Research Centre on
ZERO EMISSION
NEIGHBOURHOODS
IN SMART CITIES

NTNU SINTEF

ENERGY AND POWER IN YDALIR

Testing of Key Performance Indicators for energy and power in a ZEN pilot during the planning phase

ZEN REPORT No. 20 – 2020

Synne Krekling Lien and Christoffer Venås | SINTEF

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Preface

Acknowledgements

This report has been written within the Research Centre on Zero Emission Neighbourhoods in Smart Cities (FME ZEN). The author gratefully acknowledge the support from the Research Council of Norway, the Norwegian University of Science and Technology (NTNU), SINTEF, the municipalities of Oslo, Bergen, Trondheim, Bodø, Bærum, Elverum and Steinkjer, Trøndelag county, Norwegian Directorate for Public Construction and Property Management, Norwegian Water Resources and Energy Directorate, Norwegian Building Authority, ByBo, Elverum Tomteselskap, TOBB, Snøhetta, Asplan Viak, Multiconsult, Sweco, Civitas, FutureBuilt, Hunton, Moelven, Norcem, Skanska, GK, Caverion, Nord-Trøndelag Elektrisitetsverk - Energi, Smart Grid Services Cluster, Statkraft Varme, Energy Norway, Norsk Fjernvarme and AFRY.

The Research Centre on Zero Emission Neighbourhoods (ZEN) in Smart Cities

The ZEN Research Centre develops solutions for future buildings and neighbourhoods with no greenhouse gas emissions and thereby contributes to a low carbon society.

Researchers, municipalities, industry and governmental organizations work together in the ZEN Research Centre in order to plan, develop and run neighbourhoods with zero greenhouse gas emissions. The ZEN Centre has nine pilot projects spread over all of Norway that encompass an area of more than 1 million m2 and more than 30 000 inhabitants in total.

In order to achieve its high ambitions, the Centre will, together with its partners:

- Develop neighbourhood design and planning instruments while integrating science-based knowledge on greenhouse gas emissions;
- Create new business models, roles, and services that address the lack of flexibility towards markets and catalyze the development of innovations for a broader public use; This includes studies of political instruments and market design;
- Create cost effective and resource and energy efficient buildings by developing low carbon technologies and construction systems based on lifecycle design strategies;
- Develop technologies and solutions for the design and operation of energy flexible neighbourhoods;
- Develop a decision-support tool for optimizing local energy systems and their interaction with the larger system;
- Create and manage a series of neighbourhood-scale living labs, which will act as innovation hubs and a testing ground for the solutions developed in the ZEN Research Centre. The pilot projects are Furuset in Oslo, Fornebu in Bærum, Sluppen and Campus NTNU in Trondheim, an NRK-site in Steinkjer, Ydalir in Elverum, Campus Evenstad, NyBy Bodø, and Zero Village Bergen.

The ZEN Research Centre will last eight years (2017-2024), and the budget is approximately NOK 380 million, funded by the Research Council of Norway, the research partners NTNU and SINTEF, and the user partners from the private and public sector. The Norwegian University of Science and Technology (NTNU) is the host and leads the Centre together with SINTEF.

https://fmezen.no
@ZENcentre
FME ZEN (page)

Norwegian Summary

Beregning av nøkkelindikatorer for energi og effekt i Ydalir

Ydalir er et pilotområde i FME-ZEN. Området ligger nordøst for sentrum i Elverum. Høsten 2019 åpnet ny barneskole og barnehage i området, og det er i de kommende årene planlagt oppføring av om lag 700 boliger. Boligene planlegges og utbygges i flere trinn fram mot 2035. Det er ambisiøse energi og utslippsmål for området, og det er planlagt at byggene skal bygges etter passivhusstandard (NS3700/3701), forsynes med fjernvarme og produsere egen strøm ved hjelp av solcellepaneler.

Parallelt med planleggingen av selve Ydalirområdet, arbeides det i FME ZEN med en definisjon av nullutslippsområder (Zero Emission Neighbourhoods) og hvilke indikatorer som skal brukes for å måle oppnåelse av denne definisjonen i pilotområdene. Indikatorene som skal måle dette er delt inn i følgende kategorier: klimagassutslipp, energi, effekt, mobilitet, stedskvaliteter, økonomi og innovasjon (per høst 2019).

Det vil ha positive effekter på energibruk og energinettet å bygge Ydalir som et ZEN.

Formålet med denne rapporten er å teste ut indikatorene for energi og effekt på et ZEN pilotområde i planleggingsfasen. I rapporten gjøres det tidligfaseberegninger av de foreløpig foreslåtte indikatorene i kategoriene energi og effekt for Ydalir slik området er planlagt i dag. De samme indikatorene beregnes for Ydalir og i et referansescenario for hvordan Ydalir ville blitt utviklet dersom man kun fulgte dagens standard for områdeutvikling og minimumskravene i norsk lov.

Med metodene og antagelsene som er gjort i denne rapporten er det beregnet at netto energibehov reduseres med 27 %, at import av energi til området reduseres med 30 % og at kombinert topplast for elektrisitet og fjernvarme reduseres med 24%.

Analysen viser at det er et stort potensial for at energibehov, levert energi og utslipp knyttet til energibruk kan reduseres i Ydalirområdet, dersom utbyggingen skjer som planlagt, og bygges ut etter masterplanen samt at bruk av personbil avtar til fordel for kollektivtransport. Gjennom denne rapporten har nøkkelindikatorene (KPI) for energi og effekt som benyttes i ZEN blitt testet ut, og det viser at det er behov for å sette tydeligere systemgrenser, referansebaner og veiledende metodikk i ZENs videre arbeid med KPIene.

Involverte ZEN-partnere er SINTEF, Elverum Vekst og Elverum Kommune.

Ydalir skole (Elverum kommune).

English Summary

Calculation of Key Performance Indicators of Energy and Power in Ydalir

Ydalir is the name of a development area located northeast of the centre of Elverum. The area is one of the pilot areas in FME ZEN with ambitions of becoming a Zero Emission Neighbourhood (ZEN). At the end of the construction period the area will have a new school, a kindergarten, and about 700 residential units. There are high ambitions for the development of Ydalir. For Ydalir to fulfil the ZEN definition, it must be energy efficient, and the emissions from the area must be reduced. The emission reductions in Ydalir will be achieved through building according to the Norwegian passive house standard (NS 3700/NS3701), by using district heating, and by installing photovoltaic (PV) solar panels.

The development of the definition of a Zero Emission Neighbourhood (ZEN) and the development of assessment criteria and key performance indicators is an ongoing process that will last throughout the program period of FME ZEN. This work will enable an assessment of the performance of the ZEN pilot areas. Based on the draft for the ZEN definition, the assessment criteria and KPIs (per 2019) can be divided into the following categories: GHG Emissions, Energy, Power, Mobility, Spatial qualities, economy and innovation.

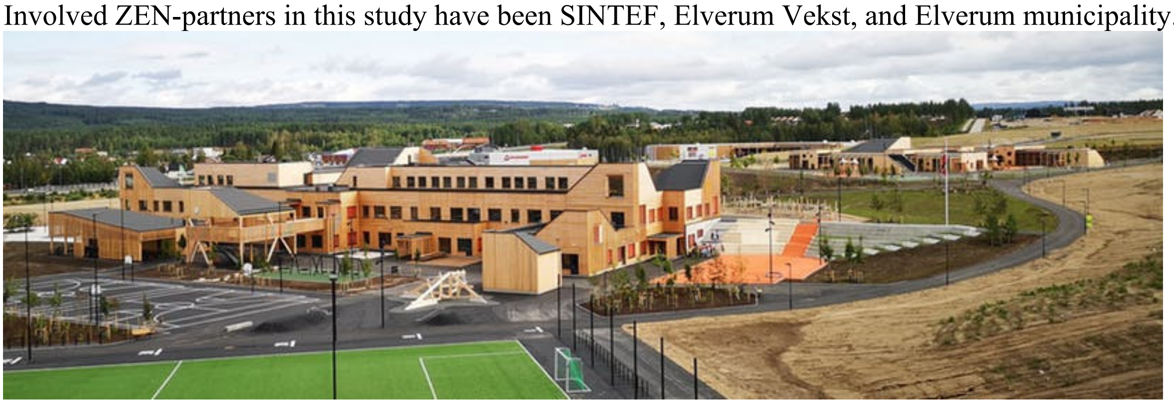
Constructing Ydalir as a ZEN will have positive impacts on energy consumption, the peak load, and the utilization of the local electricity grid.

The purpose of this report is to test the indicators on energy and power on a ZEN-pilot in the planning phase. The suggested energy KPIs and power KPIs have been tested for Ydalir for the year 2035. It is assumed that the area will be fully operational by this time. Two scenarios have been created for Ydalir, 2035: the first scenario represent the current expectations for the pilot area and is called the "ZEN Scenario". The second scenario represent the reference project, or the "Business as usual" (BAU) case for the development of Ydalir. This is called the "Baseline Scenario". The KPIs for Energy and Power have been calculated for Ydalir for both scenarios.

This analysis shows that the KPI net energy demand can be reduced by 27 %, the total import of energy can be reduced by 30%, and the combined peak load for electricity and heating can be reduced by 24% in the ZEN-scenario compared to the Baseline Scenario.

Annual energy use and emissions from the use phase can be significantly reduced if the development turns out as expected, if all developers follow the master plan, and if the use of transport by car is reduced as expected. The testing of the KPIs used in ZEN within the categories Energy and Power shows that there is a need for further work on system boundaries, the reference scenario, and finding standard methodologies.

Involved ZEN-partners in this study have been SINTEF, Elverum Vekst, and Elverum municipality.



Ydalir School (Elverum Municipality)

Contents

1. Introduction: The ZEN definition and Key Performance indicators

The goal of the Research Centre on Zero Emission Neighbourhoods in Smart Cities (FME ZEN) is to enable the transition to a low carbon society by developing sustainable neighbourhoods with zero greenhouse gas emissions (GHG).

The development of the definition of a Zero Emission Neighbourhood (ZEN) is an ongoing process that will last throughout the program period of FME ZEN. The following ZEN-definition was formulated for the first version of the ZEN definition report [1].

In the ZEN Research Centre, a neighbourhood is defined as a group of interconnected buildings with associated infrastructure[1)], located within a confined geographical area[2)]. A **zero emission neighbourhood** aims to reduce its direct and indirect **greenhouse gas (GHG) emissions** towards zero over the analysis period [3)], in line with a **chosen ambition level** with respect to which life cycle modules, buildings, and infrastructure elements to include[4)]. The neighbourhood should focus on the following, where the first five points have direct consequences for energy and emissions:

a. Plan, design, and operate buildings and their associated infrastructure components towards minimized life cycle **GHG emissions.**
b. Become highly **energy efficient** and powered by a high share of new renewable energy in the neighbourhood energy supply system.
c. Manage energy flows (within and between buildings) and exchanges with the surrounding energy system in a **flexible** way.[5)]
d. Promote **sustainable transport** patterns and smart mobility systems.
e. Plan, design, and operate with respect to **economic sustainability,** by minimising total life cycle costs and life cycle system costs.
f. Plan and locate amenities in the neighbourhood to provide good **spatial qualities** and stimulate **sustainable behavior.**
g. Development of the area is characterized by innovative processes based on new forms of cooperation between the involved partners leading to **innovative solutions.**

Footnotes:

1) Buildings can be of different types, e.g. new, existing, retrofitted or a combination. Infrastructure includes grids and technologies for supply, generation, storage and export of electricity and heat. Infrastructure may also include grids and technologies for water, sewage, waste, mobility, and ICT.
2) The area has a defined physical boundary to external grids (electricity and heat, and if included, water, sewage, waste, mobility, and ICT). However, the system boundary for analysis of energy facilities serving the neighbourhood is not necessarily the same as the geographical area.
3) The analysis period is normally 60 years into the future, assuming 60 years service life of buildings and 100 years service life of infrastructure and relevant service life for components that will be replaced.
4) The standard NS-EN 15978 "Sustainability of construction works - Assessment of environmental performance of buildings - Calculation method" and the proposed new standard NS 3720 "Methods for greenhouse gas calculations for buildings", defines a set of life cycle modules; material production (A1-A3), construction (A4-A5), operation (B1-B7 in NS-EN 15978 and B1-B8 in NS 3720), end-of-life (C1-C4), and benefits and loads beyond the system boundary (D). NS 3451 "Table of building elements" provides a structured nomenclature checklist of building elements which can be used to define the physical system boundary. A given zero emission neighbourhood should have a defined ambition level with respect to which of these life cycle modules to include, and which building and infrastructure elements to include. It is up to the owner of a ZEN project to decide such an ambition level, but this should be unambiguously defined according to the modulus principle of NS-EN 15978 and NS 3720. In the FME-ZEN Centre, further work is carried out to clarify what should be the recommended minimum ambition level for ZEN pilot projects. Further work is done to clarify how to calculate CO_2 emission gains from local renewable energy production, and the FME-ZEN does not currently bind to the method of emission calculations in NS-EN 15978 and NS 3720.Flexibility should facilitate the transition to a decarbonized energy system, low peak load capacity requirements in external grids and flexible energy exchanges with facilities in the surrounding area.
5) Flexibility should facilitate the transition to a decarbonized energy system and reduction of power and heat capacity requirements.

Pilot projects and reference projects

Pilot projects in FME ZEN are geographically limited areas in Norway where new solutions for the construction, operation and use of buildings and infrastructure are tested to cut the total greenhouse gas emissions towards zero on a neighbourhood level. Nine ZEN pilot areas are included in the ZEN Research Centre. These are: Ydalir (Elverum), Furuset (Oslo), Campus Evenstad, Mære (Steinkjer), NTNU Campus and Sluppen (Trondheim), Zero Village Bergen, Nyby (Bodø), and Fornebu (Bærum).

A reference project is a base case for comparison of the pilot areas. The reference projects represent the business-as-usual case for the pilot areas. The reference project will not use any measures in order to reach zero emissions, but follow the minimum requirements set in a business as usual (BAU) case. A representative reference project should be tailored to each pilot area, with the same floor area and number of users as the pilot area.

Key performance indicators for the categories Energy and Power

Different assessment criteria and key performance indicators are used to measure the performance of the ZEN pilot areas against the ZEN definition. Based on the draft of the ZEN definition[1], these assessment criteria and KPIs can be divided into the following categories: GHG emissions, energy, power, mobility, spatial qualities, economy, and innovation.

Assessment criteria are different aspects within a category that is important to assess the performance. They can be measured by one or more key performance indicators (KPIs). The KPIs are sets of quantifiable performance measurements that define sets of values based on measured data from a project.

In the first draft of the ZEN definition, the following assessment criteria and KPIs were considered as relevant to measure the performance of the ZEN pilots in the energy and power categories:

Assessment criteria and KPIs	**Unit**
Energy efficiency in buildings	**Annual totals**
- Net energy need	kWh/m²BRA
- Gross energy need	kWh/m² BRA
- Total energy need	kWh/m² BRA
Energy carriers	**Annual totals** **Monthly profiles**
- Energy use	kWh
- Energy generation	kWh
- Delivered energy	kWh
- Exported energy	kWh
- Self-consumption	%
- Self-generation	%
- Color coded carpet plot	kWh

Assessment criteria and KPIs	**Unit**
Power/load performance	Hourly values Yearly profiles
- Net load yearly profile	kW
- Net load duration curve	kW
- Peak load	kW
- Peak export	kW
- Utilization factor	%
Power/load flexibility	Hourly values Daily profiles
- Daily net load profile	kW

Figure 1 Suggested indicators for energy and power in 2018 [1]

The ZEN definition draft provides descriptions of system boundaries and methods for each of these indicators [1]. In parallel with the ongoing development of the ZEN definition and KPIs, a corresponding KPI tool is being developed. The purpose of this tool is to report and measure the KPIs for each of the pilot areas against their reference projects and against target values. The pilots will receive points within the KPI-tool based on how well they perform on the different indicators.

The initial energy and power KPIs suggested are all quantitative, but some of these KPIs cannot be directly compared to a reference project or a target. For example, hourly profiles for energy use and colour-coded carpet plots can graphically describe the energy flows to and from the area, but these KPIs consist of thousands of datapoints that make it challenging to compare them to the ZEN-target values.

In the early edition of the KPI tool for ZEN, it was proposed to distinguish between KPIs that can be compared directly against a target value and a reference project, and KPIs that are required as documentation of the pilot area. The following key indicators and documentation are those currently suggested for energy and power respectively at the time of writing of this report:

Table 1 Suggested KPIs and documentation for the Energy category in FME ZEN.

<table>
<tr><th>KPI ID</th><th>Assessment criteria</th><th>KPI evaluated against target</th><th>Required documentation</th></tr>
<tr><td>ENE2.1</td><td>Energy efficiency in buildings</td><td>Energy need (net energy demand in buildings)</td><td>Yearly net energy demand in buildings [kWh]</td></tr>
<tr><td>ENE2.2</td><td rowspan="2">Energy carriers</td><td>Delivered and exported energy (all energy carriers)</td><td rowspan="2">Yearly sum of energy use, local energy production, import of energy, export of energy for each energy carrier with the neighbourhood system boundary.

Hourly profiles for energy use, local energy production, import of energy, export of energy, colour coded carpet plots for electricity.

Hourly profiles for energy use/import and colour coded carpet plots for district heating and district cooling.</td></tr>
<tr><td>ENE2.3</td><td>Self-consumption and self-generation of electricity</td></tr>
</table>

Table 2 Suggested KPIs and documentation for the Energy category in FME ZEN.

KPI ID	Assessment criteria	KPI evaluated against target	Required documentation
POW3.1	Power performance	Peak load (for electricity, district heating and district cooling)	Hourly profiles for energy use, local energy production, import of energy, export of energy, colour coded carpet plots for electricity. Hourly profiles for energy use/import and colour coded carpet plots for district heating and district cooling.
POW3.2		Peak export (electricity)	
POW3.3		Utilisation factor (electricity, district heating and district cooling)	

The KPIs in the energy category include the total energy demand in the area covered by all energy carriers. The power KPI only looks at energy carriers that affect the surrounding energy system, namely electricity, district heating, and district cooling. Electricity can be exported from an area to the electricity grid today, but such arrangements are not common for the exchange of district heating and cooling. Export and production of district heating/cooling from the neighbourhood is hence not considered in a separate KPI at the current time.

The suggested KPIs are described more in depth in the following paragraphs.

ENE2.1 Net energy demand in buildings

Net energy demand in buildings is a measure of buildings' energy demand, where the losses in the buildings' heating distribution system as well as the losses in the energy system are ignored.

The annual net energy demand in buildings should be calculated for all buildings in the pilot area and in the reference project in kWh/m2 at the building level using the method defined in ISO 52000/SN-TS3031 [2], [3]. The energy demand could be reported per purpose and building category, but this is not required.

Points will be awarded within the KPI-tool based on the relative reduction of kWh/m2 in the pilot area compared to the reference area.

ENE2.2 Delivered and exported energy

Annual use, production, import and export of energy in the pilot area should be calculated per energy carrier. The system boundary for the calculation is the neighbourhood level. This includes buildings within the system boundary defined in SN-TS 3031, neighbourhood infrastructure (servers, streetlights, elevators, escalators, industrial processes within the buildings, and snow melting systems), and charging of electric vehicles.

The following must be documented for the pilot area and the reference project (either as measurements of calculations) as hourly profiles and annual sums in kWh:

Table 3 Documentation requirements for KPI ENE2.2

Energy use	Imported energy	Local energy production	Exported energy	Colour coded carpet plot
Electricity Oil (fossile) Gas (fossile) Biofuel1 (defined by user) Biofuel2 (defined by user) District heating District cooling	Electricity Oil (fossile) Gas (fossile) Biofuel1 (defined by user) Biofuel2 (defined by user) District heating District cooling	Electricity	Electricity	Electricity District heating District cooling

The temperature profile from SN-TS 3031 should be used when modelling the hourly profiles for energy demand and energy use for heating purposes.

Total delivered and exported energy is suggested as KPIs to be evaluated against a target value. The target value for this KPI has yet to be decided within ZEN.

ENE2.3 Self-consumption and Self-generation of electricity

Self-consumption and self-generation are factors that tell us about the mismatch between energy generated locally and energy used in the neighbourhood. The factors are best described by the figure below. Here, the areas A+C represent the energy produced in a building by PV-panels for every month over one year. B+C represent the energy use in the building. Area A represent the excess energy production that is not used directly in the building, C represent the overlap where the generated energy is used directly in the building, and B represent the energy demand in the building that must be covered through import of energy.

Self-consumption is defined as C/(A+C) for all hours of the year and describe the share of the annual electricity production that is consumed directly within the area. Self-generation is defined as C/(B+C) and describe the share of the annual use of electricity in the neighbourhood that is covered by local electricity production.

Self-consumption and self-generation of electricity should be calculated at the neighbourhood level for hourly use of electricity in the pilot area. A typical reference project will not have any local production of electricity, and hence, the self-consumption and self-generation in the reference case will be 0. Targets for the indicator is not decided at the current stage of the development of the ZEN definition and KPIs.

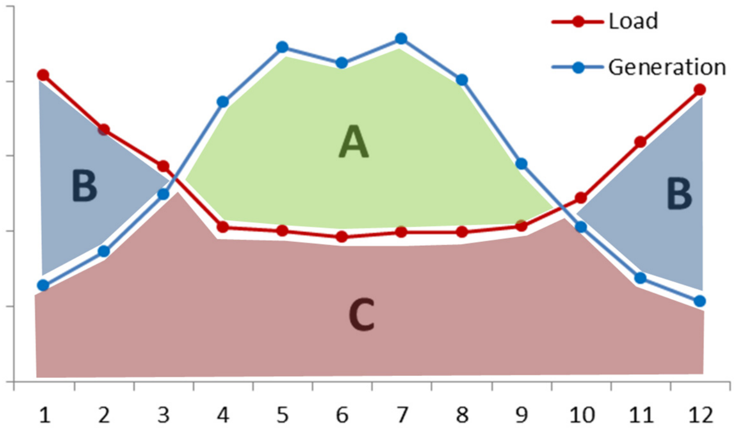


Figure 2 Typical profile for the electric load and production of electricity from PV panels for every month over the year.

POW3.1 Peak Load

The peak load KPI looks at the maximum peak load for district heating, district cooling, and electricity in the area at the hourly level over the year.

The net delivered energy curve is calculated based on the hourly profile for energy use and energy production. When this is sorted from highest to lowest values, you get the net duration curve.
The peak load is the maximum extreme value on the net duration curve. Reducing the peak load can have a positive effect on the surrounding energy grid. In order to set a target value for the reduced peak load, the change in peak loads for the electricity, district heating, and district cooling of a pilot area is compared to the reference area. The peak loads should be weighted in the comparison depending on the share of energy demand being covered by the different energy carriers.

There are currently no target values set for this KPI in the ZEN Research Centre.

POW3.2 Peak export

The peak export is the minimum extreme value on the net duration curve. The peak export usually occurs during the summer months when the energy demand is low and the energy generation is high (in the case where most of the local energy production comes from PV-panels). Grid companies in Norway generally dimension the grids for the dimensioning hours during the colder winter months, as this tends to lead to high peaks in energy use due to a high heating demand. Due to this, high peak exports are considered a smaller challenge for the energy grid than peak loads. If there is no export in the area, the peak export will be 0.

Target values have not been set for the KPI Peak Export. One suggestion is to award the pilot area one point in the category peak export as long as the peak export does not exceed the peak load.

POW3.3 Utilization factor

The utilization factor shows how well the neighbourhood utilizes the dimensioned grid capacity. The utilization factor is described using the figure below and is calculated by dividing the sum of net delivered energy, E, by the absolute peak, P = max (Pmax Load / Pmax Export), multiplied by the total hours of the year:

Utilization factor = E / (P*8760).

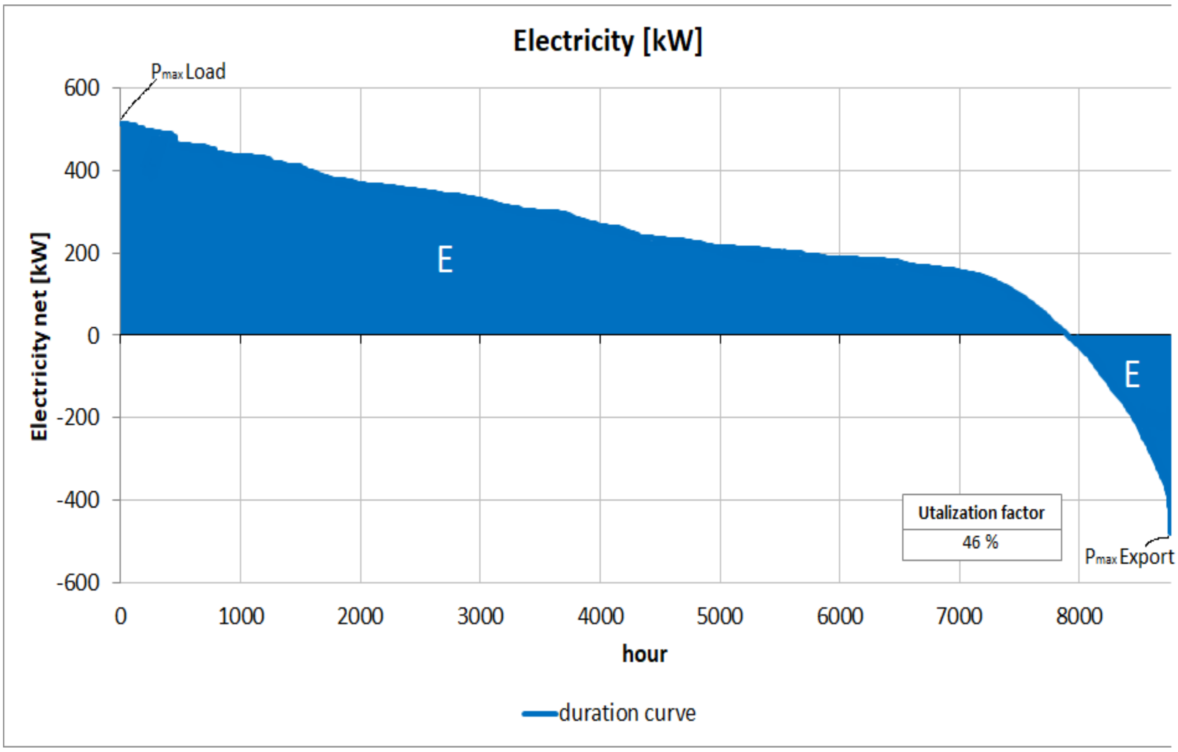


Figure 3 Duration curve for net electricity use for a building with local production of electricity.

The utilization factor should be calculated for electricity, district heating, and district cooling at the neighbourhood level for the pilot area and the reference project.

In order to compare the reference case and the pilot area, a weighted utilization factor should be calculated. A suggested method for creating a weighted utilization factor, U_w, is:

$$U_w = U_{el} \cdot f_{el} + U_{dh} \cdot f_{dh} + U_{dc} \cdot f_{dc}$$

where U_{el} is the utilization factor for electricity, f_{el} is the share of energy demand being covered by electricity, U_{dh} is the utilization factor for district heating, f_{dh} is the share of energy demand being covered by district heating, U_{dc} is the utilization factor for district cooling, and f_{dc} is the share of energy demand being covered by district cooling.

Increasing the utilization factor is considered positive as long as the energy use and absolute peak is not increased. Targets values have not been decided for the KPI at the current time.

Scope

The scope of this report is to test the indicators on energy and power on a ZEN pilot area in the planning phase. The suggested energy KPIs and power KPIs have been tested for Ydalir for the year 2035. It is assumed that the area will be fully operational by this time. Two scenarios have been created for Ydalir, 2035: the first scenario represent the current expectations for the pilot area and is called the "ZEN

Scenario". The second scenario represent the reference project, or the "Business as usual" (BAU) case for the development of Ydalir. This is called the "Baseline Scenario". The KPIs for Energy and Power have been calculated for Ydalir for both scenarios.

2. Ydalir

This chapter describes Ydalir, a pilot area in FME ZEN which is the subject of the Case Study in this report. The following chapter includes a description of the area, the goals and targets for the area, and two scenarios for the area development.

2.1 Ydalir

Ydalir is the name of a development area located 1.5-2 km to the northeast of the centre of Elverum. The area is a pilot area in FME ZEN with ambitions of becoming a ZEN. At the end of the construction period the area will have a new school (sized 6,000 m^2 for 350 pupils), a kindergarten (sized 1700 m^2 for 100 children), and about 700 residential units.

The development of Ydalir will take place over a period of 10-15 years and is scheduled to be completed between 2030-2035. The school and the kindergarten opened in august 2019.
The residential units will be constructed on different plots located around the school and kindergarten. These lots will be developed into residential apartment blocks and detached houses by different developers who have committed to the joint master plan that has been developed for the area.

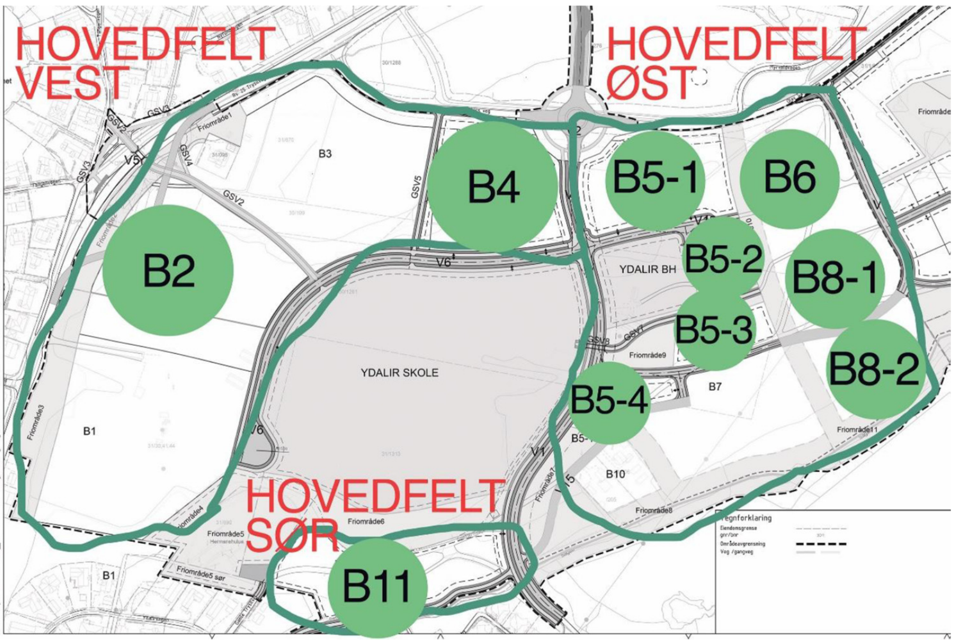


Figure 4 Map of the Ydalir development area.

Table 4 shows the expected development of the building stock in Ydalir as of the fall 2019. There is still a lot of uncertainty linked to the development of the residential buildings, regarding type of buildings, architecture, and size. The development of the different lots are currently at different stages. Some lots have not yet been sold, while others are nearly ready for the construction phase.

Table 4 Overview of Ydalir. Photo: Elverum vekst

	Category	Year of construction	Area [m2]	residents/ employees [#]	Res above 13y/ Other Users [#]
Ydalir School	School	2019	6007	40	450
Ydalir Kindergarten	Kindergarten	2019	1732	22	120
B1 (not sold/unplanned)	Residential individual housing	2028	9350	200	172
B2 (not sold/unplanned)	Residential apartment building	2028	12350	264	227
B4 (not sold/unplanned)	Residential apartment building	2028	12000	317	272
B5-1 (sold to Nordbolig, Ydalir park)	Residential apartment building	2028	6000	127	109
B5-2 (sold to Nordbolig, Ydalir park)	Residential apartment building	2028	2400	51	44
B5-3 (sold to R-byggetjenester. Høyden)	Residential individual housing	2028	2400	51	44
B5-4 (sold to R-byggetjenester)	Residential apartment building	2028	1800	38	33
B6 (not sold/unplanned)	Residential individual housing	2028	4500	95	82
B7 (owned by Terje Svenkerud, Muspelheim)	Residential individual housing	2028	4860	84	73
B8-1 (sold to Bakke Eiendom)	Residential individual housing	2028	3000	63	54
B8-2 (sold to Bakke Eiendom)	Residential individual housing	2028	2400	51	44
B-11 (sold to Vikingbygg)	Residential apartment building	2028	6000	127	109
"Gammel barnehagetomt" 12 care homes	Nursing home	2021	840	12	6
"Gammel barnehagetomt" Apartments	Residential apartment building	2021	1400	127	109

2.2 Ambitions for Ydalir

There are high ambitions related to the development of Ydalir. For Ydalir to fulfil the ZEN definition, it must be energy efficient, and the emissions from the area must be reduced.
The emission reductions in Ydalir will be achieved through building according to the passive house standard (or better), through using district heating from bioenergy, and by installing photovoltaic (PV) panels with an annual generation of minimum 10 kWh/m^2 ground floor area[4].

The main target for the development of Ydalir is to build environmentally ambitious and sustainable, with low emissions from materials and low energy use in the operational phase, but within the limits of what is considered financially responsible and low risk for the developers and users [4].

In addition, there is a goal to increase the share of green transport modes used in the area. The residential multiple family buildings shall be built without parking lots – instead there will be parking facilities established at the outskirts of the area. Single family houses will still be built with on-site parking lots. The developers in the area are encouraged to reduce the parking coverage as much as possible.

2.3 Development scenarios for Ydalir

The suggested energy KPIs and power KPIs have been tested for Ydalir for the year 2035. It is assumed that the area will be fully operational by this time.

Two scenarios have been created for Ydalir, 2035: the first scenario represent the expectations for the pilot area and is called the "ZEN scenario". The second scenario represent the reference project, or the

BAU-case for the development of Ydalir. This is called the "Baseline scenario". The building area, the number of users, and the transport demand is the same in both scenarios. The differences between the two scenarios are summed up in Table 5.

Table 5 Scenarios for Ydalir

	Baseline scenario	ZEN scenario
Building standard	Minimum requirements in Norwegian building regulations (TEK-17)	Passive house standard
Technologies for heating	Direct electricity	District heating from biofuels
Mode of transport (share of total transport demand)	32 % walking/cycling 3 % rail 6 % bus 59 % car	32 % walking/cycling 3 % rail 35 % bus 30 % car
Transport technologies	50 % of all buses are electric in 2035.	100 % of all buses are electric in 2035
Local production of energy	None.	PV panels with annual generation of energy equal to 10 kWh/m2 GFA.

More information about the assumptions and input data in the two scenarios can be found in the appendix.

3. Scenario analysis of annual energy demand and energy use in Ydalir

This chapter consists of a detailed description of methodology and the results on the KPIs annual net energy demand and energy use in the area Ydalir. The methodology and results are described subsequently for each of the indicators for both scenarios.

3.1 Methodology: Annual energy demand and annual energy use

PI-SEC Scenario Calculator was used to model the following KPIs for Ydalir in the ZEN scenario and in the baseline scenario:

- Annual net energy demand of the buildings (kWh/m2)
- Annual energy use for buildings, transport, and infrastructure in the area (kWh)
- Annual GHG-emissions linked to energy use in buildings, transport,t and infrastructure in the area. (Tonnes CO_2e)

PI-SEC is a Norwegian research project, lasting from April 2016 to March 2019. The abbreviation PI-SEC is short for "Planning Instruments for Smart Energy Communities". One of the deliverables from the PI-SEC project was the PI-SEC Scenario Calculator. The Scenario Calculator lets the users model different scenarios for the development of an area to study how energy use and emissions (among other KPIs) are affected by choices made in the planning of an area.

The methodology used in the PI-SEC Scenario Calculator is further described in the PI-SEC manual [5] and the Scenario Calculator article [6]

3.1.1 Methodology for calculating the annual energy demand of Ydalir

The PI-SEC Scenario Calculator gives the user the option to describe the different buildings in an area in regard to size, building category, age, energy demand, and building technologies.

In the baseline scenarios, it is assumed that all of the new buildings constructed in Ydalir (from Table 4) have a net energy demand that satisfies the minimum requirements in the Norwegian building code regulations (TEK17 § 14-2.)[1]. In the ZEN scenario it is assumed that the energy demand of the school and the kindergarten is as simulated in the pre-project [7], [8], and the remaining residential buildings have building envelopes that satisfy the requirements for energy demand based on the passive house standard [5]. The reader should be aware that using normative values for buildings' energy demand is a simplification. Normative energy demand values for passive house buildings are lower than for buildings that are built according to the minimum requirements in TEK-17. However, these normative values do not account for the differences in energy demands that can be caused by user behaviour, differences in the number of users per m^2, etc. The energy demands for the different buildings in each scenario may vary more in reality.

3.1.2 Methodology for calculating the annual energy use of Ydalir

The annual energy use from buildings, transport, and infrastructure in the two scenarios has been calculated using the PI-SEC Scenario Calculator as well.

Energy use in a building is defined as the sum of the net energy demand and the losses in the building's heating system. Different technologies can be used to cover the energy demand for heating and cooling in buildings. It is assumed that direct electricity (electric boilers and electric heaters) is used to cover the heating demand in the baseline scenario. In the ZEN scenario it is assumed that district heating with biofuels as energy source is used. The complete assumptions made for the heating technologies can be found in Appendix A6.

Energy use for transport (in the use phase) is calculated in PI-SEC based on a method inspired by the klimagassregnskap.no tool [9] and NS 3720[10]. It is assumed that the users in the area generate a transport demand that generates a certain number of trips to the outside of the neighbourhood boundary per day (trips within the boundary level are ignored). The total number of trips is then divided by two, as a simplified allocation of the trips between the neighbourhood (within the system boundary) and the outside world (outside of the system boundary). Energy use for transport is then calculated as the product of the number of trips, the length of the trips, the number of people travelling together, and the energy consumption per vehicle kilometre.

Information on travel habits (number of travels and travel lengths) for each building category is supplied by the user and can be based on travel surveys. Users can cover the transport demand by different modes: walking/cycling, car, bus or rail[5].. Different vehicles have different energy demands and resulting emissions. Generally, larger vehicles have a larger energy demand than smaller vehicles, and electric vehicles tend to be more energy efficient than similar fuel burning vehicles. In this analysis, the travel habit data and assumptions on the modes of transport used are based on a concept study for Ydalir,

[1] https://dibk.no/globalassets/byggeregler/regulation-on-technical-requirements-for-construction-works--technical-regulations.pdf

which was written as a final report to Enova in 2011 [11]. In this study, it was assumed that the transport demand in Elverum today is covered by 59 % car, 9% public transport, and the rest by bicycling and walking [11]. In the baseline scenario, this transport mode distribution is expected to remain unchanged. In the ZEN case it is assumed that the share of transport modes will change to 38 % for car transport, 30 % for public transport, and 32 % for walking and cycling. The share of electric vehicles are based on the concept study for Ydalir [11] and NVE's expectation of phase-in of technologies in the transport sector towards 2035[12]. It is assumed that 100% of the buses will be electric in the ZEN Scenario and that 50 % of the buses will be electric in the Baseline Scenario.

Two different system boundary levels for energy use transport have been evaluated in this analysis. The first is the system boundary used in PI-SEC Scenario Calculator, which looks at all energy consumption related to travel activity created by the transport needs of the population and users in the area. This system boundary looks at energy consumption by vehicles both covered by electricity and by fossil fuels. When using this system boundary level, it is assumed that the users in the area have a transport need that generates a certain number of trips per day. Then, it is assumed that half of the energy used to cover this energy demand is allocated to the area boundary level, while the second half is outside of the boundary level, as the generated trips go in and out of the area.

The second system boundary is at the neighbourhood level that only looks at charging of electric vehicles within the pilot area. This is calculated in an additional step outside of PI-SEC. See 6.1.2 for details. For the energy and power KPIs, it is proposed to look at the area system boundary. That is, buildings within the building system boundary SN-TS 3031, infrastructure (servers, outdoor lighting, elevators, escalators, industrial processes in buildings, and snow melting systems), and charging of electric vehicles within the area. Energy consumption of fossil fuels and charging of electric vehicles outside the area is not included.

3.2 Results: Annual energy demand and annual energy use

3.2.1 Annual net energy demand

By making these assumptions in the PI-SEC Scenario Calculator, the annual net energy demand is reduced by 27 % for the buildings in Ydalir in the ZEN scenario compared to the baseline scenario in 2035.

Table 6 Annual net energy demand

	Net energy demand [kWh]		Spesific net energy demand [kWh/m2]		Difference
	Baseline	ZEN	Baseline	ZEN	
Total	7 989 140	5 804 253	104	75	-27 %
Heating	3 374 531	1 341 683	44	17	- 60 %
Hot water	1 814 130	1 814 690	24	24	0
Cooling	0	0	0	0	0
Electricity	2 800 477	2 647 878	36	34	- 5 %

3.3.2 Annual energy use

Estimated annual energy use from electricity, district heating, and fuels in Ydalir in the ZEN Scenario and the baseline scenario for buildings, infrastructure, and transport (at the two different system boundaries) in the area is given in Table 3.

Table 7 Calculated annual energy use (kWh) in Ydalir in the Baseline Scenario and ZEN Scenario.

Boundary	Energy carrier	Total		Per m²		Difference
		Baseline	ZEN	Baseline	ZEN	
Buildings	Electricity	9879690	2647879	128	34	-73 %
	District heating	0	4868096	0	63	
	Total	9879690	7515975	128	98	-24 %
Infrastructure	Electricity	80000	80000	1	1	0 %
	District heating	0	0	0	0	0 %
	Total	80000	80000	1	1	0 %
Transport generated demand	Electricity	421859	1163241	5	15	176 %
	Fuels	4340510	2344181	56	30	-46 %
	Total	4762370	3507422	62	46	-26 %
Transport charging only	Electricity	342 301	174 050	4,42	2,25	-49 %
Area transport demand	Electricity	10381550	3891120	135	51	-63 %
	District heating	0	4868096	0	63	
	Fuels	4340510	2344181	56	30	-46 %
	Total	14722060	11103397	191	144	**-25 %**
Area only charging of cars in neighbourhood	Electricity	10301991	2901915	133	37	-72%
	District heating	0	4868096	0	63	-
	Fuels	0	0	0	0	-
	Total	10301991	7822939	133	100	**-25%**

The overall energy consumption of all energy carriers in Ydalir can be reduced by 25% in the ZEN scenario compared to the baseline scenario regardless of the system boundary level for transport.

3.2.3 Annual generation of electricity

The target for annual energy generation in Ydalir is 10-15 kWh/m² generated from local PV panels[4]. In this report, it is assumed that an average production of 10 kWh /m² is installed in Ydalir in the ZEN Scenario. Assuming that 77 039 m² of building area is constructed in the area (see Table 4), the resulting annual energy generation from solar panels in Ydalir in the ZEN Scenario must be at least 770 390 kWh/year in order to reach the goal for local energy production by renewable energy sources.

It is assumed that there is no local generation of energy in Ydalir in the baseline scenario.

4. Annual emissions related to energy use

Emissions from energy use in the operational phase is not proposed as a KPI within the categories energy and power in ZEN, but is still tested in this report. Greenhouse gas emissions are calculated in a separate category in ZEN.

4.1 Methodology: GHG-emissions

Annual emissions related to energy use in the area during the operational phase have been calculated using PI-SEC Scenario Calculator, and the calculations are made according to the method described in NS3720 - "Method for greenhouse gas calculations for buildings". The boundary level for the calculations is all emissions related to energy use and energy generation in the buildings, infrastructure, and transport (including emissions from both electric vehicles and fossil vehicles) in the area.

In NS3720, emissions from energy use are calculated as a product of delivered energy from each energy carrier and an LCA-based emission factor for the given energy carrier. The equation below shows how the emissions from the use of one heating technology in a single building is calculated in PI-SEC:

$$Emissions_{b,h,tec} = Area \cdot H_d \cdot cov_{tec} \cdot \eta_{tec} \cdot f^{CO2}{}_{source}$$

Hd, covtec, ηtec, and fCO2source represent the heat demand (kWh/m2), the coverage factor (%), the efficiency (%), and the emission factor (CO2eq/kWh) respectively.

Calculation methods of emissions from transport is not covered by a European standard. However, a method is suggested in N3720 based on the principles of NS-EN 16258. The emission factors used when calculating the emissions from transport must be life-cycle based, but the standard does not specify whether the production of the vehicles themselves should be considered in this emission factor, or whether only the LCA-emissions from the fuels used should be included. Emissions from the use of a single transport technology is calculated in PI-SEC as follows:

$$Emissions_{M,Ttec} = \frac{\left(Vkm_M \cdot cov_{Ttec} \cdot f^{CO2}{}_{M,Ttec,B}\right)}{2}$$

where Vkm_M, cov_{Ttec} ,$f^{CO2}{}_{M,Ttec,B}$ represent the annual number of vehicle kilometres (vkm) for the mode of transport generated by the travel demand in the area, the share of the technology/fuel that the mode of transport run on (either electric or fossil, %), and the emission factor for the given technology (CO_2eq/kWh). Half of the emissions generated by the vehicles are assigned to the neighbourhood.

Electricity generated in a neighbourhood can be exported to the grid. This export of energy can be deducted from the annual energy use and in turn reduce the emissions from electricity used in the area.

Emissions related to the use of electricity must be calculated using at least two different scenarios for electricity according to NS3720: a Norwegian mix (average of the lifetime of the building) with a factor of 18 g CO2e/kWh and a European mix with a factor of 136 gCO2e /kWh.

The PI-SEC Scenario Calculator has some suggested values for emission factors for different transport modes and technologies at different emission boundary levels. The proposed emission factors from PI-SEC are used in the calculation of emissions from transport in Ydalir.

4.2 Results: GHG-emissions

Figure 5 and Table 8 show the calculated annual emissions from buildings, transport, and infrastructure in Ydalir in the two scenarios. The results depend on the chosen emission factor for electricity and the choice of boundary level for the emission factors for the transport vehicles.

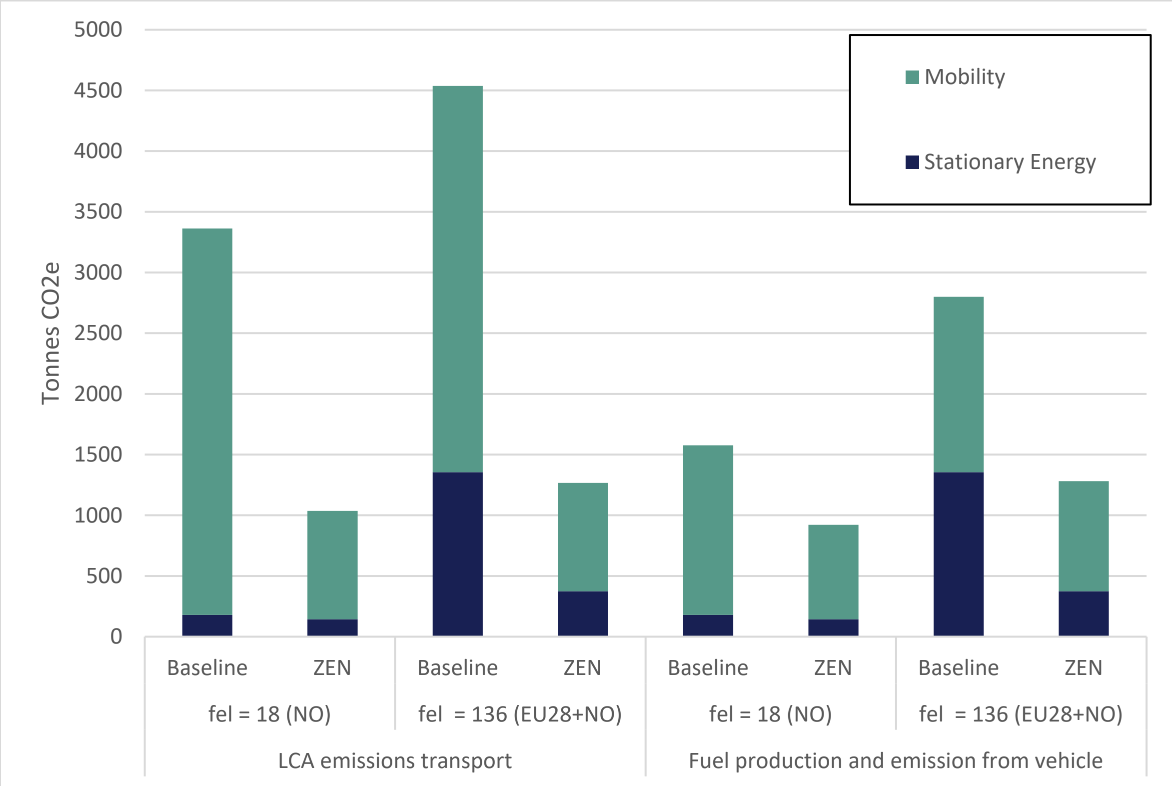


Figure 5 Calculated annual emissions from energy use in buildings, transport, and infrastructure in the two scenarios with different system boundaries for emissions from transport and different emission factors for electricity.

Table 8 Calculated annual emissions from buildings, transport, and infrastructure.

	LCA emissions transport				Fuel production and emission from vehicle			
	fel = 18 (NO)		fel = 136 (EU28+NO)		fel = 18 (NO)		fel = 136 (EU28+NO)	
	Baseline	ZEN	Baseline	ZEN	Baseline	ZEN	Baseline	ZEN
Ton CO2e	3362	1281	4537	1266	1576	921	2799	1266
Reduction	-62 %		-72 %		-42 %		-54 %	

5. Hourly profiles for electricity and district heating

Annual consumption, generation, import, and export of energy in Ydalir have been calculated within the neighbourhood assessment level (buildings+infrastructure+charging of electric vehicles).

Electricity and district heating are the only energy carriers used within this boundary level in Ydalir. Hourly profiles for consumption, generation, import, and export of electricity and district heating in the two scenarios have been calculated separately for buildings, transport, and infrastructure.

5.1 Methodology: Hourly profiles for electricity and district heating

5.1.1 Hourly profiles for building energy demand and energy use

Hourly profiles for electric services and thermal (room heating and heating of tap water) energy demand for the buildings in Ydalir have been created using a load profile generator based on load profiles from measured energy use in buildings [13]. The load profile generator separates between 11 different building categories and 2 building standards; "Normal" (average of buildings from before 2017) and "Efficient" (TEK-17 or better). The profiles generated for Ydalir in the two scenarios were then scaled to equal the annual energy demand for the buildings in PI-SEC. The reader should be aware that this can create artificially low power peaks.

It is assumed that all electric services have an efficiency of 1. This means that the energy use for electric services is assumed to be equal to the energy demand for electric services. Energy use for heating is equal to the thermal demand, plus the losses in the heating distribution system. The hourly profiles for energy for heating is calculated using the hourly demand profile for heating and multiplying it by weighted efficiencies for the heating system as used in PI-SEC.

5.1.2 Hourly profiles for charging of electric vehicles

The neighbourhood assessment level includes charging of electric vehicles within the neighbourhood.

In the method used in PI-SEC, it is assumed that the users in the area generate a transport demand that results in a certain number of trips per day. The number of trips is then divided by two, as the trips go between the neighbourhood and the outside world. Energy use for transport is then calculated as the product of the number of trips, the length of the trips, the number of people travelling together, and the energy consumption per vehicle kilometre. Due to the division of trips between the neighbourhood and the outside world, the annual energy consumption for charging of all the neighbourhoods' users' electric vehicles will be twice that of the energy consumption calculated in PI-SEC, considering all trips with the users' electric vehicles.

In Ydalir, it is assumed that all buses going to the neighbourhood will be charged outside of the area. It is assumed that there are no charging facilities at the school or at the kindergarten, but that there will be charging facilities in the residential buildings/in the parking facilities linked to the residential buildings. Only the charging of electric cars at the residential buildings are therefore considered for the neighbourhood level of Ydalir.

Using PI-SEC, the calculated energy use for charging of electric cars in the baseline scenario is 240 211 kWh/year. Considering the charging of residents' cars that is assigned to the outside area, the resulting total energy use for charging of the electric cars belonging to the residents in the area is 480 422 kWh/year. In the ZEN scenario, the corresponding values are 122 141 kWh/year and 244 282 kWh/year.

95% of the building area in Ydalir is residential. It is assumed that 95% of the energy use for charging of electric cars is linked to the activity of the residential buildings. In a report by NVE it is assumed that 75% of all charging of electric vehicles in Norway is done at home [14]. Based on this, it is assumed that the charging of electric cars within the neighbourhood level in Ydalir results in an annual use of electricity of 174 050 kWh/year in the ZEN Scenario and 342 301 kWh/year in the Baseline Scenario.

Electric cars use more energy on cold days than on warmer days - about 0.3 kWh /km on days with daily average temperature lower than 10 C on average, and about 0.13 kWh/km on warmer days. Based on this assumption, the temperature profile from SN-TS 3031 and the typical hourly profile for charging of electrical cares in residential buildings Figure 6[14] is used to make a weighted distribution of the annual energy used for charging of electric vehicles within Ydalir for every hour throughout the year. It is assumed that the charging pattern is the same both on weekdays and on weekends.

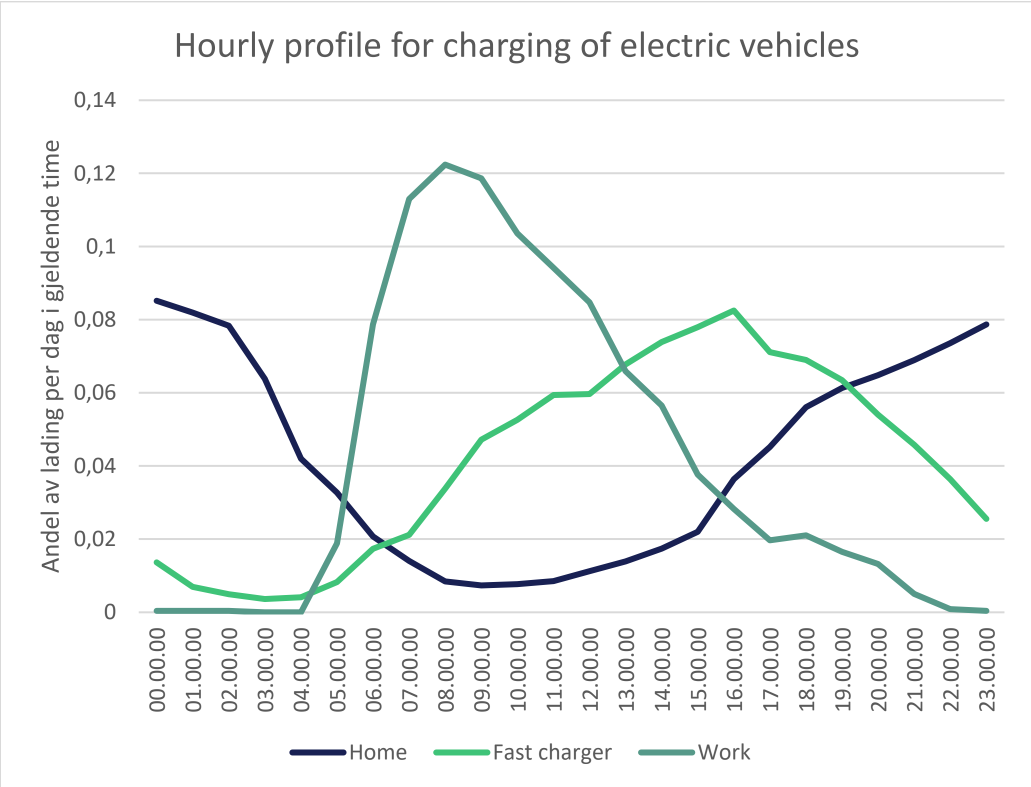


Figure 6 Charging patterns for electric vehicles [14].

5.1.3 Hourly profiles for electricity generation from PV panels

The target for annual generation of energy in Ydalir is 10-15 kWh/m^2 from local PV panels [4], resulting in a minimum annual generation of 770 360 kWh electricity in Ydalir in the ZEN-scenario.

An hourly profile of solar radiation and energy generation in Ydalir was created using PVGIS [15]. Ydalir's location was plotted into the program at the following coordinates: 60.891335, 11.579968

A sample panel of 682 kWp range with 14% system loss with "Optimize slope and azimuth" was then added in PVGIS. An hourly profile for energy generation from the solar panels was created for all hours between the 1.1.2005 and 31.12.2016 based on local solar radiation profiles. The profile for 2012 was then chosen as an example profile as the maximum peak production occurred this year, and this profile also contained values for all hours of the year. The chosen hourly profile was then adjusted so that the sum of annual energy production in all hours over the year equalled 770 360 kWh.

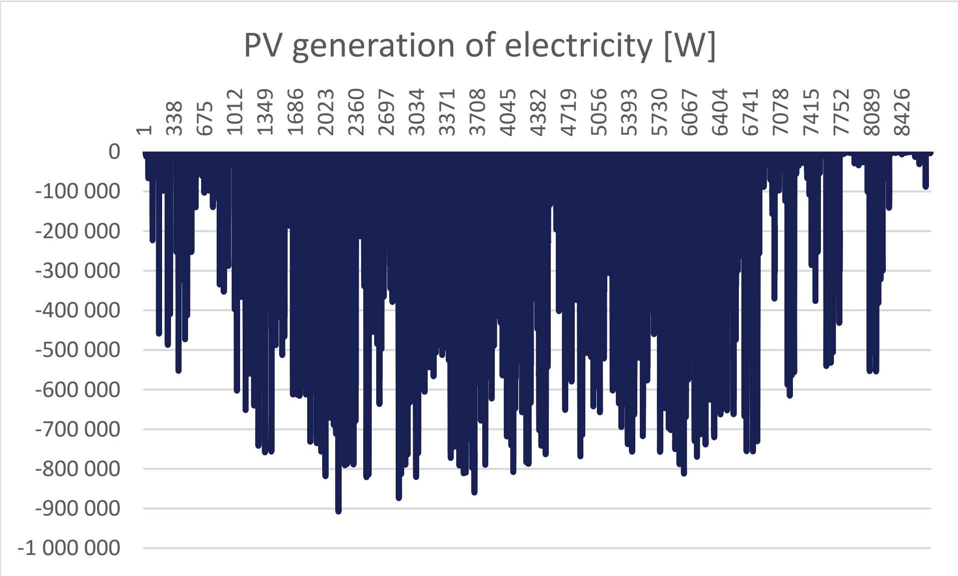


Figure 7 Hourly profile for generation of electricity in Ydalir in the ZEN scenario.

5.1.4 Method: Hourly profiles for electricity use for street lighting

It is estimated that annual the energy consumption for street lighting and infrastructure in the area is 80 000 kWh/year from electricity. Street lighting is usually only turned on between sunset and sundown. Based on the solar radiation profiles for the area, it was assumed that the annual energy use for street lighting was distributed equally between all the hours with 0 solar radiation and was otherwise set to 0.

5.2 Results: Hourly profiles for electricity and district heating in Ydalir

The resulting hourly profiles for Ydalir at the neighbourhood boundary level is presented individually for each of the two scenarios in the following. The results for Ydalir is first presented for the ZEN Scenario before the presentation of the results from the baseline scenario.

5.2.1 Results for the ZEN Scenario

In the ZEN Scenario, electricity is used for electrical appliances and services in the buildings, for street lighting, and for charging of electric cars. The electric demand is covered by electricity from the grid and through generation of electricity by the PV-panels. The hourly load profile and the load duration curve for electricity in Ydalir in the ZEN scenario is shown in Figure 8.

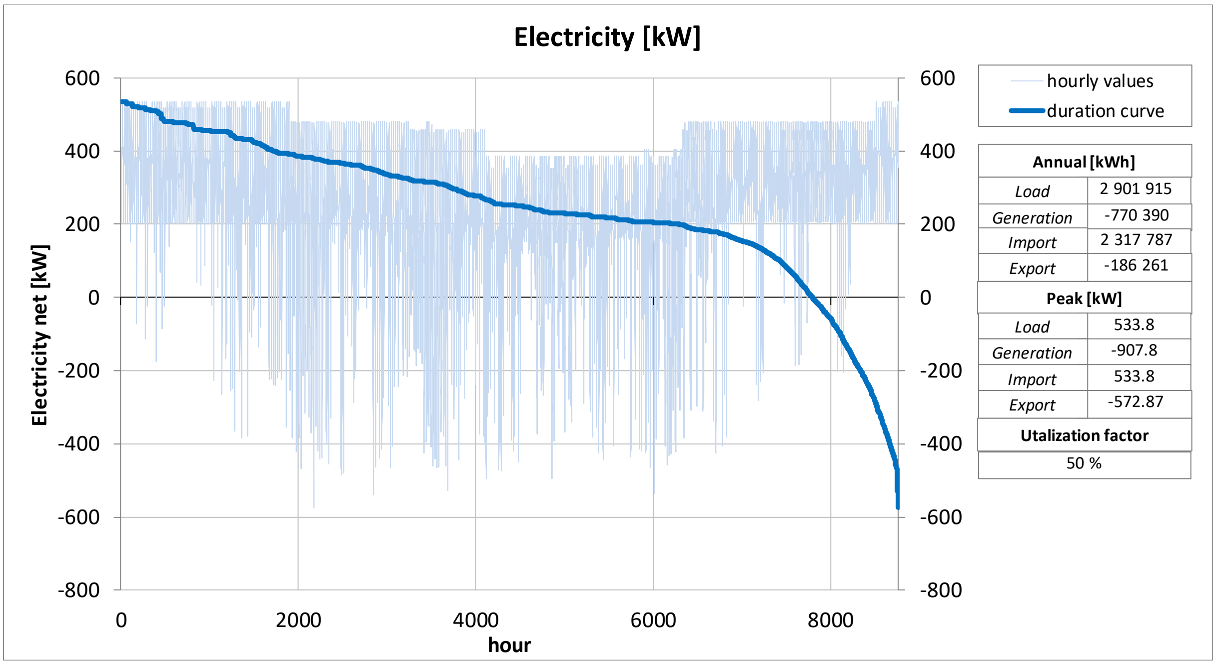


Figure 8 Hourly profile and load duration curve for net electricity use in Ydalir in the ZEN Scenario.

The seasonal variation in electricity use is the ZEN scenario is caused by a greater need for charging of the electric cars on the colder days, a higher demand for energy for lighting in the winter when the days are darker, and the seasonal difference in energy generation. Electricity is not used for heating in this scenario. Energy generation from solar panels is dependent on the solar radiation, which is highest in the summer months and in the middle of the day. The peak load for electricity is 534 kW, while the peak for export is 573 kW. A relatively low seasonal variation gives a high utilization factor for electricity in the area of 50 %.

The figure below shows the hourly load profile and load duration curve for district heating in Ydalir in the ZEN scenario. In the ZEN scenario, the buildings in Ydalir use district heating for heating of rooms, ventilation, and domestic hot water. The use of district heating is highly dependent on the outside temperature, which causes large seasonal variations. The peak load for district heating is 1 953 kW. Due to the high variations in load throughout the seasons, the utilization factor for district heating is 28% in the ZEN-Scenario.

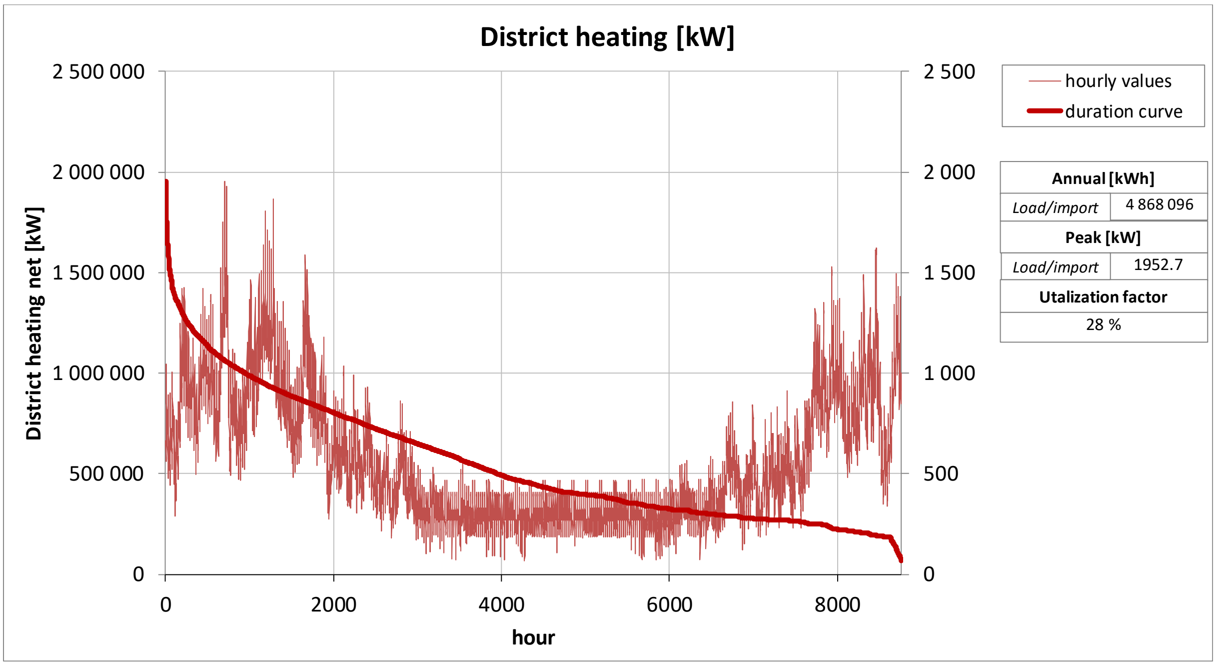


Figure 9 Hourly profile and load duration curve for the use of district heating in Ydalir in the ZEN Scenario.

Figure 10 shows a colour-coded carpet plot. This is an alternative presentation of the load profile, where the hours in a day is placed on the Y-axis while the days of the year is on the X-axis. The carpet plot for electricity shows that there is a net export of electricity for a few hours in the middle of the day in the spring and summer from Ydalir in the ZEN-scenario, while there is net import of electricity for the remaining hours.

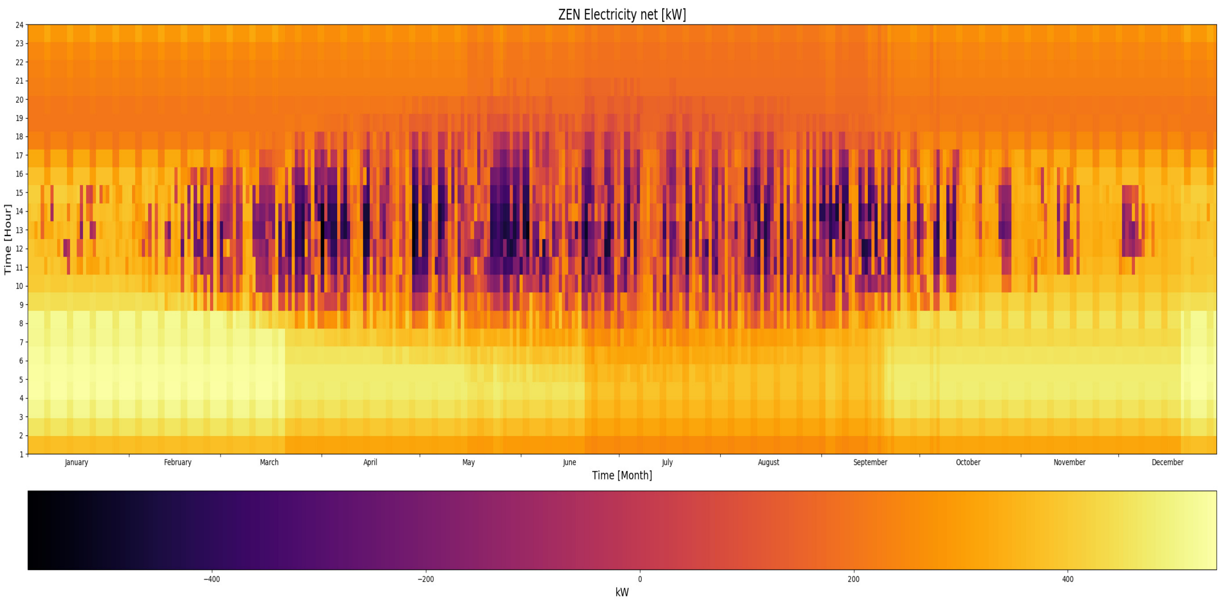


Figure 10 Colour coded carpet plot for hourly use of net electricity in Ydalir in the ZEN Scenario.

The colour coded carpet plot for district heating shows that the maximum import occurs during the morning and evening hours during the winter months. The import is low during the middle of the day, as most of the residents will be out of their homes during these hours.

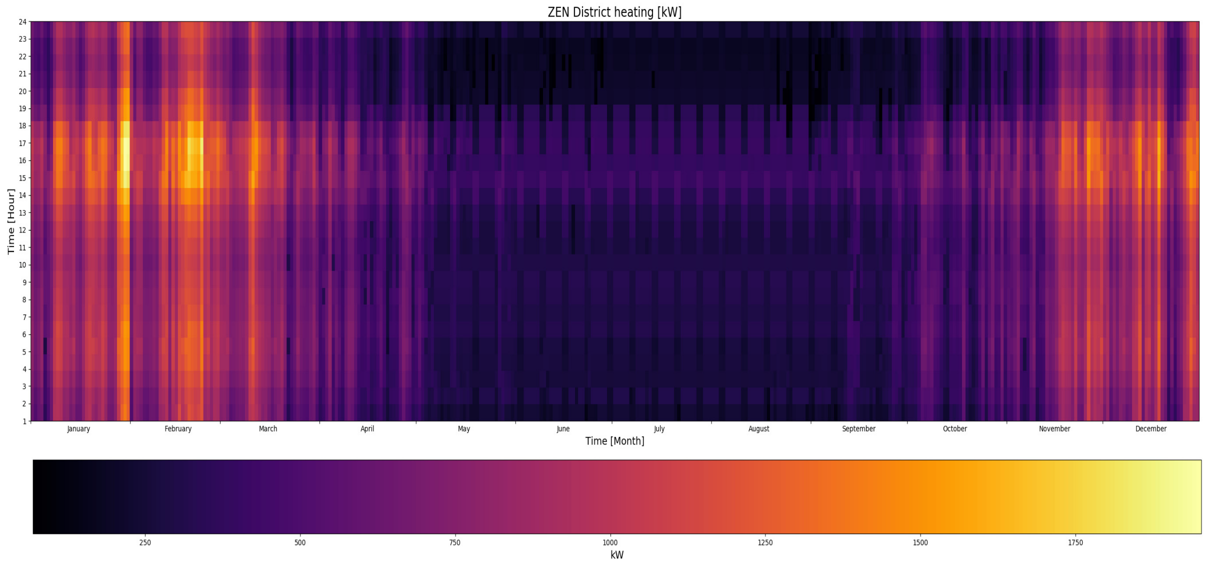


Figure 11 Colour coded carpet plot for hourly use of district heating in Ydalir in the ZEN Scenario.

The figure below shows monthly load profile and monthly energy generation profile for electricity in Ydalir in the ZEN scenario. Hourly self-generation of electricity is 20 %. Hourly self-consumption of electricity is 76 %.

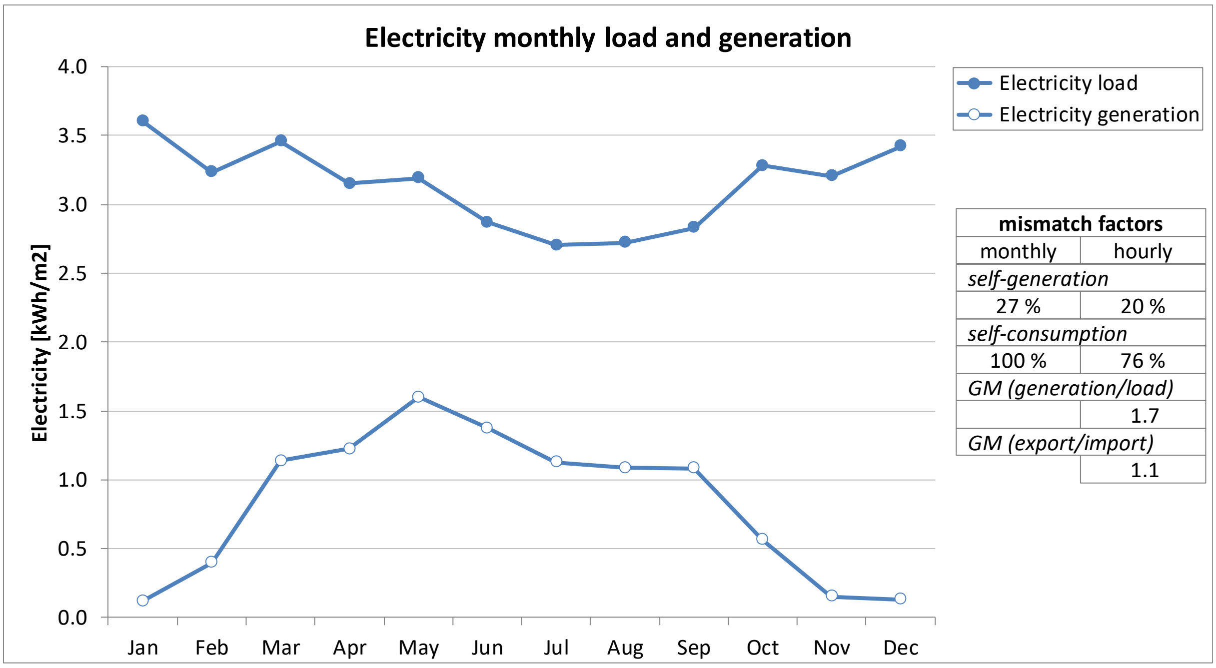


Figure 12 Monthly load profile and generation profile of electricity in Ydalir in the ZEN Scenario.

The figure below shows a typical profile for net electricity use in Ydalir in the ZEN scenario on typical (average) days in the winter, spring, summer, and autumn. In the spring and summer, there will typically be export of electricity in the middle of the day, while in the winter and autumn there will be a net import of electricity due to lower generation of electricity and higher energy demand for electricity.

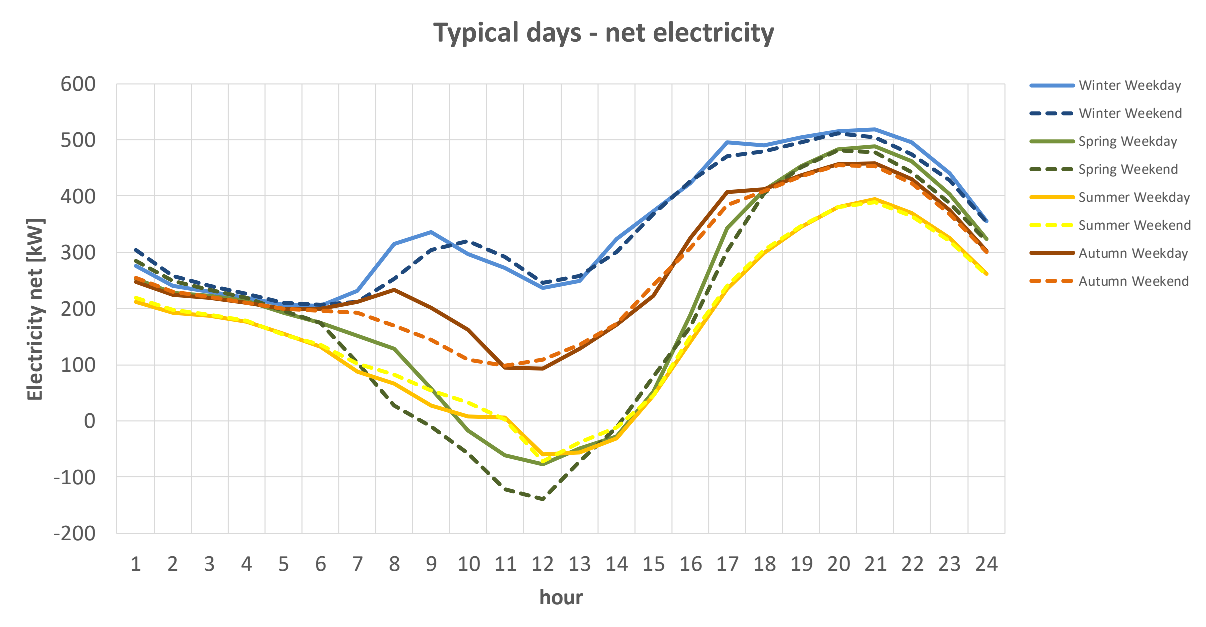


Figure 13 Typical daily profiles for net electricity use in Ydalir in the ZEN-scenario

Delivered energy from district heating is highly related to the outdoor temperature. On a typical day, the use of district heating will be a lot higher on winter days than on summer days. In the summer, there is generally no energy demand for room heating, and district heating is only used to cover the energy demand for heating of domestic hot water.

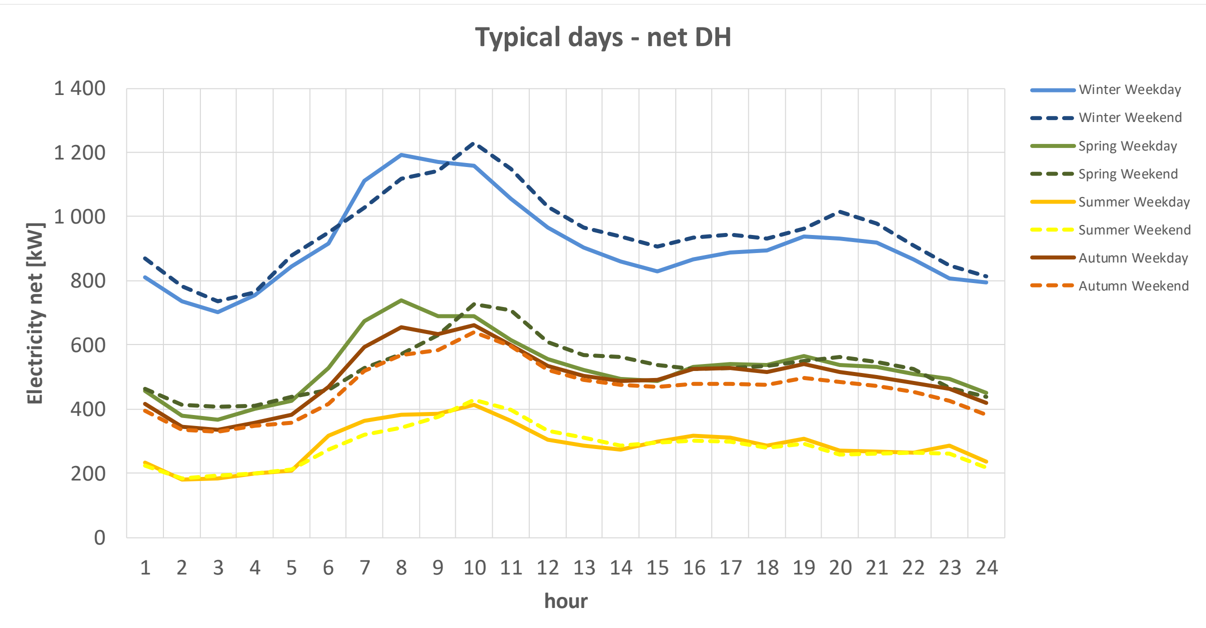


Figure 14 Typical daily profiles for the use of district heating in Ydalir in the ZEN scenario.

5.2.2 Results for the Baseline Scenario

The profile below shows the hourly use of electricity in Ydalir in the baseline scenario. In this scenario, the buildings have a somewhat higher energy demand for heating compared to the ZEN scenario, and the entire energy demand for heating is covered by direct electricity. This leads to large variations in the use of electricity throughout the year. There is no local production of electricity in this scenario, and due to this there is no export of electricity, only import. The peak load for electricity is calculated to be 3 286 kW. Large daily and seasonal variation in electricity use along with a high peak in use of electricity gives a calculated utilization factor of 37%, which is lower than the utilization factor for electricity in the ZEN scenario

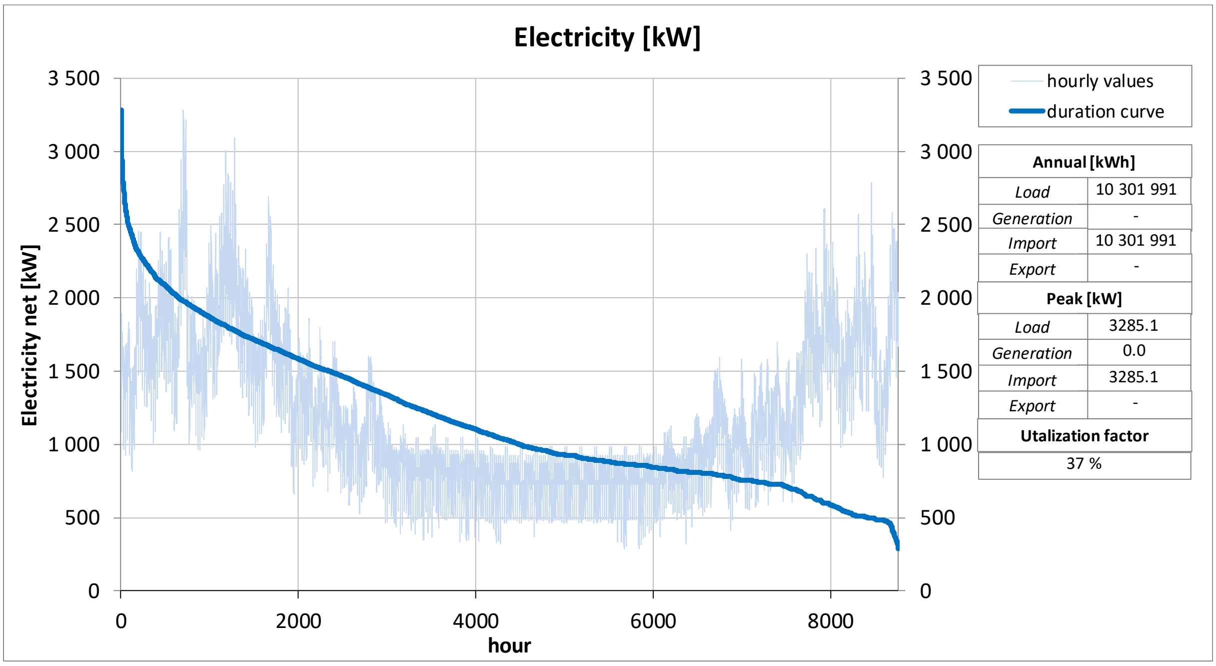


Figure 15 Hourly profile and load duration curve for net electricity use in Ydalir in the Baseline Scenario.

Below is the colour-coded carpet plot for energy use in Ydalir in the Baseline scenario.

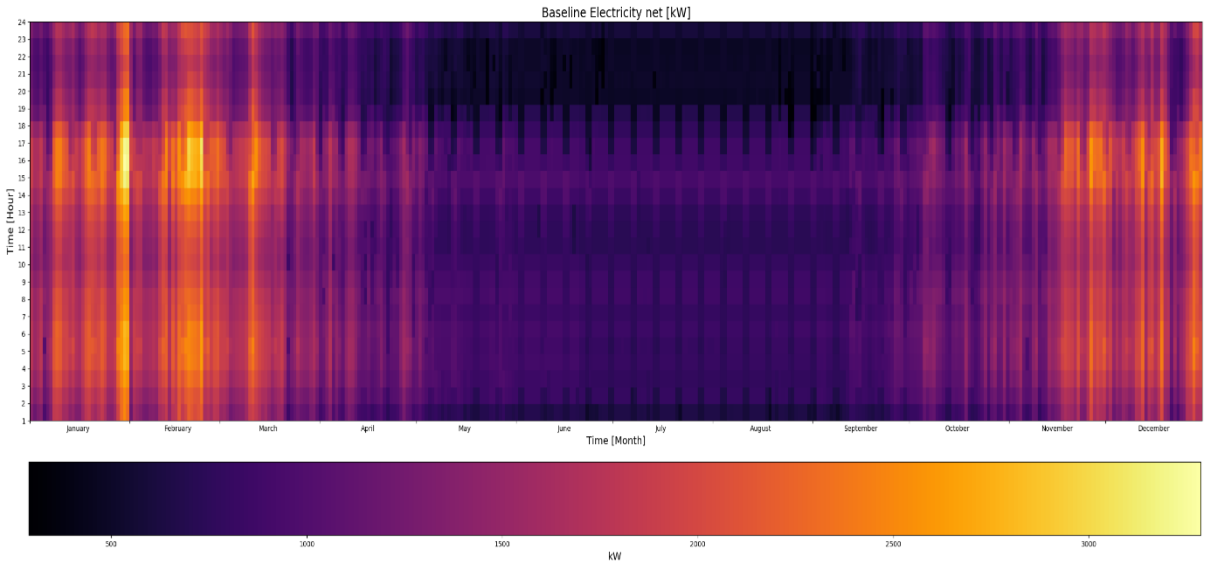


Figure 16 Colour coded carpet plot for hourly use of net electricity in Ydalir in the Baseline Scenario.

The profiles below show typical daily profiles for electricity use in Ydalir in the Baseline scenario. A large share of the electricity use is used for heating purposes, and the profile is therefore relatively similar in shape to the profile for district heating use in Ydalir in the ZEN scenario. The curves lie somewhat higher in the Baseline Scenario due to a higher energy demand.

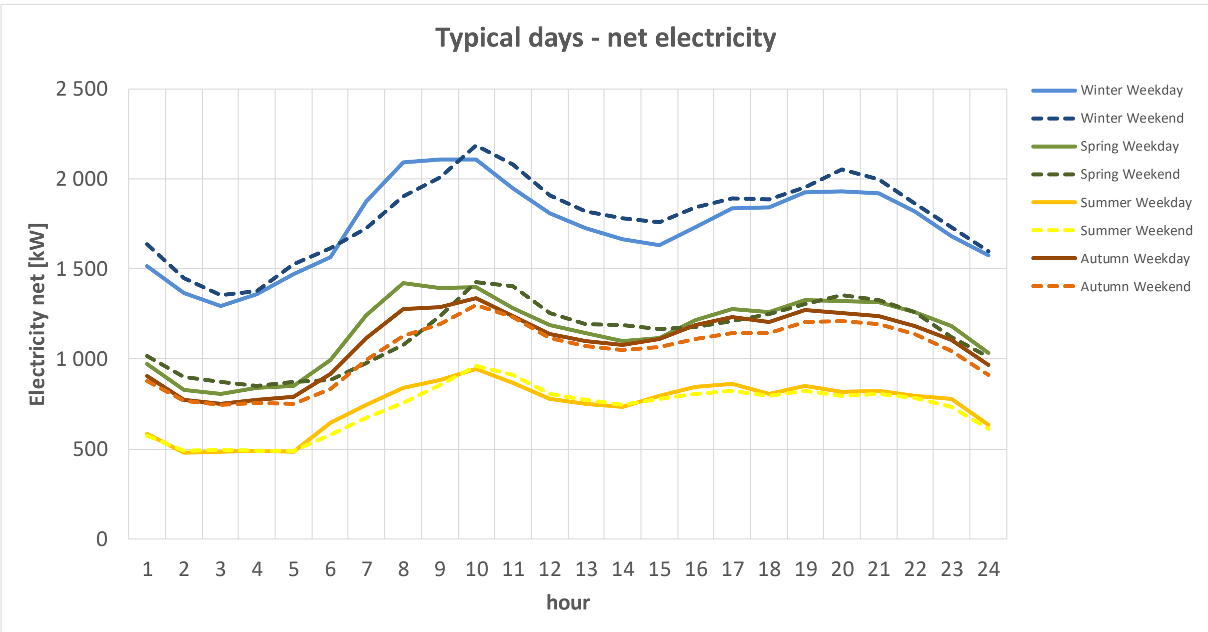


Figure 17 Typical daily profiles for net electricity use in Ydalir in the Baseline Scenario.

6. Summary of results

The following KPIs have been calculated for Ydalir in the Baseline scenario (the reference scenario) and in the ZEN scenario:

ENE2.1 Net energy requirements in buildings
ENE2.2 Delivered and exported energy to the area
ENE2.3 Own production and own use of electricity in the area
POW3.1 Maximum hourly load of electricity and district heating in the area during the year-
POW3.1 Maximum hourly export of electricity from the area during the year.
POW3.3 Utilization factor for electricity and district heating in the area

The results for all KPIs, as well as key information documented in this report can be found in the table below.

Table 9 Results from the analysis of energy and power KPIs in Ydalir in the ZEN scenario and in the Baseline Scenario.

KPI	Energy carrier	Scenario Baseline	Scenario ZEN	Difference
Net energy demand in buildings	Total	7 989 140	5 804 253	- 27 %
	/m2	104	75	
Energy use (load)	EL	10 301 991	2 901 929	
	DH	0	4 868 096	
	Tot	10 301 991	7 770 025	- 25 %
Generation		0	- 770 390	
Import	EL	10 301 991	2 317 801	
	DH	0	4 868 096	
	Tot	10 301 991	7 185 897	- 30 %
Export	El	0	-186 261	
Emissions from energy use	Se 4.2			- (42 – 72 %)
Peak load	El	3285	534	
	DH	0	1953	
	PeakEL+PeakDH	3285	2492	- 24 %
Peak generation	El	0	-908	
Peak import	El	3285	534	
	DH	0	1953	
	PeakEL+PeakDH	3285	2487	-24 %
Peak export	El	0	-573	
Utilization factor	El	37 %	50 %	
	DH	0 %	28 %	
Self-generation	EL	0 %	20 %	
Self-consumption	EL	0 %	76 %	

7. Discussion

The scope of this report is to test the indicators on energy and power on a ZEN pilot project in the planning phase. The suggested energy KPIs and power KPIs have been tested for Ydalir for the year 2035 in a Baseline scenario and in a ZEN-scenario (as planned).

In this analysis it has been assumed that all developers follow the master plan, that the building stock is developed as expected in the fall 2019, and that all buildings built in the area fulfil the passive house requirements and requirements for local energy production (in the ZEN Scenario). At the current time, it is still uncertain how large the final building stock or the number of inhabitants will be when the construction period is complete. As there is a lot of uncertainty linked to the development of the area, the input values and analysis also becomes uncertain, and the KPIs for energy and power should be recalculated at a later stage of the development of Ydalir in order to study how the area development will score on each KPI.

The reader should be aware that using normative values for buildings' energy demand is a simplification. Normative energy demand values for passive house buildings are lower than for buildings that are built according to the minimum requirements in TEK-17. However, these normative values do not account for the differences in energy demand that can be caused by user behaviour, differences in the number of users per m2, etc. The energy demand for the different buildings in each scenario may vary more in reality. The hourly profiles for charging of electric vehicles and for load profiles of buildings are general and may vary for different neighbourhoods. The hourly profiles for energy demand in buildings generated for Ydalir in the two scenarios were scaled to equal the annual energy demand for the buildings in PI-SEC. The reader should be aware that this can create artificially low power peaks in the ZEN-scenario.

The early-phase calculation of the energy and power KPIs in Ydalir shows that constructing the area as a ZEN has positive impacts on energy consumption and the electricity peak load.

The reduction in energy consumption and emissions from transport in the ZEN-scenario compared to the baseline scenario is caused by a change in travel habits of the inhabitants and users in Ydalir. The expected change in the distribution of means of transport in Ydalir in the coming years is based on the 2017 conceptual assessment [11]. The Masterplan for the area was updated in 2019. Initially, all houses were to be built without parking lots on the residential properties, but parking should be available for the residents in a common parking facility in Ydalir. In the updated version of the masterplan, this was changed, and detached houses can now be built with private parking lots on their property. This can affect the means of transport used in the area in 2035, but this is not considered in the current analysis. Reduction in emissions from transport is the biggest contribution to the overall reduction in GHG-emissions in the user phase in this analysis, and this must be considered in the further planning of Ydalir.

The testing of the proposed KPIs for energy and power has revealed a need for further work on the ZEN definition and the definition of the indicators, as well as further work on the system boundaries for the KPIs and available tools. The reduction of emissions from energy use is important in order to meet the ZEN definition. There is a need for developing a methodology for calculating emissions associated with energy use in the area. This includes determining system boundary for emissions from transport in the area and determining a reference scenario for transport (for transport demand, means of transport distribution, and use of transport technologies). This must be defined by FME ZEN in the further work.

The school and kindergarten in Ydalir are now fully operational, while the development of the residential buildings in the area is still in the planning phase. Ydalir will simultaneously be in the planning phase, the development phase, and the use phase in the coming years. The researchers in ZEN have agreed that measured values of buildings in a ZEN pilot area should be reported in the monitoring of the pilot in the use phase, and calculated values should be reported for the area for the planning phase. The mix of measured values and calculated values represents a challenge that must be handled correctly by a monitoring KPI tool.

Comparing the KPIs for a ZEN-scenario with a Baseline scenario with a different heating system has proved to be challenging. Baseline scenarios with optional heating systems should be considered in the further development of the KPI-tool as an alternative to weighting district heating and electricity for each of the Power KPIs.

Various methods have been used in this analysis in order to create load profiles for the net energy use of the buildings, transport, and infrastructure in Ydalir. Further work in FME ZEN should focus on establishing a common methodology for creating these hourly profiles for the energy KPIs.

8. Conclusion and further work

This analysis shows that net energy demand can be reduced by 27 %, total import of energy can be reduced by 30 %, and the combined peak load for electricity and heating can be reduced by 24% in the ZEN-scenario compared to the baseline scenario.

Annual energy use and emissions from the use phase can be significantly reduced if the development turns out as expected, if all developers follow the master plan, and if the use of transport by car is reduced as expected. The testing of the KPIs used in ZEN within the categories energy and power shows that there is need for further work on system boundaries, definition of the reference scenario, and finding standard methodologies. This should be further work in the ZEN Research Centre.

Involved ZEN partners in this study have been SINTEF, Elverum Vekst, and Elverum municipality.

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A Appendix

A1 Assumptions for specific net energy demand for the buildings/groups of buildings in the ZEN scenario

Building	Heating [kWh/m2]	Hot Water [kWh/m2]	Cooling [kWh/m2]	Electricity [kWh/m2]
Ydalir Skole	20.7	10.1	0.0	53.8
Ydalir Barnehage	34.2	10.0	0.0	45.3
B1	19.8	25.0	0.0	31.3
B2	14.7	25.0	0.0	32.2
B4	14.7	25.0	0.0	32.2
B5-1 Nordbolig Ydalir park 50 boenheter i massivtre	14.7	25.0	0.0	32.2
B5-2 Nordbolig Ydalir park	14.7	25.0	0.0	32.2
B5-3 R-byggetjenester "Høyden", 6-4-2 mannsbolig 80-140 m2	19.8	25.0	0.0	31.3
B5-4 R-byggetjenester	14.7	25.0	0.0	32.2
B6	19.8	25.0	0.0	31.3
B7 Muspelheim. Terje Svenkerud. Ca 40 småhus tomannsbolig.	19.8	25.0	0.0	31.3
B8-1 Bakke eiendom regulering 2022	19.8	25.0	0.0	31.3
B8-2 Bakke eiendom regulering 2022	19.8	25.0	0.0	31.3
B-11 Vikingbygg	14.7	25.0	0.0	32.2
"Gammel barnehagetomt" 12 omsorgsboliger	20.0	30.0	0.0	75.4
"Gammel barnehagetomt" leiligheter	14.7	25.0	0.0	32.2

A2 Assumptions for specific net energy demand for the buildings/groups of buildings in the Baseline scenario

Building	Heating [kWh/m2]	Hot Water [kWh/m2]	Cooling [kWh/m2]	Electricity [kWh/m2]
Ydalir Skole	45.5	10.0	0.0	54.5
Ydalir Barnehage	83.9	10.0	0.0	41.1
B1	52.0	25.0	0.0	33.0
B2	35.8	25.0	0.0	34.2
B4	35.8	25.0	0.0	34.2
B5-1 Nordbolig Ydalir park 50 boenheter i massivtre	35.8	25.0	0.0	34.2
B5-2 Nordbolig Ydalir park	35.8	25.0	0.0	34.2
B5-3 R-byggetjenester "Høyden", 6-4-2 mannsbolig 80-140 m2	52.0	25.0	0.0	33.0
B5-4 R-byggetjenester	35.8	25.0	0.0	34.2
B6	52.0	25.0	0.0	33.0
B7 Muspelheim. Terje Svenkerud. Ca 40 småhus tomannsbolig.	52.0	25.0	0.0	33.0
B8-1 Bakke eiendom regulering 2022	52.0	25.0	0.0	33.0
B8-2 Bakke eiendom regulering 2022	52.0	25.0	0.0	33.0
B-11 Vikingbygg	35.8	25.0	0.0	34.2
"Gammel barnehagetomt" 12 omsorgsboliger	91.0	30.0	0.0	109.0
"Gammel barnehagetomt" leiligheter	35.8	25.0	0.0	34.2

A3 Assumed mix of district heating energy sources in Elverum in 2035

District Heating				
Energy Source				**Distribution**
Heat Source	**Coverage [%]**	**CO2 Emission [g/kWh]**	**Production efficiency**	**Distribution losses**
Electricity		123	0.95	10 %
Heat Pump		123	3.125	
Solar Collector		0	1	
Waste Heat		0	0.9	
Waste Incineration		11	0.9	
Wood Chips	100.0 %	18	0.9	
Pellets		19	0.9	
Bio-oil		10	0.9	
Bio-gas		10	0.9	
Fossile Oil		268	0.9	
LPG		235	0.9	

[redacted]

A4 Emission factors for the different transport technologies

	All emissions related to transport (LCA)				Direct emissions and emissions from production of fuel			
	Fel=18 gCO2e/kWh		**Fel = 136 gCO2e/kWh**		**Fel=18 gCO2e/kWh**		**Fel = 136 gCO2e/kWh**	
	Fossile [g/vkm]	**Electric [g/vkm]**	**Fossile [g/vkm]**	**Electric [g/vkm]**	**Fossile [g/vkm]**	**Electric [g/vkm]**	**Fossile [g/vkm]**	**Electric [g/vkm]**
Bus	3166.4	2023.0	3166.4	2174.1	1166.4	23.0	1166.4	174.1
Rail	4582.0	688.8	4582.0	688.8	4582.0	688.8	4582.0	688.8
Car	293.6	133.1	293.6	153.1	200.6	3.1	200.6	23.1
Truck	2236.5	2010.8	2236.5	2081.6	236.5	10.8	236.5	81.6

A5 Share of electric vehicles

	Baseline	**ZEN**
Bus	50 %	100 %
Rail	50 %	50 %
Car	20 %	20 %
Truck	20 %	20 %

A6 Efficiencies of heating technologies used (production efficiency+distribution efficiency+control efficiency)

Technology	Heating	Hot water
Electric boiler	0.86	0.54
Electric heater	0.88	-
Electric water heater	-	0.58
District Heating	0.87	0.55

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