Research Centre on ZERO EMISSION NEIGHBOURHOODS IN SMART CITIES

NTNU SINTEF

THE ZEN DEFINITION – A GUIDELINE FOR THE ZEN PILOT AREAS

Version 2.0

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Research Centre on
ZERO EMISSION
NEIGHBOURHOODS
IN SMART CITIES

ZEN Report No. 40

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Preface

Acknowledgements

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The Research Centre on Zero Emission Neighbourhoods in Smart Cities

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

Researchers, municipalities, industry, and governmental organizations work together in the ZEN Research Centre to plan, develop, and run neighbourhoods with net zero greenhouse gas emissions. The ZEN Research Centre has nine pilot projects spread throughout Norway that encompass an area of more than 1 million m^2 with more than 30 000 inhabitants.

To achieve its high ambitions, the Centre, together with its partners, will:

- Develop neighbourhood design and planning instruments that integrate science-based knowledge on greenhouse gas emissions.
- Create new business models, roles, and services that address the lack of flexibility towards markets.
- Catalyse the development of innovations for broader public use, including 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 life cycle design strategies.
- Develop technologies and solutions for the design and operation of energy flexible neighbourhoods.
- Develop a decision-support tool for optimising 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, Kunnskapsaksen Sluppen and Kunnskapsaksen Campus NTNU in Trondheim, Mære landbruksskole in Steinkjer, Ydalir in Elverum, Campus Evenstad in Hedemark, Ny By – Ny Flyplass in Bodø, and Zero Village in 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.

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The editors would like to thank all ZEN practitioners and researchers for their contributions. The list below gives an overview of participants in the ZEN definition expert category groups that have contributed to the guidelines:

GHG Emissions: Marianne Kjendseth Wiik (SINTEF), Selamawit Mamo Fufa (SINTEF), Kristin Fjellheim (SINTEF), Christofer Skaar (SINTEF), Carine Lausselet (SINTEF), Håvard Bergsdal (SINTEF), Eirik Resch (NTNU), and Camille Vandervaeren (SINTEF).

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Bodø kommune, Energi Norge, Elverum Vekst, FutureBuilt, Norsk Fjernvarme, Statsbygg, and Trondheim kommune.

Document History

Version	Date	Version description
Version 1.0	2018	The first version of the ZEN definition guideline report provided a guideline for how the assessment criteria and key performance indicators (KPI) covered under each category of the ZEN definition may be assessed and followed up in ZEN pilot projects. The report explained relevant evaluation methodologies and the source and type of data used to evaluate and document each of the seven ZEN categories (GHG emission, energy, power, mobility, spatial qualities, economy, and innovation) and their related KPIs. Furthermore, the report briefly illustrated ZEN pilot projects, highlighted limitations, and described the scope for further work.
Version 2.0	2021	This second version (version 2.0) of the ZEN definition guideline report builds upon V1.0 of the ZEN definition guideline report and series of ZEN definition reports. This report gives an updated and detailed explanation of the ZEN categories, and new information about the KPI tool and framework.

Abstract

This second version (V2.0) of the ZEN definition guideline report builds upon version V1.0 of the ZEN definition guideline and series of ZEN definition reports. The ZEN categories for GHG emissions, energy, and power have been updated after having been tested in selected pilots. In addition, a description of the ZEN KPI tool and framework has been added. Finally, the ZEN categories mobility, spatial qualities, economy, and innovation have been updated.

Sammendrag

Denne andre utgaven av ZEN definisjonsveilederen bygger på versjon V1.0 av ZEN definisjons-veilederen og ZEN definisjonsrapporter. ZEN kategoriene klimagassutslipp, energi og effekt er oppdatert etter å ha blitt testet ut i utvalgte piloter. I tillegg er det lagt til en beskrivelse av ZEN KPI-verktøyet og rammeverket. Videre er ZEN kategoriene mobilitet, stedskvaliteter, økonomi og innovasjon blitt oppdatert.

Contents

1 Background

The goal of the Research Centre on Zero Emission Neighbourhoods in Smart Cities (ZEN Research Centre) is to enable the transition to a low-carbon society by developing sustainable neighbourhoods with net zero greenhouse gas (GHG) emissions. To reach this goal, there is a need for the following:

1. A clear ZEN definition with assessment criteria and key performance indicators (KPIs), which will help to plan and implement the neighbourhood and to monitor its performance,
2. A guideline for how the definition of ZEN and its KPIs can be assessed and implemented into the planning, implementation, and operational phases of new and/or existing neighbourhoods,
3. A ZEN KPI assessment tool to monitor the performance of a new and/or existing neighbourhoods with different ambition levels,
4. ZEN pilot projects to validate the ZEN definition through testing and implementation.

The ZEN Research Centre is organised into six work packages (WP), shown in Figure 1. The ZEN definition, categories, assessment criteria and KPIs are developed in WP1 and are published in a separate series of reports (1–3). The definition work is an ongoing process throughout the programme period (2017-2024). The aim of the ZEN definition guideline developed under WP6 is to describe how the KPIs can be implemented in the various ZEN pilot projects. This is an iterative process whereby the KPIs will be continually tested and further developed through the ZEN pilot projects, the results of which will be fed back into the development of the ZEN definition, assessment criteria, and KPIs in WP1.

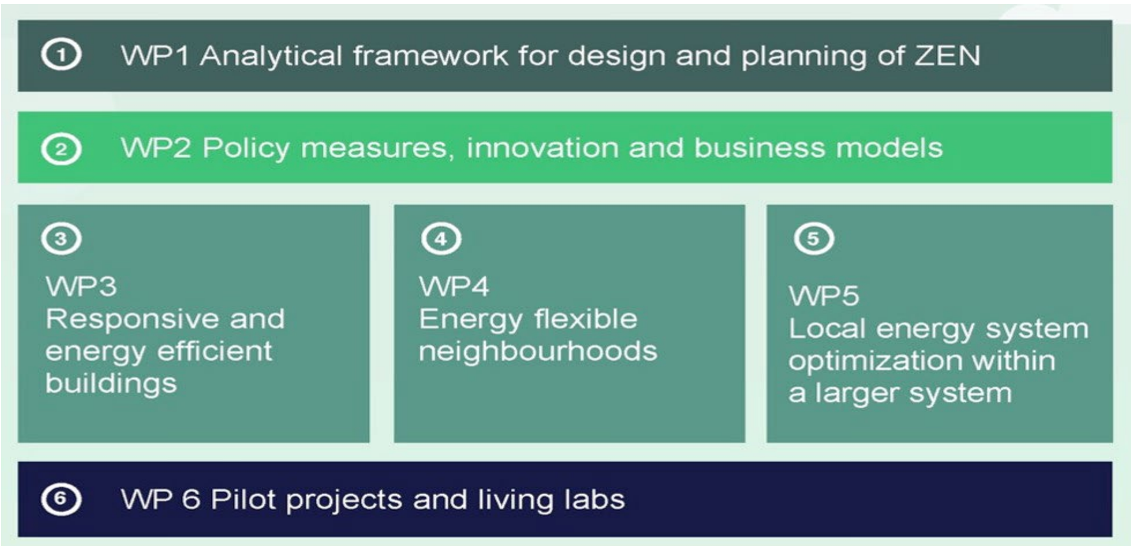

Figure 1. Work packages within the ZEN Research Centre.

1.1 The ZEN Definition

The Zero Emission Neighbourhood is defined with assessment criteria and KPIs in the ZEN Definition report (latest published version 3.0) (3). This ZEN Definition report is the backbone to the present ZEN Definition Guideline report version 2.0 and should be read beforehand. A concise ZEN definition is provided as reminder:

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 net zero over the analysis period [3)], in line with a **chosen ambition level**[4)]. The neighbourhood should focus the following aspects, where the first four have direct consequences for energy and emissions:

a. Plan, design, and operate buildings and associated infrastructure towards minimized life cycle **GHG emissions**.
b. Become highly **energy efficient** and powered by a high share of new **renewable energy**.
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.
f. Plan and locate amenities in the neighbourhood to provide good **spatial qualities** and stimulate **sustainable behaviour**.
g. Development of the area is characterised by innovative processes based on new forms of cooperation between the involved partners leading to **innovative solutions**.

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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 lives for components that will be replaced.

4) Ambition level will be further developed in future versions of the definition and when reference values are established.

5) Flexibility should facilitate the transition to a decarbonised energy system and reduced power and heat capacity requirements.

The ZEN definition consists of seven categories: Greenhouse gas emissions (GHG), Energy (ENE), Power (POW), Mobility (MOB), Spatial Quality (QUA), Economy (ECO), and Innovation (INN). Each category contains a set of assessment criteria and KPIs (except the innovation category), as presented in Table 1.

Table 1. ZEN categories, assessment criteria and key performance indicators (KPIs) (3).

Category	Assessment criteria	KPI
GHG	Emission reduction	GHG1.1 Materials (A1-A3, B4)
		GHG1.2 Construction (A4-A5)
		GHG1.3 Use (B1-B3, B5)
		GHG1.4 Operational energy use (B6)
		GHG1.5 Operational transport (B8)
		GHG1.6 End-of-life (C1-C4)
	Compensation	GHG1.7 Benefits and loads (D)
ENE	Energy efficiency in buildings	ENE2.1 Energy need in buildings
	Energy carrier	ENE2.2 Delivered energy
		ENE2.3 Self-consumption
POW	Power performance	POW3.1 Peak load
		POW3.2 Peak export
	Load flexibility	POW3.3 Load flexibility
MOB	Access	MOB4.1 Access to public transport
		MOB4.2 Travel time ratio
		MOB4.3 Parking facilities
		MOB4.4 Car ownership
	Travel behaviour	MOB4.5 Mobility pattern
		MOB4.6 Passenger and vehicle mileage
	Logistics	MOB4.7 Freight and utility transport
QUA	Process	QUA5.1 Demographic analysis
		QUA5.2 Stakeholder analysis
		QUA5.3 Needs assessment
		QUA5.4 Consultation plan
	Urban form	QUA5.5 Urban accessibility
		QUA5.6 Street connectivity
		QUA5.7 Land use mix
		QUA5.8 Green space
ECO	Life Cycle Costs (LCC)	ECO6.1 Capital costs
		ECO6.2 Operational costs
	Cost benefit	ECO6.3 Overall performance

1.2 The ZEN KPI Tool Framework

The ZEN KPI tool conceptual framework is depicted in Figure 2 and demonstrates how the ZEN definition shall be operationalised within the ZEN pilot projects (4). The ZEN KPI tool framework demonstrates how the defined scope, the different stakeholders, and the project phases (grey box) come together to select relevant tools (ZEN toolbox) to assess the assessment criteria and KPIs for each category within the ZEN definition (yellow box). The results from these assessments can be fed into the ZEN KPI tool (green box) and analysed to ascertain if the neighbourhood has achieved zero emission neighbourhood status. These results can then also be used to create various visualisations (blue box). This conceptual framework has been developed based on information and experiences from ongoing work with the ZEN definition, ZEN pilot areas, ZEN stakeholders, and existing tools, and builds upon the initial ZEN toolbox framework developed by Houlihan Wiberg and Baer (5). The ZEN KPI tool framework will be applied in different contexts and will consider different project phases, scope, and stakeholders. The main components of the framework are:

- the ZEN toolbox,
- the ZEN assessment criteria and KPIs,
- the ZEN KPI tool, and
- Visualisation.

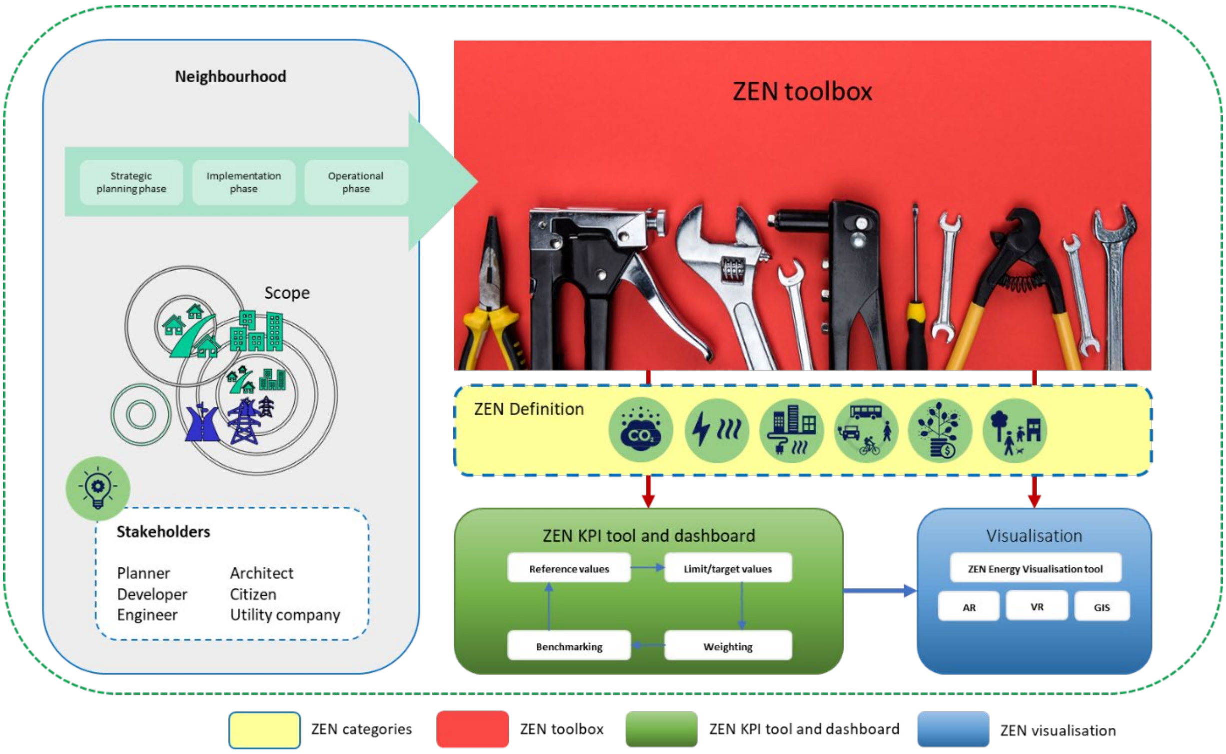

Figure 2. ZEN KPI tool conceptual framework developed from (52).

<u>Scope</u>

The scope of assessment varies from KPI to KPI, with some KPIs assessed at building level, some at neighbourhood level, and others considering both. The KPIs are assessed by a range of stakeholders, including but not limited to planners, architects, developers, citizens, engineers, consultants, and utility companies. During its lifetime, a neighbourhood will go through many project phases. The three project phases to be assessed in the ZEN definition are:

1. Strategic planning phase,
2. Implementation phase, and
3. Operational phase.

It is possible, and even likely, for one neighbourhood to experience multiple project phases simultaneously. Each ZEN pilot area should be classified according to the various planned phases of development. Each development phase will go through the same project phases, but at different times. It can therefore be ensured that each phase of the development is properly documented for each project phase, and that the project data for each phase of the development and project phase is compiled to represent the whole neighbourhood area.

<u>ZEN toolbox</u>

The ZEN toolbox depicted in Figure 3 contains suggestions of useful and existing tools that can calculate the results of various assessment criteria and KPIs in the ZEN definition. This list is not exhaustive and will be refined and expanded in the future. A first initial mapping of existing tools was carried out by ZEN stakeholders, and more tools were added to the ZEN toolbox as various assessment criteria and KPIs have been tested in the ZEN pilot areas. The tools are loosely grouped according to which category they can be used in.

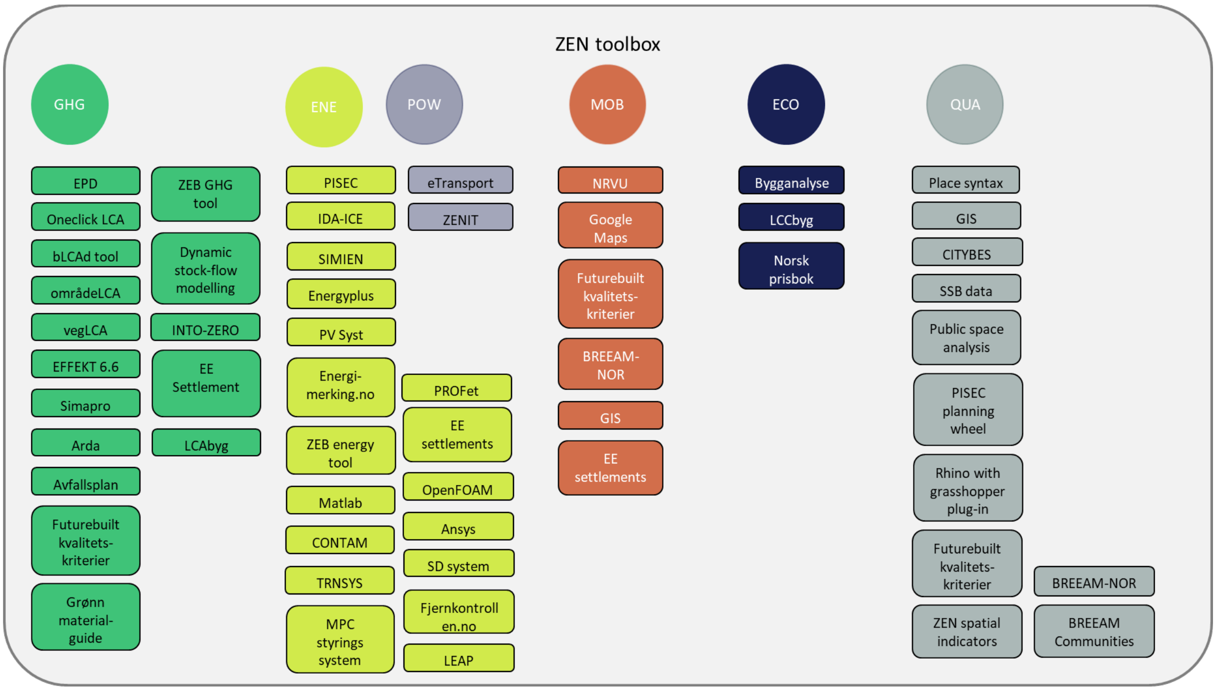

Figure 3. ZEN Toolbox overview (list of tools is not exhaustive)

The findings from the mapping of tools show a lack of harmonisation between these tools, which leads to difficulties in harmonising the inputs and outputs of a potential ZEN KPI tool. Some of the main issues include differences in system boundaries, methodology and background data (data bases) used, as well as differences in data resolution used dependent on the phase of the project (i.e., typically a low data resolution is used in the early planning phases and a high data resolution in the latter project phases). The various tools identified in the mapping use a range of different computing formats. Thus, a ZEN

KPI tool would need to be flexible and compatible with these different formats (e.g., csv, xml, json, sql, and html) (4,6). Further work will involve the continued mapping of tools for the ZEN toolbox, and connecting these tools to stakeholders, project phases, and KPIs.

ZEN KPI tool

The testing and development of the ZEN definition and ZEN KPI tool is a continuous, iterative process, which involves determining suitable reference projects and reference values, as well as limit and target values, weighting, and benchmarking for each KPI in the ZEN definition. The main purpose of the ZEN KPI tool is to operationalise the ZEN definition, and aid ZEN stakeholders through the planning, implementation, and operation of net zero emission buildings, infrastructure, and neighbourhoods. The ZEN KPI tool should therefore be flexible, easy to use and understand, and produce clear and concise results. It should also be a tool that is transparent and that can be used to compare results between different projects, and between different scenarios within a project. As the ZEN definition and the ZEN KPIs are still under development and will be tested and revised in the ZEN pilot areas, the tool will therefore have to be dynamic and easy to update during the ZEN project period. For the KPI tool to be useful it needs a clear user-perspective and the ability to be implemented in various projects phases (i.e., strategic planning phase, implementation phase, and operational phase), for various scopes of assessment (i.e., material/component, building/infrastructure, neighbourhood, and city) and for several different stakeholders (i.e. planners, developers, architects, engineers, utility companies, and citizens, etc.). The ZEN KPI tool was initially developed in MS Excel but will be further developed as a web-based tool with a user-friendly front end.

Reference projects and reference values

In some KPIs, a reference project and/or reference values are required. A reference project is a project that represents the zero emission neighbourhood if it was designed and built according to today's standards (business as usual) instead of being designed, built and managed to fulfil KPI goals or requirements. The purpose of the reference project is to act as a comparison, providing reference values to document how much a ZEN pilot area has managed to fulfil KPI goals or requirements. Reference projects use reference values based on today's technical standards. For example, a reference project may use building energy requirements from the current building code (TEK) to ascertain how much energy different buildings within the neighbourhood would use if they were not designed within the ZEN framework. A reference project might use the Norwegian travel survey (NRVU) to ascertain reference mobility patterns in the ZEN pilot area before measures have been implemented to encourage more active and public transport. A ZEN pilot area can then track how much it has been able to reduce energy or private travel demands compared to these reference values. The reference project will typically not include any zero emission strategies.

Limit and target values

Limit values are defined in regulations or national standards. They relate to the minimum requirements for upper or lower values for different aspects of performance. Target values represent an objective that goes beyond the reference value.

Weighting

Points will be allocated and awarded to each KPI within the ZEN definition. Allocation and weighting of these points will be developed in subsequent versions of the ZEN definition and guideline reports.

Benchmarking
The ZEN KPI tool will enable users to compile results from the ZEN toolbox to assess individual KPIs and receive a ZEN category rating and ZEN neighbourhood rating. The benchmarking of ZEN categories and ZEN neighbourhoods to achieve a rating will be developed in subsequent versions of the ZEN definition and guideline reports.

ZEN Visualisation Toolbox
The ZEN visualisation toolbox is a collection of externally and internally developed tools to visualise results from the ZEN toolbox and ZEN KPI tool. Such tools can include the ZEN energy visualisation tool, ZEN KPI dashboard, augmented reality (AR), virtual reality (VR), and GIS. The ZEN visualisation toolbox will be further developed in subsequent versions of the ZEN definition and guideline reports.

1.3 ZEN Pilot Projects

The ZEN Research Centre has nine ZEN pilot areas in Norway, where new solutions for the planning, implementation, and operation of buildings and infrastructure are tested to cut the total GHG emissions towards net zero on a neighbourhood scale. ZEN pilot areas function as role models, inspiring others to build zero emission neighbourhoods, and offering explanations about how the best possible results can be achieved. The nine ZEN pilot areas are: Ydalir in Elverum, Furuset in Oslo, Ny By – Ny Flyplass in Bodø, Kunnskapsaksen in Sluppen in Trondheim, Kunnskapsaksen at NTNU Campus in Trondheim, Mære landbruksskole in Steinkjer, Zero Village in Bergen, Campus Evenstad in Hedmark, and Fornebu in Bærum (Figure 4).

Figure 4. Location (left) and illustration (right) of the ZEN pilot projects. (Credits for illustration and pictures from left to right are as follows: tegn3, a-lab, Bodø Municipality, Kjeldsberg Eiendom, Koht Arkitekter, Zeiner Media, Snøhetta/Mir, Statsbygg, Wilhelm Joys Andersen).

Work has begun on testing out the various KPIs in the ZEN pilot areas. Table 2 provides an overview of which KPI categories have been tested out in the different ZEN pilot areas. The letter x indicates

KPIs assessed, whilst (x) indicates KPIs currently under investigation. So far, nearly all ZEN pilot areas have tested out the energy and power KPIs, and a few ZEN pilot areas have tested out the GHG emission KPIs. Work has begun on investigating the mobility and spatial quality KPIs in some of the pilot areas. This work will continue until all the KPIs have been tested out in all ZEN pilot areas.

Table 2. Overview of testing of KPIs in ZEN pilot areas.

	GHG	ENE	POW	MOB	QUA	ECO
Ny By – Ny Flyplass, Bodø		x			(x)	
Kunnskapsaksen, Campus, Trondheim	(x)					
Kunnskapsaksen, Sluppen, Trondheim	x	x	x		(x)	
Mære landbruksskole, Steinkjer	x	x				
Fornebu, Bærum		x	x		(x)	
Ydalir, Elverum	x	x	x	(x)	(x)	
Campus Evenstad, Hedmark		x	x			(x)
Furuset, Oslo		x	x			
Zero Village, Bergen		x	x	(x)		

x indicates KPIs assessed, (x) indicates KPIs under investigation.

1.4 The ZEN Definition Guideline

This ZEN Definition Guideline report version 2.0 builds upon the previous ZEN definition guideline report (7) and the series of ZEN definition reports (1–3). It explains six ZEN categories presented in Table 1 (all ZEN categories except Innovation) under a dedicated chapter. Each chapter outlines documentation requirements, assessment criteria, and KPIs, and includes a summary table explaining how to calculate each KPI. It should be noted that the summary table varies, whereby some are more detailed than others, depending on how far the development of the KPI has come in the testing and validation process.

The ZEN KPIs are assessed based on a basket of relevant national and international standards and reference documents. An overview of these standards is included in Appendix A to this ZEN Definition Guideline report. General familiarity with these standards and reference documents is necessary to understand the descriptions of the various KPIs, their documentation requirements, and the methodology for the calculations.

2 GHG Emissions

A zero emission neighbourhood (ZEN) focuses on strategic planning, implementing, and operating buildings and their associated infrastructure towards achieving minimised direct and indirect life cycle GHG emissions over the analysis period. Therefore, the ZEN definition category 'GHG emissions' is the only mandatory category for ZEN pilot areas. The method for the assessment of the GHG criteria and the calculation of GHG KPIs is based on the method provided by *NS 3720:2018* (8). It follows the same modularity in life cycle stages (abbreviated A1-A5, B1-B8, C1-C4 and D, see Figure 8) and similar reporting per building element (referred to by one and two digits). Deviations from this method are mentioned in the following sections.

2.1 Documentation Requirements

Scope

In the ZEN definition, GHG emissions should be calculated at four different levels: (1) building envelope, (2) advanced building, (3) infrastructure, and (4) neighbourhood (Figure 5).

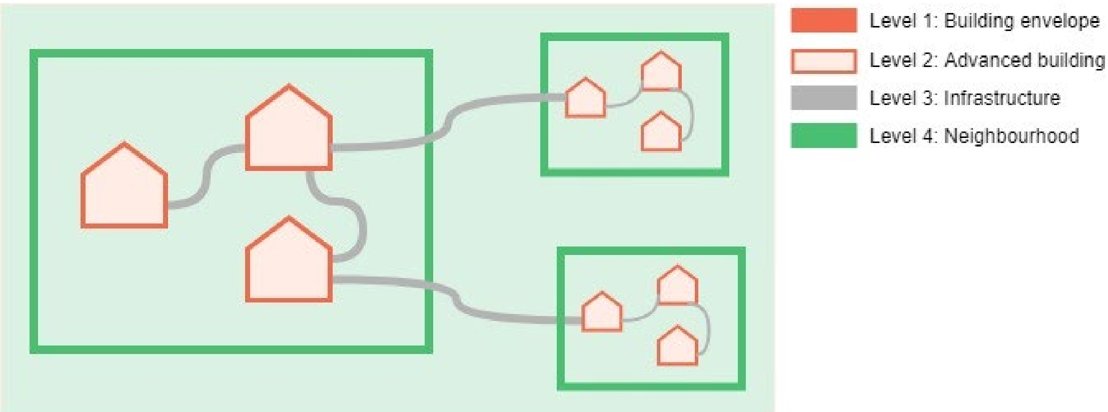

Figure 5. The four assessment levels for the GHG emissions category in the ZEN definition.

The first ZEN level, building envelope, corresponds to the *NS 3720* Basic level, and includes the building elements 21, 22, 23, 24, 25, 26, 27, 28, 29 and 49 in *NS 3451* - Table of Building Elements (9), see Appendix B. Building element 49 represents materials used for local energy production systems. For the ZEN definition, *NS 3720* Advanced level is divided in two parts: the advanced building level and the infrastructure level. At the ZEN advanced building level, building elements 21-69 should be included, which comprises the building envelope and all technical systems. The infrastructure level covers building elements 71 to 79. The neighbourhood level comprises the first three levels, hence includes building elements 21 to 79. Each assessment level corresponds to a reporting unit, as detailed in the following section. The neighbourhood level also includes the GHG emissions relating to B8: operational transport (i.e., user mobility both within the neighbourhood and to and from neighbourhoods), as a separate reporting unit (tCO_{2eq}/user/yr). The four ZEN GHG assessment levels and their correspondence to *NS 3720* levels are indicated in Table 3.

Table 3. Corresponding assessment levels in ZEN GHG emissions category and *NS 3720*, related building elements and reporting units. GFA= Gross Floor Area (in Norwegian, *Bruttoareal - BTA*), PA= Plot Area.

***NS 3720* assessment levels**	**ZEN GHG emissions assessment levels**	**Included building elements (as defined in *NS 3451*)**	**Reporting unit**
Basic, without location	(1) Building envelope	21-29 + 49	$kgCO_{2eq}/m^2_{GFA}/yr$
Advanced, without location	(2) Advanced building	21-69	$kgCO_{2eq}/m^2_{GFA}/yr$
	(3) Infrastructure	71-79	$kgCO_{2eq}/m^2_{PA}/yr$
Basic or Advanced, with location	(4) Neighbourhood	21-79	tCO_{2eq}
	B8: Operational transport		$kgCO_{2eq}/user/yr$

Reporting

The different types of buildings and infrastructure types within a ZEN pilot area should be described to at least a 2-digit level according to the building element table found in *NS 3457-3* (see Appendix B) (10). Building areas, number of users, reference study period, system boundaries, scenario descriptions, bill of material quantities, and emissions data sources should be reported per ZEN GHG emissions assessment level for each life cycle module (see Figure 8) and building part (see Appendix B). All GHG results from the four assessment levels, i.e., Building envelope, Advanced building, Infrastructure, and Neighbourhood (Table 3), should be reported for each building element and life cycle module in a reporting matrix. An example of this reporting matrix can be found in Appendix B. The result of the assessment of GHG emissions associated to the ZEN pilot areas should be reported in the following units:

1. tCO_{2eq}
2. $kgCO_{2eq}/m^2_{GFA\ (gross\ floor\ area)}/year$
3. $kgCO_{2eq}/m^2_{PA\ (plot\ area)}/year$
4. $kgCO_{2eq}/user\ /year$

The first unit expresses the total GHG emissions in terms of tonnes of carbon dioxide equivalents (tCO_{2eq}). This unit is valid for the Neighbourhood assessment level. The second unit expresses the total GHG emissions in buildings per square meter of gross floor area (m^2_{GFA}), as defined in *NS 3940* (11) - Bruttoareal (BTA) in Norwegian [corresponding to Gross Floor Area (GFA)], and as shown in Figure 6. This unit is only valid for the first (Building envelope) and second (Advanced building) ZEN assessment levels. The third unit corresponds to plot area (PA). This unit is valid for the third assessment level (Infrastructure). The fourth unit, $kgCO_{2eq}/user/year$, expresses the GHG emissions per user in the studied system (building or neighbourhood) during one year of operation. This unit is valid for KPI GHG1.5 Operational transport (B8). It will be considered whether other GHG indicators should also use a reporting unit per user.

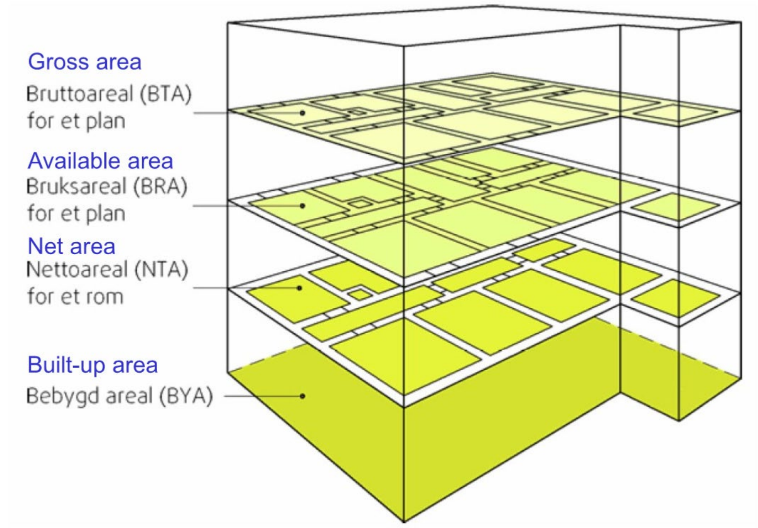

Figure 6. Building areas according to *NS 3940* (11). The ZEN definition uses Gross area (BTA) for GHG assessment levels 1 and 2 and adds the plot area (PA) for the assessment level 3.

Reference study period and estimated service life

In line with *NS 3720,* the reference study period (RSP) of the building, infrastructure, and neighbourhood is set to 60 years. The estimated service life (ESL) of the buildings and neighbourhood is 60 years. Infrastructure has an ESL of 100 years. Estimated service lives for materials, components, and products will vary according to areas of application. The reference study period for mobility is one year.

Allocation of material and energy flow beyond the ZEN

In line with *NS 3720,* existing buildings and infrastructure are considered to have no GHG emissions for the original production, transportation, and installation of the building and infrastructure elements. The impacts from changes made to existing buildings and infrastructure (e.g., through refurbishment) during the RSP should be included in the assessment.

The allocation of building materials and elements that are reused, recycled, or incinerated with energy recovery should follow the methodology described in *EN 15804+A2:2019* (12). For the neighbourhood level, allocations rules still need to be further developed by the ZEN partners. Concerning material reuse at neighbourhood level, four types of material reuse could occur. The first type of material reuse relates to the materials kept in place without disassembly or transport. These materials are expected to have limited cleaning, repair, and reprocessing activities. The second type relates to materials relocated within the neighbourhood. The third type occurs when materials are removed and transported outside the boundaries of the neighbourhood. The fourth type of material reuse occurs if external (reused) materials are imported into within the boundaries of the neighbourhood.

Environmental data for Life Cycle Impact Assessment

In a strategic planning phase, generic data (e.g. data from Ecoinvent (13)) may be used. In the implementation and operational phases, individual (also called specific) Environmental Product Declarations (EPDs) developed according to *NS-EN 15804* should be used for product-specific emission factors. When no individual EPDs are available, then joint EPDs (i.e., data from a group of manufacturers (14)), average EPDs (i.e., data from individual and joint EPDs (14)), or generic data from Ecoinvent can be used, according to the hierarchy of environmental data in Figure 7. Generic emission factors can also be used from published LCA reports or articles. As a rule, specific data should not be older than five years, and generic data should not be older than ten years.

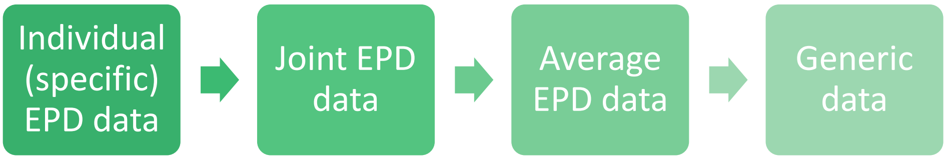

Figure 7. Hierarchy of environmental data types to use in the calculation of GHG KPIs.

Biogenic carbon

Since the whole life cycle of the ZEN pilot area is to be included, biogenic carbon for wood and wood-based products should be calculated according to *NS-EN 16449* (15) and *NS-EN 16485* (16). Similarly, carbonation of concrete should be calculated according to *NS-EN 16757* (17).

2.2 Assessment Criteria

The GHG emissions category is divided into two assessment criteria: 'Reduction' and 'Compensation'. The Reduction criterion emphasises life cycle modules A to C, as defined in *NS 3720,* and has six related KPIs (8). The Compensation criterion emphasises module D and has one related KPI. Figure 8 shows how KPIs relate to these life cycle stages. Note that life cycle module B7 (operational water use) is not considered in the GHG emissions category.

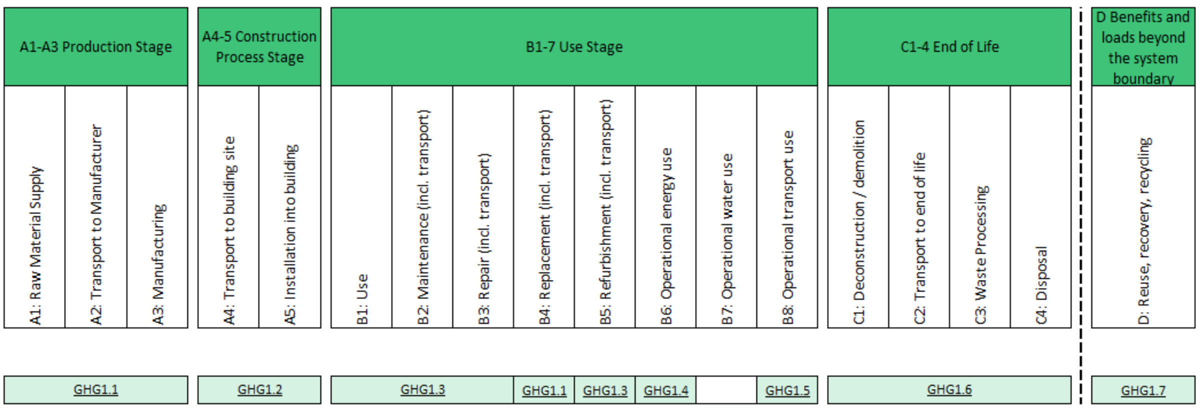

Figure 8. How KPIs relate to the life cycle stages defined in the *NS 3720* (8).

2.3 KPIs

GHG1.1 Materials (A1-A3, B4)

The objective of this KPI is to minimise the total embodied GHG emissions from a building or neighbourhood (existing or new) life cycle, with a focus on material use across a reference study period of 60 years (Table 4). The goal is to reduce the embodied GHG emissions from the production and replacement phases of materials (life cycle modules A1-A3 and B4) for each building and infrastructure component within the neighbourhood. The calculation of this KPI should be completed according to the *NS 3720* advanced calculation for life cycle module A1-A3 and B4.

In the strategic planning phase, material quantities can be obtained from architect and planner drawings, from building information modelling (BIM), and from city information modelling (CIM). In the implementation and operational phases, material quantities can be checked against the bill of quantities produced by the quantity surveyor, against product orders and bills from the contractor and sub-contractors, and through site inspections.

To develop realistic scenarios for material replacement, data in EPDs should be used when available. If not, then the SINTEF design guideline for replacement and maintenance intervals for building parts *(Bks 700.320 intervaller for vedlikehold og utskiftninger av bygningsdeler)* (18) can be used to ascertain reference service lifetimes of construction components.

Table 4. Summary for calculating KPI GHG1.1.

GHG1.1	**Materials (A1-A3, B4)**
Objective	To minimise the total embodied GHG emissions from a building, infrastructure, or neighbourhood's life cycle, with a focus on material use, across a reference study period of 60 years.
Description	Reduce total embodied GHG emissions from the production and replacement phases of materials (life cycle modules A1-A3, B4) for each building and infrastructure within the neighbourhood.
Method	*NS 3720* (Method of GHG emissions calculation for buildings), *NS 3451* (Table of Building Elements), *EN 15804* (EPD methodology for construction products)
ZEN KPI assessment	The target values for *NS3720* building basic will be ascertained through the ZEN case on GHG emissions requirements for material use in buildings (19), and aligned with limit values from the forthcoming revision of Norwegian building regulations (TEK21), which should include GHG emission requirements for buildings. These target values will be published in a future ZEN report.

GHG1.2 Construction (A4-A5)

The objective of this KPI is to achieve waste-free and emission-free construction. It focuses on life cycle stage A4 (transport of material to construction site) and A5 (installation and construction).

The construction activities system boundary for ZEN pilot areas is based on *NS 3720* (8), as depicted in Figure 9. Activities included are

- production and transport of additional materials such as glue, screws, and tape for installing construction products,
- transport of construction machinery and personnel to and from the construction site,
- transport and disposal of waste generated during construction works (including packaging) to waste treatment,
- energy use on site (e.g. building heating and drying during the construction phase),
- internal transport,
- storage,
- temporary works,
- operation of construction machinery on site.

Water use and demolition works are not included.

In the strategic planning phase, knowledge gained from previous projects may be used to estimate the life cycle inventory for construction activities. In the implementation and operational project phases, the life cycle inventory for construction activities can be gathered from construction machinery and transport logs from the construction site, filled out by the contractor and sub-contractors. These data can be verified against product orders, bills, and through onsite inspections. In addition, information on transport of materials to site can be extracted and adapted from the transport scenarios provided in EPDs. An overview of the additional materials and energy used for installing products can be ascertained from installation manuals and product data sheets from manufacturers. Information on the amount and type of waste produced on site can be extracted from the waste plan (*avfallsplan*) that is reported by the contractor to the local authorities. The waste plan can also be used in the strategic planning phase. The waste plan shall include waste fractions in kg for untreated wood; paper, cardboard and carton; glass; iron and other metals; gypsum-based materials; plastic; concrete, brick, and other heavy building materials; electric and electronic waste; mineral wool insulation; mixed construction waste; hazardous or special waste; and total construction waste sorted. It shall also include the total amount of waste generated on site (kg/m^2) and the percentage of waste fraction recycled. Waste treatment scenarios can be developed according to current waste treatment practices (20). Further work is needed to harmonise this KPI with the coming Norwegian Standard for emission free building and construction sites (pr*NS 3770*) and the upcoming report of the ConZerW research project (21).

Measuring GHG emissions from construction sites is a relatively new field of research, and as a result, sources of specific emission factors are limited. Transport emission factors for goods and person transport from *NS-EN 16258* (22) may be used in emission calculations (Table 10). The appendices of *NS 3720* also include additional emission factors for various modes of transport. When using emission factors for transport, it is important to use 'well-to-wheel' emission factors that include infrastructure and the complete life cycle of vehicle and fuel production.

Table 5. Summary for calculating KPI GHG1.2.

GHG1.2	**Construction (A4-A5)**
Objective	To achieve emission-free and waste-free construction.
Description	An emission-free construction site is a construction site that doesn't have any direct GHG emissions from its construction site activities. Electric or hydrogen powered construction machinery, electricity use for heating, drying and electricity, use of zero emission vehicle transport to, from, and on the construction sites are some of examples of emission free alternatives (41). A fossil-free construction site is a construction site that doesn't use any fossil fuels in any of its on-site activities. Fossil-free construction sites may use bioenergy or biofuels while emission-free construction sites use only renewable energy resources such as electricity and hydrogen (41). A waste-free construction site is defined as a construction site that doesn't generate waste from construction site activities - involving no transport of products from the construction site to material and energy recovery or landfill (21).
Method	*NS 3720* (Method of GHG emissions calculation for buildings), NS 3451 (Table of Building Elements), *EN 15804* (EPD methodology for construction products), *NS-EN 16258* (Methodology for calculation and declaration of energy consumption and GHG emissions of transport services), *prNS 3770* Emission free building and construction sites
ZEN KPI assessment	Target values will be connected to the steps identified in Figure 9.

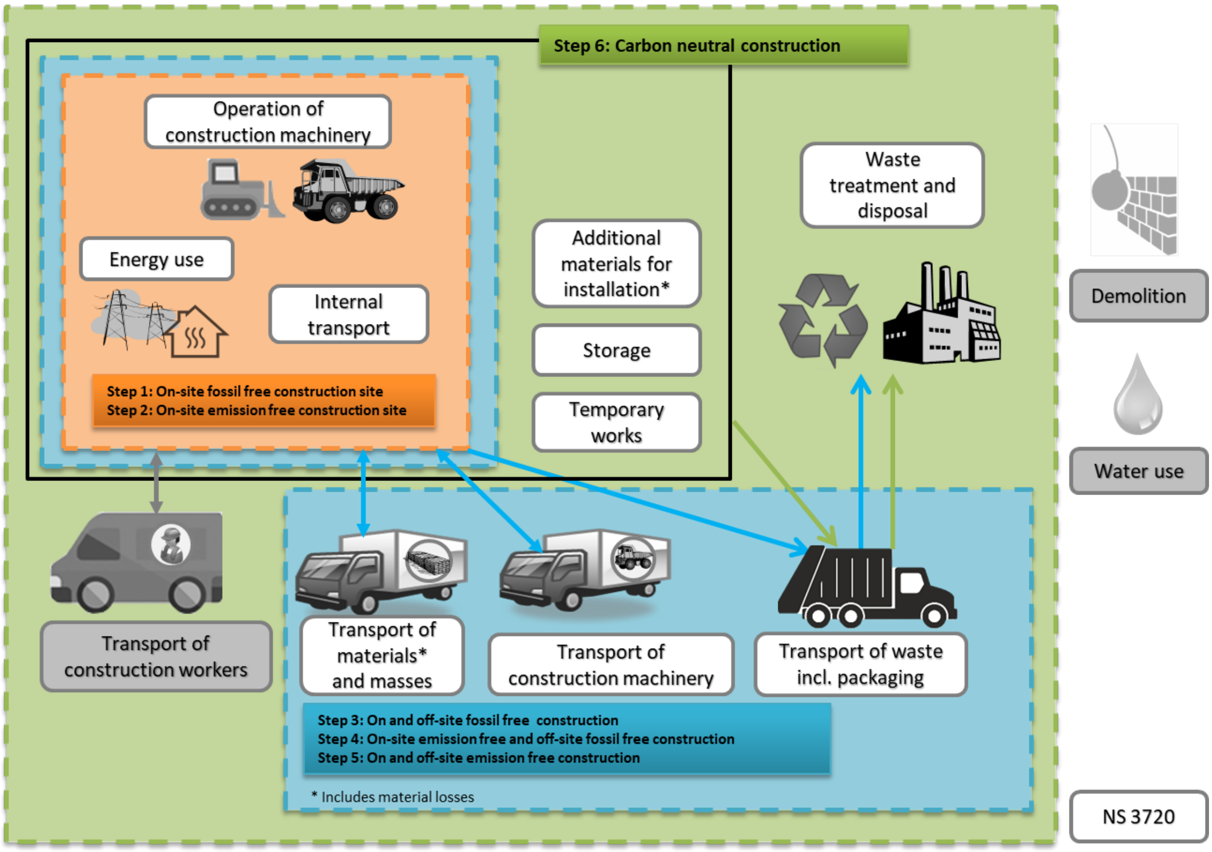

Figure 9. Overview of the system boundary for the construction phase, adapted from (23,24).

GHG1.3 Use (B1-B3, B5)

The use stage (B1-B3, B5) KPI considers GHG emissions from the operation of buildings and infrastructure: emissions resulting from installed products in buildings (B1 e.g., release of GHG substances from surfaces, carbonation of concrete), maintenance operation (B2 e.g., cleaning, changing filters), repair (B3 e.g., fixing a broken glass pane, keeping the windows frame), and refurbishment (B5 e.g., refurbishment of a kitchen, bathroom, or facade). Another important aspect of this KPI will involve mapping the resources used within the neighbourhood. Possible approaches include the use of material passports or digital twins (e.g., boligmappa.no) which may include product documentation; lifetimes; technical performance and characteristics; warranties and guarantees; EPDs; information on management, maintenance, repairs, refurbishment, and demountability of components for future reuse.

Table 6. Summary for calculating KPI GHG1.3.

GHG1.3	**Use (B1-B3, B5)**
Objective	To reduce GHG emissions towards zero from the operation of buildings and infrastructure (life cycle modules B1-B3 and B5).
Description	This KPI involves calculating GHG emissions from B1-B3 and B5 stages, and a mapping of resources used within the building, infrastructure project, or the neigh-bourhood.
Method	*NS 3720* (Method of GHG emissions calculation for buildings), *NS 3451* (Table of Building Elements)
ZEN KPI assessment	The limit and target values will be developed in future ZEN work.

GHG1.4 Operational energy use (B6)

The operational energy use (B6) KPI aims to reduce GHG emissions from energy used during the operational stage of the building or neighbourhood. The use of KPI ENE2.2 Delivered energy is a prerequisite for this KPI. The calculation of this KPI should be completed according to *NS 3720* for life cycle module B6. The GHG emissions from exported energy over the building's system boundary should be reported separately under GHG1.7 Benefits and loads (D).

Table 7. Summary for calculating KPI GHG1.4.

GHG1.4	**Operational energy use (B6)**
Objective	To reduce the GHG emissions from energy used during the operational stage of the building or neighbourhood.
Description	This KPI involves calculating GHG emissions relating to operational energy use. Completing ENE2.2 Delivered energy is a prerequisite.
Method	*NS 3720* (Method of GHG emissions calculation for buildings), *NS 3451* (Table of Building Elements)
ZEN KPI assessment	The limit and target values will be developed in future ZEN work.

The methodology outlined in *NS 3720* will be used for GHG emission calculations in ZEN, including the energy emission factors for various energy carriers as outlined in Table 8. This will be the case until ZEN-specific emission factors have been developed. Scenarios for GHG emissions using different energy carriers should be performed based on *NS 3720* scenario 1 (Norwegian electricity mix) and scenario 2 (European electricity mix), reported as two separate results. The method for GHG emission calculation of district heating/cooling shall also follow *NS 3720.* For district heating and cooling, a case specific emission factor can be developed by modelling the proportion of different energy carriers for a specific company or region from *fjernkontrollen*[1] and by using the emission factors given below (Table 8) (25). Alternatively, a national emission factor for district heating can be developed using the same modelling principles. Figure 10 gives an example from *fjernkontrollen* of the different energy carriers for district heating on a national basis for 2020. Infrastructure energy use (e.g., servers, street lighting, lifts, escalators, industrial processes, and snow melting) and energy use for charging electric vehicles is included at the neighbourhood level.

[1] *fjernkontrollen* (the remote control) is a data service provided by the Norwegian District Heating Association (Norsk Fjernvarme), available at fjernkontrollen.no (only in Norwegian)

Table 8. Energy emission factors per energy carrier, from *NS 3720*.

Energy Carrier	Emission factor [gCO_2e/kWh]
Electricity	Scenario 1 NO: 18 Scenario 2 EU28+NO: 136
Hydroelectricity	2-20
Wind power	3-41
Coal power	660-1300
Natural gas	380-1000
Solar energy (PV)	13-190
Biothermal	8,5-130
Nuclear power	3-35
Thermal power from natural gas with CCS	≈100
Thermal power in Norway	450
Thermal power in EU	800

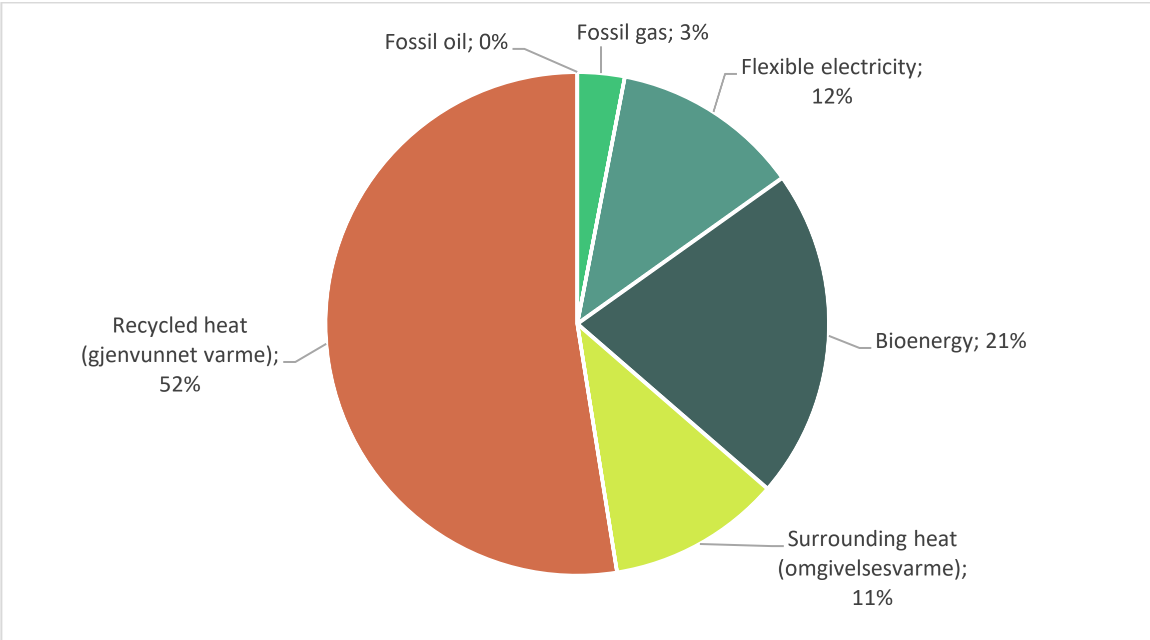

Figure 10. Proportion of different energy carriers for district heating on a national level in 2020, from *fjernkontrollen* (25).

GHG1.5 Operational transport (B8)

The operational transport (B8) KPI aims to reduce GHG emissions related to the mobility patterns of ZEN users. A prerequisite for this KPI is that MOB4.5 Mobility pattern has been completed. The calculation of this KPI should be completed according to *NS 3720* for life cycle module B8, this includes well-to-wheel transport emission factors for various energy carriers as outlined Table 10.

Table 9. Summary for calculating KPI GHG1.5.

GHG1.5	**Operational transport (B8)**
Objective	This KPI aims to reduce the GHG emissions related to transport during operation as defined in the *NS 3720.*
Description	This KPI involves calculating GHG emissions related to the operational transport (life cycle module B8) according to the *NS 3720*. Completing MOB4.5 Mobility pattern is a prerequisite.
Method	*NS 3720* (Method of GHG emissions calculation for buildings), *NS-EN 16258* (Methodology for calculation and declaration of energy consumption and GHG emissions of transport services)
ZEN KPI assessment	The limit and target values will be developed in future ZEN work.

Table 10. Well-to-wheel transport emission factors per energy carrier.

Energy Carrier	**NS-EN 16258 (gCO_2e/kWh)**
Diesel	251
Petrol	248
Marine gasoil	253
Bioethanol	161
Biodiesel	163
Heavy fuel oil	234
Natural gas (LNG)	380-1000
LPG (propane and butane)	209
Electricity	Scenario 1 NO: 18 Scenario 2 EU28+NO: 136

GHG1.6 End-of-life (C1-C4)

The goal of this KPI is to increase resource efficiency while reducing GHG emissions by preserving existing buildings, infrastructure, components, and materials. This KPI includes emissions from demolition and disposal activities. The emissions from these activities are calculated using scenarios for the percentage of reuse, recycling, energy recovery and/or landfill, and the emissions generated by each of these waste treatments. The calculation of this KPI should be completed in accordance with *NS 3720* for life cycle module C1-C4. Other important aspects for this KPI will involve diverting resources from their end-of-life to reuse, recycle, and recover as benefits and loads beyond the system boundary in Module D instead. There shall therefore be an emphasis on increasing building circularity.

Table 11. Summary for calculating KPI GHG1.6.

GHG1.6	**End-of-life (C1-C4)**
Objective	To increase resource efficiency and reduce GHG emissions by diverting resources from their end-of-life to reuse, recycle, and recover as benefits and loads beyond the system boundary in Module D. Materials and components that do reach their end-of-life will be deconstructed, transported, and disposed of in such a way as to reduce associated GHG emissions.
Description	The construction industry is responsible for 40% of all resource consumption. New buildings make up 1-2% of total construction activity annually, and around 22,000 existing building are demolished each year in Norway, leading to higher GHG emissions and higher resource use. In addition, the EU requires 70% of all construction waste to be recycled by 2020 (26). High intensity carbon emitters such as cement and steel are used extensively in groundworks and foundations. It is therefore better to renovate and reuse these than cast new foundations. There is a large untapped potential in utilising the existing building stock.
Method	*NS 3720* (Method of GHG emissions calculation for buildings), *NS 3451* (Table of Building Elements)
ZEN KPI assessment	The limit and target values will be developed in future ZEN work.

GHG1.7 Benefits and loads (D)

The goal of the KPI Benefits and loads (D) is to compensate for GHG emissions from life cycle modules A1-C4, in order to create a net zero emission balance for the neighbourhood. This will be achieved through increased resource efficiency through the implementation of circular economy principles, as well as through the export of local renewable energy production. This includes the benefits and loads outside of the system boundary linked to reuse, recycling, material energy recovery from the end-of-waste state, and the export of local renewable energy production. The calculation of this KPI should be performed in accordance with *EN15804: 2012 +A2:2019* (12).

Table 12. Summary for calculating KPI GHG1.7

GHG1.7	**Benefits and loads (D)**
Objective	To compensate for GHG emissions from life cycle modules A1-C4 to achieve a net zero emission balance for the neighbourhood.
Description	This includes the benefits and loads outside of the system boundary linked to reuse, recycling, material energy recovery from the end-of-waste state, and the export of local renewable energy production.
Method	*EN15804: 2012 +A2:2019*
ZEN KPI assessment	The limit and target values will be developed in future ZEN work.

3 Energy

One of the most important goals for a zero emission neighbourhood is that it should be become highly energy efficient (27), as the most environmentally friendly energy is energy that is not used. Thus, reducing energy demand and subsequent energy use should always be a priority in the transition towards reaching a decarbonised energy system. A zero emission neighbourhood shall be powered by smart, renewable energy sources (27). This means that design and operation of a ZEN pilot area must be focused on using renewables which operate in synergy with the surrounding energy system. To achieve this, there will be a focus on energy storage, power/load management, digitalisation, smart grids, and system optimisation.

The KPIs in the energy category refer solely to the energy flows in operation, and thus exclude embodied energy. This is because embodied energy is already covered indirectly by the GHG emission category. However, the operational energy flows will be modelled and/or estimated in all project phases. During the strategic planning and implementation phases the KPIs should be estimated, e.g., by means of simulations. During the operational phase, measurements should be used when available and be substituted by simulations only where measurements are not available. The energy demand and energy use of the neighbourhood should be calculated/measured over one year with hourly resolution.

3.1 Documentation Requirements

Documentation requirements for the energy category KPIs are outlined in this chapter, as well as common assumptions and methodologies. Completion of these documentation requirements and energy category KPIs is a prerequisite for the power category KPIs in Chapter 4 Power.

Boundary levels

The energy KPIs are calculated at either the building assessment boundary level (B) or the neighbourhood assessment boundary level (N). The building assessment boundary level (B) includes energy use within the buildings, harmonised with SN-NSPEK 3031:2020 (28). The neighbourhood assessment boundary level (N) is an expansion of the building assessment boundary. It includes energy use for: people transport inside buildings (e.g., elevators, escalators), data servers, refrigeration and other industrial processes inside buildings, outdoor lighting, snow melting, and the charging of electric vehicles, whether inside or outside of buildings. Local energy generation not connected to a specific building is also considered. In other words, the neighbourhood assessment boundary includes, in principle, all energy flows within the neighbourhood.

Description of ZEN pilot area and reference project

In the energy category, the KPIs should be calculated for both the pilot and the reference project. The reference project represents business-as-usual for the ZEN pilot area and is based on current building regulations (TEK) for new buildings (29) and relevant historical building regulations for existing buildings.

A representative reference project should be tailored to each ZEN pilot and have the same floor area and number of users. A new building will typically use direct electric heating. For some KPIs it might be necessary to calculate an intermediate reference project with district heating. Table 13 gives an example of assumptions made for a ZEN pilot area neighbourhood and reference project.

Table 13. A reference project with electric heating, created for a ZEN pilot area.

	ZEN pilot area	Reference project
Building standard	Passive house (30,31)	TEK-17 minimum requirements (29)
Energy storage solutions	None	None
Local energy production	Photovoltaic (PV) panels with annual generation of energy equal to 10 kWh/ m² GFA	None
Heating	District heating	Electric boiler
Transport technologies	100 % of all buses are electric in 2035	50 % of all buses are electric in 2035

Table 14 lists all required documentation to be presented when calculating the energy category KPIs. The last column, KPI status, indicates whether the KPI is used for documentation only (Doc. only) or if the KPI is used for the evaluation of the performance of the pilot within the categories - in such cases the KPI is listed, and the row is highlighted in colour.

Table 14. List of required documentation when calculating the energy KPIs. HFA = Heated Floor Area (in Norwegian *Bruksareal* (BRA), as shown in Figure 6). kWh/y = energy consumption per year. kWh/h = energy consumption per hour.

Documentation	Data type	Unit	Assessment level	KPI status
Net/gross energy demand in buildings	Annual totals and load curves	$kWh/m^2_{HFA}/y$	B	ENE2.1 Energy need in buildings
Energy use	Annual totals and load curves	kWh/h* kWh/y*	N	Doc. only
Energy generation	Annual totals and load curves	kWh/h* kWh/y*	N	Doc. only (Input for GHG1.7 Benefits and loads (D)
Delivered energy (imported)	Annual totals and load curves	kWh/h* kWh/y*	N	ENE2.2 Delivered energy (Input for GHG1.4 Operational energy use (B6))
Exported energy	Annual totals and load curves	kWh/h* kWh/y*	N	Doc. only
Net yearly load profile	Annual totals and load curves	kWh/h* kWh/y*	N	Doc. only
Load duration curve	Annual totals and load curves	kWh/h* kWh/y*	N	Doc. only

Self-consumption	**Factor**	**% Electricity**	**N**	**ENE2.3 Self-consumption**
Self-generation	Factor	% Electricity	N	Doc. only

* Per energy carrier: electricity, district heating, bioenergy and other

These KPIs are not independent. Delivered and exported energy are the net values of energy use and energy generation (when generation is considered as negative) and are collected from the net yearly load profile. The load duration curve is the net yearly load profile, only sorted from the highest to the lowest value.

Energy demand and energy use

Energy demand (or energy need) is a theoretical value used to describe the energy demand linked to energy services and energy needs in buildings, such as the demand for energy for heating of domestic hot water, space heating, ventilation, lighting, plug loads and so on. When calculating the energy demand, losses in the system are ignored. Depending on the system boundary, the calculated energy demand is referred to as net energy demand or gross energy demand. The energy demand in buildings is considered in KPI ENE2.1 Energy need in buildings and is the basis for the other documentational requirements and KPIs. See ENE2.1 Energy need in buildings for further details.
Energy use is a measurable value which can be linked to both energy services and energy carriers (such as electricity, fuels, district heating, etc.), which also considers losses within the system boundaries.

Energy use and energy generation

Profiles for energy use and energy generation should be calculated at the neighbourhood assessment boundary level, per energy carrier, with hourly or sub-hourly resolutions. The hourly electricity use and electricity generation is shown in Figure 16 for ZEN pilot Ydalir. This ZEN pilot has non-electric heating and PV-panels. Only the electric energy demand is covered by electricity while the thermal energy demand is covered by another energy carrier. Electricity use is assigned a positive value, while electricity generation is assigned a negative value.

The load profiles for energy use and generation per carrier in the buildings can be calculated using building energy performance simulation tools. If only energy demand simulations are available (such as when using PROFet), assumptions must be made about the heating system (the energy carrier of the system and the system efficiency) to create the energy use profile. Energy generation may be modelled separately (for instance using PV-generation simulation tools, building simulation tools, or other similar tools). Methods for simulating load profiles of electric vehicle charging is currently being developed within the ZEN research centre.

Import and export of energy

The delivered and exported quantities of an energy carrier are two sides of the same variable - see ENE2.2 Delivered energy for more information on calculation of delivered energy. When we know the hourly electricity use and generation, the delivered and exported electricity can be found by subtracting the energy generated in a ZEN pilot from the energy use for each time interval. Subtracting the electricity generated from the electricity used in Figure 16 produces the net yearly load profile shown in Figure 11. In the net yearly load profile, energy import has a positive value while export has a negative value. The load duration curve can be found by sorting the values of the net load profiles.

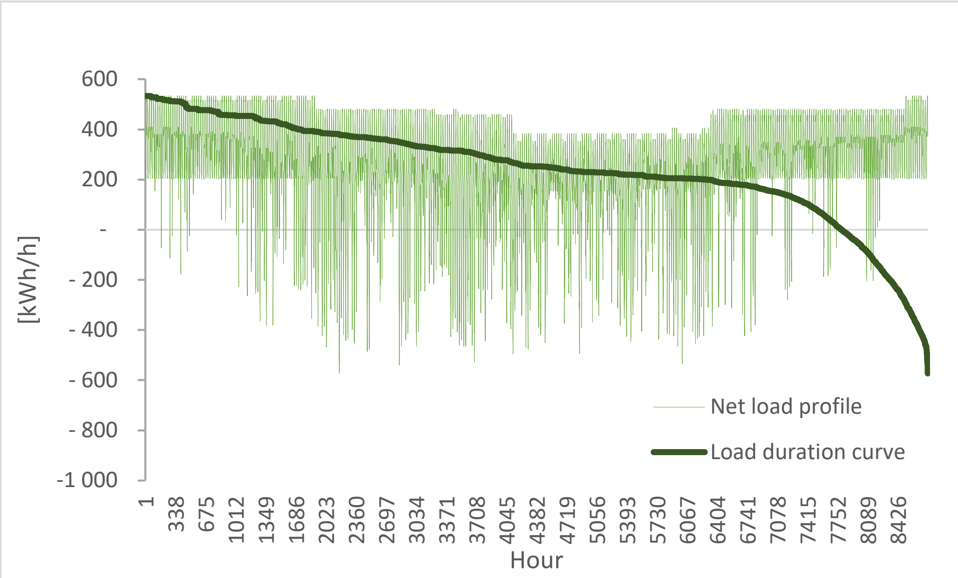

Figure 11. Hourly net load profile and load duration curve of electricity in ZEN Ydalir.

The net yearly load profile and load duration curve are calculated or measured at the neighbourhood assessment boundary level, per energy carrier, with hourly or sub-hourly resolutions. They should be calculated for the ZEN pilot and the reference project. The net yearly load profile gives an illustration of the energy flows throughout the year. The net load duration curve provides useful information for the strategic planning, implementation, and operation of the energy system. This kind of graphical information gives an immediate visual understanding of the differences between two alternative solutions. For example, a neighbourhood with or without local district heating would result in two substantially different yearly load profiles and duration curves for electricity. The same holds true for a neighbourhood with or without extensive use of solar PV or local storage. The area under the load profiles shows the annual totals of electricity use, generation, import, and export. Figure 13 shows a summary of these annual totals.

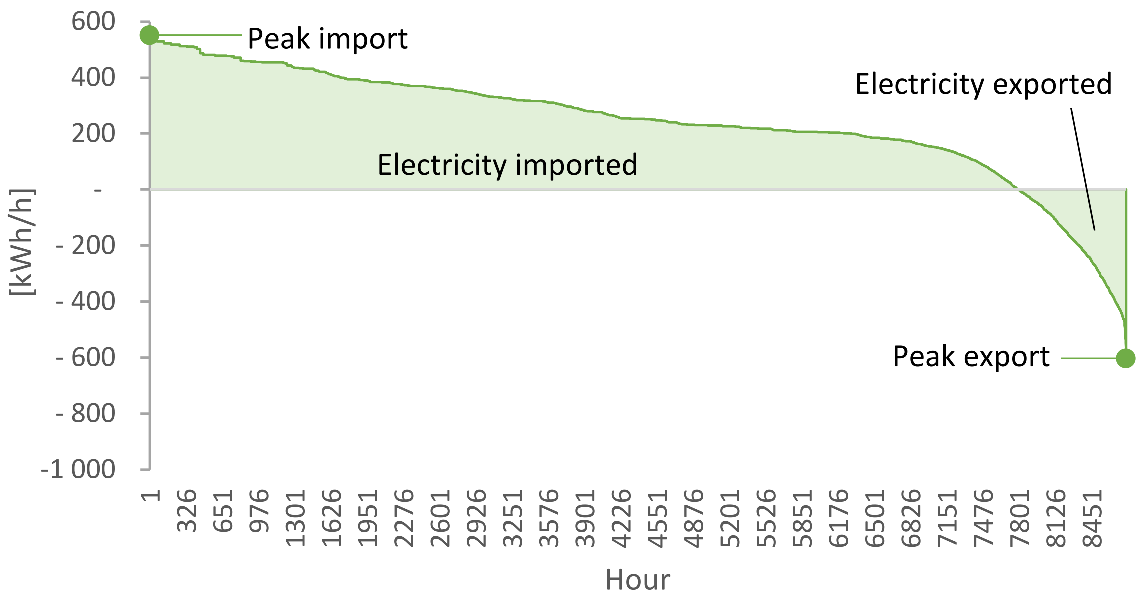

Figure 12. Explanation of the load duration curve of the net electricity use in ZEN Ydalir.

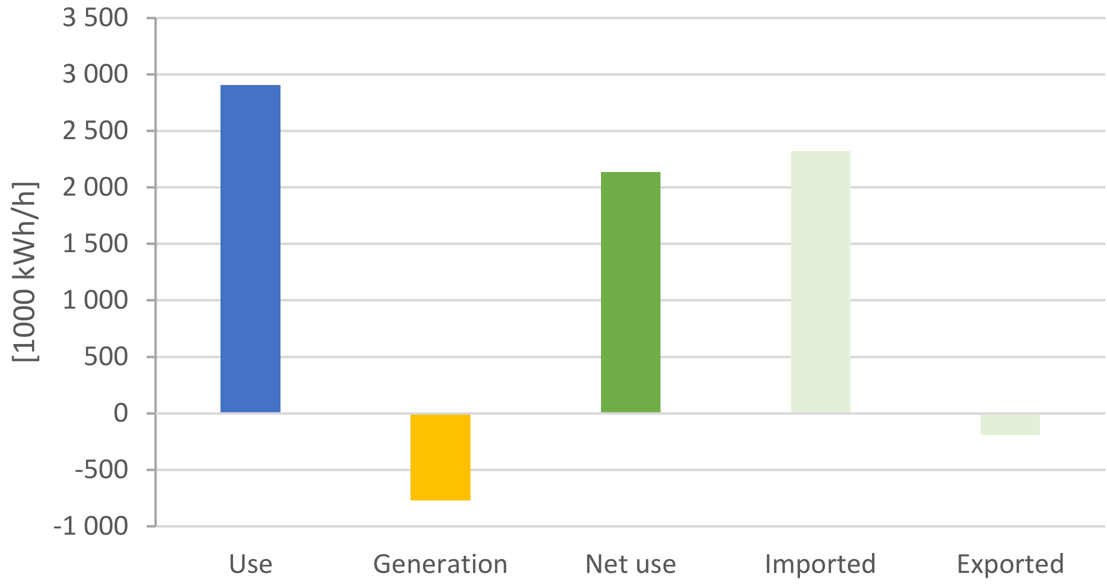

Figure 13. Annual totals of electricity use, generation, net energy use, import, and export in ZEN Ydalir.

Load profiles

The level of detail and source of data may differ according to the various project phases. For example, simulation tools used in the strategic planning and implementation phases can be substituted by monitoring data in the operational phase, while design parameters, e.g., air tightness, may be substituted by measured values. Local storage systems, both electric (including bidirectional / vehicle-to-grid (V2G) with supported battery electric vehicles) and thermal, may already be in place or under evaluation during the strategic planning phase. This will affect the KPIs. As a result, it may be desirable to show the effect of local storage by itself, or in terms of a different control strategy, by means of presenting KPI results with and without the storage system.

Suggested workflow

Working with the energy category in a ZEN requires the collection and calculation of detailed documentation. A workflow similar to the one shown in Figure 14 is recommended when performing KPI calculations.

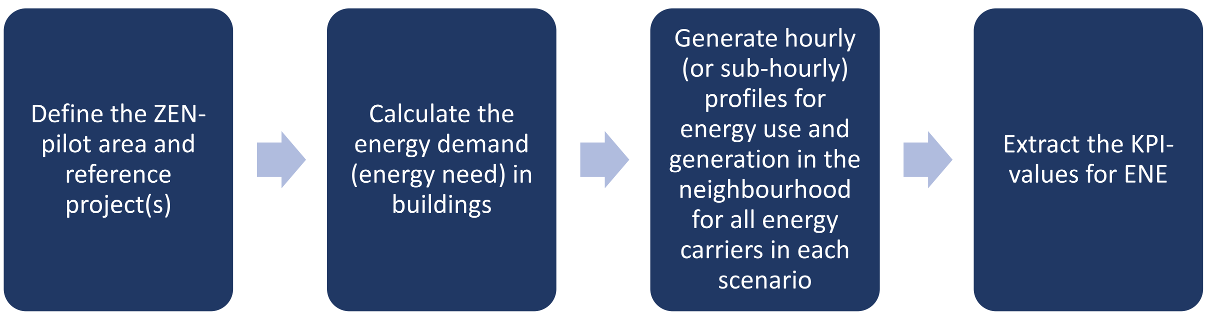

Figure 14 Suggested workflow for calculating KPIs in the energy category.

As an intermediatory step, consider calculating all KPIs at the building boundary level (B). The available national and international norms only apply to the building boundary level, so it would be straightforward to take this first step. Thereafter, the calculations can be extended to the neighbourhood boundary level. This would make it possible to distinguish clearly between the effect of measures within buildings and between buildings.

3.2 Assessment Criteria

The energy category is split into two assessment criteria measured during the operational phase, namely 'energy efficiency in buildings' and 'energy carriers'. The energy efficiency in buildings assessment criterion looks at the energy performance of buildings within the building assessment level. It considers energy demand within buildings and is suitable for buildings in the strategic planning and implementation project phases. The energy carriers assessment criterion considers energy use, energy generation, and energy flows per energy carrier in the ZEN pilot area at the neighbourhood assessment level.

3.3 KPIs

ENE2.1 Energy need in buildings

The energy need in buildings KPI shows the total energy demand of all buildings in a ZEN pilot area, calculated per kWh of m^2 heated floor area (HFA) per year ($kWh/m^2_{HFA}/yr$) on the building assessment level for the ZEN pilot area and for the reference project. The purpose of this KPI is to reduce the energy demand of buildings as much as possible. The KPI will be assessed on the reduction in energy demand in the ZEN pilot area compared to the energy demand in the reference project.

Energy need in buildings is a KPI which must be simulated as it shows the energy need of the building envelope when the losses in the building heating system are not accounted for. The energy need is calculated according to the *building assessment boundary*, which must be harmonised between ISO 52000 (32) and *SN-NSPEK 3031* (28) when calculating the KPIs. This typically includes building energy need for: heating, cooling, ventilation, domestic hot water, lighting, and plug loads. The buildings are separated according to *NS 3457-3* (10) and *SN-NSPEK 3031*, which covers building categories, such as apartment buildings, schools, and nursing homes. The energy need in buildings is calculated as an annual total and is not measured in the operational phase of the neighbourhood. Local energy generation is not considered, only the *calculated energy demand* of the buildings is considered.

The energy demand in buildings should be calculated at an hourly or sub-hourly level for a period of one year. This can be calculated using PROFet (33) or building energy performance simulation tools. Energy demand should be calculated per energy service, with a minimum of reporting at 'top-level' as shown in Table 15. 'Top level' resolution involves reporting the energy demand for thermal energy need and electric energy need, finer detailed results can be reported, as described in Table 15. Figure 15 shows the calculated hourly energy demand for all buildings in ZEN pilot area Ydalir.

Table 15. Energy services: level of detailing.

All energy services	**Energy Service - top level**	**Energy Service - lower level**	**Energy Services according to *SN-NSPEK 3031:2020***	
Energy demand in buildings	Thermal energy need	Space heating energy need	1a	Room heating
			1b	Ventilation heating
		Hot water energy need	2	Hot water
	Cooling energy need*	Cooling energy need	3a	Room cooling
			3b	Ventilation cooling
	Electric energy need	Electric energy need	4a	Fans
			4b	Pumps
			5	Lighting
			6	Technical equipment

* Sometimes considered as part of electric energy need, other times as thermal.

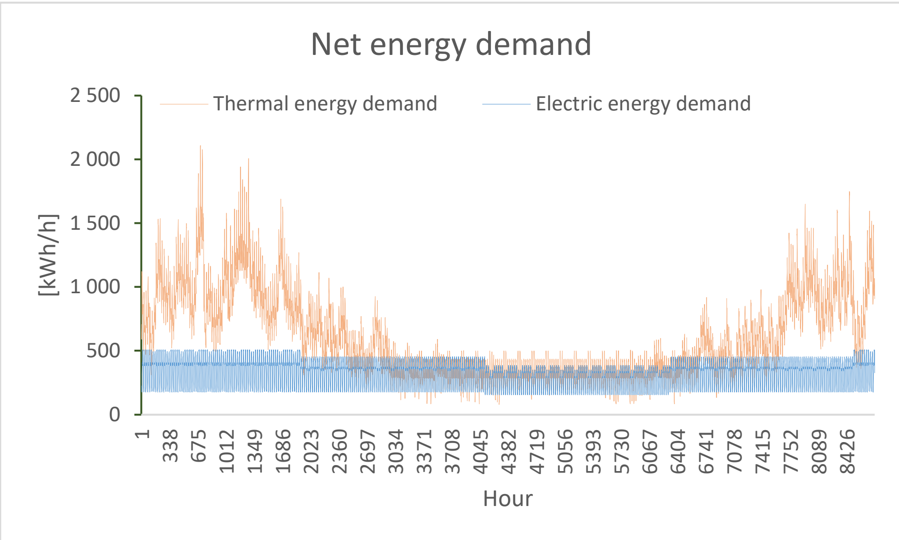

Figure 15. The hourly (net) energy demand for thermal energy (space heating and domestic hot water) and electric services in the buildings at ZEN Ydalir.

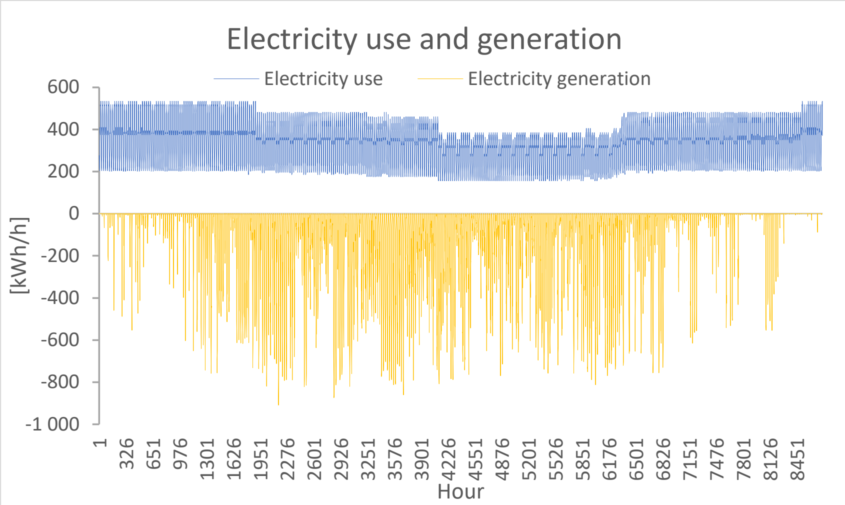

Figure 16. The hourly electricity use and electricity generation with non-electric heating and PV in ZEN Ydalir.

Table 16. Summary for calculating KPI ENE2.1.

ENE2.1	**Energy need in buildings**
Objective	Increase the energy efficiency of the building envelope to reduce the energy demand of buildings as much as possible.
Description	Specific total energy needs for all buildings within the building assessment level calculated per kWh of m^2 heated floor area (HFA) per year in the ZEN pilot area and in the reference project.
Method	The energy demand in buildings should be calculated at an hourly or sub-hourly level for a period of one year according to *SN-NSPEK 3031:2020*. This can be calculated using the tools PROFet or building energy performance simulation tools. The energy demand should be calculated per energy service, with a minimum 'top level' resolution (reporting the energy demand for thermal energy services and electric energy services).
ZEN KPI assessment	The KPI will be assessed on the percentage (%) reduction in energy demand in the ZEN pilot area compared to the energy demand in the reference project. The limit and target values will be developed in future ZEN work.

ENE2.2 Delivered energy

The delivered energy KPI evaluates the delivered energy at the neighbourhood assessment level for all energy carriers. The delivered energy (imported energy) should be calculated as an hourly or sub-hourly mismatch between energy use and energy generation. As this KPI refers to the annual totals for delivered energy, it can be reported in a table format. The purpose of this KPI is to reduce the delivered energy.

Table 17. Summary for calculating KPI ENE2.2.

ENE2.2	**Delivered energy**
Objective	Reducing the delivered energy of the neighbourhood.
Description	The delivered energy (imported energy) should be calculated as an hourly or sub-hourly mismatch between energy use and energy generation and is collected from the net load duration curve for each energy carrier. The net load profile and net load duration curve are calculated or measured at the neighbourhood assessment boundary level, per energy carrier, with hourly or sub-hourly resolutions (see chapter 3.1 for more information). For this KPI, delivered energy should be reported as annual totals for all energy carriers at the neighbourhood assessment level for the ZEN pilot area and the reference project.
Method	The load duration curve for each energy carrier can be calculated using building performance simulation tools, energy generation tools, and PROFet. It may be necessary to combine several tools. In the user phase, measurements can be used.
ZEN KPI assessment	The KPI will be assessed on the percentage (%) reduction in delivered energy in the ZEN pilot area compared to the delivered energy in the reference project. The limit and target values will be developed in future ZEN work.

ENE2.3 Self-consumption

The self-consumption KPI tells us about the mismatch between energy generated locally and energy used in the neighbourhood. The calculation is typically carried out in two steps.

First, energy use and energy generation are considered separately, without considering their interaction. The interaction between energy use and energy generation is considered on an hourly basis, and the overall result over the year is expressed numerically in terms of self-consumption and self-generation. The same concepts are often presented with different names. For example, in (34) these are called 'self-consumption' and 'self-sufficiency', respectively; while in (35) they are called 'supply cover factor' and 'load cover factor', respectively. Here, the wording self-generation is chosen for consistency with 'energy generation', while the wording 'self-consumption' is chosen because it has gained a certain popularity in everyday speech (implying that energy use and energy consumption are used as synonyms).

Self-consumption and self-generation express two complementary aspects of the interaction between energy use and energy generation. This can be better explained with reference to a graph showing daily profiles, such as in Figure 17, where electricity is considered, and PV is assumed as local generation in a single building. The areas A and B represent the electricity delivered and electricity exported, respectively. The overlapping part in area C is the PV power that is utilised directly within the building.

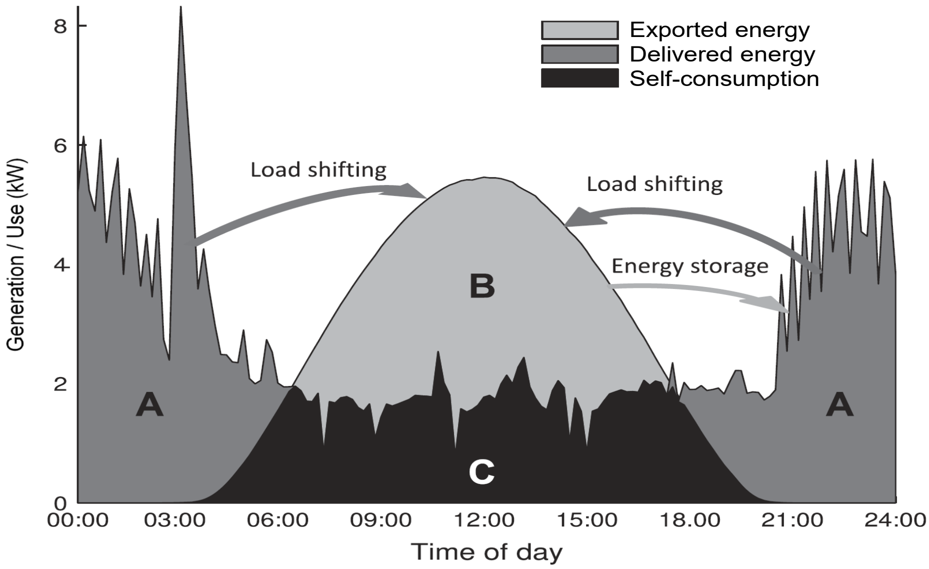

Figure 17. A schematic outline of the daily energy use (A + C), energy generation (B + C), and self-consumption (C) in a building with on-site PV. It also indicates the function of the two main options (load shifting and energy storage) for increasing self-consumption, adapted from (36).

In this example (figure, the daily self-consumption KPI is calculated as the self-consumed part (area C) of locally generated energy relative to the total generation (area B+C), while the self-generation KPI is the self-consumed part (area C) relative to the total energy use (area A+C). For example,

$$\text{Self-consumption} = \frac{\textit{local energy generation consumed on premises}}{\textit{total local energy generation}} = \frac{C}{B+C} \quad [1]$$

$$\text{Self-generation} = \frac{\textit{energy use covered by local energy generation}}{\textit{total energy use}} = \frac{C}{A+C} \quad [2]$$

The above formulas should be calculated with an hourly or sub-hourly resolution, and the effect of local storage should be considered, as shown in (34) and (37). In ENE2.3 the self-consumption should be calculated with at least hourly resolution over a period of 1 year.

Numerically, the two indicators will have the same value only when the total annual energy generation is equal to the total annual energy use, such as in the case of annual net zero energy use (for a specific energy carrier). For small amounts of generation, self-consumption will be high, close to 100%, while self-generation will be small, close to 0%. If local generation increases beyond the net zero point (for example, when the neighbourhood becomes a net annual exporter of energy), then the behaviour of the two indicators reverses, with self-generation being higher than self-consumption. However, the two will never reach extreme values. Typically, as the local generation increases, the two indicator values change with a sort of logarithmic behaviour: faster changes at the beginning, followed by a slower rate of change. Of course, this general behaviour would be affected by using local energy storage.

Table 18. Summary for calculating KPI ENE2.3.

ENE2.3	Self-consumption
Objective	Increase the self-consumption of locally generated electricity.
Description	The self-consumption KPI is calculated on an hourly or sub-hourly resolution at the neighbourhood assessment level according to formulas [1] and [2].
Method	Self-consumption is derived from hourly load profiles of electricity generation and electricity use in the ZEN pilot area. Hourly load profiles can be generated using building energy performance simulation tools, PV-generation tools, and PROFet (it may be necessary to combine several tools). Where hourly measurements are not available, the self-consumption calculations can be complemented or substituted with simulations.
ZEN KPI assessment	The KPI will be assessed on the percentage (%) value for self-consumption of electricity in the ZEN pilot area. The limit and target values will be developed in future ZEN work.

4 Power

A zero emission neighbourhood manages the energy flows within and between buildings and exchanges with the surrounding energy system in a **flexible** way, responding to signals from smart energy grids, and facilitates the transition towards a **decarbonised energy system** (3). Therefore, the ZEN definition has a strong focus on energy flows through energy grids (electricity and district heating).

4.1 Documentational Requirements

The KPIs in the power (POW) category refer the energy flows between the neighbourhood and energy grids in the operational phase. However, the operational energy flows should be estimated in all project phases. During the strategic planning and implementation phases the KPIs should be estimated, e.g., by means of simulations. During the operational phase, the KPIs should be evaluated directly from measurement (as far as possible). All KPIs are calculated with an hourly or sub-hourly resolution. Completion of the energy category documentation requirements and KPIs is a prerequisite for the power category KPIs (see Chapter 3, Energy). The documentation requirements for the power category build upon the documentation requirements and KPIs for the energy category. Table 19 lists required documentation when calculating the power KPIs. The column 'KPI status' indicates whether the KPI is used for documentation only ('Doc. only') or if the KPI is used directly for the evaluation of the performance of the ZEN pilot area (the KPI-ID is in that case listed.).

Table 19. List of required documentation when calculating the power KPIs.

KPI	Data type	Unit	Assessment level	KPI status
Peak load (import)	Peak value from net load duration curve	kWh/h*	N	POW3.1 Peak load
Peak export	Peak value from net load duration curve	kWh/h*	N	POW3.2 Peak export
Colour-coded carpet plot of net energy use	Carpet plot	kWh/h* kWh/year*	N	Doc. only
Load flexibility - Typical daily profiles of net electricity use	Hourly daily profile	kWh/h kWh/year	N	POW3.3 Load flexibility

* For electricity and district heating

Colour-coded carpet plot

A colour-coded carpet plot is a visualisation of the delivered and exported energies (like the net yearly load profile) and is a convenient graphical visualisation of the energy exchanged between the neighbourhood and the energy grids. First, delivered and exported energy are summed together into a single quantity, such as for the net load curve, assuming that export is positive and that delivery is negative. This quantity may also be read from a net metering system. Hourly data are arranged on two axes, with hours of the day (24 hours) on the *y*-axis, and days of the year (365 days) on the *x*-axis. A colour scale is added to render the gradation between net delivery and net export of energy to and from the neighbourhood. Two color-coded carpet plot examples are shown in Figure 18 and Figure 19.

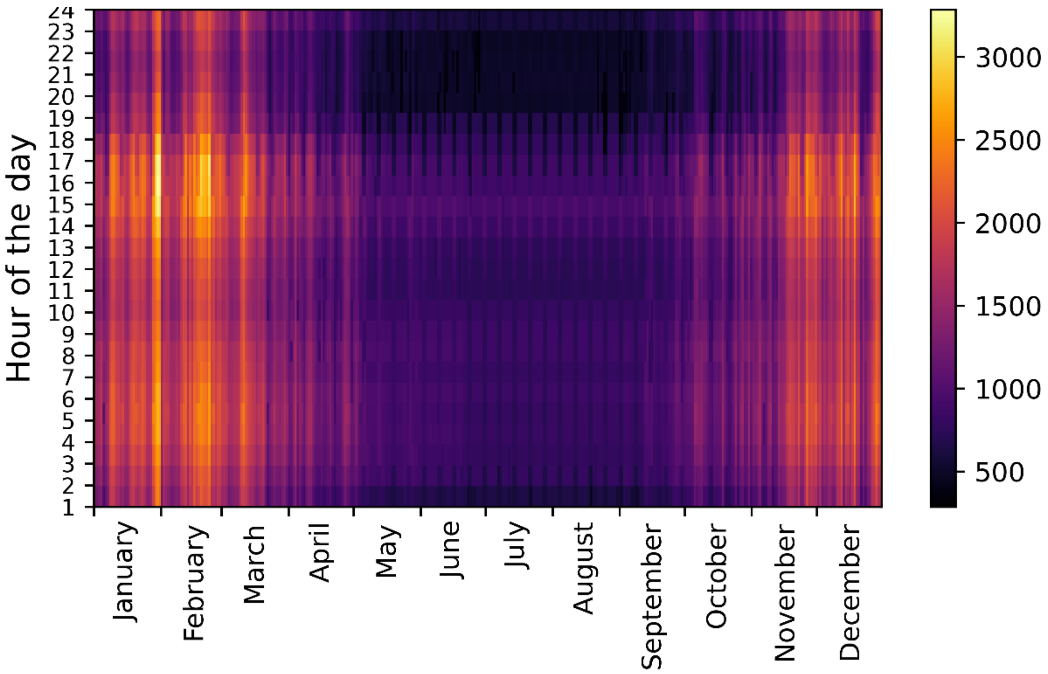

Figure 18. Colour-coded carpet plot showing the net electricity import for Ydalir in the reference project (with electric boiler) (38).

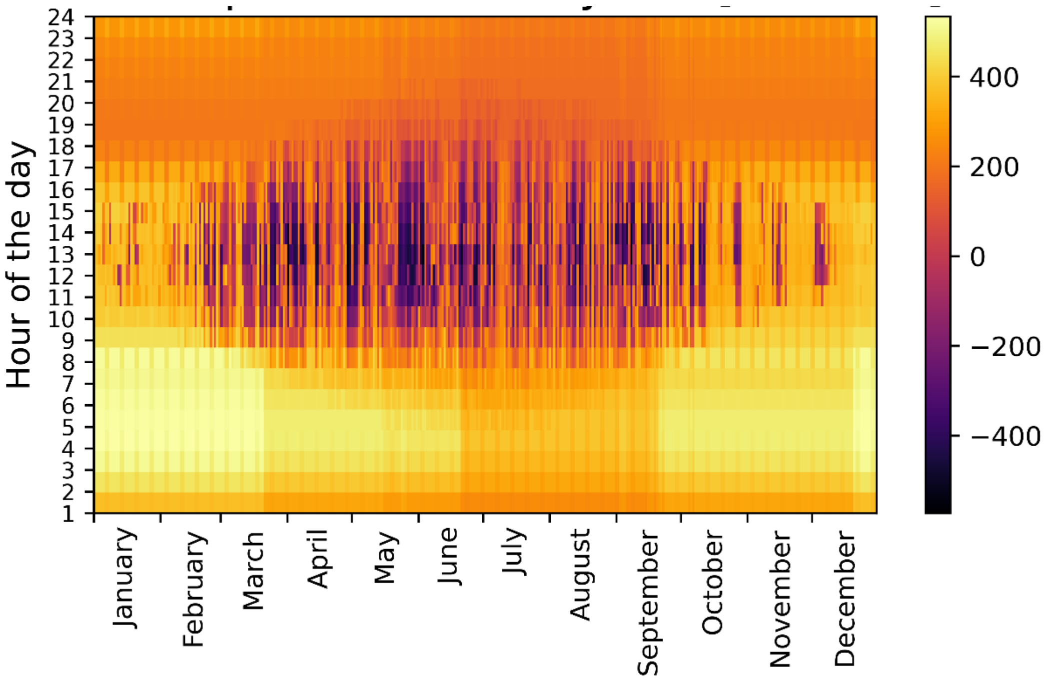

Figure 19. Colour-coded carpet plot showing the net electricity import for Ydalir as planned (with district heating and PV). Negative values indicate electricity export to the grid (38).

<u>Suggested workflow</u>

Working with the energy and power categories in a ZEN pilot requires the collection and calculation of detailed documentation. A workflow like the one shown in Figure 20 is recommended when performing KPI calculations for the Power-category.

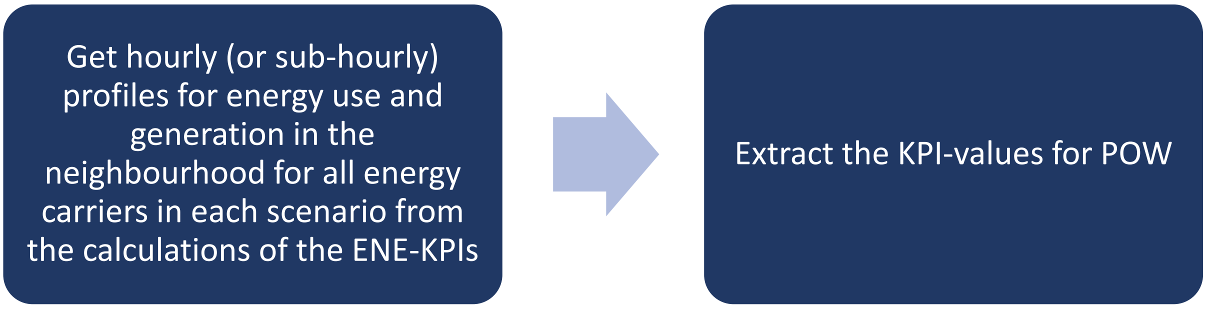

Figure 20. Suggested workflow for calculating KPIs in the power category.

4.2 Assessment Criteria

The power category is split into two assessment criteria, namely 'power performance' and 'load flexibility'.

Power performance: This assessment criterion contains the dimensioning peak load and peak export. The purpose of the assessment criteria is to evaluate the peak strain on the electricity and district heating grid.

Load flexibility: This assessment criterion reflects whether the neighbourhood exchanges energy with the surrounding energy system (electric and district heating) in a flexible way. Since the coordination of energy flows with smart grids (both electric and thermal) occurs at an hourly or sub-hourly level, the focus is on the optimisation of the net load profiles on typical days, distinguishing between seasons (e.g., winter, summer) and weekdays (e.g., weekday, weekend). The load flexibility indicators will reflect the difference in load profiles in the ZEN and in a reference project, where there is limited control and demand response.

4.3 KPIs

There are currently three Power KPIs, which are calculated according to the *neighbourhood assessment boundary* level for electricity and district heating. In addition to the calculation of the Power KPIs there are requirements set to document the net annual load profile and the load duration curve for electricity and district heating. 'Utilisation factor' was previously a KPI in the power category, but has been removed after testing in several pilots, as it was not a good fit for its intended purpose (38).

POW3.1 Peak load

The peak load KPI and the peak export KPI are simply the extreme values of the net duration curve as illustrated in Figure 12 (see Chapter 3.1). The peak load KPI refers to the maximum positive hourly import load of electricity and district heating to the neighbourhood during an operational year. The peak load should be calculated for the ZEN pilot area and the reference project.

Table 20. Summary for calculating KPI POW3.1.

POW3.1	**Peak load**
Objective	To reduce the peak load of electricity and district heating, to reduce the strain on the energy grid.
Description	Hourly or sub-hourly peak load of electricity and district heating at the neighbourhood assessment level is calculated for the ZEN pilot area and reference project.
Method	IEA EBC Annex 67, Engineering practices in the ZEN research centre
ZEN KPI assessment	The KPI will be reported as a percent (%) reduction in peak load in the ZEN pilot area compared to the reference area. The limit and target values will be developed in future ZEN work.

POW3.2 Peak export

The peak export KPI refers to the maximum net hourly export load of electricity (when electricity production is higher than electricity use) from the neighbourhood during an operational year. If there is no net export, then the peak export is equal to zero. Export of district heating is currently not considered in this KPI as export of heat is more complicated than the export of electricity, but it may become relevant in future versions of the ZEN definition.

Table 21. Summary for calculating KPI POW3.2.

POW3.2	**Peak export**
Objective	The peak export should not exceed the peak load (import) and should be the dimensioning factor for the electricity grid.
Description	Hourly or sub-hourly peak export at the neighbourhood assessment level in the ZEN pilot area during a period of one year.
Method	IEA EBC Annex 67, Engineering practices in the ZEN research centre
ZEN KPI assessment	The target value will be based on the following: Peak export of electricity < Peak load of electricity in the ZEN pilot area

POW3.3 Load flexibility

The load flexibility assessment criterion and KPIs are still under development and reflects whether the neighbourhood exchanges energy with the surrounding energy system (i.e., electric and district heating) in a flexible way. Since the coordination of energy flows with smart grids (both electric and thermal) occur at an hourly or sub-hourly level, the focus is on the optimisation of the net load profiles on typical days, distinguishing between seasons (e.g., spring, summer, autumn, and winter, coldest and hottest days) and days (e.g., weekday versus weekend).

For load flexibility, the value of the net load daily profiles provides an immediate visual impression when comparing two alternatives. The load flexibility KPI is useful to evaluate the effects of short-term load shifting[2] and storage solutions, and their effectiveness in responding to signals from smart energy grids. Such signals might be price signals, information on the CO_2 content of energy produced at different hours throughout a day, as well as information on grid congestion problems, e.g., peak load hours in the (distribution) grid. The focus of this KPI is on short-term variations and short-term storage, both thermal and electric, because this is what is usually available in a neighbourhood. With storage we mean both physical storage, such as hot water tanks and batteries (including bidirectional / vehicle-to-

[2] Load shifting might span from the simple shifting of a washing machine's start-time to the more complex scheduling of heating resources.

grid (V2G) with supported battery electric vehicles) and virtual storage, such as changing the heating pattern of a building to serve other purposes and responding to the grid's signals instead of just thermostatic control. This entails a combination of physical heat storage in the building's thermal mass and a change in the indoor temperature profile. Furthermore, both physical and virtual storage may be controlled in different ways, giving rise to different 'smart control' strategies that serve different purposes. Figure 21 illustrates an example of a single building, with PV and battery, where the goal is to limit the net electricity export to the grid.

The load flexibility assessment criterion will be further developed to reflect these differences in load profiles. Additional KPIs for load flexibility will be tested and eventually included in the power category, as and when they emerge either from the ZEN research centre or from external sources. These KPIs will likely be calculated at either the neighbourhood assessment level or building assessment level, with an hourly or sub-hourly resolution.

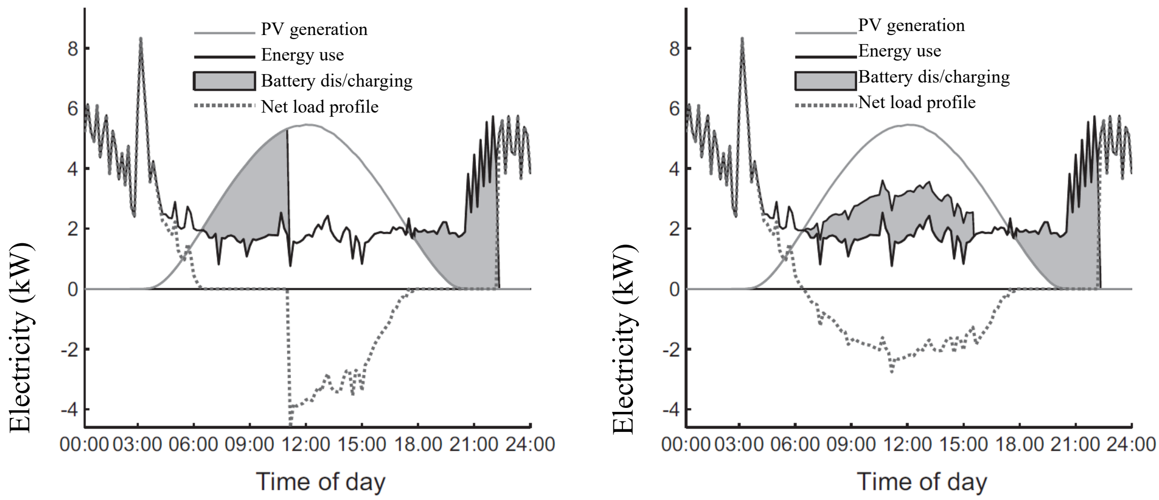

Figure 21. Example of electricity net load daily profile (dotted line), with a PV-battery system with different rates of charging. On the left, 100% of the surplus PV power is stored until the battery is fully charged. On the right, charging is limited to 40% of the surplus PV power, thus lowering the peak export power. The total battery capacity is the same in both cases. Source: adapted from (36).

5 Mobility

The ZEN definition focuses on promoting sustainable transport patterns and smart mobility systems both locally and regionally. This can be achieved through good physical planning and good logistics.

5.1 Documentation Requirements

Mobility KPIs will be assessed at the neighbourhood level and do not include transport within buildings (e.g., lifts and escalators). Air and sea transport are excluded. Factors which have significant effect on travel behaviour, such as socio-economic (e.g., income and occupation), demographic (e.g., gender and age), travel preferences and attitudes, and other contextual factors (e.g., parking availability and weather) are addressed under the spatial qualities category. The KPIs for the mobility category are to be implemented during the strategic planning, implementation, and operational phases. Further documentation requirements for the mobility category will be developed in subsequent versions of the ZEN definition and guideline reports.

5.2 Assessment Criteria

The mobility category is split into three assessment criteria, namely 'access', 'travel behaviour', and 'logistics'. The access assessment criterion includes MOB4.1 Access to public transport, MOB4.2 Travel time ratio, MOB4.3 Parking facilities, and MOB4.4 Car ownership. The travel behaviour assessment criterion includes MOB4.5 Mobility pattern and MOB4.6 Passenger and vehicle mileage, whilst the logistics assessment criterion includes MOB4.7 Freight and utility transport.

5.3 KPIs

<u>MOB4.1 Access to public transport</u>

The KPI will consider links to existing and planned transport nodes (such as trains, buses, trams, or metro), as well as links to local city centres. The distance from a building within the ZEN pilot area to the nearest transport node, as well as transport frequency in peak and low times in urban and rural areas, as specified in BREEAM Communities technical manual, can be used as a reference (9). The Norwegian travel survey (NRVU) includes questions about distance from dwelling to transport stations or stops and frequency of departures from the transport stations or stops. Based on these two conditions, a qualitative variable is calculated that describes public transport access on a five-point scale from Very good to Very poor. Local NRVU data can be used directly, if available for the ZEN pilot area. If such data is not available, then the procedure described in NRVU 2018/19 key report (39) can be used to calculate access to public transport for existing or planned stops and services.

Access to public transport services is classified according to the method used in NRVU, combining the number of departures per hour on weekdays and the distance from home to the station or stop normally used, see Table 22. To follow is an explanation of the five-point scale:

1. *Very good access:* At least 4 departures per hour and less than 1 km to the station or stop.
2. *Good access:* 2-3 departures per hour and less than 1 km to the station or stop, or at least 4 departures per hour and 1-1.5 km to the station or stop.
3. *Medium quality access:* 1 departure per hour and less than 1 km to the station or stop, or 2-3 departures per hour and 1-1.5 km to the station or stop.
4. *Poor access:* Departure every second hour or less frequent and less than 1 km to the station or stop, or 1 departure per hour and 1-1.5 km to the station or stop

5. *Very poor or no access:* No public transport service within 1.5 km from home, or departures less frequent than every second hour and 1-1.5 km to the station or stop.

Table 22. Access to public transport

Frequency \ Distance to the stop	< 1 km	1 - 1.5 km	> 1.5 km
At least 4 per hour	1	2	5
2-3 per hour	2	3	5
1 per hour	3	4	5
Less frequent	4	5	5

Table 23. Summary for calculating KPI MOB4.1.

MOB4.1	Access to public transport
Objective	The objective of this KPI is to facilitate frequent and easily accessible public transport, as a climate-efficient transport choice in the ZEN pilot area.
Description	A qualitative variable is calculated that describes public transport access on a five-point scale from Very good to Very poor, based on distance from house/neighbourhood to the station or stop normally used, and frequency of departures from the station or stop.
Method	BREEAM Communities, NRVU

MOB4.2 Travel time ratio

Travel time information can be obtained from travel planners such as EnTur[3] and the equivalent offered by various local public transport companies, possibly in combination with information from map-based apps or services. Travel times and travel time conditions can be calculated and retrieved for both rush and low traffic periods, to capture any queue problems, and should include walking times to and from the stop or parking. Travel times by public transport can be adjusted for changes in the need to change mode of transport and associated waiting times, related to changes in public transport routes caused by the ZEN pilot area. The likelihood of such adjustments must be considered when calculating KPI limit and target values for the completed ZEN pilot area. The KPI is calculated as a ratio of travel $time_{public}$ / travel $time_{private}$, and travel $time_{public}$ / travel $time_{active}$.

Table 24. Summary for calculating KPI MOB4.2

MOB4.2	Travel time ratio
Objective	The objective of this KPI is to consider the competitive relationship between private motorised, public transport, and active transport options for movements between the pilot area and the city centre, and/or closer local centres.
Description	The KPI is a proxy for the competition between active modes, public transport, and the private car in an everyday situation with time constraints.
Method	Travel times to city centre or local centre by private car, public transport, and active modes respectively, can be retrieved from national or local travel planners, e.g., EnTur and apps/services. The KPI is calculated as a ratio of travel $time_{public}$ / travel $time_{private}$, and travel $time_{public}$ / travel $time_{active}$.

[3] https://entur.no/

MOB4.3 Parking facilities

The parking norm specifies local regulations for how many parking spaces should and can be established to residents or workers in an area. In areas with low parking capacity, and/or high costs associated with parking, this may incur restrictions on residents' ability to own a car themselves. Parking options can be specified as the number of parking spaces available per unit, possibly in combination with the cost of using parking facilities. This KPI will be further developed in the next version of the ZEN definition guideline and may include topics such as charging facilities for electric vehicles, as well as bicycle parking facilities and electric bicycle charging facilities, with a view to reduce GHG emissions associated with private mobility (transitioning from fossil-fuel to electric) and to encourage more active mobility (electric bicycles and manual bicycles).

Table 25. Summary for calculating KPI MOB 4.3

MOB4.3	**Parking facilities**
Objective	The objective of this KPI is to consider the physical facilitation of car ownership or driving a car in, to, and from a neighbourhood, in terms of access to a space to park the vehicle when not in use.
Description	Parking options can be specified as the number of parking spaces available per building unit, possibly in combination with the cost of using the parking facilities.
Method	The parking norm, planned facilities, and cost regime.

MOB4.4 Car ownership

Car ownership is an important explanatory factor for both the extent of travel activity and the use of travel modes. NRVU provides information about car ownership in households and can be used alone or in combination with information about parking facilities, and the correlation between parking facilities and car ownership, to calculate expected car ownership per household in the ZEN pilot area. NRVU also provides information about energy carriers (e.g., petrol, diesel, electric, hydrogen, and various hybrids) for the vehicle fleet. This KPI will be further developed in the next version of the ZEN definition guideline and may also include access to any vehicles included in car sharing schemes, as well as bicycle ownership.

Table 26. Summary for calculating KPI MOB 4.4

MOB4.4	**Car ownership**
Objective	The objective of this KPI is to consider the resident's car ownership or access to a car, as an important condition for choice of transportation mode and mobility patterns.
Description	The KPI describes household access to private (or shared) vehicles. The KPI can be expressed as an average number of cars per household, and/or distribution of households on levels of car ownership, from zero to multiple vehicles. The KPI can be further split into categories based on type of energy carrier (e.g., fossil and zero emission) for the vehicles in question.
Method	NRVU

MOB4.5 Mobility pattern

NRVU can be used directly or in combination with information about MOB4.3 Parking facilities and MOB4.4 Car ownership to calculate expected trip production and distribution by mode of transport, adapted to the ZEN pilot area. The KPI includes the total number of trips per person per day; number of trips by mode of transport and share of trips by each mode of transport. Changes in trip length and choice of transport mode due to shifts in spatial quality and availability of local services and attractions, can be considered based on KPIs under the spatial qualities category.

Table 27. Summary for calculating KPI MOB4.5

MOB4.5	Mobility pattern
Objective	The purpose of this KPI is to calculate the total trip production (number of daily trips per person) for users, and how these trips are distributed according to active modes of travel (e.g., pedestrian and bicycle), public transport (e.g., bus, tram, boat, train, and tram) and private motorised means of transport (e.g., private car).
Description	KPIs include the total number of trips/person/day; number of trips/person/day by mode of transport, and % share of trips by each mode of transport. The KPIs for private motorised vehicles can be further split into categories based on type of energy carrier (e.g., fossil and zero emission) for the vehicles in question.
Method	NRVU, KPIs under the Spatial qualities category

MOB4.6 Passenger and vehicle mileage

The calculated trip production and distribution of transport alternatives in KPI MOB4.5 Mobility pattern is used together with information about distance for the daily travels to calculate the total annual travel distance for passengers (person km/year) and private motorised vehicles (vehicle km/year) for the neighbourhood users. Average trip lengths can be fetched from NRVU. This data should be used in combination with trip lengths derived from KPIs under the spatial qualities category, if available. Vehicle travel distance can further be split into fossil fuel and zero-emission alternatives respectively. The results from this KPI can be used in KPI GHG1.5 Operational transport (B8) in the GHG emissions category.

Table 28. Summary for calculating KPI MOB4.6

MOB4.6	Passenger and vehicle mileage
Objective	The purpose of this KPI is to calculate the total annual travel distance for passengers and vehicles, and the vehicle travel distance with fossil and zero-emission energy carriers respectively.
Description	The KPI can be expressed as total annual travel distance for passengers (person km/year) and private motorised vehicles (vehicle km/year) for the neighbourhood users, with a further split of vehicle travel distance into fossil fuel and zero-emission alternatives respectively. The results from this KPI can be used in KPI GHG1.5 for GHG1.5 Operational transport (B8) in the GHG emissions category.
Method	NRVU, KPIs under the spatial qualities category

MOB4.7 Freight and utility transport

This KPI will be further developed in the next version of the ZEN definition guideline.

6 Spatial Qualities

In this report, spatial qualities refer to the physical shape of the built environment and how it is perceived by its users. For developing spatial qualities, it is important to engage citizens and users and understand local needs, as well as reach a consensus on how urban form and land use influence attractiveness and sustainability.

6.1 Documentation Requirements

Urban form

For the urban form assessment criterion, the following documentation and KPI metrics are required:

- A map containing urban attractions within 500 metres from the ZEN pilot area and a table showing walking distances to each category of urban attractions.
- A map showing the street network within 500 metres from the ZEN pilot area (with buildings and height curves in the background) and a table showing the number of well-integrated streets to surrounding neighbourhoods and distance from the ZEN pilot area to other neighbourhoods along each well integrated street. A space syntax analysis based on axial lines that represents the street network is recommended but not necessary (medium resolution and radius 7).
- A table showing number of residents and workers within 500 metres air distance from the ZEN pilot area and the share of residents.
- A map showing valuable green open public space within 500 metres from the ZEN pilot area and a table showing size of valuable green open public space and total accessible land area within 500 metres from the ZEN pilot area.
- Documentation on how each KPI value is accounted for by using GIS software or manual drawings.

Process

For the process assessment criterion, information is generated from the project owner or local authorities. The assessment criterion should document the following:

- A copy of the stakeholder analysis at different stages of development.
- A copy of the demographic analysis at different stages of development.
- A copy of the needs assessment report.
- A copy of the consultation plan.
- Evidence on how the consultation plan has guided the implementation (from the strategic planning phase to the operational phase) of the ZEN pilot area.
- Documentation showing the output of the facilitated community consultation exercise.

6.2 Assessment Criteria

The KPIs for the spatial qualities category are grouped into two assessment criteria, 'process' and 'urban form'. The spatial qualities category has been developed since 2018 and has been tested in several pilots. Further exploration will be carried out in 2022, and a more detailed description of the KPIs will follow in subsequent versions of the ZEN definition guideline.

The process assessment criterion ensures that the developed strategic plans for the neighbourhood are based on local demographic trends and priorities, as well as user needs, ideas, and knowledge. By assessing the user needs, the quality and acceptability of the development throughout the design, construction processes and operation phase, are ensured.

The urban form assessment criterion can be seen as a summary of the ZEN spatial indicators and can highlight some of the most fundamental aspects of urban form and land use. The spatial indicators have been developed in close collaboration with ZEN pilot projects in Trondheim, Bærum, and Bodø. All metrics used can be measured with open-source GIS software. The required background data are usually available at Norwegian municipalities (alternative methods for measuring the KPI value have also been proposed in the definition guideline report).

6.3 KPIs

QUA5.1 Demographic analysis

A **demographic analysis** should be implemented to define the scope of the proposed development regarding current demographic profiles and future trends of the neighbourhood. A demographic analysis should be done in collaboration with the city's statistical office prior to conducting a stakeholder analysis. The purpose is to determine who are the existing (for an upgrade or densification project), potential, and intended future inhabitants of the planned neighbourhood. This analysis must be aligned with the demographic profiles and trends of the larger region to ensure that general trends and requirements are considered. General trends and requirements may include urban growth policies and political priorities as well as demographic changes, as an aging population may affect the implementation of a ZEN pilot area.

Table 29. Summary for calculating KPI QUA5.1

QUA5.1	Demographic analysis
Objective	Identification and characterisation of existing (for an upgrade or densification project), potential, and intended future inhabitants of the planned neighbourhood.
Description	The demographic profile should include information over time about total number of inhabitants and users, and characteristic projections on age distribution, gender, minority and cultural background, household size, values, headship rate, employment (sectors, incomes, businesses, unemployment), education, skills, training, and health.
Method	Data to describe the demographic profile for the ZEN pilot area should be available from the local authorities. Quantitative (statistical analysis) and qualitative (e.g., questionnaires and interviews); BREEAM Communities SE 02

QUA5.2 Stakeholder analysis

The stakeholder analysis KPI involves identifying the inhabitants, users, and stakeholders that are important to include in the development of a ZEN pilot area. The following list consists of potential stakeholders to identify in the ZEN pilot area:

- Actual and/or intended inhabitants and users of the neighbourhood
- Neighbours that may be affected by, or that may influence, the final design
- Representatives of nearby communities: If the site is a new development, representatives are sought from surrounding communities, from a similar type of project, or data from similar projects can be used
- Potential users of any on-site or shared facilities. This should include:
    - A selected sample based on the intended mix of people in the future ZEN pilot area
    - Periphery users can be represented through end-user organisations (e.g., such as organisations for people with disabilities),
    - Institutions that may have a large impact on end-user awareness, such as schools, sport clubs, churches, mosques, etc.
    - Local or national historic/heritage, ecology, cultural, residents, business groups, etc.
- Representatives of the planning and implementing stakeholders; including:
    - energy utility companies
    - private developers
    - real estate companies
    - transport providers
    - architects, engineers, site managers, contractors, suppliers, etc.

- Representatives for distributors of services to the ZEN pilot area (e.g., district nurses or garbage collection companies) that may impact the infrastructure and accessibility aspects
- Representatives of specialist services and maintenance contractors

Table 30. Summary for calculating KPI QUA5.2

QUA5.2	Stakeholder analysis
Objective	Identification of the neighbourhood inhabitants, users, and stakeholders as a target group to include in QUA5.4 Consultation plan.
Description	Stakeholder identification and description of interest and power as a necessary step to include stakeholders in QUA5.4 Consultation plan.
Method	Different methodologies available, free to choose.

QUA5.3 Needs assessment

The needs assessment KPI provides information about the needs and requirements of the users of the ZEN pilot area neighbourhood. Consideration should be given to how the demographics of the community will change over the lifetime of the development (based on QUA5.1 Demographic analysis) as it is important to plan and design for adaptability and flexibility. The following aspects should be considered in the needs assessment (40):

- community buildings and local meeting places
- dwellings, including affordable homes and mixed tenure
- education and library services
- green spaces (see QUA5.8 Green space)
- leisure facilities (free and priced) and other sports facilities (e.g., tennis courts, football fields, and swimming pools, etc.)
- health and social care services such as pharmacies and medical centres
- shops and farmers markets selling food and fresh groceries
- community gardens or places growing fresh fruit and vegetables
- playgrounds and childcare facilities
- communication services such as public internet access and postal facilities
- bank and/or cash machine
- community house
- places of religious worship and gathering

Table 31. Summary for calculating KPI QUA5.3

QUA5.3	Needs assessment
Objective	Identification of needs and requirements of inhabitants and users of the ZEN pilot area
Description	The knowledge of needs and requirements of (future) inhabitants and users enables the strategic planning, implementation, and operation of ZEN pilot areas in line with user demands.
Method	Various, including qualitative and quantitative methods, depending on the context of the neighbourhood, e.g., if it is an existing or planned neighbourhood, BREEAM Communities GO 01

QUA5.4 Consultation plan

The consultation plan KPI should be developed to ensure the inclusion of the user needs in the ZEN pilot area process. The aim of the consultation plan is to ensure that the needs, ideas, and knowledge of the community are used to improve the quality and acceptability of the ZEN pilot area throughout the strategic planning and implementation phases and into the operational phase.

It is important to consult the local authority about planning and align it with requirements for citizen consultation in the official planning procedure. Consultation should take place early enough in the process for the stakeholders to influence key decisions. This may be during the pre-application stage of the planning process, such as the planning strategy on a neighbourhood level. The plan includes timescales and methods of consultation, clearly identifying:

- at which points the users and other stakeholders can usefully contribute
- how they will be kept informed about the progress of the project
- how and when feedback will be provided about how consultation input will be considered
- appoint a designated person who is responsible for carrying out the consultation activities throughout project development timeframe
- implement an approach to target and provide for minority and 'hard to reach' groups (e.g., elderly, youth, disabled, and those with limited time to participate)

The consultation plan should detail the level of consultation for different stakeholders, when consultation will take place, and the methods that will be used. The consultation plan should consider the following, as a minimum:

- Inclusion of different stakeholders in design reviews of plans for delivery of amenities, public parking, landscaping, community management, pedestrian pathways, cycling facilities, and transport facilities.
- Impacts of the development upon the surrounding community during construction and following completion (including the protection of areas of historic and heritage value).
- Accountability: The consultation plan is completed by people who are trained in human centred and/or participatory design processes. Accountability means that the input from users is handled in an open manner and decisions regarding what is implemented of user ideas and needs are openly discussed. The designated person responsible for the consultation plan and the rest of the stakeholders have accountability for ensuring that the needs defined in the consultation plan are considered at all defining stages of the planning process. A coherent plan for consultation and planned process for ensuring impact of the consultation on final design must be available and publicly shared on a location that is well-known, easy to access, and written in a language that everyone can understand.
- The design input should not only include the design of the neighbourhood in a hand-over state, but also include work on needs and expectations regarding management, maintenance, or operational issues seen from the end user as well as professional viewpoints (such as cleaners, food distributors, healthcare assistants, etc.).
- Opportunities for shared use of facilities and infrastructure with the existing or adjacent community.

The consultation of the users of the neighbourhood must include a facilitated community consultation method to engage the community on specific aspects of the design. There are many methodologies available to engage users about the formulation and design of development proposals. The following principles should be adhered to:

- the consultation exercise has a clearly communicated purpose
- participants understand how their views will be used in plans for the development
- expectations are set as to which options are open for discussion and revision
- reasonable advance notice is given to potential participants of the consultation exercise

- efforts are made to include hard-to-reach groups
- specific attention must be taken to ensure a clear language and no use of discipline specific wording
- the consultation is facilitated by a person or organisation that is independent from the project owner

Table 32. Summary for calculating KPI QUA5.4

QUA5.4	Consultation plan
Objective	To ensure that the needs, ideas, and knowledge of the community are used to improve the quality and acceptability of the ZEN pilot area throughout the strategic planning and implementation phases and into the operational phase.
Description	A plan for a guided process of stakeholder involvement to guarantee the inclusion of inhabitants and users.
Method	Depending on the local context different methodologies are appropriate to design and conduct the consultation plan, such as BREEAM Communities or CityKeys.

QUA5.5 Urban accessibility

The urban accessibility KPI assesses access to the following five categories of urban attractions within 1 km walking distance for at least 90 % of the residents and workers in an area: local public transport, fast regional public transport, elementary school, local service cluster, and attractive open public spaces. In future work, the scope of this KPI will be explored in conjunction with MOB4.1 Access to public transport and QUA5.3 Needs assessment to ensure that relevant categories of urban attraction are identified.

Table 33. Summary for calculating KPI QUA5.5

QUA5.5	Urban accessibility
Objective	The access to a variety of urban attractions within walking distance has shown to be important for urban attractiveness (41) as well as for increasing the share of sustainable transport patterns (42).
Description	Access to the following five categories of urban attractions within 1 km walking distance for at least 90 % of the residents and workers in an area: 1. local public transport (with at least one departure per 15-minute daytime), 2. fast regional public transport 3. elementary school 4. Local service cluster* 5. attractive open public space * Categories identified in QA5.1-5.3 of service along a street or in a local centre, for example grocery store, pharmacy, café or restaurant, health care, package pickup /post
Method	GIS mapping with Space syntax tool or other GIS applications that can measure walking distance (alternatively walking distance can be measured manually in various map services).

QUA5.6 Street connectivity

The street connectivity KPI assesses the number of spatially integrated streets and walking distance to surrounding neighbourhoods.

Table 34. Summary for calculating KPI QUA5.6

QUA5.6	Street connectivity
Objective	To encourage walkability and social and economic exchange within surrounding neighbourhoods and provide an interconnected network of streets. Spatial integration, in the sense how different neighbourhoods are linked to each other based on the street network, has shown significant effect on social segregation (43), natural pedestrian movement (44) and perceived closeness within the urban fabric.
Description	Street connectivity is the number of spatially integrated streets and walking distance to surrounding neighbourhoods.
Method	GIS mapping with Place syntax tool or other GIS applications that can measure spatial integration Alternatively, street connectivity can be assessed manually by visualising the shape of street networks together with height curves and building heights on a map.

QUA5.7 Land use mix

The land use mix KPI assesses the balance between residents and workers within the neighbourhood and a buffer area of 500 metres air distance.

Table 35. Summary for calculating KPI QUA5.7

QUA5.7	Land use mix
Objective	The UN Habitat highlights the importance of a certain of mix of residents and workers. A balance is important for co-use, level of service, social safety, and increased potential for sustainable transportation.
Description	Land use mix is the balance between residents and workers within the neighbourhoods and a buffer area of 500 metres air distance.
Method	Number of residents and workers within the ZEN pilot area together with the buffer area are summarised. The planned density can be recalculated to number of people living and working in the area by using locally suitable conversions, for example 50 m^2 gross floor area per resident or 20 m^2 per office worker

QUA5.8 Green space

The green space KPI assesses the share of valuable green open public space of all land area within the neighbourhood and a buffer area of 500 metres air distance.

Table 36. Summary for calculating KPI QUA5.8

QUA5.8	Green space
Objective	A sufficient share of green space has a positive impact on health and well-being and is also vital for climate adaptation and GHG sequestration. UN Habitat recommends that at least 15 % of land use should be open public space.
Description	Green space is the share of green open public space of all land area within the neighbourhood plus a buffer area of 500 meters air distance.
Method	Percentage (%) of green open public space (clearly public qualitative green areas that are at least 0.2 hectares in size) of total ground surface land area within 500 metres air distance.

7 Economy

Economic sustainability is an important consideration if ZENs are to be mainstreamed. Developing a group of interconnected buildings into a ZEN pilot area will likely entail increased capital costs during the implementation phase, but these could be offset by lower operational costs during the operational phase. Economy KPIs are therefore important and relevant - they are also included in other neighbourhood evaluation frameworks, such as Sustainable Positive Energy Neighbourhoods (SPENs) (45), and are also being developed in research networks such as IEA EBC Annex 83 Positive Energy Districts (2020-2024) Subtask C (46) and COST PED EU NET (2020-2024) (47).

7.1 Documentational Requirements

Life cycle costs

Life cycle costing (LCC) is an economic evaluation methodology which compiles and assesses costs related to building and construction assets over the entire life cycle of a building or neighbourhood. LCC should be calculated according to *NS 3454* Life cycle costs for construction works - Principles and classification (48). *NS 3454* defines LCC as including both original costs and costs incurred throughout the whole functional lifetime. *NS 3454* defines the lifetime costs as the net present value (NPV) of the LCC and the annual costs as the annuity of the LCC. LCC can be useful in all project phases. In the strategic planning phase, LCC forecasting may use 'benchmark costs' based on historical costs of previous projects. LCC in early project stages is used for studying the consequences of the performance requirements before any decisions are made. As the design evolves and more detailed information becomes available, benchmarks should be substituted with project-specific estimated costs. The strategic planning and implementation phases have the greatest potential to influence the operational life cycle costs. Thus, LCC should be completed as early as possible in the design process to maximize the outcome and ensure opportunities to positively influence the project (49). Continuous monitoring and optimisation of LCC should continue throughout the project life cycle.

7.2 Assessment Criteria

In the economy category, costs are considered from the perspective of the building owner. The economy category is comprised of two assessment criteria, namely life cycle costs (LCC) and cost benefit.

Life cycle costs

Using LCC as part of the decision-making process requires good accessibility to reliable input data, starting with generic information (i.e., statistics and historical costs) and going on to more specific information. Cost information can be obtained from manufacturers and suppliers, contractors, testing and research organisations, publications, commercial databases, feedback from operational assets, and organisations' internal data. Data from the Norwegian Price book (Norsk prisbok) (50) can also be used as reference values. LCC at the building and neighbourhood assessment boundary levels can be broken down into the following categories (48):

- Capital and residual costs
- Management costs
- Operating and maintenance costs
- Replacement and development costs
- Consumption costs
- Cleaning costs

Reporting units for LCC are aligned with reporting units in Chapter 2 GHG Emissions and are as follows; Norwegian kroner per square meter gross floor area (GFA) per year ($NOK/m^2_{GFA}/yr$) for buildings, Norwegian kroner per square meter of plot area (PA) per year ($NOK/m^2_{PA}/yr$) for infrastructure, and Norwegian kroner per user (NOK/user) for operational transport. The preliminary thinking is to consider ECO 6.1 Capital costs and ECO6.2 Operating costs to demonstrate the economic performance of each ZEN pilot area.

Cost benefit analysis

The cost benefit assessment criterion allows ZEN partners to weigh the cost and benefits of implementing zero emission strategies or measures to reach the ZEN aim of reducing direct and indirect GHG emissions towards net zero. This assessment criterion is still under development and will outline a set of KPIs that provide an evaluation to building owners and developers of the relative benefits of a particular choice of zero emission strategies or measures.

7.3 KPIs

ECO 6.1 Capital costs

This KPI captures capital costs calculated according to *NS 3454* (51). Capital costs refer to building construction costs and the cost of assets or items that are purchased or implemented with the aim of improving the carbon emissions of the ZEN pilot area. It is expected that there will be a higher investment in more energy-efficient and net zero emission buildings and infrastructure. This KPI will be assessed at both the building and neighbourhood level and will ascertain costs associated with, amongst other things, the energy system and material procurement.

Table 37. Summary for calculating KPI ECO6.1

ECO 6.1	Capital costs
Objective	Economic sustainability will be important for the mainstreaming of ZENs, where building owners and investors need to articulate a business case in developing a group of interconnected buildings into a ZEN pilot area, which will likely entail higher upfront costs with investments in energy, heating and storage systems, and material costs. This KPI aims to capture those capital costs.
Description	Capital costs refer to building construction costs and the cost of assets or items that are purchased or implemented with the aim of improving the carbon emissions of the ZEN pilot area.
Method	To be developed in collaboration with ZEN partners and will be elaborated in subsequent versions of the ZEN guideline report.

ECO6.2 Operating costs

This KPI captures annual operating costs, such as management, operation, maintenance, replacement, development, consumption, and cleaning costs. In other words, operating costs refer to capital-related annual costs for those assets or items purchased or implemented for improving the carbon emissions of the ZEN pilot area. This KPI will be assessed at both the building and neighbourhood level.

Table 38. Summary for calculating KPI ECO6.2

ECO 6.2	**Operating costs**
Objective	Economic sustainability will be important for the mainstreaming of ZENs, where building owners and investors need to articulate a business case in developing a group of interconnected buildings into a ZEN pilot area, which will likely entail higher upfront costs with investments in energy, heating and storage systems, and material costs, but offset this investment by lower operational costs during the operational phase. This KPI tries to capture these operational costs.
Description	Operating costs refer to capital-related annual costs for those assets or items purchased or implemented for improving the carbon emissions of the neighbourhood
Method	To be developed in collaboration with ZEN partners and will be elaborated in subsequent versions of the ZEN guideline report.

ECO6.3 Overall performance

This KPI will outline a set of indicators that provide an evaluation for building owners and developers of the relative benefits of a particular choice of zero emission strategies or measures. This set of indicators will summarise both the capital and operational costs in a single indicator. As the ZEN research centre is interested in the cost and benefits of implementing zero emission strategies or measures in order to reach the ZEN definition (52), one preliminary plan is to look at the cost of implementing different zero emission strategies and/or measures in a neighbourhood in terms of NOK/CO_2e saved. This set of indicators can also consider additional indicators such as payback period or return on investment (ROI) that are familiar to investors. The preliminary thinking is to consider ECO6.3 Overall performance to summarise both capital and operational costs into a single indicator. Many options are available as a KPI for overall cost benefit analysis:

- ***The net present value (NPV)***: is the sum of the discounted future cash flow used for comparing alternatives over the same period of analysis. NPV should be calculated by discounting future cash flows to present value. LCC is typically presented in real cost figures to ensure accuracy regardless of the point in time at which the costs are incurred. A predefined real discount rate of 4% is considered in the Norwegian Digitalisation Agency (*Digitaliseringsdirektoratet*) guide for public buildings (53).
- ***Annual cost (AC) or annual equivalent value (AEV)***: is a uniform annual amount equivalent to the project net costs, considering the time value of money throughout the period of analysis. The annual costs are calculated as an annuity, meaning that the costs are averaged to be the same amount every year. The annual equivalent value is the regular annual cost that when discounted equals NPV of the investment.
- ***Payback period***: is the time it takes to cover investment costs and is considered as an additional criterion used to assess the period during which an investment is at risk. It is calculated as the number of years elapsed before the NPV of the cumulative returns exceeds the initial investment. Simple payback takes real (non-discounted) values, while discounted payback uses present (discounted) value. The costs and savings occurred after payback has been reached, are not considered.
- ***Internal rate of return (IRR)***: is the compound rate of interest that makes costs equal to benefits when cash flows are reinvested at a specified interest rate. IRR defines the discount rate that produces a NPV of zero (or the rate at which the costs equal the benefits of the investment). IRR enables the evaluation of the feasibility of an investment or comparison between possible different investments.
- ***Net savings (NS)***: is the difference between the present worth of income generated by an investment and the amount invested. It is expressed in values (discounted) and unit of currency.

Table 39. Summary for calculating KPI ECO6.3

ECO 6.3	Overall performance
Objective	Economic sustainability will be important for the mainstreaming of ZENs, where building owners and investors need to articulate a business case in developing a group of interconnected buildings into a ZEN pilot area.
Description	Overall performance based on life cycle costing approach.
Method	To be developed in collaboration with ZEN partners and will be elaborated in subsequent versions of the ZEN guideline report.

8 Limitations and Further Work

This is the second version of the ZEN definition guideline report. It builds upon the ZEN definition report series and ZEN definition guideline report and provides more detailed descriptions of the ZEN categories, assessment criteria and KPIs that are included in the definition, along with relevant evaluation methodologies and sources of data that can be used to evaluate the ZEN pilot areas. The report has highlighted some limitations and provided scope for further work, which will be covered in future editions of the ZEN definition guideline report. During the next two-year period, the ZEN definition guideline working group will focus on the following activities:

- **Testing and evaluation of assessment criteria and KPIs in all ZEN pilot projects**: All ZEN pilot areas shall select a number of ZEN assessment criteria and KPIs to be tested and evaluated. Knowledge gained from this testing shall be used to evaluate reference values set and establish limit and target values.
- **Validate reference projects and reference values**: In this ZEN definition guideline report, basic background information used for developing reference projects and reference values are incorporated. Reference projects and reference values shall evaluate and document how much a ZEN pilot area has managed to fulfil KPI criteria.
- **Establish limit and target values, weighting and benchmarking**: Next steps in the development of the ZEN definition include setting limit and target values after testing and evaluating assessment criteria and KPIs in pilot project against reference projects and reference values, and developing a weighting and benchmarking system for the evaluation and rating of ZEN pilots at the category and neighbourhood levels.
- **Cross-reference KPIs:** Cross-reference KPIs between categories to ensure good coverage, harmonised methods (where this is possible) and avoid double-counting.
- **ZEN KPI tool:**
  - **Data collection and documentation**: Develop a transparent system for data collection, monitoring, evaluation, and documentation, including the type and availability of data, who should assess the data, at what quality (including source and age of data) and regularity.
  - **ZEN Toolbox**: ZEN pilot projects need tools which enable them to assess, analyse, monitor, and visualise assessment criteria and KPIs, and engage relevant stakeholders in different phases. Existing tools and tools developed by the ZEN research centre will be mapped according to project phase, stakeholder, and KPIs assessed. This shall also include a ZEN visualisation toolbox.
  - **Multi-criteria analysis**: In this guideline report, the assessment criteria and KPIs are described separately. A methodology for multi-criteria analysis approach for evaluating, measuring, and reporting the interconnection between criteria and KPI results under each category will be developed.

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Appendix A: Standards and references

The development of each ZEN category builds on existing standards and reference documents cited hereunder. Unless otherwise specified, the most recent edition of the references document (including any amendments) applies.

Greenhouse gas emissions (GHG)

NS 3720:2018 Metode for klimagassberegninger for bygninger / Method for greenhouse gas calculations for buildings

NS 3457-3 Klassifikasjon av byggverk — Del 3: Bygningstyper / Classification of construction works — Part 3: Building types

NS 3451. Bygningsdelstabell / Table of Building Elements

NS-EN 15804 Bærekraftige byggverk - Miljødeklarasjoner - Grunnleggende produktkategoriregler for byggevarer / Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products

NS-EN 15978 Bærekraftige byggverk - Vurdering av bygningers miljøprestasjon – Beregningsmetode / Sustainability of construction works - Assessment of environmental performance of buildings - Calculation method

NS-EN 16258 Metode for beregning av og deklarering av energiforbruk og klimagassutslipp for transporttjenester (vare- og persontransport) / Methodology for calculation and declaration of energy consumption and GHG emissions of transport services (freight and passengers)

NS-EN 16449 Tre og trebaserte produkter - Beregning av biogent karboninnhold i tre og omdanning til karbondioksid / Wood and wood-based products - Calculation of the biogenic carbon content of wood and conversion to carbon dioxide

Energy (ENE) and Power (POW)

SN-NSPEK 3031:2021 Bygningers energiytelse — Beregning av energibehov og energiforsyning / Energy performance of buildings — Calculation of energy needs and energy supply

ISO 52000-1:2017 Bygningers energiytelse - Overordnet vurdering av bygningers energiytelse - Del 1: Generelt rammeverk og prosedyrer / Energy performance of buildings -- Overarching EPB assessment -- Part 1: General framework and procedures

Method developped within the IEA EBC Annex 52 Task 40 project (Solar Heating and Cooling): (37) *Analysis of Load Match and Grid Interaction Indicators in NZEB with High-Resolution Data*

Methods developed within IEA EBC Annex 67 project: (54) *Characterization of Energy Flexibility in Buildings* and (55) *Principles of Energy Flexible Buildings*

Mobility (MOB)

NRVU (56): Den nasjonale reisevaneundersøkelsen / The national travel habits survey

TØI's report for input data for national transport models (57)

Spatial qualities (QUA)

BREEAM (58): an environmental assessment method for new building designs using a balanced scorecard approach with tradable credits to enable the market to decide how to achieve optimum environmental performance for the project.

City Keys (59): indicators for smart city projects and smart cities

DGNB System (60): certification scheme for buildings, districts and interiors, developed by the he German Sustainable Building Council

IPCC 2014 (61): Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change

UN Habitat (42) New Strategy of Sustainable Neighbourhood Planning

Economy (ECO)

NS 3454:2013. Livssykluskostnader for byggverk - Prinsipper og klassifikasjon / Life cycle costs for construction works - Principles and classification

Norsk prisbok (62): an updated price database that contains diverse price information regarding costs for a construction project in Norway.

Appendix B: Reporting Matrix for GHG Emissions.

<table>
<tr><th></th><th>A1-A3: Product stage</th><th>A4: Transport to site</th><th>A5: Installation</th><th>B1: Use</th><th>B2: Maintenance</th><th>B3: Repair</th><th>B4: Replacement</th><th>B5: Refurbishment</th><th>B6: Operational energy use</th><th>B7: Operational water use</th><th>B8: Operational transport use</th><th>C1: Deconstruction</th><th>C2: Transport to end of life</th><th>C3: Waste processing</th><th>C4: Disposal</th><th>D: Reuse, recovery and recycling</th><th>Total</th></tr>
<tr><td>20 Building, general</td><td colspan="10" rowspan="10">Level 1: Building envelope</td><td rowspan="37"></td><td colspan="6" rowspan="10">Level 1: Building envelope</td></tr>
<tr><td>21 Groundwork and foundations</td></tr>
<tr><td>22 Superstructure</td></tr>
<tr><td>23 Outer walls</td></tr>
<tr><td>24 Inner walls</td></tr>
<tr><td>25 Floor structure</td></tr>
<tr><td>26 Outer roof</td></tr>
<tr><td>27 Fixed inventory</td></tr>
<tr><td>28 Stairs and balconies</td></tr>
<tr><td>29 Other</td></tr>
<tr><td>30 Heating, ventilation and sanitation, general</td><td colspan="10" rowspan="27">Level 2: Advanced building</td><td colspan="6" rowspan="27">Level 2: Advanced building</td></tr>
<tr><td>31 Sanitary</td></tr>
<tr><td>32 Heating</td></tr>
<tr><td>33 Fire safety</td></tr>
<tr><td>34 Gas and air pressure</td></tr>
<tr><td>35 Process cooling</td></tr>
<tr><td>36 Ventilation and air conditioning</td></tr>
<tr><td>37 Comfort cooling</td></tr>
<tr><td>38 Water treatment</td></tr>
<tr><td>39 Other</td></tr>
<tr><td>40 Electric power, general</td></tr>
<tr><td>41 Basic installation for electric power</td></tr>
<tr><td>42 High voltage power</td></tr>
<tr><td>43 Low voltage power</td></tr>
<tr><td>44 Lighting</td></tr>
<tr><td>45 Electric heating</td></tr>
<tr><td>46 Standby power</td></tr>
<tr><td>49 Other</td></tr>
<tr><td>50 Tele. and Automation</td></tr>
<tr><td>51 Basic installation</td></tr>
<tr><td>52 Integrated comms</td></tr>
<tr><td>53 Telephone and paging</td></tr>
<tr><td>54 Alarm and signal</td></tr>
<tr><td>55 Sound and picture</td></tr>
<tr><td>56 Automation</td></tr>
<tr><td>57 Instrumentation</td></tr>
<tr><td>59 Other</td></tr>
</table>

	A1-A3: Product stage	A4: Transport to site	A5: Installation	B1: Use	B2: Maintenance	B3: Repair	B4: Replacement	B5: Refurbishment	B6: Operational energy use	B7: Operational water use	B8: Operational transport use	C1: Deconstruction	C2: Transport to end of life	C3: Waste processing	C4: Disposal	D: Reuse, recovery and recycling	Total
60 Other installation, general																	
61 Prefabricated unit																	
62 Passenger and goods transport																	
63 Transport facilities for small goods																	
64 Stage equipment																	
65 Waste and vacuum cleaning																	
66 Fixed furniture																	
67 Loose furniture																	
69 Other																	
7 Outdoor, general																	
71 Adapted terrain																	
72 Outdoor construction																	
73 Outdoor heating, ventilation and sanitation																	
74 Outdoor electric power	Level 3: Infrastructure											Level 3: Infrastructure					
75 Outdoor tele and automation																	
76 Roads and courtyards																	
77 Parks and gardens																	
78 Outdoor infrastructure																	
79 Other																	
Total	Level 4: Neighbourhood																