

RESEARCH AND EDUCATION

The ZEN Centre is a research centre on environmentally friendly energy established by the Research Council of Norway.

SNAPSHOTS OF OUR RESEARCH

Distributed-to-Centralized Data Management in Smart Cities

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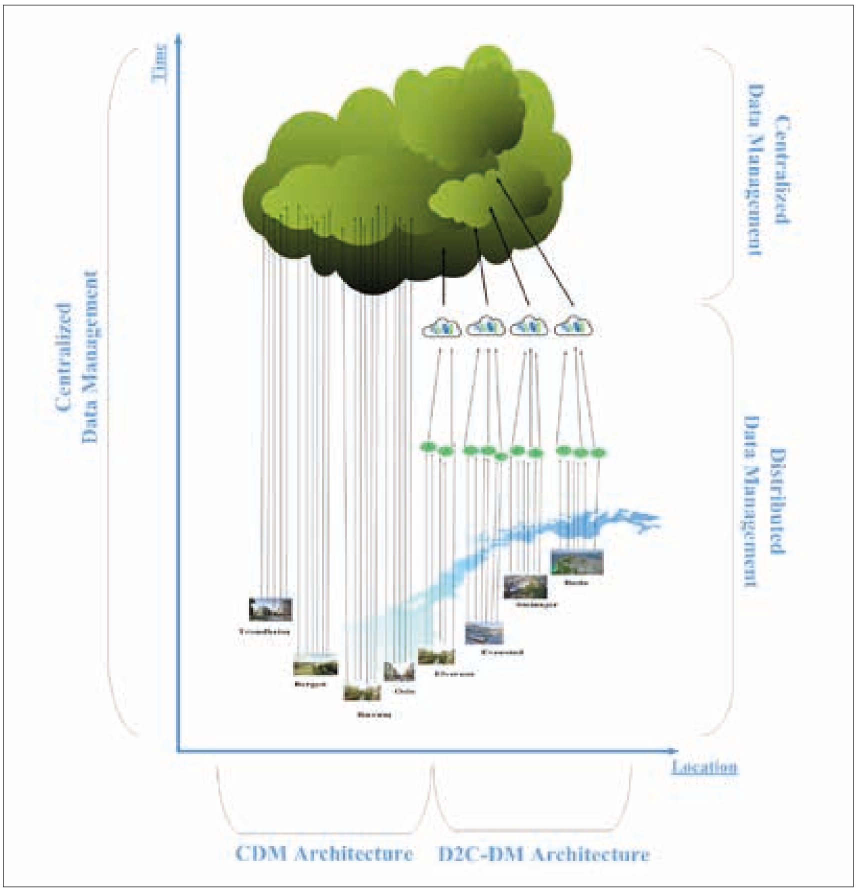
Data is one of the most valuable elements in Smart Cities, and data management strategies are required to deal with user needs and business models. Data makes a city smart, agile, and creative through the citywide use of appropriate services based on user requirements and related business models.

Centralized and distributed data management architectures are proposed for the Smart City. Extensive literature about Centralized Data Management (CDM) architecture exists; e.g. [1], but there are few related works about Distributed-to-Centralized Data Management (D2C-DM) architecture; e.g. [2]. The CDM architecture refers to a centralized place (mainly technologies in a Cloud) that can organize and manage all data sources from the city. The D2C-DM base manages the data from data creation to data consumption (the full Data LifeCycle). There are several good reasons for organizing the large amount of data produced in Smart Cities in D2C-DM architecture:

- In Smart Cities the data volume is growing exponentially;
- The data is generated by distributed data sources (such as sensors or social media);
- Data has a variety of types and formats;
- Smart services require both real-time and historical data.
- Some data is not relevant for all.
- Flexibility to apply local data policies and data governance.

The main contribution of our work is to design an effective ICT architecture for the ZEN Centre [3]. To do this, we will use the potential of D2C-DM, which is tailored to take advantage of both centralized and distributed data management in one unified data management architecture. The figure below illustrates the D2C-DM architecture for the ZEN Centre. The left-hand side of the figure shows a CDM approach with data storage and processing on the centralized cloud-based storage. The right-hand side of the figure shows a D2C-DM approach where the data may be stored and processed locally as well as some data that is pushed into the centralized storage.



CDM and D2C-DM architecture in ZEN neighbourhoods.

Distribuert-til-sentralisert datahåndtering i smarte byer

Data er et av de mest verdifulle elementene i smarte byer, og strategier for datahåndtering er helt nødvendige for å håndtere brukernes behov og ulike forretningsmodeller. Data gjør en by smart, smidig og kreativ gjennom byens bruk av tjenester basert på det brukerne trenger.

Sentraliserte og distribuerte datahåndteringsarkitekturer er foreslått for smarte byer. Det finnes mye litteratur om sentrale datahåndterings (CDM) arkitekturer [1], men lite om distribuert til sentralisert datahåndterings (D2C-DM) arkitektur [2]. CDM-arkitektur refererer til et sentralisert sted (hovedsakelig teknologier i skyen) som kan organisere og administrere alle datakilder fra en by. D2C-DM arkitektur administrerer data fra den skapes til den forbrukes (som tilsvarer datalivsyklus [4]).

Det er flere grunner til å organisere den store mengden av produsert data i smarte byer med en D2C-DM arkitektur. Disse er:

- Datavolumet vokser eksponentielt i en smart by
- Data genereres av distribuerte datakilder (f.eks. sensorer eller sosiale media)
- Data har en rekke typer og formater
- Smarte tjenester trenger både sanntidsdata og historiske data
- All data er ikke relevant for alle
- Det er behov for fleksibilitet til å anvende lokale regler for data og datastyring.

Hovedbidraget med vårt arbeid er å designe en effektiv IKT-arkitektur (inkludert datahåndtering) for forskningssenteret ZEN (FME ZEN) med fokus på den smarte bykonteksten [3]. For å gjøre dette bruker vi D2C-DM som er skreddersydd for å utnytte både sentralisert og distribuert datahåndtering i en enhetlig datahåndteringsarkitektur. Figuren på s. 14 illustrerer D2C-DM arkitekturen for FME ZEN. På venstre side av figuren vises en CDM-tilnærming med datalagring og behandling på det sentraliserte skybaserte lagringsområdet. På høyre side av figuren vises en D2C-DM-tilnærming hvor dataene kan lagres og behandles lokalt, samt noen data som skyves til den sentraliserte lagringen.

Referanser

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[2] Sinaeepourfard, A., Garcia, J., Masip-Bruin, X., Marin-Tordera, E.: Fog-to-Cloud (F2C) Data Management for Smart Cities. In: Future Technologies Conference (FTC) (2017).

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Foto: Thomas Klungland.

The ZEN Definition and Key Performance Indicators

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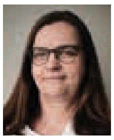

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A zero emission neighbourhood will be evaluated according to a comprehensive ZEN definition with a set of assessment criteria and key performance indicators. How should this be done?

One of the main outcomes of the previous Zero Emission Building (ZEB) Research Centre was a ZEB definition guideline report [1] that outlined the final definition of a zero emission building and the associated calculation methodologies. Similarly, the Zero Emission Neighbourhood (ZEN) in Smart Cities Research Centre has now developed a first version of a ZEN definition with a set of assessment criteria and key performance indicators (KPIs), for use when planning, implementing, and assessing the qualities of a zero emission neighbourhood project [2,3].

In the ZEN Research Centre, a neighbourhood is defined as a group of interconnected buildings with associated infrastructure, located within a confined geographical area. A zero emission neighbourhood aims to reduce its direct and indirect greenhouse gas (GHG) emissions towards zero over the analysis period. The neighbourhood should focus on the categories, assessment criterias, and KPIs shown in figure 4 (p. 17).

The ZEN definition, assessment criteria, and KPIs are already used in the planning, implementation, and operation phases of ZEN pilot projects. During 2019, they will be tested with respect to data accessibility, usability, and performance in the pilot projects of the ZEN Research Centre. It is expected that this testing process will give valuable feedback on the further specification, development, and use of KPIs. One of the questions that is uncertain at present is how to access good quality data and background information needed to determine KPI values at the different stages of the planning process. Another question is how to determine the uncertainty level of such values, and how this may influence decisions in the planning processes of ZEN pilot projects. Furthermore, it is necessary to better understand how the use of KPIs can help guide the pilot projects in technology and design choices, and how to maximise the usefulness of the ZEN definition and KPIs in practice.

Parallel to the testing of KPIs in the ZEN pilot projects, the ZEN Research Centre has started a process of developing a

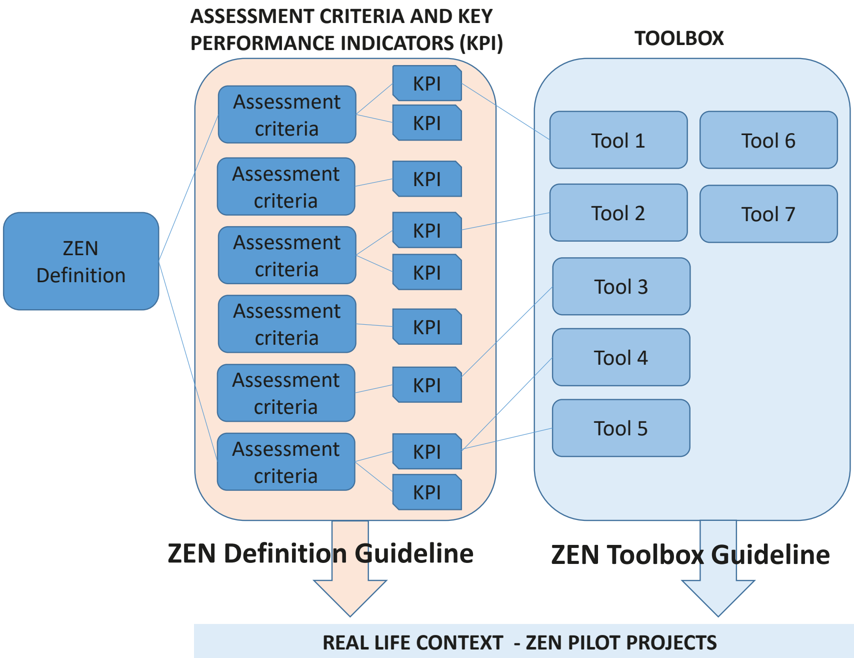


Figure 3. KPI results feeding into tools in the ZEN Toolbox.

so-called "KPI Tool", which is to become a multi-criteria decision analysis tool for the overall evaluation of trade-offs and performances across the KPIs for a ZEN project. Such a tool is required for the total qualitative evaluation of projects, when comparing alternative solutions within one project, or when comparing these to a reference base case.

Figure 3 indicates how the ZEN definition and KPI output results for a given project may be fed into different tools in the ZEN Toolbox that is to be developed by the ZEN Research Centre. One such tool will be the "KPI Tool", which might provide a visualisation of the overall performance of a given ZEN pilot project in accordance with the ZEN definition, assessment criteria, and KPIs. As proposed in Figure 5 (p. 18), the overall performance of a ZEN project could be shown across different assessment criteria and normalised according to a dimensionless scale from 0 to 6, where the reference base case is set to zero for all categories. An under-performing pilot project would have a negative score, while a high performing pilot project would have a high positive score. At present, this is only one possible solution, and several details remain to be resolved in the development of this procedure (references p. 19).

	Kategori	Vurderingskriterier og KPIer	Enhet
CO_2	Planlegging, design og drift av bygninger og deres tilhørende infrastruktur komponenter med sikte på **null klimagassutslipp** over livsløpet.	Totale klimagassutslipp. Reduksjon i klimagassutslipp.	tCO_2eq $kgCO_2eq/m^2BRA/år$ $kgCO_2eq/m^2BAU/år$ $kgCO_2eq/person$ % reduksjon fra referanse
	Oppnåelse av høy **energieffektivitet** og en høy andel av **ny fornybar energi** i områdets forsyningssystem for energi.	Energieffektivitet i bygninger (flere delkriterier). Energibærere (flere delkriterier). Egenforbruk/egenprodusert.	$kWh/m^2BRA/år$ kWh/år for hver energibærer % for hver energibærer
	Smart styring av energiflyten i området (i bygg og mellom bygg) og av utvekslinger med det omkringliggende energisystemet, som sikrer **fleksibilitet**.	Effekt (flere delkriterier). Utnyttelsesfaktor. Effektfleksibilitet.	kW % kW
	Fremme **bærekraftige transportmønstre** og smarte mobilitetssystemer.	Transportmåte. Tilgang til kollektivtransport.	% andel Meter, frekvens
	Planlegging, design og drift med hensyn på **økonomisk bærekraft**, ved minimerte levetidskostnader.	Livssykluskostnader (LCC).	NOK $NOK/m^2BRA/år$ $NOK/m^2BAU/år$ NOK/person
	Arealplanlegging sikrer gode **stedskvaliteter** og stimulerer bærekraftig atferd.	Demografiske behov og konsultasjonsplan. Offentlige rom	Kvalitativt Antall, meter avstand Kvalitativt
	Utviklingen av området er preget av innovative prosesser som benytter nye former av samarbeid mellom de involverte aktører som fører til **innovative løsninger**.	Foreløpig ikke besluttet.	Foreløpig ikke besluttet.

Figure 4. ZEN assessment criteria and Key Performance Indicators (KPIs).

ZEN definisjonen og prestasjonsindikatorer

Et nullutslippsområde vil evalueres i henhold til en helhetlig ZEN definisjon med et sett av vurderingskriterier og presta-sjons-indikatorer. Hvordan kan dette gjøres?

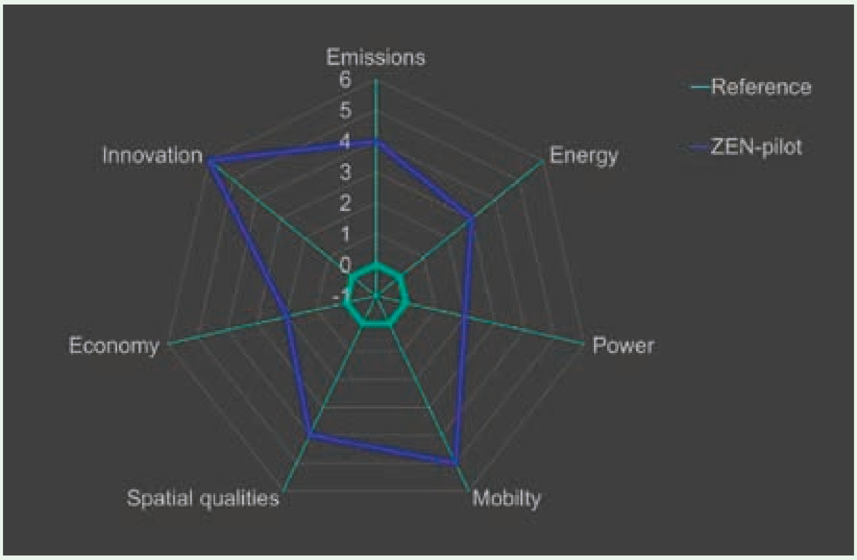
Et av de viktigste resultatene fra Forskningssenteret for nullutslippsbygg (ZEB) var ZEB definisjonen og tilhørende veileder [1], som inneholdt en beskrivelse av hvordan nullutslippsbygg kan defineres, med tilhørende beregningsmetodikk. På samme måte har Forskningssenteret for nullutslippsområder (ZEN) i smarte byer nå utviklet en første versjon av en ZEN definisjon med et sett av vurderingskriterier og prestasjonsindikatorer (KPIer), og en veileder for bruk ved planlegging, implementering og vurdering av kvalitetene til et ZEN prosjekt [2,3].

I ZEN senteret defineres et område som en samling av bygninger med tilhørende infrastruktur, lokalisert innenfor et avgrenset geografisk område. Et nullutslippsområde har som målsetning å redusere sine direkte og indirekte utslipp av klimagasser mot null innenfor en gitt analyseperiode. Området skal ha fokus på kategorier, vurderingskrietrier og KPI-er som vist i figur 4 (s. 17).

ZEN definisjonen, med vurderingskriterier og KPI'er, er allerede i bruk i ulike faser i senterets pilotprosjekter. I løpet av 2019 vil disse testes ut med hensyn til datatilgjengelighet, egnethet i bruk, og hvilke prestasjonsnivå ulike pilotprosjekter kan ha. Det forventes at denne testingen vil gi verdifulle tilbakemeldinger til den videre spesifiseringen, utviklingen og bruken av KPI'ene. Ett av spørsmålene som er uavklart i dag er hvordan man kan få tilgang til data og annen bakgrunnsinformasjon med tilstrekkelig høy kvalitet, i tråd med hva som trengs for å bestemme KPI-verdier i de ulike stadiene i planleggingsprosessen for et prosjekt. Et annet spørsmål er hvordan man skal bestemme usikkerhetsnivået for slike verdier, og hvordan usikkerhet vil påvirke beslutninger i planprosessen for et prosjekt. I tillegg er det nødvendig å forstå bedre hvordan bruken av KPI'er kan hjelpe pilotprosjektene i valg av teknologier eller utformingsløsninger, og hvordan man kan få størst mulig nytte av ZEN definisjonen og KPI'ene i praksis.

Parallelt med denne uttestingen vil ZEN senteret utvikle et verktøy som tentativt kalles "KPI Tool". Dette er et multikriterie beslutningsstøtteverktøy som skal brukes for samlet vurdering av prestasjonsnivået til ZEN prosjekter. Et slikt verktøy trengs for å kunne gjøre en total kvalitetsvurdering av et prosjekt, for komparative studier av ulike prosjekter, for sammenligning av ulike løsningsalternativ innenfor det samme prosjektet, eller ved sammenligning av ulike alternativ mot en referansesituasjon.

ZENs 7 KPI'er.



Figur 5. En måte å illustrere KPI resultater på for et gitt ZEN prosjekt sammenlignet med en referanse.

Figur 3 s. 16 viser hvordan ZEN definisjonen og KPI-verdier for et gitt prosjekt kan mates inn i ulike verktøy i en 'ZEN Toolbox'. "KPI Tool" vil være et av disse verktøyene, og vil kunne gi en visualisering av den samlede kvalitetsprestasjonen til et gitt pilotprosjekt, i tråd med ZEN definisjonen, dens vurderingskriterier og KPI'er. Som skissert i figur 5, kan den samlede prestasjonen for et pilotprosjekt vises på tvers av vurderingskriteriene. Her er dette normalisert til en dimensjonsløs skala fra -1 til 6, der referansealternativet er satt til verdien null for alle kategoriene. Et prosjekt som underpresterer i forhold til referansen vil få en negativ verdi, mens et prosjekt som presterer bedre enn referansen får en positiv verdi på skalaen. Denne fremstillingsmåten er en av flere muligheter som vurderes i dag, og en rekke detaljer må avklares ytterligere før man endelig velger hvordan dette skal gjøres.

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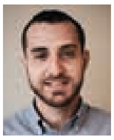
Public private collaboration in ZEN projects



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Neighbourhood scale projects, unlike individual buildings, have a wider and more diverse portfolio of actors which may translate into additional complexity and uncertainty, see figure 7. In addition, low carbon neighbourhood projects contain by nature socio-economic and technological challenges. Collaboration allows two or more organizations to solve a set of problems which neither can solve individually [1]. Hence, understanding collaboration in its narrow and wider senses in ZEN is critical to overcoming the above mentioned challenges, and eventually accelerating the transition towards a low carbon society.

My PhD project aims at a better understanding of how collaboration works between actors with different interests, and in particular, how dialogue based procurement strategies can create better conditions for innovation and collaboration. Investigating the literature of sustainable neighbourhoods is the point of departure to summarize the basic issues affecting collaboration in a ZEN. Identified issues will be sorted and analyzed following ZEN phases in order to outline the specific success/failure factors related to each phase. Next we study the interplay between identified issues and the procurement process to propose better procurement strategies safeguarding the prosperity of a ZEN without compromising the actors' aspirations. Case study research is planned to provide us with a better picture and an in-depth understanding of ZEN [3], and the ZEN pilot project Ydalir is chosen as our first case. The project is led by Elverum Tomteselskap (ETS), a semi-public organization which aims to support population growth in the municipality of Elverum.

Ydalir represents an opportunity to advance our knowledge on collaboration between public and private actors, between public actors, and between private actors. The project contains a variety of contractual arrangements, where public and private purchasing schemes are both being followed in the project. For example, a school and a kindergarten, shown in figure 6, were procured through a public procurement arrangement, while private developers buy land through a private contracting arrangement. Moreover, we aim to investigate the challenges and uncertainties surrounding the implementation phase, i.e. reducing the perceived risk by project actors regarding ZEN ambitions. This research can contribute to solving some of the challenges found in ZEN pilot projects and encourage ZEN actors to adopt more relationship-based solutions.

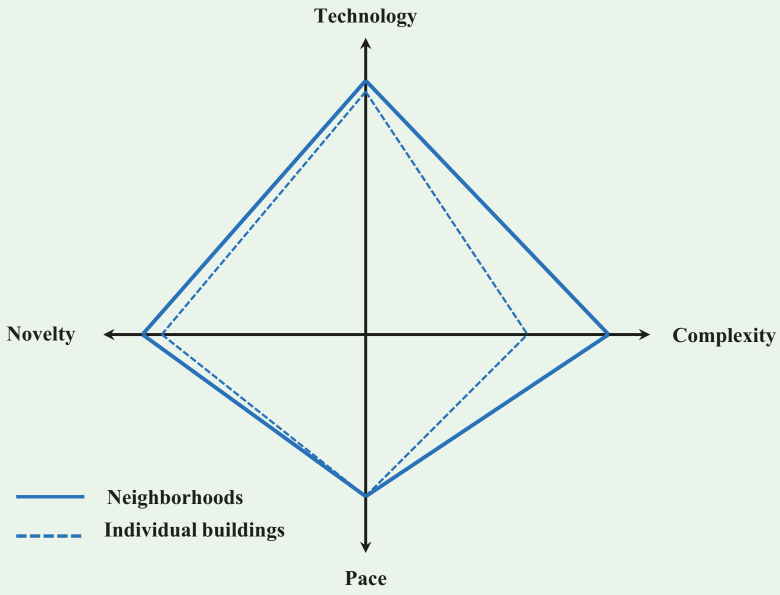
Figure 6. Aerial photo of the Ydalir project.
Source: Elverum Vekst.

Betydningen av privat-offentlig samarbeid for utviklingen av ZEN

I motsetning til andre byggeprosjekter har prosjekter i nabolagsskala bredere og mer varierende grupper av aktører. Dette kan bidra til mer kompleksitet og usikkerhet i prosjektene og kommer på toppen av de sosioøkonomiske og teknologiske utfordringene byggeprosjekter ofte møter (se figur 7).

Samarbeid mellom to eller flere involverte aktører gjør det mulig å løse eventuelle utfordringer som vanskelig kan løses av den enkelte [1]. For å overvinne nevnte utfordringer er det avgjørende med en bedre forståelse av samarbeid. En slik forståelse kan bidra til raskere overgang til lav-karbon samfunnet.

I mitt PhD prosjekt har jeg som mål å gi en bedre forståelse av hvordan samarbeidet fungerer mellom ZEN aktører med forskjellige interesser. Jeg er spesielt interessert i hvordan dialogbaserte anskaffelsesstrategier kan skape bedre forhold for både innovasjon og samarbeid. Bærekraftige nabolagsprosjekter vil grupperes og analyseres i hht de ulike fasene i utviklingen av et ZEN for å demonstrere faktorer for suksess/feiling knyttet til hver fase. Dernest studeres samspillet mellom de identifiserte forholdene og anskaffelsesprosessen. Målet med dette er å kunne foreslå bedre anskaffelsesstrategier som ivaretar fordelene med ZEN uten å gå på bekostning av ambisjonene. Vi vil bruke casestudier for å få et bedre bilde og en inngående forståelse av ZEN [3], og Ydalir er vårt første case (se figur 6). Elverum Tomteselskap (ETS) er byggherre i prosjektet og har som formål å fremme befolkningsvekst i Elverum Kommune.



Figur 7. Kompleksitet i nabolags_prosjekt. Utarbeidet fra: [2]

Ydalir gir oss en god mulighet til å få mer kunnskap om samarbeid mellom offentlige og private aktører, mellom offentlige aktører, og mellom private aktører. Prosjektet har ulike kontraktsmessige avtaler og benytter både offentlige og private anskaffelsestilnærminger. For eksempel ble skolen og barnehagen (figur 6) anskaffet gjennom offentlige anskaffelse, mens utbyggerne bruker private kjøpekontrakter for å anskaffe sine tomter.

Ved å bruke Ydalir som case vil jeg belyse utfordringer og usikkerhet i gjennomføringsfasen av et ZEN, f.eks. hvordan risiko oppfattes av prosjektaktørene. Denne forskningen bidrar til å finne gode løsninger på utfordringer som finnes i pilotområdene og vil gjøre ZEN aktører i stand til å ta i bruk mer relasjonsdrevne løsninger.

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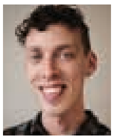
Local energy supply at Campus Evenstad: Consequences and opportunities



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Statsbygg

Statsbygg wanted to gain knowledge about environmental, economic, and technical consequences of relevant levels of ambition at Campus Evenstad. We were especially interested in the consequences of different degrees of self-supply by on-site renewable energy. Is for example 100 % self-supply a good level of ambition? What would different degrees of self-supply mean for future investments, value creation, business opportunities, and operational control and emission reductions? What is optimal and what measures should we implement?

LOCAL ENERGY SUPPLY IS MOST VALUABLE IF IT IS USED WITHIN THE NEIGHBOURHOOD

Local electricity supply creates most monetary value through saved costs from reduced grid import because of the net-metering policy. It was estimated that local electricity supply reduced the electricity bill in 2016 with about 16 %. Campus Evenstad saved about 0.6-0.8 NOK per kWh of locally produced electricity that was not exported to the grid.

Future investments in the energy system at Campus Evenstad was analyzed using an optimization model. The results show that the most cost-effective way of achieving annual compensation of emissions is by investing in more solar cells. In addition, optimization of operation through planned charging of batteries and electric vehicles or through pre-heating spaces and hot water storage tanks to reduce peak loads and minimize operational costs should be prioritized. More energy production on sunny days is expected if more solar cells are installed, and this energy production generates most monetary value with current agreements if operational control can ensure that the produced electricity is consumed in the neighbourhood (not exported).

Campus Evenstad should aim for consuming locally generated electricity on-site to minimize emissions. This is due to the assumption that the local units are based on renewable energy sources that replace energy produced with fossil fuels in Europe.

In order to support research on the best pathway towards ZEN development and validation, a common database for storing energy data should be prioritized. Subsequently, the potential for increased energy efficiency in buildings should be mapped. The local heating network also has potential for improvement through minimizing electric heat supply, adding additional buildings, and optimizing the temperature level. Additional local energy production and renovation of older buildings to achieve ZEN targets should be analyzed and compared after these measures have been pursued.

Photo: Leikny Havik Skjærseth.

Lokal energiforsyning på Campus Evenstad: Konsekvenser og muligheter

Statsbygg ønsket å få kunnskap om relevante ambisjoner for Campus Evenstad og hvilke miljømessige, økonomiske og tekniske konsekvenser disse ville ha. Vi var særlig interessert i konsekvenser av ulik grad av selvforsynt, fornybar energi på campus. Bør det for eksempel være et mål å være 100 % selvforsynt? Hva innebærer ulik grad av selvforsyning for fremtidige investeringer, verdiskaping, forretningsmuligheter og ikke minst, driftsoptimalisering og utslippsreduksjoner? Hva er det optimale, og hvilke tiltak bør vi satse på?

LOKAL ENERGIPRODUKSJON ER MEST VERDIFULL HVIS DEN BRUKES INNENFOR NABOLAGET

Lokal elektrisitetsforsyning skaper økonomisk verdi hovedsakelig gjennom sparte kostnader. Dette skjer som følge av mindre behov for strømimport siden avregningen er på netto strømforbruk. I 2016 reduserte Campus Evenstad strømregningen med 16 % ved hjelp av lokal strømforsyning. Da ble det spart mellom 0,6-0,8 NOK per kWh av lokalprodusert strøm som ikke ble eksportert til nettet.

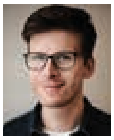
Det er undersøkt potensielle, fremtidige investeringer i energisystemet for Campus Evenstad ved hjelp av en optimeringsmodell. Analysene antyder at den mest kostnadseffektive måten å oppnå årlig kompensering av utslipp på er gjennom investeringer i flere solceller. I tillegg bør driftsoptimalisering gjennom planlagt ladning av batteri og elbiler, eller for-oppvarming av rom og vann for å redusere topplaster og minimere driftskostnader, prioriteres fremover. Dersom flere solceller installeres, blir det mer strømproduksjon på solfylte dager. Denne produksjonen gir høyest, økonomisk gevinst med dagens avtaler dersom driftsoptimalisering sørger for at den produserte strømmen brukes lokalt i nabolaget (ikke eksporteres).

Campus Evenstad bør i størst mulig grad benytte lokale enheter ved energiforsyning for å minimere utslipp. Denne påstanden kan forsvares med at de lokale enhetene kun er driftet på fornybare energikilder som erstatter energi produsert med fossile energikilder andre steder i Europa.

Utvikling og validering av et felles system for logging av energidata bør prioriteres videre for å forstå den beste veien mot ZEN. Deretter bør potensialet for økt energieffektivitet i bygg kartlegges. Nærvarmenettet har også potensiale for videreutvikling gjennom minimering av elektrisk varmeforsyning, tilkobling av flere bygg og oppgraderinger knyttet til temperaturnivå. Ytterligere lokal strømproduksjon og renovering av gamle bygg for å oppnå ZEN-mål bør vurderes etter at disse tiltakene er gjennomført.

Foto: Thomas Klungland.

Can new methods determine the energy performance of a building based on data from on-site energy measurements?



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Today, large buildings have advanced systems for building management or remote energy monitoring. Many energy meters are installed, but their full potential is often not exploited. Data acquisition and data-driven analysis methods are critical to the development of new services for efficient operation of buildings and utilisation of local energy resources. (figure 9).

The ZEN Research Centre participates in the international technology network IEA EBC Annex71, a five-year research collaboration tackling the building energy performance gap. The problem of performance evaluation has shifted from theoretical calculations to identifying important parameters using data-driven models.

The main challenge is to find a model that represents the physical reality and has a complexity in agreement with the level of information available in the logged data. The collected data reflects the intricate interdependencies of the building envelope, the building services, and its users. Can this be done with fewer sensors?

The PhD-research, linked to the work in Annex 71, focuses on determining the energy performance of a building based on data from on-site energy measurements. The research method combines physical modelling with data-driven analysis techniques to create new indirect insights, identifying parameters that are not easily measured, e.g. the overall heat loss, the solar heat gains, and the envelope capacity to store heat. The first step in this direction has been to develop a model using weather forecasts from yr.no to calculate solar radiation (inclined on facades, roof, and PV installations) and to capture local climate effects surrounding a building, without relying on a weather station on site.

In this research, we use detailed measurements coming from the ZEB Living Lab. This facility provides the data to develop and evaluate models. At the same time, it gives us the possibility to evaluate the best sensor placement and to compare the setup with a reduced number or cheaper type of sensors. In this way, it will be possible to evaluate the benefits of having a more versus a less detailed monitoring system (Figure 8).

ZEB Living Lab. Photo: Geir Mogen.

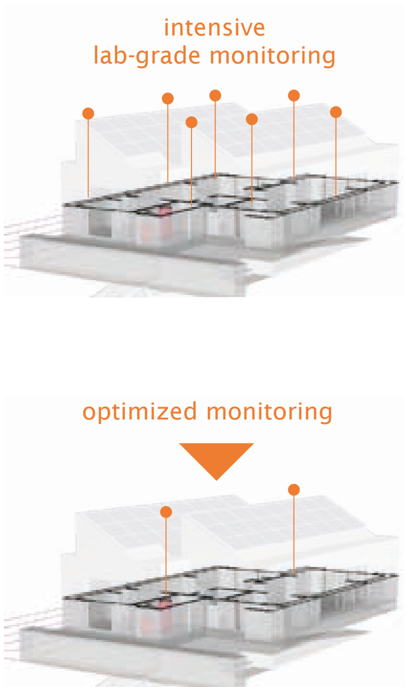


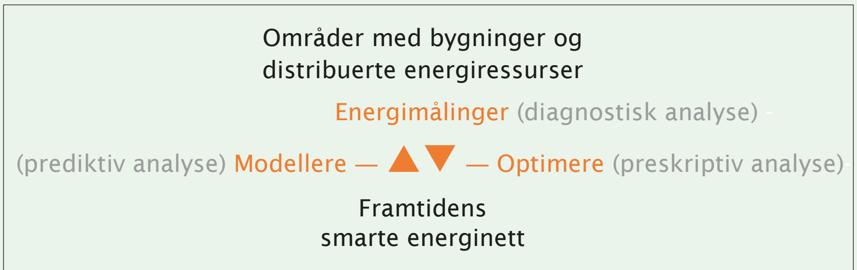
Figure 8. Monitoring complexity comparison.

Kan nye metoder bidra til å bestemme energiytelsen til en bygning basert på data fra energimålere?

Store bygninger kan i dag ha avanserte anlegg for driftsovervåking (SD-anlegg) og energioppfølgings¬systemer (EOS). Mange energimålere er installert, uten at en klarer å nyttiggjøre seg av mulighetene som ligger i dette. Oppfølging er kritisk, og er sammen med datadrevne analysemetoder viktig i utviklingen av tjenester knyttet til energieffektiv driftsstyring av bygg som kan utnytte lokale energiressurser (figur 9).

Forskningssenteret ZEN deltar i det internasjonale teknologinettverket IEA EBC Annex 71, et femårig forskningssamarbeid som adresserer problemet med avvik mellom beregnet, forventet og faktisk energibruk i bygg. Innsatsen er flyttet fra teoretiske energiberegninger til å identifisere viktige parametere med datadrevne modeller.

Hovedutfordringen med å bestemme energiytelsen til en bygning fra måledata, er å finne fram til modeller som representerer fysiske forhold og har en detaljeringsgrad som er i samsvar med informasjonen som er tilgjengelig i måledataene. Detaljerte energi- og temperaturmålinger gjenspeiler samspillet mellom bygningskroppen, de tekniske installasjonene og brukerne i bygget. For å fange opp dette er det nødvendig å undersøke hva som trengs for å ha gode nok data med så få sensorer som mulig.



Figur 9. Hvordan energimålinger og ulike analyseteknikker kan brukes til driftsstyring av bygg.

Kristian i teknisk rom på ZEB Living Lab. Foto: Thomas Klungland.

Doktorgradsarbeidet som er knyttet til Annex 71 fokuserer på å bestemme energiytelsen til en bygning utfra målinger. Forskningsmetoden kombinerer fysisk modellering og datadrevne teknikker for å få ny, indirekte innsikt om prosesser som ikke så enkelt kan måles direkte. Modellene kan for eksempel brukes til å identifisere parametere som er avgjørende for solvarmetilskuddene, varmetapet og varmekapasiteten til bygningen. Et første steg i denne retningen har vært å utvikle en modell som bruker værmeldingen fra yr.no til å beregne solstråling (på fasader, takflater og solcellepaneler) og beskriver lokale klimaforhold rundt en bygning, uten å ha montert en værstasjon på stedet.

I denne forskningen benytter vi detaljerte målinger i fra ZEB Living Lab til å utvikle modeller og sjekke disse. Samtidig gir dette mulighet til å vurdere plasseringen av sensorer og sammenligne med det å ha færre målepunkt eller å ta i bruk rimeligere sensorer. Dette gjør det mulig å vurdere nytteverdien av et mer kontra et mindre detaljert målesystem (figur 8).

Til høsten kommer deltakerne i Annex 71 til Trondheim. Da blir det avholdt et heldagsseminar om ulike metoder for karakterisering av bygningers energiytelse.

Smart commercial buildings: The ZEN case

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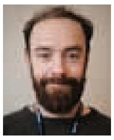

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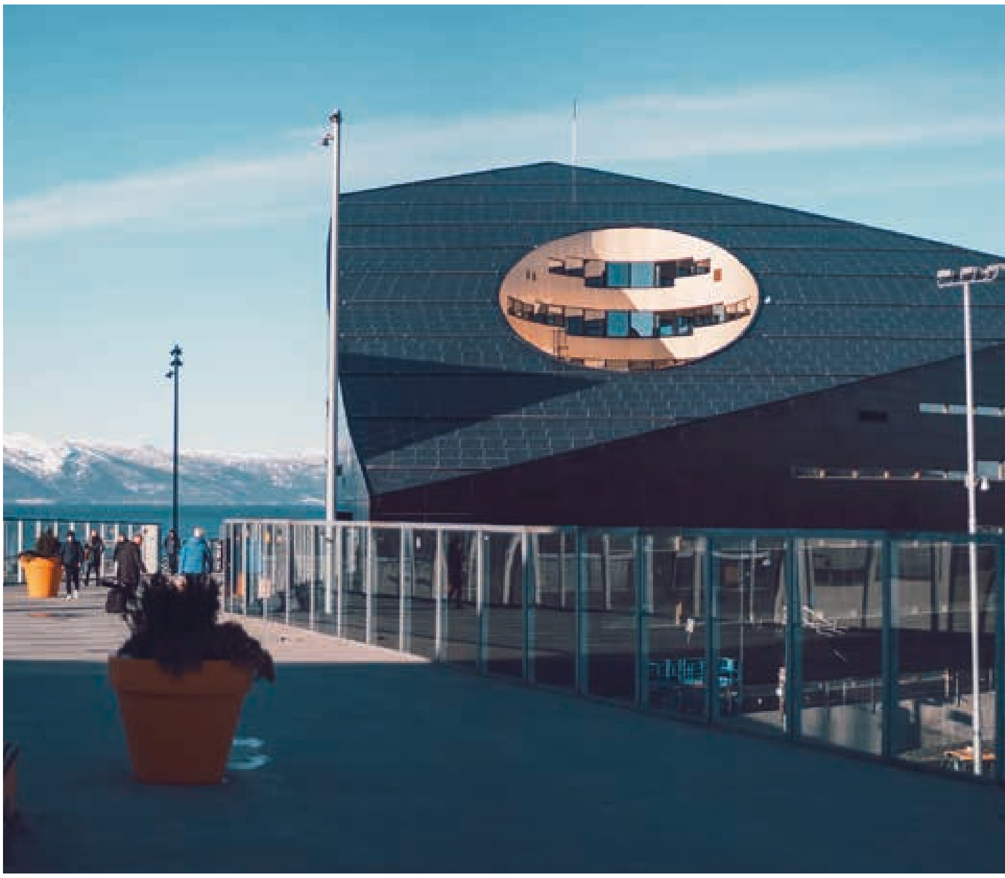
Research Manager, SINTEF

The Powerhouse collaboration, consisting of ZEN partners Snøhetta, Skanska, and Asplan Viak, in addition to Entra and the environmental organization ZERO, has since May 2018 worked on creating a guide for resource-efficient and functional commercial buildings. The ambition has been to provide a base for discussions about the development of smart buildings by key partners. Researchers from FME ZEN have helped to clarify the problems dealt with in the guide and ensured a suitable level of detail for the functional requirements. The guide "Smart by Powerhouse" was recently published on the Powerhouse website and is now freely available.

The Powerhouse collaboration believes that a building cannot claim to be smart without also being green and that technology should not be the aim in itself, but an instrument for achieving increased value for users, tenants, building owners, society, and the environment. During the development of the guide, the case collaboration with FME ZEN has been very valuable. ZEN researchers joined the process in the early stages, providing insight into the international activity on the definition of smart buildings. During subsequent discussions, it became clear that developing yet another definition of smart buildings should not be the project's key contribution to the industry. On the other hand, it also became clear that greater detail was necessary. Through the involvement of specialists in the various companies, the functional requirements that we believe should form the basis of smart commercial buildings were mapped out. In this work, FME ZEN has contributed by participating in workshops and through feedback throughout the process. The help in breaking down the challenges to reach the appropriate level of detail regarding the functional requirements has been particularly appreciated.

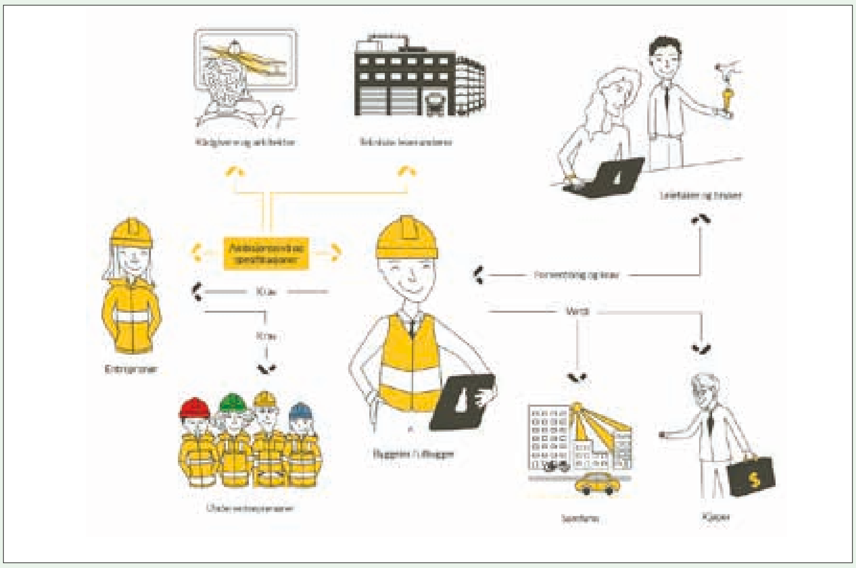
Several companies in the industry outside the Powerhouse collaboration and FME ZEN have also contributed to the final result. On December 3, an open workshop was organised with 46 participants at Skanska's offices in Oslo, where the work so far was presented and the participants were active in providing feedback. ZEN presented smart buildings in a global perspective and participated as a host in a session about energy and resource efficient buildings. The day was a success and an important milestone. The expertise of the FME ZEN has been crucial in reaching the finishing line.



Powerhouse Brattøra. Photo: Thomas Klungland.

ZEN-caset Smarte næringsbygg

Powerhouse-samarbeidet, bestående av ZEN-partnerne Snøhetta, Skanska og Asplan Viak, i tillegg til Entra og miljøstiftelsen ZERO, har siden mai 2018 jobbet med å lage en veileder for ressurseffektive og funksjonelle næringsbygg. Ambisjonen har vært å bidra med et diskusjonsunderlag for utvikling av smarte bygg, på tvers av sentrale samarbeidspartnere. Forskerne i FME ZEN har bidratt til å konkretisere problemstillingene i veilederen og til å treffe riktig nivå med funksjonskravene. Veilederen Smart by Powerhouse ble nylig publisert på Powerhouse sine nettsider og ligger der tilgjengelig for alle interesserte i bransjen.



"Ambisjon". Illustrasjon: Snøhetta.

Innstillingen i Powerhouse-samarbeidet har vært at et bygg ikke kan påberope seg å være smart uten at det også er grønt. Perspektivet har vært at teknologi ikke skal være fokuset, men et virkemiddel for å oppnå økt verdi for bruker, leietaker, byggeier, samfunn og miljø. I så måte har tilknytningen til FME ZEN i form av å være et case-prosjekt vært svært verdifull. ZEN-forskerne kom tidlig inn i prosessen og ga oss et innblikk i den internasjonale bredden av ulike definisjoner av smarte bygg allerede i et av de første arbeidsmøtene. I den etterfølgende diskusjonen og rekken av arbeidsmøter ble det tydelig at å utvikle enda en definisjon av smarte bygg ikke burde være prosjektets sentrale bidrag til bransjen. Derimot ble det tydelig at vi måtte gå enda mer ned i detaljene og, gjennom involvering av spesialister i de ulike selskapene, samle og uttrykke de funksjonskravene vi samlet mener bør ligge til grunn for smarte næringsbygg. I dette arbeidet har FME ZEN bidratt gjennom deltakelse på workshops og gjennom tilbakemeldinger underveis. Hjelpen til å bryte opp problemstillingene og treffe riktig nivå med funksjonskravene har vært spesielt verdsatt.

«Innstillingen i Powerhouse-samarbeidet har vært at et bygg ikke kan påberope seg å være smart uten at det også er grønt.»

Også aktører i bransjen utover Powerhouse-samarbeidet og FME ZEN har bidratt til det endelige resultatet. Den 3. desember ble det arrangert en åpen workshop med 46 deltakere hos Skanska i Oslo, der arbeidet så langt ble presentert, og deltakerne var aktive med å gi tilbakemeldinger. ZEN presenterte smarte bygg i et globalt perspektiv og deltok som vert på workshop-stasjonen for energi- og ressurseffektive bygg. Dagen ble en suksess og var en viktig milepæl som markerte starten av innspurten. En innspurt der kompetansen i FME ZEN har kommet til nytte hele veien inn.

Characterizing the energy flexibility of buildings and districts

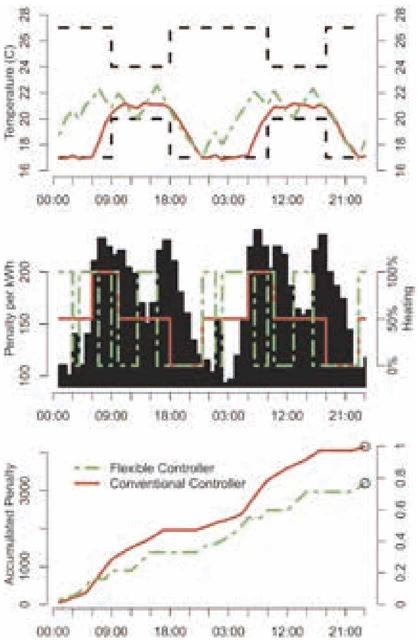
Karen Byskov Lindberg
Senior Researcher,
SINTEF

How do we measure energy demand's flexibility?

Realizing power systems that rely mostly on intermittent renewable energy sources, such as solar and wind, leads to challenges in planning and controlling the energy production, transmission, and distribution. Even in Norway, where green electricity comes from controllable hydropower, optimal utilization of the grid's capacity is a challenge, since investment and maintenance costs are dictated by high peaks in demand that occur only during a few hours in a year. The same challenges apply to district heating systems. Part of the solution is a paradigm shift from supply control to demand control.

Flexibility is already present in buildings, e.g. through heat storage, and it can be harnessed under the assumption that the buildings are able to respond to an external penalty signal. Depending on the context, e.g. local energy mix, energy system constraints, or even societal ambitions, different penalty signals can be constructed by the grid operator in order to tailor the optimal energy demand.

Possible penalty signals with an hourly resolution are: energy cost, environmental footprint (CO_2 emissions), peak loads, and availability of sun or wind. A typical example is a building that needs to be heated, using the energy price as the penalty. In this case, the penalty-aware controller will try to keep the building within thermal comfort boundaries at the lowest possible cost (see figure).



Top plot: An example of the temperature in a building controlled by a penalty-aware controller (green, dashed) and a conventional controller (red, solid). Both controllers are restricted to stay within the dashed lines.

Middle plot: The black shading gives the penalties, while the green and red lines show when the two controllers heat, respectively.

Bottom plot: These graphs illustrate the accumulated penalty for each of the controllers.

The first step is a formal and robust characterization of the energy flexibility on the demand side. A novel methodology is proposed to characterize the energy flexibility as a dynamic function, known as the *Flexibility Function*. Based on it, several *Flexibility Indexes*, that describe to which extent a building is able to respond to the grid's need as expressed by the different penalty signals can be derived.

Possible applications include measuring the flexibility function of a large number of buildings with non-intrusive measurements and mapping the resulting flexibility indexes according to the needs of the energy system in a given area. ZEN partners in this work have been SINTEF and DTU, while several industrial partners have participated in a workshop where the flexibility indexes have been presented and discussed, identifying those most suitable for the Norwegian conditions and the goals of the ZEN Centres, namely those relating to penalty signals on: peak loads, energy emissions, and energy cost.

Based on the article by Rune Grønborg Junker, Armin Ghasem Azar, Rui Amaral Lopes, Karen Byskov Lindberg, Glenn Reynders, Rishi Relan, Henrik Madsen, "Characterizing the energy flexibility of buildings and districts" (2018) Applied Energy, Volume 225, 1 September 2018, Pages 175-182.

Hvordan måler vi energibehovets fleksibilitet?

Realisering av et kraftsystem som baserer seg på lite regulerbare fornybare energikilder, slik som sol og vindkraft, fører til utfordringer i planlegging og styring av energiproduksjon, kraftoverføring og distribusjon. Selv i Norge, hvor fornybar energi kommer fra regulerbar vannkraft, er optimal utnyttelse av overførings- og distribusjonsnettet en utfordring. Dette er fordi investerings- og vedlikeholdskostnadene er drevet av høye effekttopper som forekommer i kun korte tidsperioder. De samme utfordringene er tilstede i fjernvarmenettene. En del av løsningen på disse utfordringene er et paradigmeskifte i kraftsystemet: fra forsyningskontroll til etterspørselskontroll.

Fleksibilitet er allerede tilgjengelig i bygninger, for eksempel gjennom varmelagring, og den kan utnyttes dersom bygningene kan respondere i henhold til et eksternt signal. Avhengig av omstendighetene (for eksempel den lokale energimiksen, restriksjoner i distribusjonsnettet eller samfunnsmessige ambisjoner) kan ulike kostnads-signaler utformes av nettoperatøren for å oppnå optimal energietterspørsel.

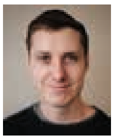
Mulige kostnads-signaler med timesoppløsning er: Energipris, klimafotavtrykk (CO_2 utslipp), topplast eller tilgjengelighet av sol og vindkraft. Et typisk eksempel er et bygg som trenger oppvarming, med energipris som kostnads-signal. I et slikt tilfelle vil et prisavhengig kontrollsystem prøve å holde kostnaden nede, samtidig som bygningens komfortkrav tilfredsstilles.

Første steg på veien er en formell og robust karakterisering av tilgjengelig fleksibilitet på etterspørselssiden. En ny metodikk for karakterisering av fleksibilitet som en dynamisk funksjon er foreslått. Denne kalles fleksibilitetsfunksjonen. Basert på denne kan flere fleksibilitetsindekser utvikles. Disse vil beskrive i hvilken grad en bygning kan respondere på nettets behov gjennom ulike kostnads-signaler.

Mulige anvendelser for dette inkluderer måling av fleksibilitetsfunksjonen i et stort antall bygg med lite inngripende målinger og kartlegging av fleksibilitetsindeksene i henhold til kraftsystemets behov innenfor et gitt område. ZEN forskningspartnere i dette arbeidet har vært SINTEF og DTU. Flere industripartnere har deltatt på en workshop der fleksibilitetsindekser ble presentert og diskutert. Målet var å finne de mest egnede for norske forhold og målene i ZEN senteret. Dette gjelder i hovedsak indeksene som er knyttet til kostnads-signaler for: topplast, utslipp og energikostnad. Se referanse på s. 28.

Foto: Samuel Zeller Unsplash.

4th generation district heating, a sustainable solution for supplying heat to zero emission neighbourhoods



Øystein Rønneseth
Researcher,
SINTEF

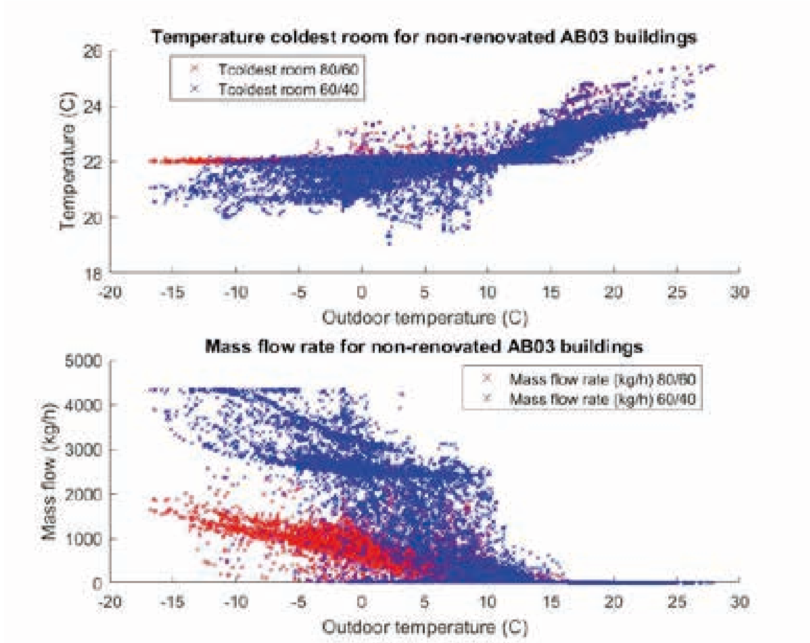
4th generation district heating represents the new generation of district heating systems. It reduces heat loss from the grid, enables better use of surplus heat and renewable energy sources, and reduces the strain on the electricity grid. In short, 4th generation district heating is a sustainable solution for supplying heat to Zero Emission Neighbourhoods.

There are however, technical challenges to be solved before it is introduced. One of them is to determine how low the supply temperature can be in different types of buildings so that we can identify the minimum district heating supply temperature. In our research, we evaluated the minimum supply temperature in Norwegian apartment buildings by improving the thermal envelope and reducing the temperature levels for the heating system. Our analysis focuses on whether the reduced supply temperature guarantees thermal comfort in the building.

Our project required developing a database of building models representative of Norwegian apartment buildings. The building models consisted of eight age groups and three levels of energy performance. We performed simulations with two different temperature levels for the radiators typical for Norwegian buildings: 80/60 and 60/40 °C.

We found that reducing the supply temperature to the radiators from 80 to 60 °C is possible in buildings newer than from 1970, even for non-renovated buildings. For older buildings, an intermediate renovation, i.e. upgrading the windows, is necessary to maintain temperatures above the minimum acceptable temperature of 19 °C. We recommend a more ambitious renovation of these buildings to reduce the number of hours with significantly reduced indoor temperatures compared to the setpoint temperature of 22 °C. In addition to reducing the heating demand and thus achieving energy savings, this will also ensure that the occupants are satisfied with their thermal environment.

The results can be used by district heating companies, building owners, contractors, and consulting companies, in order to evaluate the introduction of 4th generation district heating in Norwegian apartment buildings. The models and Excel sheets with hourly results for energy need are available for partners and researchers within FME ZEN, and they could potentially be used for other purposes as well. See reference on p. 31.



Example of results from the simulations of a typical apartment building from the 1970s (AB03). The upper graph shows indoor temperature in the coldest room relative to outdoor temperature throughout the year. The lower graph shows the radiator system's mass flow rate also relative to the outdoor temperature.

Fjerde generasjons fjernvarme, ein berekraftig løysing for å levere varme til nullutsleppsområder

Fjerde generasjon fjernvarme representerer den nye generasjonen. Den reduserer varmetap frå nettet, mogleggjer betre utnytting av overskotsvarme og fornybare energikjelder, i tillegg til å redusere belastninga på straumnettet. Kort fortald, fjerde generasjons fjernvarme er ein berekraftig løysing for å levere varme til nullutsleppsområder.

Det er likevel nokon tekniske utfordringar som må løysast før det blir introdusert. Ei av dei er å avgjere kor låg turtemperaturen kan vere i forskjellige bygningstypar, slik at vi kan identifisere minimum turtemperatur i fjernvarmenettet. I forskinga vår har vi evaluert minimumsturtemperaturen i norske bustadblokker basert på effektar av å forbetre bygningskroppen og redusere temperaturnivået for varmesystemet. Analysen vår fokuserer på om ein ved redusert turtemperatur klarar å opprettholde termisk komfort i bygningen.

Prosjektet vårt omfatta å utvikle ein database av bygningsmodellar representative for norske bustadblokker. Bygningsmodellane omfatta åtte aldersgrupper og tre ulike energistandardar. Vi utførte simuleringane ved to ulike dimensjonerande temperaturnivå for radiatorane som er typiske for norske bygningar: 80/60 og 60/40 °C.

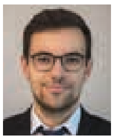
Vi fann ut at det er mogleg å redusere turtemperaturen til radiatorane frå 80 til 60 °C for bygningar nyare enn frå 1970, sjølv for ikkje-renoverte bygningar. For eldre bygningar er det tilstrekkeleg å utføre ein mellomliggande renovering, dvs. å oppgradere vindauga, for å halde innetemperaturen over det lågaste akseptable nivået på 19 °C. Vi tilråder likevel å utføre ein meir ambisiøs renovering for desse bygningane for å redusere talet på timar med betydeleg redusert innetemperatur i forhold til settpunkttemperaturen på 22 °C. I tillegg til å redusere oppvarmingsbehovet og dermed føre til energisparing, vil dette også sikre at bebuarane er nøgd med deira termiske miljø.

Resultata kan brukast av fjernvarmeleverandørar, byggeigarar, entreprenørar og konsulentfirma for å vurdere introduksjonen av fjerde generasjons fjernvarme i norske bustadblokker. Modellane og Excel-ark med resultat inkl. timesverdiar for energibehov er tilgjengelege for partnarar og forskarar innan FME ZEN, slik at dei og kan brukast til andre føremål.

Basert på ZEN rapport av Øystein Rønneseth og Igor Satori (2018) "Possibilities for supplying Norwegian apartment blocks with 4th generation district heating." ZEN Report 8.

Øystein ved radiatoren i ZEB Living Lab. Foto: Thomas Klungland.

Local energy system investment optimization within a larger system



Dimitri Pinel
PhD candidate ZEN,
NTNU

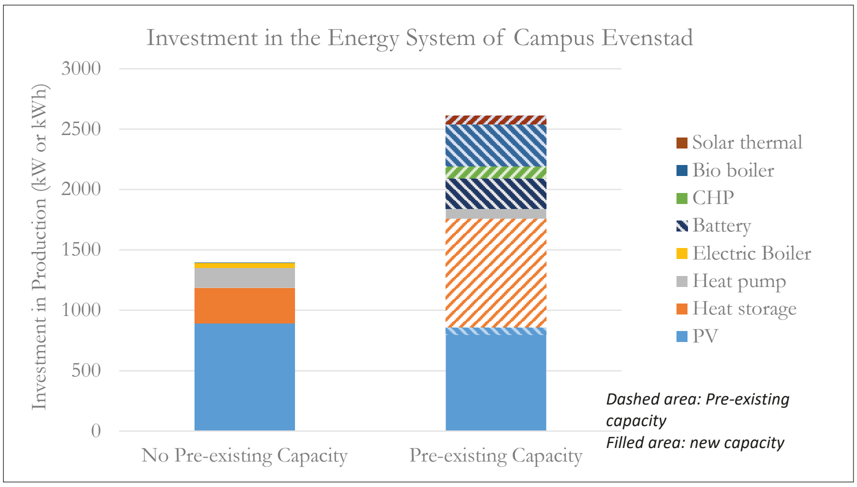
An energy system investment optimization model has been applied to look at what is necessary for a neighborhood to become a ZEN in different scenarios. This research has been presented in three publications in 2018. In one article [1], focusing on presenting the optimization model used, it was shown that in order for Campus Evenstad to become a ZEN, it is necessary to invest in a combination of an electric boiler, heat pumps, and a PV system. The highest share of the investment would be the PV system, with a size of about 800kW. Refurbishment was not studied even though it may reduce the overall investment. The economic optimum with refurbishment remains uncertain.

It was also found that, in the case of Campus Evenstad, the additional investment in the energy system was made in the same technologies whether you included the sustainable technologies already installed there or not. There are 2 cases in the study, one considers the technologies of the energy system already existing today at Evenstad while the other was greenfield investment. In the case of greenfield investment the invested capacity for the heat pump is 200 kW. In the case where the pre-existing capacity is considered, the invested capacity in the heat pump is 70kW [1].

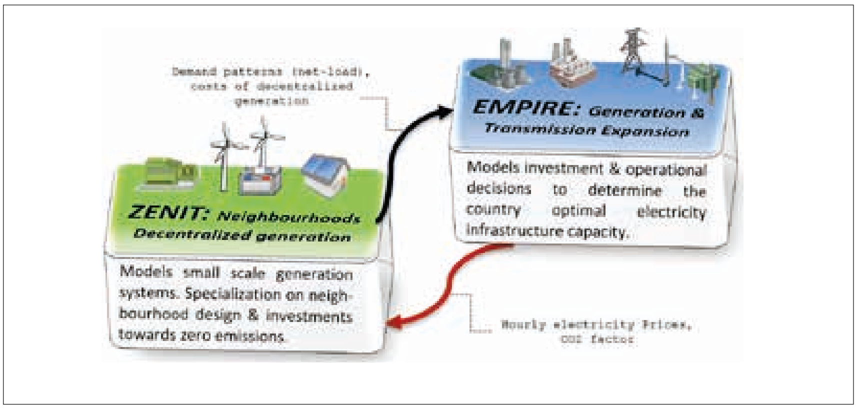
Further analysis on Campus Evenstad was performed for a Memo on local energy supply [2]. The study looked into the difference in investments with different ambition levels and highlighted once more the impact of the definition of the CO_2 factors of electricity. In addition, it also studied the impact of regulatory limitations of electricity exports.

Under export limitations, a large investment in batteries is chosen by the optimization model. This increases the cost (from 4 100k€ to 5 807k€), but it also reduces the emissions (by around 40%) and the dependence on the grid and increases the self-consumption. The new regulatory framework is thus making it cheaper to reach the Zero Emission criteria.

The possibility of studying the future investments in ZEN at the European level in a capacity investment model by soft-linking two models with different spatial resolutions [3] was also validated. This was done in a collaboration with Working Package 2.



Difference in the Energy System Investments for Campus Evenstad to be a ZEN



Principle of the soft-linking performed in [3].

Optimalisering av investeringer i lokale energisystemer innenfor et større system

For å undersøke hva som er nødvendig for at et nabolag skal bli et ZEN har vi brukt en modell for energisystemoptimalisering. Denne forskningen har blitt presentert i tre publikasjoner i løpet av 2018. En av artiklene [1] presenterer denne optimaliseringsmodellen og viser at Campus Evenstad må investere i en kombinasjon av elektrisk kjele, varmepumper og et PV system for å bli et ZEN. Den største andelen av investeringene vil være PV systemet, som bør kunne levere rundt 800 kW. Renovering ble ikke undersøkt, selv om det kan redusere den totale investeringen. Det er altså fortsatt usikkert om renovering er økonomisk optimalt.

Det ble også funnet at i Campus Evenstad-caset ble det investert i de samme nye teknologiene enten man tok hensyn til de som allerede var installert der eller ikke. Størrelsen på investeringen var imidlertid varierende. Ved å ta hensyn til de eksisterende enhetene reduseres for eksempel behovet for nye varmepumper fra 200 kW til 70 kW [1].

Videre ble det gjort en mer omfattende analyse av lokal energiforsyning på Campus Evenstad [2]. Studien så på forskjellen i investeringer med ulike ambisjonsnivåer og viste igjen hvor stor virkning valget av CO_2-faktor for elektrisitet har. I tillegg ble også virkningen av regulatoriske begrensninger for eksport av elektrisitet studert.

Under eksportbegrensninger ble en stor investering i batterier valgt av optimaliseringen, noe som øker totalkostnaden (fra 4 100k € til 5 807k €). Det reduserer imidlertid utslippene (ca. 40%) og avhengigheten av nettet, og øker egenforbruket av lokal produsert strøm. Det nye regelverket gjør det altså billigere å nå nullutslippskriteriene for bygg og nabolag.

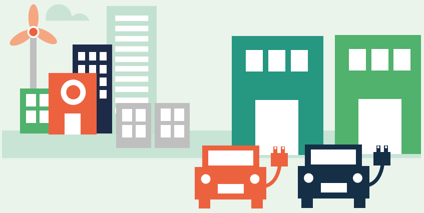
Vi demonstrerte også hvordan man kan koble en lokal modell og en Europeisk modell for å studere hvordan fremtidige investeringer i ZEN påvirker det europeiske energisystemet og vice versa [3]. Dette ble gjort i samarbeid med arbeidspakke 2.

Referanser

[1] "Cost Optimal Design of ZENs Energy System: Model Presentation and Case Study on Evenstad," av Dimitri Pinel, Magnus Korpås, Karen B. Lindberg. Presentert ved ISESO, 2018, skal publiseres som konferanseartikkel.

[2] "Consequences of local energy supply in Norway: A case study on ZEN pilot Campus Evenstad," av Stian Backe, Åse L. Sørensen, Dimitri Pinel, John Clauß, Carine Lausselet og Ruth Woods. Sendt til publisering.

[3] "Towards Zero Emission Neighborhoods: Implications for the Power System," av Stian Backe, Dimitri Pinel, Pedro Crespo Del Granado, Magnus Korpås, Asgeir Tomasgard og Karen Byskov Lindberg. Presentert ved 15th International Conference on the European Energy Market, 2018.



Låven på Evenstad. Foto: Tove Lauluten.

Zero energy concept on a neighbourhood level: Advantages and challenges

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In the future we can expect buildings to become a more integrated and active part of the power system. My research considers how regulations, taxes and tariffs should be designed in a way that facilitates decentralized decisions that are also system optimal.

Buildings are responsible for a significant part of the total primary energy consumption in EU. To reduce the amount of energy required by buildings, the European Union has set ambitious targets through the energy performance of buildings directives (EPBD), most recently in a revised version in 2018 [1]. Among other things, the EPBD promotes development of cost effective nearly zero energy buildings (NZEBs) by 2020. Although the exact definition of NZEB is not clearly defined, and each EU member state has some flexibility when making national definitions, developing NZEBs in the building sector means that we move from focusing on reducing energy needs towards also generating energy at the distributed level to accommodate increasingly ambitious targets.

The concept of zero energy can also be considered at other scales than individual buildings, for example neighbourhood or city levels. By extending the system boundary to several buildings it is possible to obtain additional benefits compared to considering individual buildings separately. In my PhD-project I am researching how to properly design regulatory conditions and market mechanisms for coupling zero energy neighbourhoods (ZEN) to the rest of the power system. In contrast to a system optimization where one assumes that all decisions are controllable directly, my research has an agent-based approach to allow for several stakeholders pursuing their individual objectives. This approach is relevant for ZEN where more than one stakeholder is involved, for example if there are several owners of different buildings in a ZEN neighbourhood, allowing for assessments of various market mechanisms and regulatory conditions together.

The concept of ZEN facilitates investments that are not available for individual buildings, such as central solar plants [2]. To realize such projects, it is necessary to create a form of cooperation across several owners within the same ZEN. In this context, my research considers how a ZEN with a number of owners can efficiently utilize and share such resources and how we can incentivize the individual owners to participate in projects that are beneficial for the community.

Nullenergikonseptet på nabolagsnivå: Gevinster og utfordringer

I fremtiden kan vi forvente at bygninger spiller en mer aktiv rolle i energisystemet. I min forskning ser jeg på hvordan forskrifter, skatter og tariffer bør designes for å tilrettelegge for desentraliserte avgjørelser som er optimale for energisystemet.

Bygninger står for en betydelig andel av primærenergibruken i EU. For å redusere energibruken i bygg har EU satt ambisiøse mål gjennom bygningsenergidirektivet (EPBD), som sist ble revidert i 2018 [1]. EPBD promoterer blant annet en utvikling mot kostnadseffektive nær nullenergi bygninger (NZEB) innen 2020. Selv om den eksakte definisjonen av NZEB ikke er tydelig definert, og hvert medlemsland i EU har noe fleksibilitet når de skal lage nasjonale definisjoner, så betyr utviklingen mot NZEB i bygningssektoren at vi går fra å fokusere på å redusere energibruken i bygninger til å også produsere energi på lavspenningsnettet for å tilfredsstille skjerpede krav.

Konseptet nullutslipp kan også gjelde for andre nivåer enn enkeltbygg, for eksempel nabolag eller bynivå. Ved å utvide systemgrensen til flere bygninger så er det mulig å realisere gevinster som ikke er tilgjengelige for enkeltbygg. I doktorgraden min ser jeg på hvordan man bør utforme regulatoriske rammevilkår og markedsmekanismer for å koble sammen nullutslippsnabolag (ZEN) med resten av kraftsystemet. I motsetning til en systemoptimering hvor man antar at man kontrollerer alle beslutninger direkte så er forskningen min aktørbasert for å kunne se på samhandling mellom ulike aktører i et ZEN. Denne tilnærmingen er relevant for ZEN med flere aktører involvert, for eksempel hvis vi har flere bygninger med ulike eiere. Det muliggjør analyser av ulike markedsmekanismer og regulatoriske rammevilkår.

ZEN konseptet muliggjør investeringer som ikke er tilgjengelige for enkeltbygg, som sentrale solanlegg [2]. For å realisere slike prosjekter er det nødvendig å få til et samarbeid på tvers av ulike eiere innad i samme ZEN. I forskningen min ser jeg på hvordan et ZEN med ulike eiere kan utnytte og dele slike ressurser effektivt, og hvordan vi kan få enkeltaktører til å delta i prosjekter som er fordelaktige for samfunnet.

Gløshaugen campus in the background.
Photo: Thomas Klungland.

Referanser:

[1] European Commission, "Directive (EU) 2018/844," *Off. J. Eur. Union*, 2018.

[2] J. Burch, J. Woods, E. Kozubal, and A. Boranian, "Zero energy communities with central solar plants using liquid desiccants and local storage," *Energy Procedia*, vol. 30, pp. 55–64, 2012.

What is a ZEN living lab?

Thomas Berker, Professor, NTNU
Ruth Woods, Postdoctoral Fellow, ZEN, NTNU

In the context of sustainable urban planning, since the early 2000s living labs have become a widely used tool to involve citizens in the shaping of their cities and neighbourhoods.

In line with this international state of the art, the FME Research Centre on Zero Emission Neighbourhoods in Smart Cities (ZEN) has chosen living labs to secure user engagement and to organise user involvement in pilot projects. To respond to the specific demands and conditions encountered in ZEN pilot areas, the ZEN Centre has developed its own tailored concept, which clarifies the difference between our application of the term and the use of the living lab concept outside ZEN. The ZEN concept also enables others to follow the same steps.

A ZEN living lab includes a number of aspects. Firstly, representatives from different user groups affected by the sustainable neighbourhood transition proposed by ZEN should be included. A clearly defined geographical place is also required. In ZEN, this is supplied by pilot projects. In addition, a ZEN living lab should include a number of repeatable activities, be primarily qualitative, and include methods such as interviews, workshops, and participant observation. The final aspect that is included is an experiment arising from information supplied by the aforementioned qualitative activities. An experiment tests ideas, based on challenges, technology, and needs, supplied by the neighbourhood.

The ZEN living lab concept has been applied at Campus Evenstad. Most users groups on campus have no relation to or knowledge of the technical systems used to achieve zero emissions. A series of workshops with different user groups were conducted, and this resulted in an experiment in July 2018 that tested low-tech solutions to reducing energy use on campus. The experiment took place in collaboration with facility managers and a group of Evenstad employees who have office space in the old administration building. Follow-up interviews and discussions took place in November 2018. The experiment enabled us to highlight the changes taking place on campus for different user groups. It also offered insight into a particular social and technical context, one that is not always high-tech and that can be a challenge to the technical ambitions, indicating potential hindrances to transference of similar technical solutions to other locations.

Campus Evenstad. Photo: Fellesfilm, Statsbygg.

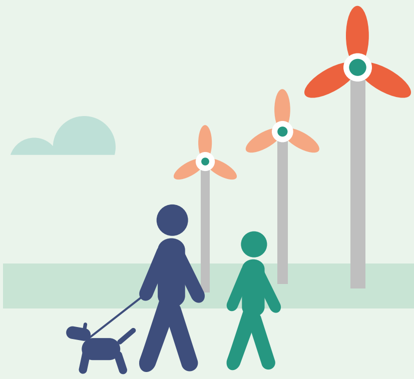
Hva er en ZEN living lab?

Siden tidlig 2000-tallet har «living labs», eller «levende laboratorier», blitt et populært verktøy for å oppnå brukermedvirkning i bærekraftig teknologi- og byutvikling.

I tråd med denne internasjonale trenden har Forskningssenter for nullutslippsområder i smarte byer (FME ZEN) valgt «living labs» som et format for å involvere brukerne og sikre brukerengasjement i senterets pilotprosjekter. ZEN senteret utviklet et eget skreddersydd konsept som tydeliggjør forskjellen mellom bruken av begrepet i og utenfor ZEN. Dette er for å imøtekomme spesifikke krav og forhold som oppstår i pilotområdene. ZEN konseptet gjør det også mulig for andre å følge de samme stegene.

En ZEN living lab inneholder en rekke aspekter. For det første bør representanter fra ulike brukergrupper som er berørt av bærekraftige endringer foreslått av ZEN inkluderes. Det er også viktig med et klart geografisk definert område. I ZEN er dette representert av pilotprosjekter. I tillegg bør en ZEN living lab gjennomføre en rekke repeterbare, kvalitative aktiviteter som inkluderer metoder som intervjuer, workshops og deltakende observasjon. Det siste aspektet som inngår i en ZEN living lab er et eksperiment basert på informasjon fra de nevnte kvalitative aktivitetene. Et slikt eksperiment tester idéer basert på utfordringer, teknologi og behov som belyses i pilotprosjektet.

ZEN living lab-konseptet har blitt gjennomført på Campus Evenstad. De fleste brukergruppene på campus har lite eller ingen kunnskap om de tekniske systemene som brukes for å oppnå nullutslipp. En rekke workshops med ulike brukergrupper ble gjennomført og dette resulterte i et eksperiment i juli 2018. Eksperimentet testet lavteknologiske løsninger for å redusere energibruk på campus. Forsøket foregikk i samarbeid med driftspersonellet og en gruppe Evenstad ansatte som hadde kontorer i den gamle administrasjonsbygningen. Oppfølgingsintervjuer og diskusjoner fant sted i november 2018. Eksperimentet synliggjorde endringene som foregår på campus for ulike brukergrupper og gav oss innsikt i en sosial og teknisk kontekst som ikke alltid er høyteknologisk. Denne konteksten kan utfordre tekniske ambisjoner og indikerer hindringer som kan oppstå når lignende tekniske løsninger tas i bruk andre steder.



Folk på Gløshaugen. Foto: Thomas Klungland.

ZEN arrives at Fornebu

Lars Einar Teien
Project Developer,
Bærum Municipality

Petter Haug Sandbu
Head of Department,
Bærum Municipality

Katinka Sætersdal Remøe
Communication Advisor,
ZEN

Fornebu in Bærum Municipality is the latest addition to ZEN's pilot projects. Fornebu will strive to be a zero emission neighbourhood from 2027, with climate-friendly buildings, fossil-free transport solutions, and multi-functional urban structures. These are ambitious goals requiring the best professional competence in the field. Being a ZEN pilot project will help to achieve just that.

Becoming a zero emission society was already politically anchored in Bærum Municipality when ZEN entered the picture. Since the Paris agreement in 2015, the political will to achieve zero emissions has been strong in the municipality, reflected by the establishment of a separate climate panel for Bærum municipality. The "Climate Strategy 2030" from 2018, further clarified the municipality's emphasis on CO_2 reductions. One of the main goals of the strategy is to make Bærum Municipality a zero-emission society by 2050. Fornebu was declared a test area for zero emissions, with the goal that buildings and the surrounding urban structure should be neutral regarding emissions during their lifetime from 2027.

The ambitious goals of the Fornebu project has raised many new questions. How do you define a zero emission area? How is zero emission to be measured and followed up to ensure a positive change? Help from a strong research environment became crucial, and in the spring of 2018 the area was declared a ZEN pilot project.

By being a ZEN pilot project, Bærum Municipality wishes to develop a concrete understanding of a "zero emission neighbourhood" in order to communicate this clearly internally, to the population, and to political bodies. A ZEN collaboration will help the municipality to develop strong competence within the field and provide an arena for exchanging experiences and knowledge. ZEN is also needed to develop good indicators and assessment tools.

The pilot projects at Fornebu are in two different phases: Oksenøya is already designed and will soon enter the construction phase. The focus is on innovative solutions for sustainable buildings and transportation. The old control tower, on the other hand, is still in the planning phase. Here, new methods for planning and concept development will lay the foundations for a neighborhood that is attractive for people to live in, where it is easy to make environmentally friendly choices. These are exciting times, and Bærum Municipality is very happy to be on the ZEN team.

Fornebu. Photo: Wilhelm Andersen, Wikimedia Commons.

ZEN lander på Fornebu

Fornebuområdet i Bærum kommune er det nyeste tilskuddet til ZENs pilotprosjekter. Området skal jobbe mot å være et nullutslippsområde fra 2027, med klimavennlige bygg, fossilfrie transportløsninger og flerfunksjonelle bystrukturer. Dette er ambisiøse mål som krever den beste fagkompetansen på området. Å være pilotprosjekt i ZEN hjelper kommunen med nettopp dette.

Ambisjonen om Bærum kommune som et nullutslippssamfunn var allerede politisk forankret da ZEN kom inn i bildet. Helt siden Parisavtalen ble vedtatt i 2015 har det vært sterk politisk vilje til null utslipp i kommunen, noe som reflekteres gjennom etablering av et eget klimapanel for Bærum kommune. Med rådmannens «Klimastrategi 2030» i 2018 ble dette ytterligere konkretisert. Et av hovedmålene i strategien er å gjøre Bærum kommune til et nullutslippssamfunn innen 2050. Fornebu ble erklært testområde for null utslipp, med mål om at bygg og bystruktur skal være utslippsnøytrale gjennom sin levetid fra 2027.

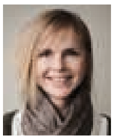
Fornebuprosjektets ambisiøse mål fikk mange nye spørsmål opp til overflaten. Hva legger man egentlig i et nullutslippsområde? Hvilke måleindikatorer brukes og hvordan skal prosjektet følges opp slik at kommunen forsikrer seg om at de gjør en forskjell? Å ha med sterke forskningsmiljø som et tiltak ble avgjørende, og våren 2018 ble området erklært pilotprosjekt i ZEN.

Ved å være konsortiedeltager i ZEN ønsker Bærum kommune konkretisere forståelsen av «nullutslippsområde» slik at dette kan kommuniseres tydelig internt, overfor befolkningen, og for politiske organer. Å utvikle høy kompetanse på fagområdet er et av hovedmålene, og da er et ZEN-samarbeid helt sentralt. ZEN trengs for å utvikle gode indikatorer og vurderingsverktøy som kan måle en positiv retning. Kommunen ser også samarbeidet i ZEN som en arena for å utveksle erfaringer og kunnskap om gode løsninger og brukerinvolvering.

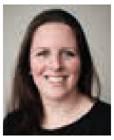
Pilotprosjektene på Fornebu er i to helt ulike faser: Oksenøya er prosjektert og står foran en byggefase med fokus på innovasjon på bærekraftige bygg og transportløsninger. Flytårnet er et stort planområde der nye metoder for planlegging og konseptutvikling skal legge grunnlaget for et nabolag der det er attraktivt for folk å bo og lett å ta miljøvennlige valg. Dette er spennende tider, og Bærum kommune er svært glad for å være med på ZEN-laget.

Fornebuparken. Foto: Dokospar, Wikimedia Commons.

FROM IDEA TO INNOVATION



Ann Kristin Kvellheim
Senior Adviser,
SINTEF



Anne Nuijten
Innovation Manager,
ZEN, NTNU

Starting from 2018 there has been an increased focus on innovation in ZEN. The ZEN Board approved our first innovation strategy, which states that open innovation is important in ZEN. Openness provides better opportunities for learning and disseminating ideas developed by the centre and will help to speed up the process towards a zero-emission society. The pilot projects in ZEN are our most important innovation arenas. They are places where researchers and partners meet, work together and where innovations are tested and demonstrated. Showing the rest of the world what we have achieved also helps to lower the threshold for the development and application of new ideas.

Applying and utilizing new technological opportunities is important for the level of innovation in ZEN. We therefore organized an open seminar on artificial intelligence at Dokkhuset in Trondheim, where different approaches were used to look into possible areas of application and relevance for ZEN. This will be followed up with other events focusing on new technological opportunities.

An analysis of the effect of energy research was done together with the other FMEs and completed in the autumn, 2018. Each center identified a number of different innovations where the impact and potential was described and, where possible, quantified. This exercise showed that our ability to influence the market, and in particular the regulatory authority, is of great importance.

In ZEN, we have worked to create a common understanding and culture for innovation. We will follow up ideas with an innovation potential from an early stage and are working on a method to identify and register innovations. We are also in the process of defining success criteria for innovation. This work will continue in 2019.

At the beginning of 2019, we have strengthened the team with the appointment of an innovation manager. In 2019, ZEN will coordinate an innovation leader forum across all the FMEs. We have many common challenges and expect to achieve more in cooperation with like-minded people. We look forward to a new innovative year!

Photo: Thomas Klungland.


Bodø ©Bodø Municipality


Furuset ©Oslo Municipality


Steinkjer ©Steinkjer-Avisa


Campus Evenstad ©Statsbygg


NTNU Campus ©Koht Architects


Ydalir ©tegn_3


Zero Village Bergen ©Snøhetta


Fornebu ©Wilhelm Andersen, Wikimedia Commons.


Sluppen ©R.Kjeldsberg

Nine ZEN pilot projects act as innovation hubs and a testing ground for the solutions developed in the ZEN Research Centre.

COLLABORATION AMONG OUR PARTNERS

The ZEN Centre has a number of regular activities designed to involve and actively follow up all of the ZEN partners; these include the general assembly, ZEN partner seminar, lunch lectures, and the biannual conference, which was organised in Oslo in April 2018. In addition, in 2018, the ZEN Centre has organised twelve workshops/seminars with partners, and WP 3 has organised a series of six meetings tailor-made for partner requirements. Another important activity was the workshop collaboration with Skanska that resulted in the Smart by Powerhouse guide.

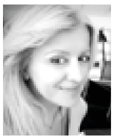
Site visit at Heimdal High School. Partner seminar October 2018. Photo: Spesiellise Foto & Design.

ZEN PARTNER WORKSHOPS AND SEMINARS IN 2018

Work package (WP)	Topics of the workshop/seminar	Date, place
Joint	ZEN general assembly	16.04.2018, Oslo
Joint	ZEN conference	17.04.2018, Oslo
Joint	19 lunch lectures	All year, Trondheim + Skype
Joint	ZEN partner seminar	24-25.10.18, Trondheim
WP 1	PI-Sec seminar in collaboration with ZEN	10.01.2018, Trondheim
WP 1	Gemini IoT Center Seminar	20.06.2018, Trondheim
WP 1	Bylab sesjon i ISOCARP konferansen om problemstillinger i brukerinvolvering i ZEN	01.10.2018, Bodø
WP 1	Meeting with Trondheim Kommune (Eiendom)	14.11.2018, Trondheim
WP 1 / LCA	ZEN LCA workshop	20.11.2018, Trondheim
WP 2/Innova-tion	"Muligheter og utfordringer når kunstig intelligens inntar byggebransjen"	20.09.18, Trondheim
WP 3	Meeting series with partners Caverion, Norcem, Hunton, Skanska	30.01.2018 Trondheim 13.03.2018 Trh/Lysaker skype (Norcem/Contiga) 09.04.2018 Trh/Gjøvik skype (Hunton) 12.04.2018 Trondheim, site-visit Kiwi Dalgård (Caverion) 31.08.2018 Trondheim/Oslo skype (Skanska) 20.11.2018 Trondheim
WP 3	Skanska Smart by Powerhouse, participation workshop on the smart building guide	31.08.2018 planning 04.09.2018 ws1 16.10.2018 ws2 19.11.2018 ws3 03.12.2018 ws4
WP 4	Partners workshop " Energy/Power flexibility indicators "	14.03.2018 Oslo
WP 6	ZEN living lab, Evenstad	05.03. 2018, Evenstad
WP 6	ZEN living lab, Evenstad	22-23.05.2018, Evenstad
WP 6	Workshop Ydalir	11.08.2018, Elverum

INTERNATIONALIZATION

Annemie Wyckmans
Professor
NTNU



Niki Gaitani
Project Manager,
ZEN

Arild Gustavsen
Professor & Centre Director,
ZEN

Internationalization is a success criterion for FME Centres. This includes active collaboration with in international research groups, participating in EU's framework programmes, and attracting international researchers to the centre.

The ZEN Centre has clearly articulated objectives for international cooperation. In 2018, the ZEN Centre initiated the work on an internationalization strategy. The main aims are to

- Jointly develop new projects and target corresponding funding opportunities;
- Participate in international fora to exchange knowledge and experience;
- Organize secondments and staff exchange among partners;
- Develop joint publications;
- Share laboratory infrastructure

Through these activities, the ZEN Centre aims to strengthen its existing, and create new networks with international partners from research, industry, public authorities, and citizen organisations to gain a competitive position in Nordic, European and global society and markets.

The ultimate goal is to strengthen the international recognition and the quality and relevance of the ZEN Centre's activities in research, development, and innovation.

One of the first internationalization actions in 2018 was the selection of an International Scientific Committee:

- Steve Selkowitz, Lawrence Berkeley National Laboratory, USA
- Eva Heiskanen, University of Helsinki, Finland
- Lieve Helsen, KU Leuven, Belgium
- Kristina Mjörnell, RISE, Sweden

Furthermore, an Adjunct Professor has been appointed (Henrik Madsen, DTU) and more are to follow.

ZEN researchers have joined several EU proposals and coordinated one proposal in 2018 (LC-SC3-RES-8-2019: Combining renewable technologies for a renewable district heating and/or cooling system, Deadline 11.12.2018)

The ZEN Research Centre has participated in several conferences and EU 2020 events to obtain higher visibility for its research activities, e.g.:

- Keynote speaker at Towards Low Carbon Cities Conference 21 May 2018 in Helsinki
- Invited speaker at the conference on 'Livability & Affordability in the Digitized City', organized by Housing Europe, 7 June 2018 in Tallinn

ZEN further organized a seminar at the European Parliament 27 June 2018, titled Accelerating the clean energy transition: The strategic contribution of zero emission buildings and neighborhoods. The event was organized as part of the Sustainable Energy Week (EUSW), an initiative of the European Commission.

The ZEN Centre has in addition been asked to be the Norwegian advisor to the SET-Plan Action 3.2 on Smart Cities and Communities, aiming to create 100 Positive Energy Districts by 2025. This effort comes in addition to the development of a Research and Innovation programme, coordinated by the NTNU-led Joint Programme on Smart Cities within the European Energy Research Alliance (EERA JP Smart Cities). In order to support this effort and the connection to the ZEN Centre, SINTEF became a full partner in EERA JP Smart Cities at the end of 2018.

In 2019, the ZEN Centre will continue these efforts to create close cooperation with research, public, and private sector partners in the Nordic region, Europe and globally based on shared challenges, societal values, and market opportunities.

AGENDA

16.00 OPENING SPEECH
Massimiliano Salini MEP, EPP Group

16.10 KEY NOTES

Current and future strategies for transforming the built environment in the European Union
Hans Van Steen, Advisor to the Director, DG ENER, DIR C: Renewables, Research and Innovation, Energy Efficiency

From zero emission buildings to zero emission neighbourhoods
Arild Gustavsen, Director, Research Centre on Zero Emission Buildings in Smart Cities, Norwegian University of Science and Technology (NTNU)

The importance of ICT technologies in the overall energy transition
Henrik Madsen, Director CITIES project, technical University of Denmark (DTU)

Densification through new energy plus buildings for NZE urban contexts
Giovanni Semprini, University of Bologna (UNIBO)

Future R&I developments and needs from the Construction sector
Alain Zarli, Secretary General, The European Construction Technology Platform (ECTP)

17.30 DEBATE with the speakers and open Q&A session
Moderator: Massimo Busuoli, Head of NTNU Brussels Office

#EUSEW18

LEAD THE CLEAN ENERGY TRANSITION

Agenda from the seminar at the European Parliament, June 27th 2018.

RESEARCHER TRAINING AND RECRUITMENT

Hans Martin Mathisen
Professor,
NTNU

Thomas Berker
Professor,
NTNU

At the end of 2018 14 PhDs and 3 postdocs were part of the ZEN Research Centre. i.e. they were funded directly or by in-kind by research partners. In addition, 12 other candidates were doing ZEN related research.

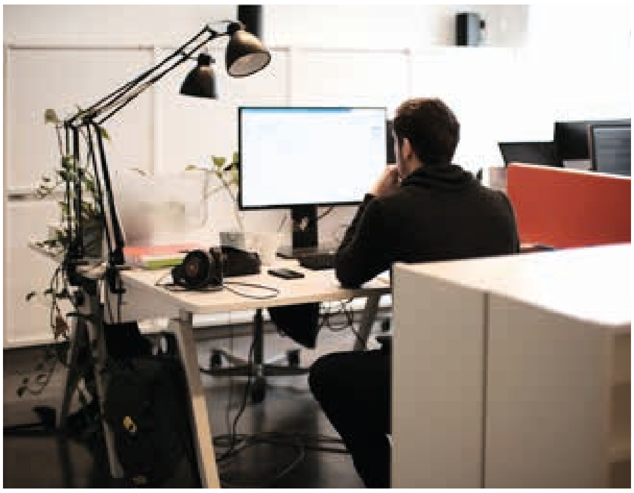
Many of these, and also researchers, have a need for advanced simulations methods. A course in Grey box modelling was therefore arranged in cooperation with Technical University of Denmark (DTU). The course constituted of two parts, one arranged at NTNU in April with the title *"ZEN course in Time Series Analysis - with a focus on Modelling and Forecasting in Energy Systems"*, with 27 participants. The second part was arranged as an international summer school in August at DTU, with 32 participants from nine countries. Henrik Madsen from DTU, who is engaged as adjunct professor by ZEN was responsible for the course.

In Spring 2018, the ZEN Centre conducted a PhD course for its PhD candidates, which was also attended by PhDs from other programs. Topics covered by the course reflected the Centre's interdisciplinary character. The 14 participants met and discussed with the Centre's work package leaders, visited the ZEN pilot in Evenstad and heard lectures for example about Swedish zero emission neighbourhoods, the history of modern urban planning, the European power system, responsible research and innovation (RRI), and sustainability transitions. More details on the course can be found here: https://kult-ntnu.github.io/ZEN-PhD-Course/

In addition, several master students have ZEN PhD candidates and postdocs as supervisors for their work. In the course *"Integrated Energy Design – Theory", within the Master program on Sustainable Architecture,* ZEN pilot projects have been used as cases for project exercises.

ZEN's PhD candidate Shabnam Homaei and her group win the Nordic Startup Award for their videogame about climate science at the annual Nordic Ideation Day in Trondheim. Photo: Climate KIC Nordic.

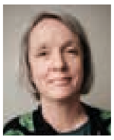
ZEN lunch lecture. Photo: Thomas Klungland.



ZEN landscape. Photo: Thomas Klungland.

COMMUNICATION IN THE ZEN RESEARCH CENTRE

Katinka Sætersdal Remøe
Communication Adviser,
ZEN



Ruth Woods
Postdoctoral Fellow
and Coordinator,
ZEN

The ZEN Research Centre has worked continuously with external and internal communication throughout 2018. There has been substantial media coverage in both technical journals and traditional press, 84 features in total. In addition to this, ZEN researchers and PhDs have published 12 blogposts, 10 scientific articles and 27 scientific reports. These publications can be found on the Centre's webpage **fmezen.no.** Also, **@fmeZEN** on Facebook and **@ZENcentre** on Twitter have been updated regularly with recent news, events, and publications.

We have continued already well-established and popular activities, such as our newsletter "ZEN Partnernytt" (Partners News), and ZEN researchers and PhDs have held twice monthly "lunch lectures" about their research in the ZEN lunchroom. We hope in the near future that the partners themselves will hold lunch lectures. These activities have been polished and improved where possible; for example, lectures are now accessible through Skype for ZEN's partners and others unable to join us at the ZEN Centre. The first ZEN Conference was held at Vulkan Arena in Oslo on April 17th, and in May we organized a course in communication for ZEN PhDs and Postdocs. We held our 2nd partner seminar in Trondheim 24.-25. October, where partners, researchers, PhDs, and postdocs were able to plan and exchange ideas for the year to come. We rounded off the year with a ZEN Christmas calendar, presenting the ZEN PhDs and their work. The calendar was disseminated as a digital newsletter to recipients of the ZEN Partnernytt, one for each day of December.

ZEN PhDs on the stage at the ZEN Conference.

ZEN partner seminar, Trondheim, October 2018.

ZEN Christmas calendar 2018.

COMMUNICATION ACTIVITIES IN 2018

29
Newsletter
«ZEN Partnernytt»

45
Scientific publications

53
Presentations

96
Media features

19
Lunch
lectures

Bærekraftige byer på programmet

Elverum satser grønt

Teknisk sett

5 spørsmål om energieffektive bygg

Camilla (3) tok det første spa'taket i Ydalir sammen med ordføreren

– Du må ikke ødelegge sandkaka da, Erik

Nå skal staten avgjøre Ådland-boligenes fremtid

Analyserer opplevd inneklima i bygningsteknisk laboratorium

– Vi planlegger fo

Smart miljø:

Overskuddslageret

Jakten på Den Grønne Diamanten: Å bygge smarte hus handler om mer enn teknologi, mener daglig leder i plusshus-samarbeidet Powerhouse.

TOBB-ZEN

Halverte strømforbruket med et enkelt, lavteknologisk grep

Hvordan kan man selv legge til rette for et energieffektivt hjem?

APPENDICES

PERSONELL

ZEN management team

Last name	First name	Position	Main research area	Institution
Bremvåg	Annika	Communication adviser & coordinator Maternity leave from Oct. 2018		FME ZEN
Gustavsen	Arild	Centre director / professor		NTNU
Jacobsen	Terje	Centre liaison / vice president research		SINTEF Byggforsk
Sætersdal Remøe	Katinka	Communication adviser Temporary from Oct. 2018		NTNU
Solberg Hopstad	Lasse	Project accounting		NTNU
Woods	Ruth	Centre coordinator / postdoc WP6 Temporary from Oct. 2018		NTNU

Work package leaders

Last name	First name	Position	Main research area	Institution
Wyckmans	Annemie	WP1 Leader (until 15 March 2018, then international coordinator) / professor	WP1	NTNU
Brattebø	Helge	WP1 Leader from 15 March 2018 / LCA Coordination / professor	WP1	NTNU
Tomasgard	Asgeir	WP2 Leader / professor On leave second half 2018	WP2	NTNU
Kvellheim	Ann Kristin	WP2 leader / Senior adviser Temporary second half 2018	WP 2	SINTEF Byggforsk
Thomsen	Judith	WP3 Leader / research manager	WP3	SINTEF Byggforsk
Sartori	Igor	WP4 Leader / senior research scientist	WP4	SINTEF Byggforsk
Wolfgang	Ove	WP5 Leader / research scientist	WP5	SINTEF Energi
Andresen	Inger	WP6 Leader / professor	WP6	NTNU

Key researchers

Last name	First name	Position	Main research area	Institution
Ahcin	Peter	Research scientist	WP2	SINTEF Energi
Houman Andersen	Poul	Professor	WP2	NTNU & Aalborg University
Andersen	Tuva	Communication		NTNU
Baer	Daniela	Research scientist	WP1	SINTEF Byggforsk
Bergsdal	Håvard	Senior research scientist	WP1&3	SINTEF Byggforsk
Berker	Thomas	Living lab coordination / professor	WP6	NTNU
Bø	Lars Arne	Senior adviser	WP1	SINTEF Byggforsk
Cao	Guangyu	Professor	WP3	NTNU
Carlucci	Salvatore	Professor	WP3&4	NTNU
Farahmand	Hossein	Associate professor	WP5	NTNU
Mamo Fufa	Selamawit	Research scientist	WP1&6	SINTEF Byggforsk
Gaitani	Niki	Project Manager, ZEN		NTNU
Goia	Francesco	Associate professor	WP3	NTNU
Graabak	Ingeborg	Research scientist	WP5	SINTEF Energi
Gullbrekken	Lars	Research scientist	WP4	SINTEF Byggforsk
Grynning	Steinar	Research Manager	WP3	SINTEF Byggforsk
Hamdy	Mohamed	Associate professor	WP3&4	NTNU

Hestnes	Anne Grete	Senior scientific adviser/ Professor		NTNU
Holmen	Elsebeth	Professor	WP2	NTNU
Holøs	Sverre	Senior research scientist	WP3	SINTEF Byggforsk
Laura Pauliina Kauko	Hanne	Research scientist	WP5	SINTEF Energi
Lorentzen Kolstad	Magne	Research scientist	WP5	SINTEF Energi
Korpås	Magnus	Professor	WP5	NTNU
Kvellheim	Ann Kristin	Innovation coordination/ Senior adviser	WP2	SINTEF Byggforsk
Labonnote	Nathalie	Senior research scientist	WP3	SINTEF Byggforsk
Larssæther	Stig A.	Coordinator NTNU Sustainability	WP6	NTNU TSO Sustainability
Lindberg	Karen Byskov	Senior research scientist	WP4	SINTEF Byggforsk
Manum	Bendik	Professor	WP6	NTNU
Mathisen	Hans Martin	ZEN services coordination / professor	WP 3&4	NTNU
Nord	Natasa	Associate professor	WP4	NTNU
Nordström	Tobias	Research scientist	WP6	NTNU
Novakovic	Vojislav	Professor	WP3	NTNU
Nuijten	Anne	Innovation Manager		FME ZEN
Petersen	Idar	Research scientist	WP5	SINTEF Energi
Petersen	Sobah Abbas	ICT coordination / Associate professor	WP1	NTNU
Risholt	Birgit	Senior research scientist	WP3	SINTEF Byggforsk
Rønneseth	Øystein	Research scientist	WP3&4	SINTEF Byggforsk
Sandberg	Nina	Postdoc	WP1	NTNU
Skaar	Christofer	Senior research scientist	WP 3&6	SINTEF Byggforsk
Strømman	Anders	Professor	WP2	NTNU
Sørnes	Kari	Research scientist	WP3/4	SINTEF Byggforsk
Thunshelle	Kari	Senior research scientist	WP3/4	SINTEF Byggforsk
Taxt Walnum	Harald	Research scientist	WP4	SINTEF Byggforsk
Wiberg	Aoife	Associate professor	WP1	NTNU
Wiik	Marianne	Research scientist	WP1&6	SINTEF Byggforsk

OUR PHDS AND POSTDOCS

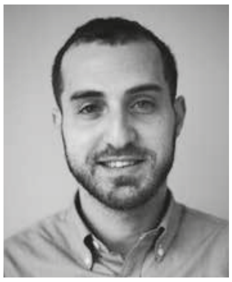
PhD candidates with financial support from the centre budget


Magnus Askeland
WP5, NTNU


Stian Backe
WP2, NTNU


Johannes Brozovsky
WP1&6, NTNU


Matteo Favero
WP4, NTNU


Hasan Ahmed Hamdan
WP2, NTNU


Shabnam Homaie
WP3, NTNU


Maria Justo Alonso,
WP3, NTNU


Carine Lausselet
WP1, NTNU

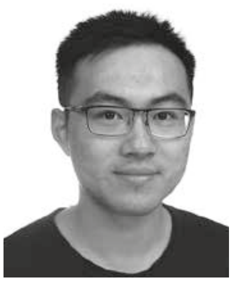

Dimitri Pinel
WP5, NTNU


Lillian Rokseth
WP6, NTNU


Daniel Satoła
WP3, NTNU


Kristian Skeie
WP3, NTNU


Åse Lekang Sørensen
WP6, NTNU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STATEMENT OF ACCOUNTS

FUNDING AND COSTS

Funding [1]	Amount	Total
The research Council		22 488
The Host institution (NTNU)		10 686
Research partners		
Sintef Energi		307
Sintef AS		7 648
Enterprise partners		8 224
ByBo AS	192	
AS Civitas	50	
Boligbyggelaget TOBB	554	
Caverion Norge AS	100	
Energi Norge AS	276	
ÅF Engineering AS	250	
Asplan viak	340	
GK Norge AS	571	
Hunton Fiber AS	752	
Moelven industrier ASA	328	
Norcem AS	461	
Norsk fjernvarme	697	
Snøhetta Oslo AS	303	
Sweco Norge AS	358	
Multiconsult ASA	200	
Skanska Norge AS	1 069	
Smart grid services cluster	-	
Elverum tomteselskap AS	1 579	
NTE Marked	146	
Public partners		5 108
FutureBuilt	99	
Bergen kommune	230	
Bodø kommune	343	
Bærum kommune	758	
Direktoratet for byggkvalitet	200	
Elverum kommune	150	
Norges vassdrag og energidirektorat (NVE)	221	
Oslo kommune - klimaetaten	583	
Statkraft varme AS	290	
Statsbygg	1 029	
Trondheim kommune	954	
Trøndelag fylkeskommune	250	
Steinkjer kommune	-	
Funding transfered to next year		- 5 829
Total		48 632

(1) The table shows the funding per partner (all figures in NOK 1000), both cash and in-kind. In-kind reported after this year's financial statements: Statkraft varme: 166 138,-, ByBo AS: 199 650,-, Bodø kommune: 69 300,-, Trøndelag fylkes-kommune: 271 950,-

Cost [2]	Amount	Total
The Host institution (NTNU)		19 879
Research partners		
Sintef Energi		2 231
Sintef AS		19 021
Enterprise partners		5 294
ByBo AS	42	
AS Civitas	-	
Boligbyggelaget TOBB	454	
Caverion Norge AS	-	
Energi Norge AS	126	
ÅF Engineering AS	-	
Asplan viak	140	
GK Norge AS	321	
Hunton Fiber AS	502	
Moelven industrier ASA	78	
Norcem AS	211	
Norsk fjernvarme	567	
Snøhetta Oslo AS	103	
Sweco Norge AS	158	
Multiconsult ASA	-	
Skanska Norge AS	969	
Smart grid services cluster	-	
Elverum tomteselskap AS	1 479	
NTE Marked	146	
Public partners		2 208
FutureBuilt	99	
Bergen kommune	30	
Bodø kommune	93	
Bærum kommune	258	
Direktoratet for byggkvalitet	-	
Elverum kommune	-	
Norges vassdrag og energidirektorat (NVE)	21	
Oslo kommune - klimaetaten	333	
Statkraft varme AS	40	
Statsbygg	629	
Trondheim kommune	704	
Trøndelag fylkeskommune	-	
Steinkjer kommune	-	
Total		48 632

(2) The table shows the cost per partner (all figures in NOK 1000), in-kind.

NB: We have distributed all costs from partners evenly throughout the six work packages.

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