Research Centre on
ZERO EMISSION
NEIGHBOURHOODS
IN SMART CITIES

THE ZEN DEFINITION – A GUIDELINE FOR THE ZEN PILOT AREAS

Version 3.0.

ZEN REPORT No. 44 - 2022

SINTEF | NTNU

Research Centre on
ZERO EMISSION
NEIGHBOURHOODS
IN SMART CITIES

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Preface

Acknowledgements
This report has been written within the Research Centre on Zero Emission Neighbourhoods in Smart Cities (FME ZEN). The authors gratefully acknowledge the support from the Research Council of Norway, the Norwegian University of Science and Technology (NTNU), SINTEF, the municipalities of Oslo, Bergen, Trondheim, Bodø, Bærum, Elverum and Steinkjer, Trøndelag county, Norwegian Directorate for Public Construction and Property Management, Norwegian Water Resources and Energy Directorate, Norwegian Building Authority, ByBo, Elverum Tomteselskap, TOBB, Snøhetta, Tegn_3 , Asplan Viak, Multiconsult, Sweco, Civitas, FutureBuilt, Hunton, Moelven, Norcem, Skanska, GK, Caverion, Nord-Trøndelag Elektrisitetsverk (NTE), Smart Grid Services Cluster, Statkraft Varme, Energy Norway and Norsk Fjernvarme.

The Research Centre on Zero Emission Neighbourhoods (ZEN) in Smart Cities
The ZEN Research Centre develops solutions for future buildings and neighbourhoods with no greenhouse gas emissions and thereby contributes to a low carbon society.

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

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

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

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

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The editors would like to thank all 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), Camille Vandervaeren (SINTEF), Helge Brattebø (NTNU), Edgar Hertwich (NTNU), Jan Sandstad Næss (NTNU), Inger Andresen (NTNU), Patricia Schneider-Marin (NTNU), Juudit Ottelin (NTNU).

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Mobility: Solveig Meland (SINTEF), Unn Karin Thorenfeldt (SINTEF), Bendik Manum (NTNU), Peter Schön (NTNU), Eva Heinen (NTNU), Hampus Karlsson (SINTEF) and Astrid Bjørgen (SINTEF).

Economy: Caroline Cheng (SINTEF), Kristin Tolstad Uggen (SINTEF), Stian Backe (NTNU), Anne Gunnarshaug Lien (SINTEF).

Urban form and land use: Tobias Nordström (NTNU), Lillian Sve Rokseth (SINTEF), Daniela Baer (SINTEF), Judith Thomsen (SINTEF), Lars Arne Bø (SINTEF), Bendik Manum (NTNU), Johannes Brozovsky (NTNU) and Peter Schön (NTNU).

In addition, the ZEN definition guideline report was sent for internal hearing to ZEN researchers and partners. The editors would like to thank ZEN researchers and partners for their contributions.

Document History

Version	Date	Version description
Version 1.0	2018	The first version of 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, source and type of data used to evaluate and document 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 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 detailed explanation of the ZEN categories and new information about the KPI tool and framework.
Version 3.0	2022	This third version (version 3.0) of the ZEN definition guideline report builds upon V.1.0 and V.2.0 of the ZEN definition guideline reports and series of ZEN definition reports. This report gives further details on the ZEN KPI tool and on ZEN KPI reference, limit and target values. A major change involves lifting the process KPIs out of spatial qualities and incorporating them into a process guideline for designing ZENs. Details have been added to each KPI to explain to what degree it contributes to the main goal of ZEN, and examples of best practice are given. Additional power KPIs have been added. The spatial qualities category has been renamed to urban form and land use, and additional KPIs have been added.

Abstract

This third version of the ZEN definition guideline report builds upon version 1.0 and 2.0 of the ZEN definition guideline reports and series of ZEN definition reports. This report gives further details on the ZEN KPI tool and on ZEN KPI reference, limit, and target values. A major change involves lifting the process KPIs out of spatial qualities and incorporating them into a process guideline for designing ZENs. Details have been added to each KPI to explain to what degree it contributes to the main goal of ZEN, and examples of best practice are given. Additional power KPIs have been added. The spatial qualities category has been renamed to urban form and land use.

Sammendrag

Denne tredje utgaven av ZEN definisjonsveilederen bygger på versjon 1.0 og 2.0 av ZEN definisjonsveilederne og ZEN definisjonsrapporter. Denne rapporten presenterer ZEN KPI verktøyet i mer detalj og gir mer informasjon om ZEN KPI referanse-, grense-, og målverdier. En stor endring inkluderer å løfte prosess KPI ut av stedskvaliteter kategorien og å tilpasse dem til en prosessveileder for design og planlegging av ZEN områder. Detaljer har blitt supplert på hver KPI for å forklare i hvilken grad de bidrar til målsetningen av ZEN samt gir eksempler på beste praksis. Noen nye KPI har blitt lagt til. Navnet på stedskvaliteter kategorien har blitt endret til byform og arealbruk.

Contents

Background

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

1. A clear ZEN definition
2. Assessment criteria and key performance indicators (KPIs), which will help to plan and implement the neighbourhood and to monitor its actual performance,
3. A ZEN KPI assessment tool to monitor the performance of a new and/or existing neighbourhoods with different ambition levels,
4. 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
5. ZEN pilot projects to validate the ZEN definition through testing and implementation

The ZEN research centre is organised into six work packages (WP), see 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 and the results of which will be fed back into the development of the ZEN definition, assessment criteria and KPIs in WP1.

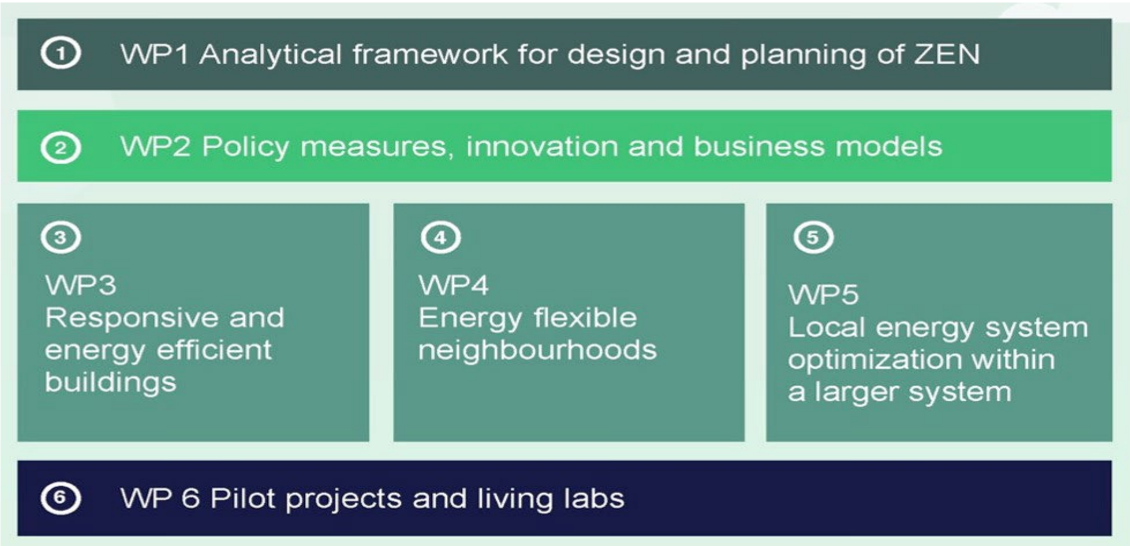


Figure 1. Work packages within the FME ZEN research centre.

The ZEN Definition

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 net **zero emission neighbourhood** aims to reduce and compensate its direct and indirect **greenhouse gas (GHG) emissions** towards zero over the analysis period, in line with a **chosen ambition level**. The neighbourhood should focus on the following:

a. Plan, design and operate buildings and their associated infrastructure components towards minimized life cycle **GHG emissions** and compensating remaining GHG emissions to obtain a net zero emission neighbourhood.
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 to facilitate the transition to a decarbonised energy system and reduction of power and heat capacity requirements.
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 to achieve affordable zero emission neighbourhoods and choose cost optimal GHG emission reduction strategies.
f. Plan and locate amenities in the neighbourhood to provide good **urban form and land use** and stimulate **sustainable behaviour**.

The ZEN Definition Guideline

This ZEN definition guideline report version 3.0 builds upon the previous ZEN definition guideline reports (4,5) and the series of ZEN definition reports (1–3). The ZEN definition consists of six categories. Each category contains a set of assessment criteria and KPIs, as presented in Table 1. Each category in the ZEN guideline report is explained under a dedicated chapter, which outlines documentational requirements, assessment criteria and KPIs, and includes a summary table explaining how to calculate each KPI. However, it should be noted that the summary tables vary, whereby some are more detailed than others, depending on how far the development of the KPI has come in the testing and validating process.

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

Category	Assessment criteria	KPI	Points
GHG	Emission reduction	*GHG1.1 Materials (A1-A3, B4)*	11
		GHG1.2 Construction (A4-A5)	2
		GHG1.3 Use (B1-B3, B5)	1
		GHG1.4 Operational energy use (B6)	12
		GHG1.5 Operational transport (B8)	19
		GHG1.6 End-of-life (C1-C4)	1
	Compensation	*GHG1.7 Benefits and loads (D)*	4
ENE	Energy efficiency in buildings	*ENE2.1 Energy need in buildings*	8

[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, as well as infrastructure for mobility.
[2] The area has a defined physical boundary to external grids (electricity, heat, and mobility). The system boundary for analysis of energy facilities serving the neighbourhood may not be the same as the geographical area.

Category	Assessment criteria	KPI	Points
	Energy carrier	*ENE2.2 Delivered energy*	8
		ENE2.3 Self-consumption	2
		ENE2.4 Net load profiles	1
		ENE2.5 Colour-coded carpet plots	1
POW	Power performance	*POW3.1 Peak load*	6
		POW3.2 Peak export	2
		POW3.3 Energy stress	6
		POW3.4 Representative days	2
	Load flexibility	*POW3.5 Delivered energy difference*	1
		POW3.6 Operational cost difference	1
		POW3.7 Energy stress difference	1
		POW3.8 Peak load difference	1
URB	Density and land use mix	*URB4.1 Population density*	2
		URB4.2 Block density	1
		URB4.3 Land use mix	2
		URB4.4 Access to a diversity of amenities	2
	Building layout	*URB4.5 Dwelling type*	1
		URB4.6 Multifunctional building roofs	1
		URB4.7 Active frontages	2
	Street network	*URB4.8 Street connectivity*	2
		URB4.9 Street intersection density	1
		URB4.10 Walkable and bikeable streets	1
	Green open space	*URB4.11 Share of green open space*	2
		URB4.12 Share of green permeable area	2
		URB4.13 Preserving and planting trees	1
MOB	Access	*MOB5.1 Access to public transport*	3
		MOB5.2 Travel time ratio	3
		MOB5.3 Parking facilities	3
		MOB5.4 Vehicle ownership	3
	Travel behaviour	*MOB5.5 Mobility pattern*	3
		MOB5.6 Passenger and vehicle mileage	3
	Logistics	*MOB5.7 Freight and utility transport*	2
ECO	Life Cycle Costs (LCC)	*ECO 6.1 Capital costs*	6
		ECO6.2 Operating costs	6
	Cost benefit	*ECO6.3 Overall performance*	8

Despite having different categories within the ZEN definition there are many synergies between categories and KPIs which all contribute to the main goal of net zero emission neighbourhoods (nZEN) either directly or indirectly. For example, results from *ENE2.1 Energy need in buildings* is used to calculate *GHG1.4 Operational energy use (B6)*, results from *MOB5.5 Mobility pattern* are used to calculate *GHG1.5 Operational transport (B8)*, the same material inventory can be used to calculate GHG emissions in the GHG KPIs and costs in the ECO KPIs.

These synergies are represented in Figure 2, which depicts the interrelationship and synergies between ZEN KPIs whereby each coloured spot represents a KPI in the ZEN definition, and each black line shows which KPIs have a direct connection.

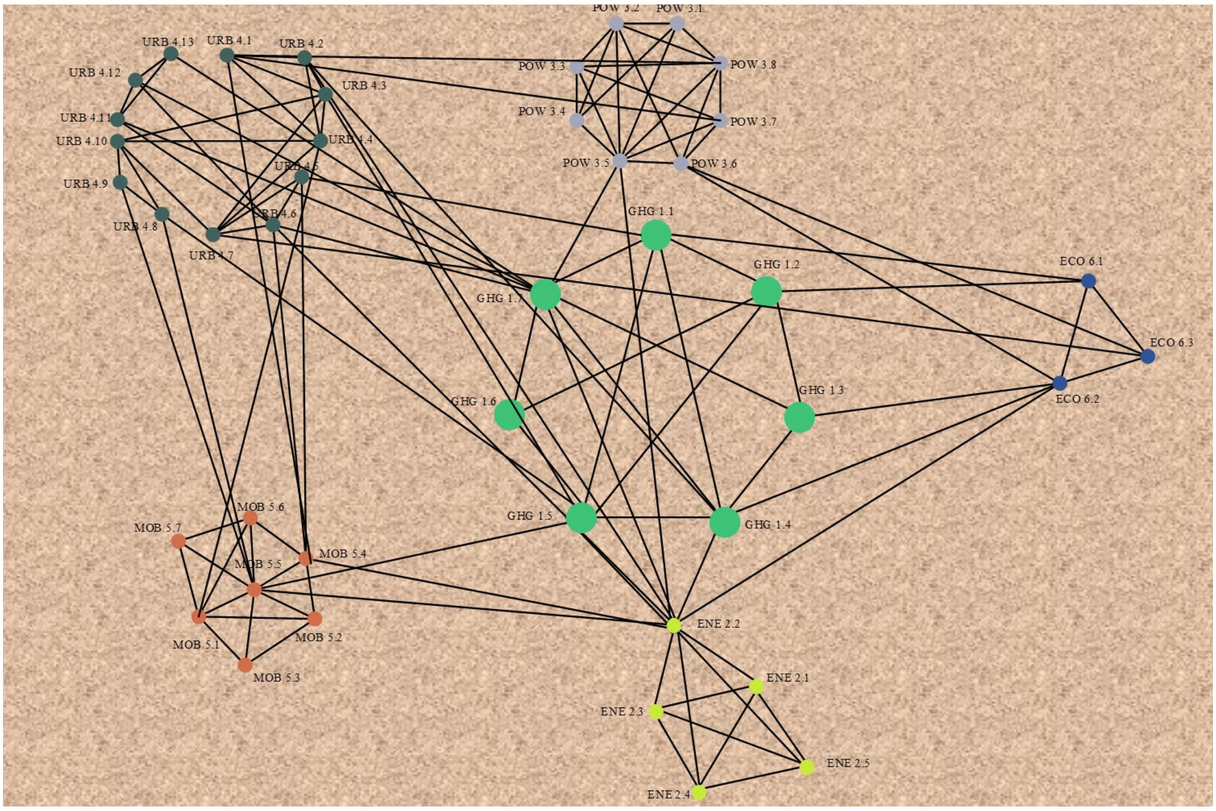


Figure 2. Diagram that depicts the interrelationship between ZEN KPIs.

Process

The main goal in the ZEN definition is nZEN. The main principle for achieving nZEN is first reduction of GHG emissions and then compensation, see Figure 3. Reduction measures may include choosing locally sourced materials with lower GHG emissions, reducing energy demands or planning for low emissions. Compensation can be achieved through for example local, renewable energy production, carbon storage or dismantling and reusing buildings. All the ZEN categories and KPIs in the ZEN definition contribute to achieving this goal.

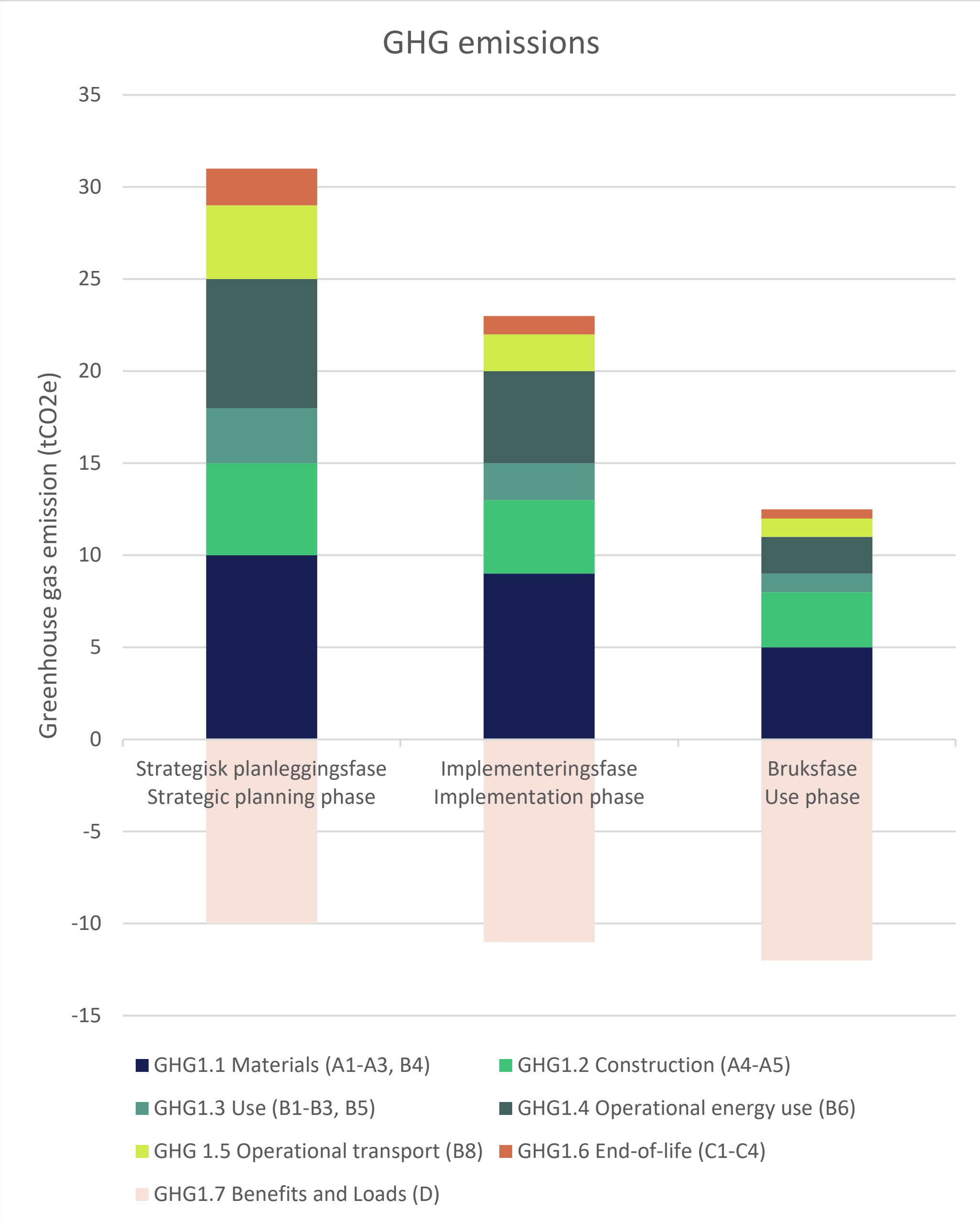


Figure 3. Main principle of nZENs – reduction, and then compensation.

To create a successful ZEN, the neighbourhood needs to be a good environment for its users. Within the ZEN definition, we have identified four elements which contribute towards the process of developing a ZEN in line with user needs. Additionally, the associated project Planning Instruments for Smart Energy Communities (PI-SEC) developed a broad toolkit for planning of smart energy communities (6,7). Also relevant are the criteria for social sustainability developed by FutureBuilt (8). While the Norwegian Planning and Building Act is mandatory to follow (9), it does define the baseline for user involvement. This process guideline for user involvement suggests additional steps to enable for co-creation of solutions and social innovation within ZEN development.

For the process guideline for user involvement, it is recommended that the project owner or local authorities complete the following:

- A demographic analysis
- A stakeholder analysis
- A needs assessment report
- A consultation plan

This will ensure that the developed strategic plans for the neighbourhood are based on local demographic trends and priorities, as well as the users' needs, ideas, and knowledge. By assessing the users' needs and the active engagement of users in the development of a ZEN, the quality and acceptability of the development throughout the project phases are ensured. An active engagement will also frame the basis for social innovation and contribute to social sustainability (10).

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 identify who are the existing (if it is an upgrade or densification project), potential, and intended future inhabitants of the planned neighbourhood. The demographic profile should include information over time about total number of inhabitants and users, age distribution, gender, minority and cultural background, household size, employment (sectors, incomes, businesses, unemployment), education, skills, and health. This analysis must be aligned with the demographic profiles and trends of the larger region to ensure that general trends and requirements are considered. Future projections of the demographic profile are recommended to take demographic changes into consideration for the design and operation of the neighbourhood. Data to describe the demographic profile for the ZEN pilot area should be available from the Norwegian statistical office (SSB) and the local authorities.

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

- Actual, future and/or intended inhabitants and users of the neighbourhood. Periphery users can be represented through end-user organisations (e.g., such as organisations for people with disabilities)
- Neighbours or representatives of nearby communities
- Planning and implementing stakeholders; including e.g., 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.

It is recommended to use the power-interest matrix as a methodology for stakeholder analysis as it identifies relevant stakeholders as well as their interest and power on the development. Additionally, it is suggested to run the stakeholder analysis for different phases of the ZEN development to identify future stakeholders and users as well as to repeat it frequently, e.g., at the start of a new project phase. The execution of the stakeholder-mapping in a multi-stakeholder-setting helps to foster a common understanding of relevant stakeholders. In addition to a generic stakeholder-mapping on the general scope of the ZEN development, we suggest implementing this methodology on relevant topics and projects within ZEN development such as the energy system or for mobility.

The **needs assessment** provides information about the needs and requirements of the users of the neighbourhood. 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. Consideration should be given to how the demographics of the community will change over the lifetime of the development based on the demographic analysis as it is important to plan and design for adaptability and flexibility. General needs of users of the built environment are in addition to the physiological core needs (e.g., food, water, air, shelter) belonging, meaning, sociability, joy, health, equity, ease, and resilience (11). The design and operation of the neighbourhood should be in line with the fulfilling of these needs to guarantee a liveable neighbourhood. Many of the urban form indicators relate to user needs and their appliance in planning and design to help indicate how some of the user needs are fulfilled within the neighbourhood. In addition, it is recommended to involve actual and future users directly to express their needs and wishes about the design and operation of the neighbourhood. Various qualitative and quantitative methods, depending on the context of the neighbourhood, are available for involving users and getting a deeper understanding of their needs towards a ZEN neighbourhood (12).

The **consultation plan** should be developed to ensure the inclusion of the users in the ZEN pilot area process. The aim of the consultation plan is to ensure that the needs, ideas, and knowledge of the users 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 design and align it with requirements for citizen consultation in the official planning procedure. The required involvement of citizens regulated in the Plan and Building Act is referred to as a baseline, and it is suggested to use the consultation plan as a guiding document to exploit the full potential of user engagement and co-creation with regards to innovation and sustainability achievements. 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:

- A timeline for stakeholder mapping activities and updated demographic analysis and needs assessment
- At which points the users and other stakeholders can usefully contribute and expected outcomes
- List of appropriate tools for user and stakeholder engagement (see ZEN toolbox)
- 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)
- Point to other relevant institutions and processes to align participation activities

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 additionally the following:

- Inclusion of different stakeholders in design reviews of plans for delivery of amenities, public local 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 should be 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 users' 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 users' as well as professionals' viewpoints (such as cleaners, food distributors, healthcare assistants, etc.).
- Opportunities for shared use of facilities and infrastructure with the existing or adjacent community.

There are many methodologies and tools available to engage users in sustainable neighbourhood development (13–15). Depending on the local context, the set of stakeholders and the expected outcome different methodologies are appropriate to conduct the consultation plan:

- 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

User engagement is an iterative process involving many project phases and stakeholders, see Figure 4.

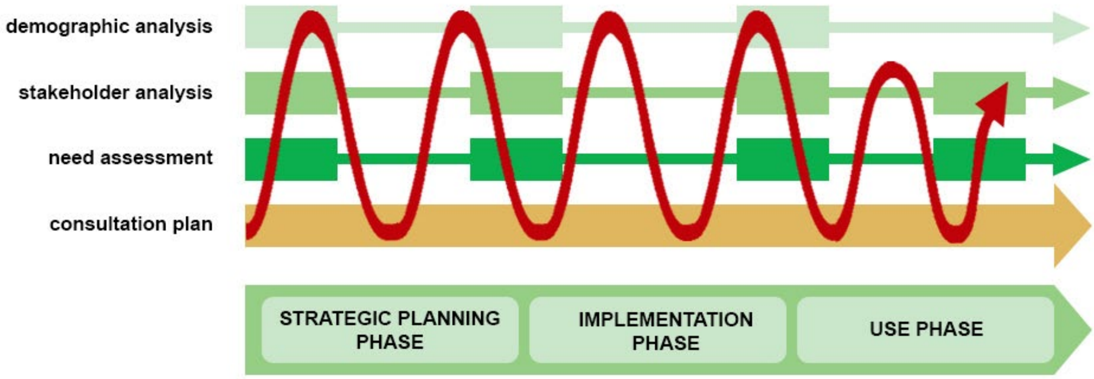


Figure 4 Iterative process of creating a nZEN.

GHG Emissions

A ZEN aims to reduce its direct and indirect greenhouse gas (GHG) emissions towards zero over the analysis period. The neighbourhood focuses on strategic planning, implementing and operating buildings and their associated infrastructure components towards minimised life cycle GHG emissions. More detailed information on GHG emission calculation methodological choices can be found in (16).

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, see Figure 5.

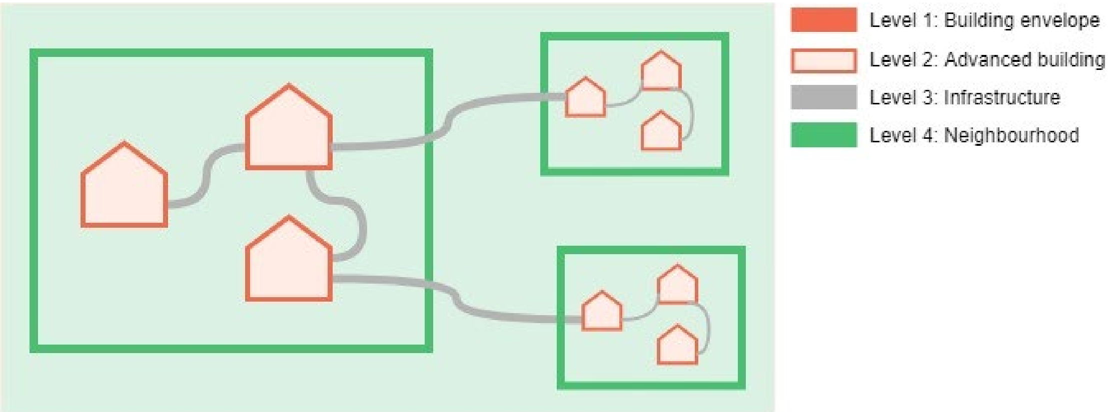


Figure 5. The four different assessment levels for the GHG emissions category in the ZEN definition.

The first ZEN level, (a) main building, 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 (17), see Appendix A. 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 (b) technical systems level, building elements 21-69 should be included, which comprises the main building and all technical systems, and corresponds to the building assessment boundary level (B). The (c) infrastructure level covers building elements 71 to 79. The (d) neighbourhood level comprises the first three levels, hence includes building elements 21 to 79, and corresponds to the neighbourhood assessment boundary level (N). Each assessment level corresponds to a reporting unit, as detailed in the following section. The neighbourhood level also includes the GHG emissions relating to mobility and corresponds 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 2.

Table 2. Corresponding assessment levels in ZEN GHG emissions category and *NS 3720*, related building elements and reporting units.

NS 3720 assessment levels	ZEN GHG emissions assessment levels	Included building elements (as defined in *NS 3451*)	Reporting unit
Basic, without location	(a) Main building	21-29 + 49	$kgCO_{2eq}/m^2_{GFA}/yr$ $kgCO_{2eq}/user/yr$
Advanced, without location (B)	(b) Technical systems	21-69	$kgCO_{2eq}/m^2_{GFA}/yr$ $kgCO_{2eq}/user/yr$
	(c) Infrastructure	71-79	$kgCO_{2eq}/m^2_{PA}/yr$ $kgCO_{2eq}/user/yr$
Basic or Advanced, with location (N)	(d) Neighbourhood	21-79	tCO_{2eq} $kgCO_{2eq}/m^2_{GFA}/yr$ $kgCO_{2eq}/user/yr$
	(e) Mobility (B8)		$kgCO_{2eq}/user/yr$

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* (18). Building areas, number of users, reference study period, system boundaries, scenario descriptions, bill of material quantities emission data sources, results should be reported per ZEN GHG emissions assessment level for each life cycle module (see Figure 12) and building part (see Appendix A). All GHG results from the four assessment levels, i.e., Building envelope, Advanced building, Infrastructure, and Neighbourhood (Table 4), 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 A. 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 (*bruttoareal* in Norwegian, (m^2_{GFA}), defined in *NS 3940* as the total floor area of the building, including external walls, where the floor-to-ceiling height is at least 1.90 meter and the width of the room is at least 60 cm (19). 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 *GHG1.5 Operational transport (B8).*

Reference study period and estimated service life

The reference study period (RSP) of the building, infrastructure and neighbourhood is set to 50 years to align with Norwegian building code's (bygg tekniskforskrift) guideline on preparation of GHG emission calculations, the EU taxonomy and Level(s) (20–22). The estimated service life (ESL) of the buildings and neighbourhood is 50 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

Existing buildings and infrastructure are considered to have no GHG emissions for the original production, transportation, and installation of the building and infrastructure elements. This is in line with *NS 3720*. 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* (23). 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 disassembled from the neighbourhood and are transported outside the boundaries of the neighbourhood. The fourth type of material reuse occurs when external materials are imported within the boundaries of the neighbourhood.

Impact assessment

All GHG emissions should be calculated according to the life cycle assessment methodology as described in *NS 3720:2018* (24), for all project phases unless otherwise stated in the KPI description. In a strategic planning phase, generic data may be used. In the implementation and operational phases, individual Environmental product declarations (EPDs) developed according to *NS-EN 15804* for product-specific emission factors should be used. When no individual EPDs are available, joint EPDs (i.e., group of manufacturer's data), average EPDs (i.e., group of individual and joint EPDs), or generic data from Ecoinvent (25) can be used, in this order. This hierarchy of emission data is illustrated in Figure 6. Generic emission factors can also be used from published life cycle assessment (LCA) reports or articles. However, these data sources must be quality assured by an LCA expert. As a rule, specific data, including joint and average EPD data, should not be older than five years, and generic data should not be older than ten years.

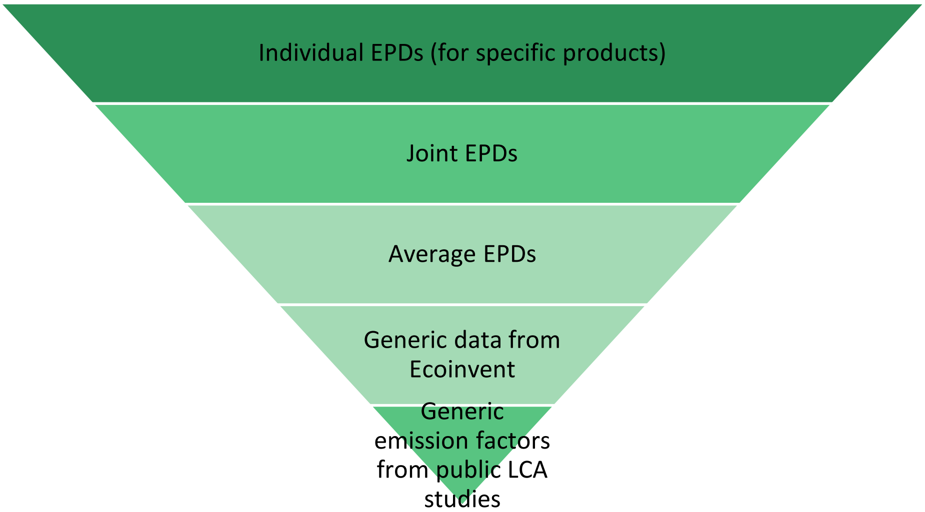


Figure 6. Order in which the emission data should be sourced in the implementation and operational phases. Emission data can be collected from a lower-ranked source only if no higher-ranked source is available.

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* (26) and *NS-EN 16485* (27). Similarly, carbonation of concrete should be calculated according to *NS-EN 16757* (28). The effect of biogenic carbon should be reported in a separate line in the reporting matrix, see Appendix A. More details on biogenic carbon are presented in (16).

Assessment Criteria

The GHG emissions category is divided into two assessment criteria "Reduction" and "Compensation". The Reduction criteria emphasises life cycle modules A to C, as defined in *NS 3720* and has six related KPIs (29). The Compensation criteria emphasises module D and is reported in *GHG1.7 Benefits and loads (D)*. Figure 7 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.

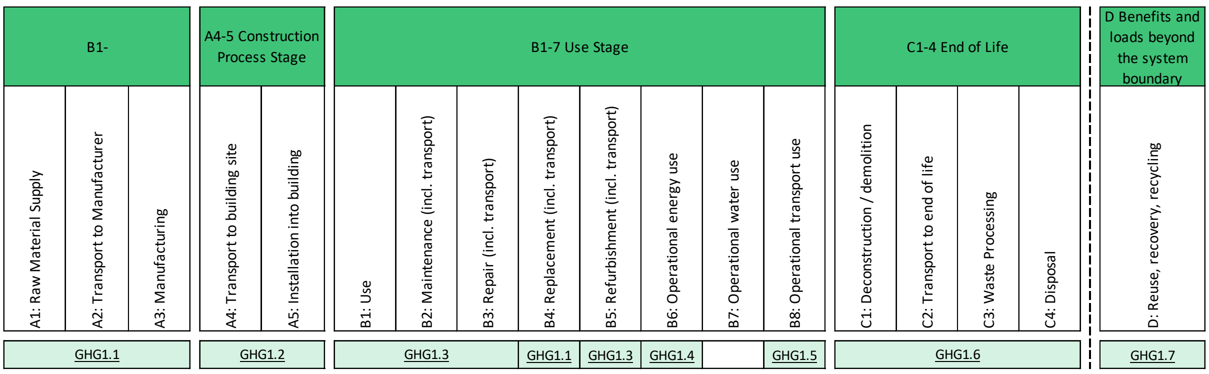


Figure 7. How KPIs relate to the life cycle stages defined in the *NS 3720* (29).

<u>GHG1.1 Materials (A1-A3, B4)</u>

The objective of this KPI is to minimise total embodied GHG emission from buildings, infrastructure, and neighbourhood's (existing or new) life cycle towards zero with a focus on material use across a reference study period of 50 years (see Table 3). The goal is to reduce the embodied GHG emission from the production and replacement phases of materials (life cycle modules A1-A3 and B4) for each building and infrastructure within the neighbourhood. The calculation of this KPI should be completed according to *NS 3720* Advanced for life cycle module A1-A3 and B4.

In the strategic planning phase, material quantities can be obtained from architect's and planner's 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 from 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)* (30) can be used to ascertain reference service lifetimes of construction components.

Table 3. Summary for calculating KPI GHG1.1.

GHG1.1	**Materials (A1-A3, B4)**
Objective	To minimise the total embodied GHG emissions from buildings, infrastructure, and neighbourhood's life cycle towards zero, with a focus on material use, across a reference study period of 50 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)
Points available	11 points GHG1.1a (a) main building level – 5 points GHG1.1b (b) technical systems level – 3 points GHG1.1c (c) infrastructure level – 3 points
ZEN KPI assessment	For this KPI, GHG emissions are assessed at the (a) Main building level, (b) technical systems level, and (c) infrastructure level. The target and limit values for (a) main building level are ascertained through the ZEN report on GHG emissions requirements for material use in buildings (31), see Table 4. For (b) technical systems level one point is awarded for documenting GHG emissions from all technical system building parts (31-69), and two additional points are awarded for reducing GHG emissions from these building parts by 50% compared to a TEK reference building. For (c) infrastructure level one point is awarded for documenting GHG emissions from all infrastructure (71-79), and two additional points point are awarded for reducing GHG emissions from these building parts by 50% compared to a TEK reference building.

GHG1.1	**Materials (A1-A3, B4)**
Best practice	- Use existing buildings and infrastructure where possible instead of demolishing and building new. - Use reclaimed, recovered, and recycled building materials. - Choose construction methods and materials with low embodied GHG emissions e.g., prefabricated elements, timber, low carbon concrete, recycled steel etc. - Ask for environmental product declarations (EPDs).

Table 4. Limit values for point allocation for GHG1.1.a ascertained through ZEN report no. 24 (31).

GHG1.a points	**Calculated GHG emissions at the main building level (kg CO_2/m^2 GFA/yr)**	
	From	**To**
1	6	5.6
2	5.5	4.5
3	4.4	3.4
4	3.3	2.3
5	2.2	0

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), see Table 5.

The construction phase consists of a range of activities. The construction activities included in the system boundaries for ZEN pilot areas are depicted in Figure 8. It includes transport of materials, transport of construction machinery and transport of personnel to the construction site, transport of the waste generated during construction works (including packaging) to waste treatment, and its disposal, energy use (e.g. building heating and drying during the construction phase, energy use on site), internal transport, production and transport of additional materials such as glue, screws, and tape for installing construction products, storage, temporary works, as well as the operation of construction machinery on site. Water use is excluded from the system boundaries. This system boundary is in accordance with *NS 3720* (29).

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 report 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 (32). 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 (33).

Measuring GHG emissions from construction sites is a relatively new field of research, and as a result, there are few sources of specific emission factors. Transport emission factors for goods and person transport from *NS-EN 16258* (34) may be used in emission calculations, see 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 whole 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 and indirect 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 at 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 use bioenergy and biofuels or alternative emission free 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 and transport of products to and from the construction site, that go to material and energy recovery and landfill (33).
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*.
Points available	2 points
ZEN KPI assessment	Target values are connected to the steps identified in Figure 8. 1 point – step 2 2 points – step 5

GHG1.2	Construction (A4-A5)
Best practice	- Choose locally sourced materials with short transport distances. - Ask contractors, subcontractors, and suppliers to use electric vehicles for transport of construction materials and machinery, masses, construction workers and waste to and from construction sites. - Use emission free construction machinery and equipment for construction operations and heating and drying. - Plan for the energy use on construction site to reduce peak loads, especially for critical construction activities that demand high amounts of energy such as groundworks and foundations or when multiple construction machineries need to charge simultaneously. - Sort and recycle construction waste. - Follow the fuel hierarchy in Figure 9.

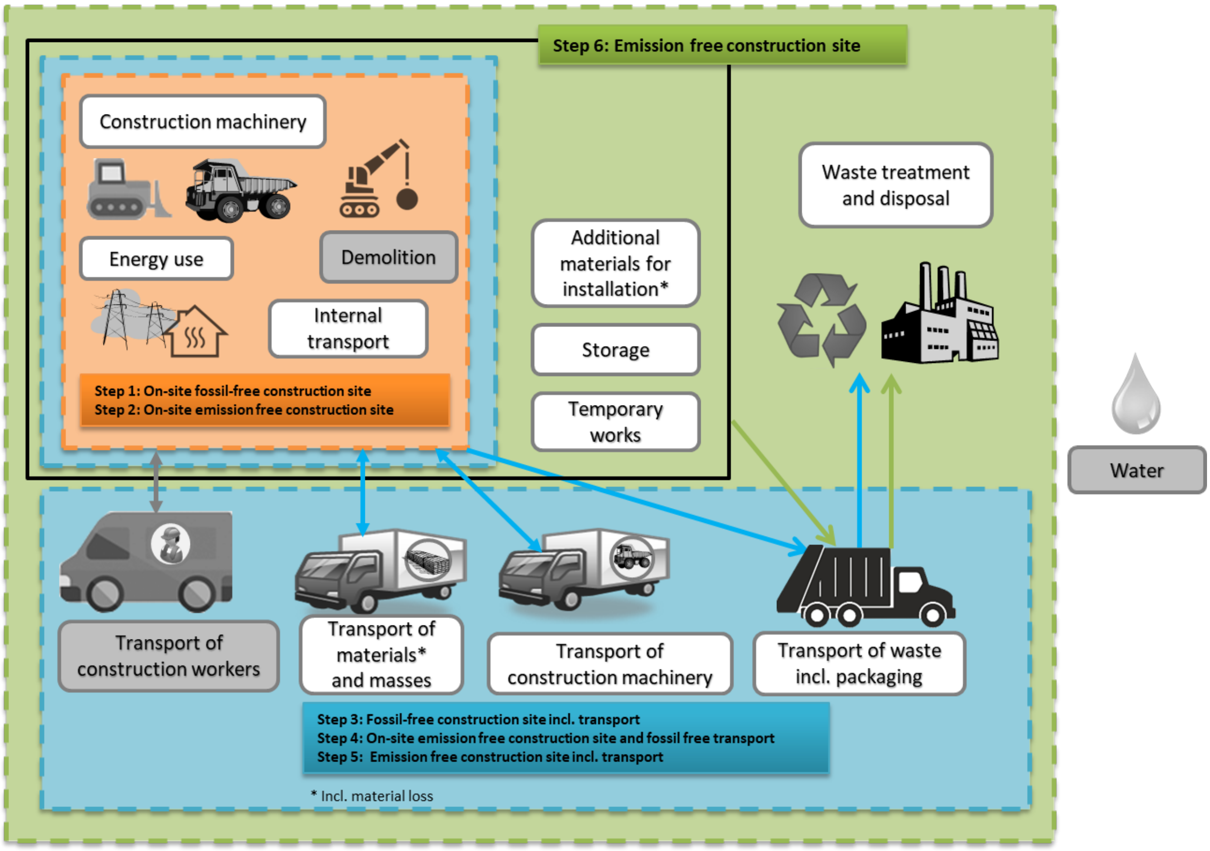


Figure 8. Overview of the system boundary for the construction phase, adapted from (35,36).

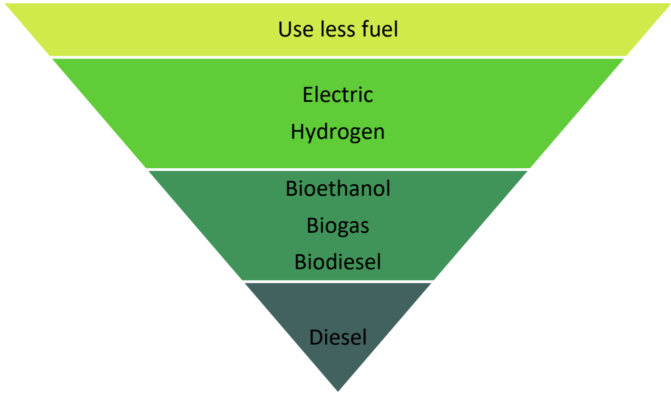


Figure 9. Fuel hierarchy, translated from (37). Electric and hydrogen er considered emission-free, biofuels are considered fossil-free.

GHG1.3 Use (B1-B3, B5)

The use (B1-B3, B5) KPI tackles the 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 façade), see Table 6. Another important aspect of this KPI will involve mapping the resources used within the neighbourhood through for example material passports, or digital twins (for example boligmappa.no) which may include information such as 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 neighbourhood.
Method	*NS 3720* (Method of GHG emissions calculation for buildings), *NS 3451* (Table of Building Elements)
Points available	1 point
ZEN KPI assessment	Point awarded for calculating GHG emissions from life cycle modules B1-B3 and B5 for the whole neighbourhood.
Best practice	- Plan and carry out scheduled maintenance checks for your building, infrastructure, and neighbourhood. - Maintain and repair components within the neighbourhood to avoid more frequent replacement and/or refurbishment of buildings and infrastructure. - Use environmentally friendly cleaning products. - Select environmentally friendly materials that do not emit GHG substances from surfaces. - Ensure a high level of surface exposure (where appropriate) when concrete is used.

GHG1.3	Use (B1-B3, B5)
	- Consider repairing or replacing the broken or worn-out part of a material instead of replacing a whole component or refurbishing an entire room.

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 and focuses on life cycle module B6, see Table 7. Calculating *ENE2.2 Delivered energy* is a prerequisite for this KPI and the total energy use result should be used (kWh) to avoid mixing differing definitions of area between the energy and GHG emission categories. The calculation of this KPI should be completed according to *NS 3720* for life cycle module B6. The GHG emission reductions from exported energy over the building's system boundary should be reported separately under *GHG1.7 Benefits and loads (D)*, see Figure 11.

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)
Points available	12 points
ZEN KPI assessment	The limit and target values will be developed in future ZEN work.
Best practice	- Choose energy carriers with low embodied GHG emissions. - See *ENE2.2 Delivered energy.*

The methodology outlined in *NS 3720* will be used for GHG emission calculations in ZEN, this includes 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 in work package 5. 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). This will result in 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 and by using the emission factors given below (38). 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.

Table 8. Energy emission factors per energy carrier (29).

Energy Carrier	NS 3720 (gCO_2e/kWh)
Electricity	Scenario 1 NO: 18 Scenario 2 EU28+NO: 136
- Hydropower	2-20
- Wind power	3-41
- Coal power	660-1300
- Solar energy	13-190
- Biothermal	8,5-130
- Nuclear power	3-35
- Thermal power from natural gas with CCS	Ca. 100
- Thermal power in Norway	450
- Thermal power in EU	800

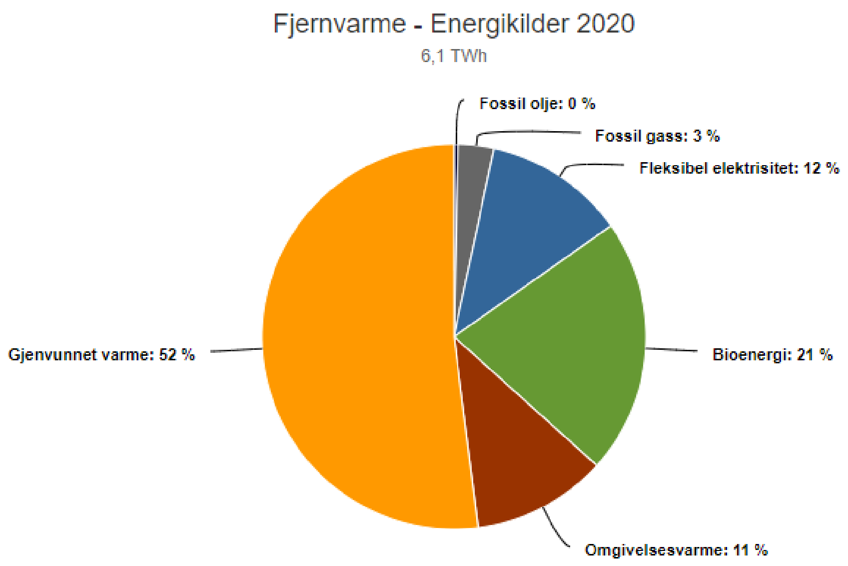


Figure 10. Proportion of different energy carriers for district heating on a national level, based on data from fjernkontrollen in 2020 (38).

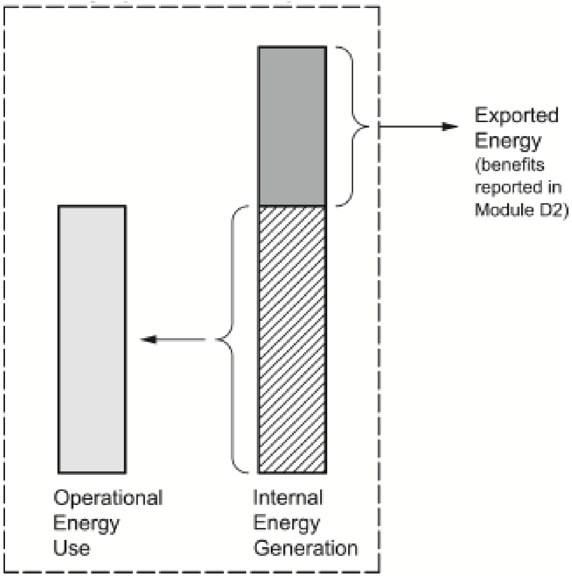


Figure 11. Diagram showing the allocation principle of operational energy use and exported energy (29).

GHG1.5 Operational transport (B8)

The operational transport (B8) KPI aims to reduce GHG emissions related to the mobility patterns of ZEN users, see Table 9. A prerequisite for this KPI is that *MOB5.6 Passenger and vehicle mileage* 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 *MOB5.5 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)
Points available	19 points
ZEN KPI assessment	The limit and target values will be developed in future ZEN work.
Best practice	- Choose modes of transport with low GHG emissions. - See *MOB5.6 Passenger and vehicle mileage*

Table 10. Well-to-wheel transport emission factors per energy carrier (34).

Energy Carrier	NS-EN 16258 (gCO2e/kWh)
Diesel	251
Petrol	248
Marine gasoil	253
Bioethanol	161
Biodiesel	163
Heavy fuel oil	234
Natural gas (LNG) (kg/Sm3)	380-1000
LPG (propane and butane)	209
Electricity	Scenario 1 NO: 18 Scenario 2 EU28+NO: 136

<u>GHG1.6 End-of-life (C1-C4)</u>

The goal of this KPI is to increase resource efficiency, and GHG emissions by preserving existing buildings, infrastructure, components, and materials, see Table 11. 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 *GHG1.7 Benefits and loads (D)* instead. There shall therefore be an emphasis on increasing building circularity and closing the loop.

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 ca. 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 require 70% of all construction waste to be recycled by 2020. Reusing material resources is simpler and more effective than demolition. High intensity carbon emitters such as cement and steel are used extensively in groundworks and foundations. It is therefore better to rehabilitate and reuse these than cast new foundations. There is a large untapped potential in utilising existing building stock.
Method	*NS 3720* (Method of GHG emissions calculation for buildings), *NS 3451* (Table of Building Elements)
Points available	1 point
ZEN KPI assessment	One point is awarded for calculating GHG emissions for life cycle modules C1-C4 and developing an end-of-life plan, which shows the reuse, recovery, and

GHG1.6	End-of-life (C1-C4)
	recycling potential (in percentages) of materials and components within the neighbourhood.
Best practice	- Follow circular economy principles and the waste hierarchy, see Figure 12. - A reduction in waste can be achieved by prolonging service lifetimes of materials, components, buildings and infrastructure. - A reduction and reuse of waste can be achieved by rehabilitating and refurbishing existing buildings instead of demolishing and building new. - Recovery can involve material and energy recovery. - Design for demountability (DfD). - Use homogenous materials and components, avoid using composite materials which are difficult to recover or recycle. - Use a digital twin of the neighbourhood and material passports. - Refurbish instead of demolishing. - Dismantle the building and infrastructure for reuse on-site, or to other construction projects nearby.

Figure 12. The waste hierarchy (39).

GHG1.7 Benefits and loads (D)

The benefits and loads (D) KPI goal is to compensate for the remaining GHG emissions from life cycle modules A1-C4 to create a net zero emission balance for the neighbourhood, see Figure 3 and Table 13. 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* (23). D1 can be reported for products (e.g., recycled waste), buildings and neighbourhoods (e.g., reuse of a building). Table 12 gives an example of reporting compensation of GHG emissions in a neighbourhood for a nZEN balance. ISO IWA42: 2022 (40) has introduced a new definition for net zero which does not allow for compensation through residual emissions. The focus is on reduction of emissions by 90-95% from a baseline scenario, and then compensating the residual emissions through removal. 'Human-led removals include ecosystem restoration, direct air carbon capture and storage, reforestation and afforestation, enhanced weathering, biochar and other effective methods.' This issue will be addressed in the next version of the ZEN definition guideline.

Table 12. Example of reporting compensation of the remaining GHG emissions for a nZEN balance

Measure	Compensation
D1a Reuse potential	-XX $kgCO_2e$
D1b Recycling potential	-XX $kgCO_2e$
D1c Recovery potential (incineration)	-XX $kgCO_2e$
D2 Exported energy potential	-XX $kgCO_2e$
Total	-XX $kgCO_2e$

Table 13. Summary for calculating KPI GHG1.7

GHG1.7	Benefits and loads (D)
Objective	To compensate for the remaining GHG emissions from life cycle modules A1-C4 and create 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*
Points available	4 points
ZEN KPI assessment	The assessment of this KPI will be based on a net zero emission balance for the whole neighbourhood considering the reduced GHG emissions from life cycle modules A1-C4 and compensation from life cycle module D. It is a prerequisite that GHG emissions for the whole life cycle (life cycle modules A1-C4 and D, building elements 21-79) have been calculated to obtain points for the net zero emission balance of the neighbourhood. Points are awarded based on target values for the closer the neighbourhood comes to achieving net zero GHG emissions. 1 point – 25% of emissions from A1 - C4 are compensated for 2 points – 26 - 50% of emissions from A1 - C4 are compensated for 3 points – 51 - 75% of emissions from A1 - C4 are compensated for 4 points – 76 - 100% of emissions from A1 - C4 are compensated for
Best practice	- See the accumulation of best practices for the GHG category.

Energy

One of the most important goals for a ZEN is that it should be become highly **energy efficient** (41), as the most environmentally friendly energy is the energy not used. Thus, reducing energy demand and energy use should always be a priority in the transition towards reaching a **decarbonised energy system**. A ZEN shall be powered by smart, **renewable energy** sources (41). 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, energy storage, power/load management, digitalisation, smart grids, and system optimisation are included.

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 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 as far as possible, and be substituted by simulations where measurements are not available. The energy demand and energy use of the neighbourhood should be calculated/measured over one year with an hourly resolution. Completion of the energy category KPIs is a prerequisite for the power category KPIs.

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 (42). 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, most notably, 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 (Z) and reference project (R)

In the energy category, the KPIs should be calculated for both the pilot (Z) and pilot's reference project (R). The reference project represents business-as-usual for the ZEN pilot area and is based on current building regulations (TEK) for new buildings (43) 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 a reference project with district heating. Table 14 gives an example of assumptions made for a new neighbourhood and its' reference project. Table 15 lists all required documentation to be presented when calculating the energy category KPIs.

Table 14. An example reference project with electric heating, created for a ZEN pilot area.

	ZEN pilot area (Z)	**Reference project (R)**
Building standard	Passive house (44,45)	TEK-17 minimum requirements (43)
Energy storage solutions	None.	None.
Local energy production	Photovoltaic (PV) panels with annual generation of energy equal to 10 kWh/ m^2 GFA.	None.
Heating	District/Local heating.	Electric boiler.
Transport technologies	100 % of all buses are electric in 2035.	50 % of all buses are electric in 2035.

Table 15. List of required documentation when calculating the energy KPIs.

KPI	**Description**	**Data type**	**Unit**	**Assess-ment level**	**Scenarios**
ENE2.1 Energy need in buildings	Net/gross energy demand in buildings	Annual totals and load curves	kWh/m^2_{HFA}/ year	B	Z and R
Input for *GHG1.4 Operational energy use (B6)*	Energy use	Annual totals and load curves	kWh/h* kWh/year*	N	Z and R
Input for *GHG1.4 Operational energy use (B6)* and *GHG1.7 Benefits and loads (D)*	Energy generation	Annual totals and load curves	kWh/h* kWh/year*	N	Z and R
ENE2.2 Delivered energy. Input for *GHG1.4 Operational energy use (B6)*	Delivered energy (imported)	Annual totals and load curves	kWh/h * kWh/year*	N	Z and R
Input for *GHG1.4 Operational energy use (B6)* and *GHG1.7 Benefits and loads (D)*	Exported energy	Annual totals and load curves	kWh/h* kWh/year*	N	Z and R
ENE2.4 Net load profiles . Input for *POW3.1 Peak load* and *POW3.2 Peak export*	Net yearly load profile and load duration curve per energy carrier	Annual totals and load curves	kWh/h* kWh/year*	N	Z and R
ENE2.5 Colour-coded carpet plots	Colour-coded carpet plot of net energy use	Carpet plot	kWh/h* kWh/year*	N	Z and R
ENE2.3 Self-consumption	Self-consumption	Factor	% Electricity	N	Z
Doc. Only	Self-generation	Factor	% Electricity	N	Z

* 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 similar to the net yearly load profile, only sorted from the highest to the lowest value.

Energy demand and energy use

Energy demand is a theoretical size 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. **Energy use** is a measurable size 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 need in buildings

The energy need (or energy demand) in buildings is considered in *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 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 13 for ZEN Ydalir. This ZEN pilot has non-electric heating and PV-panels. Only the electricity-specific 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 if the ZEN pilot has PV). Methods for simulating load profiles of charging electric vehicles is currently being developed within the ZEN research centre.

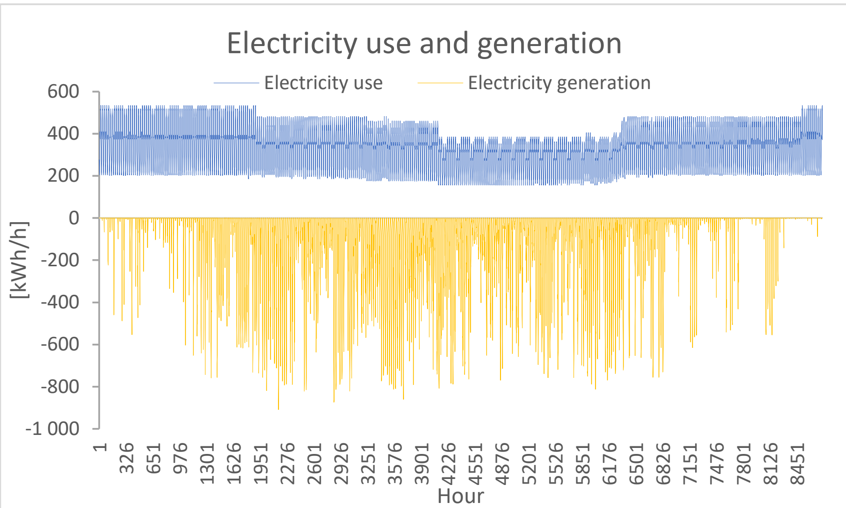


Figure 13. The hourly electricity use and electricity generation with non-electric heating and PV in ZEN Ydalir

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 every time interval. Subtracting the electricity generated from the electricity used in Figure 13 produces the net yearly load profile shown in . In the net yearly load profile, energy import is assigned a positive value and export a negative value. The load duration curve can be found by sorting the values of the net load profiles.

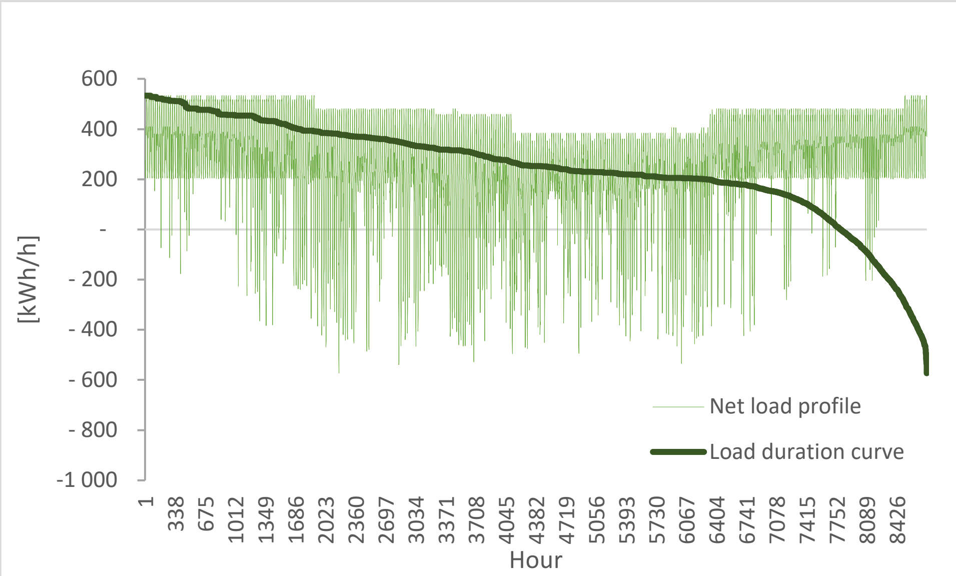


Figure 14. Hourly net load profile and load duration curve of electricity in ZEN Ydalir.

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 value of the net load yearly profile is to give an illustration of the energy flows throughout the year. The value of the net load duration curve is to provide 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 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 as shown in Figure 15. Figure 16 show a summary of these annual totals.

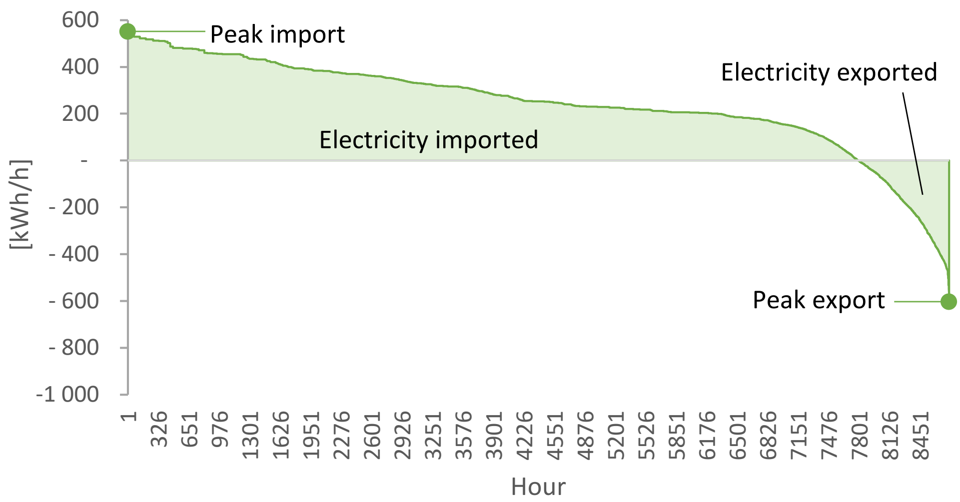


Figure 15. Explanation of the load duration curve of the net electricity use in ZEN Ydalir.

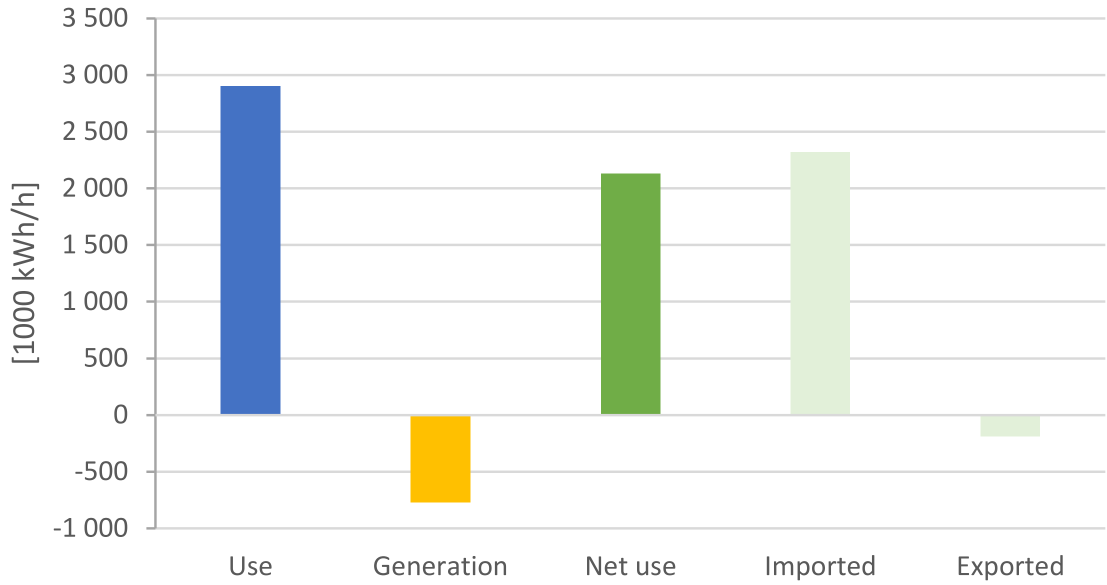


Figure 16. Annual totals of electricity use, generation, net energy use, import and export in ZEN Ydalir.

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 the batteries of 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. The workflow shown in Figure 17 is recommended when calculating KPIs.

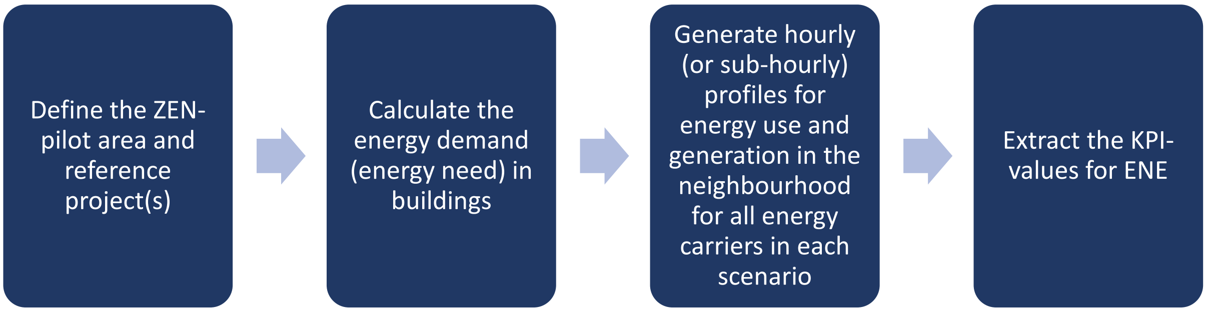


Figure 17 Suggested workflow for calculating KPIs in the energy category.

As an intermediatory step, it may be worth 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.

Assessment Criteria

The energy category is split into two assessment criteria, namely 'energy efficiency in buildings' and 'energy carriers'. The energy efficiency in buildings assessment criteria 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 carrier assessment criteria consider energy use, energy generation, and energy flows in the ZEN pilot area at the neighbourhood assessment level. It looks at energy flow per energy carrier. The KPIs within these assessment criteria are measured during the operational phase.

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 and is 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, see Table 17. 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 (also in the use phase) as it shows the energy need of the building envelope when the losses in the buildings' heating system is not accounted for. The energy need is calculated according to the *building assessment boundary*, which must be harmonised between ISO 52000 (46) and *SN-NSPEK 3031* (42). 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* (18) and *SN-NSPEK 3031*, which covers building categories, such as apartment buildings, schools and nursing homes. The energy need in buildings is calculated as annual totals 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 (47) or building energy performance simulation tools.

Energy demand should be calculated per energy services, with a minimum resolution of splitting the energy demand for thermal energy services and electric energy services but can also be reported with more detailing, as described in Table 16. Figure 18 shows the calculated hourly energy demand for all buildings in ZEN pilot area Ydalir, as planned.

Table 16. 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.

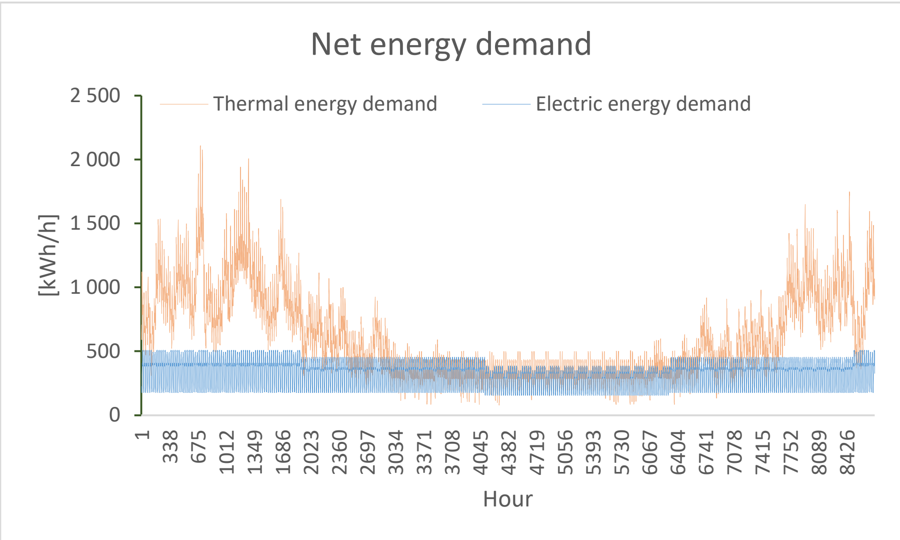


Figure 18. The hourly (net) energy demand for thermal energy (space heating and domestic hot water) and electric services in the buildings at ZEN Ydalir.

Table 17. Summary for calculating KPI ENE2.1.

ENE2.1	**Energy need in buildings**
Objective	To increase the energy efficiency of the building envelope by reducing the energy demand of buildings as much as possible. More energy efficient buildings use less energy and have peak load requirements which will reduce GHG emissions from *GHG1.4 Operational energy use (B6)* and by reducing the peaks in the energy grid, the neighbourhood can reduce the demand for grid investments and related emissions as well as other environmental impacts.

ENE2.1	**Energy need in buildings**
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 services, with a minimum resolution of splitting the energy demand for thermal energy services and electric energy services.
Points available	8 points
ZEN KPI assessment	The KPI will be assessed based 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.
Best practice	- New buildings are constructed as passive house buildings with low U-values and low energy demand. - Existing buildings are upgraded to the current building minimal standard (or better).

ENE2.2 Delivered energy

The delivered energy KPI evaluates the delivered energy at the neighbourhood assessment level for all energy carriers, see Table 18. 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 amount of delivered energy.

Table 18. Summary for calculating KPI ENE2.2.

ENE2.2	**Delivered energy**
Objective	More energy efficient buildings use less energy and have peak load requirements which will reduce GHG emissions from *GHG1.4 Operational energy use (B6)* and by reducing the peaks in the energy grid, the neighbourhood can reduce the demand for grid investments and related emissions.
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. 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 for example 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.
Points available	8 points

ENE2.2	**Delivered energy**
ZEN KPI assessment	The KPI will be assessed based 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.
Best practice	- New buildings are constructed as passive house buildings with low U-values and low energy demand. - Existing buildings are upgraded to the current building minimal standard (or better). - Using heat pumps and/or non-electric heating will reduce the electricity use. - Solar panels reduce the demand for imported electricity.

ENE2.3 Self-consumption

The self-consumption KPI informs about the mismatch between energy generated locally and energy used in the neighbourhood, see Table 19. The calculation is typically carried out in two steps. First, energy use and energy generation are considered separately, i.e., 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. In literature, the same concepts are presented with different names. For example, in (48) these are called ‘self-consumption’ and ‘self-sufficiency’, respectively; while in (49) 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 19, 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.

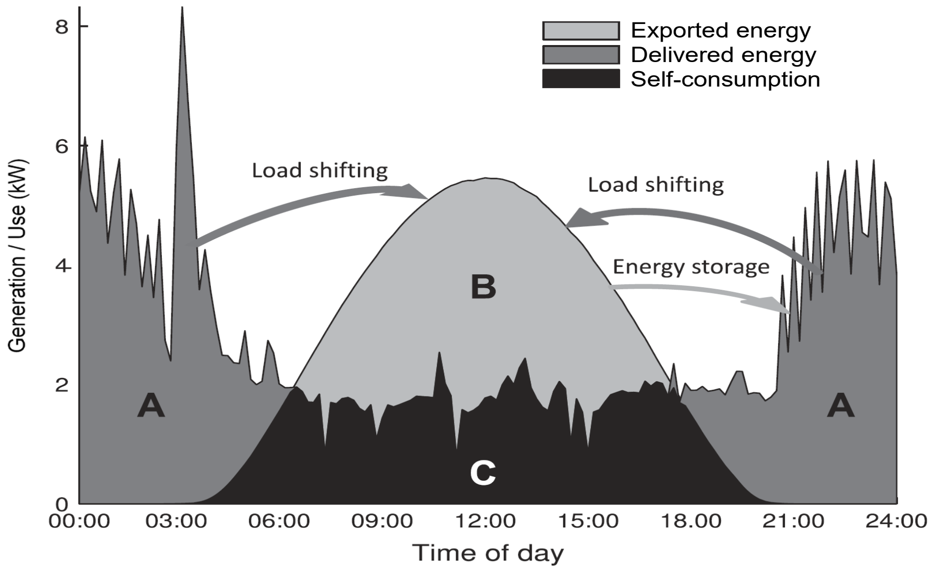


Figure 19. A schematic outline of the daily energy use (A + C), energy generation (B + C), and self-consumption (C) in a building with on-site PV. It also indicates the function of the two main options (load shifting and energy storage) for increasing self-consumption. Source: adapted from (48).

In this example (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,

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

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

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 (48) and (50). In *ENE2.3 Self-consumption* 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 indicators' 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 19. Summary for calculating KPI ENE2.3.

ENE2.3	**Self-consumption**
Objective	To increase the self-consumption of local electricity production. Introducing local electricity generation from renewable sources will reduce the need for imported energy and GHG emissions from *GHG1.4 Operational energy use (B6)*.
Description	The self-consumption KPI is calculated for electricity 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.
Points available	2 points
ZEN KPI assessment	The KPI will be assessed on the percentage (%) value for self-consumption of electricity in the ZEN pilot area. 1 point if self-consumption is 25 < 50 %

ENE2.3	Self-consumption
	2 points if self-consumption is > 50 %
Best practice	- Storage solutions (electricity) and optimal control can increase the self-consumption by shifting electricity use to hours of electricity production. - The orientation of PV can be adjusted to better fit with the energy use of the neighbourhood.

ENE2.4 Net load profiles

The annual net load profile shows the net delivered and exported energy for different energy carriers for the neighbourhood over one year for every time interval, see Table 20. In the annual net load profile, energy import is assigned a positive value and export a negative value as shown in Figure 14. The load duration curve can be found by sorting the values of the net load profiles.

The annual net 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 value of the annual net load profile is to give an illustration of the energy flows throughout the year. The value of the net load duration curve is to provide 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 alternative solutions.

Table 20 Summary for calculating KPI ENE2.4.

ENE2.4	Net load profiles
Objective	To get a visual understanding of the energy flows between the neighbourhood and surrounding energy grid, and the net energy use for each energy carrier. This can help reduce the peak load and peak export of electricity and district heating to reduce the strain on the energy grid in the planning stage. By reducing the peaks in the energy grid, the neighbourhood can reduce the demand for grid investments and related emissions.
Description	The annual net 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.
Method	IEA EBC Annex 67, Engineering practices in the ZEN research centre
Points available	1 point
ZEN KPI assessment	The point is awarded for documenting the net load profile for hourly (or sub-hourly) net energy use of electricity and district heating in Z and R over one year.
Best practice	- An energy efficient building can reduce the demand for energy during the hours with the highest energy demand. - Using heat pumps and/or non-electric heating will reduce the electricity demand during the hours with the highest energy demand (compared to direct electric heating).

ENE2.4	**Net load profiles**
	- Solar panels reduce the demand for imported electricity but can increase the export. Increasing the self-consumption of solar energy can reduce export peaks. - Storage solutions (heating and electricity) can shift the demand for energy import at grid stress hours. - Optimal control can shift the demand for energy import at energy stress hours and create a flatter profile.

ENE2.5 Colour-coded carpet plots

The colour-coded carpet plot is an alternative visualisation of the delivered and exported energy flows between the neighbourhood and the surrounding energy grids and is based on the same information as the net load profiles, see Table 21. A color-coded carpet plot 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 negative. This quantity may also be read from a net metering system. Hourly data are arranged on two axes, with 24 hours of a day on the *first axis*, and 365 days of the year on the *Second 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 20 and Figure 21.

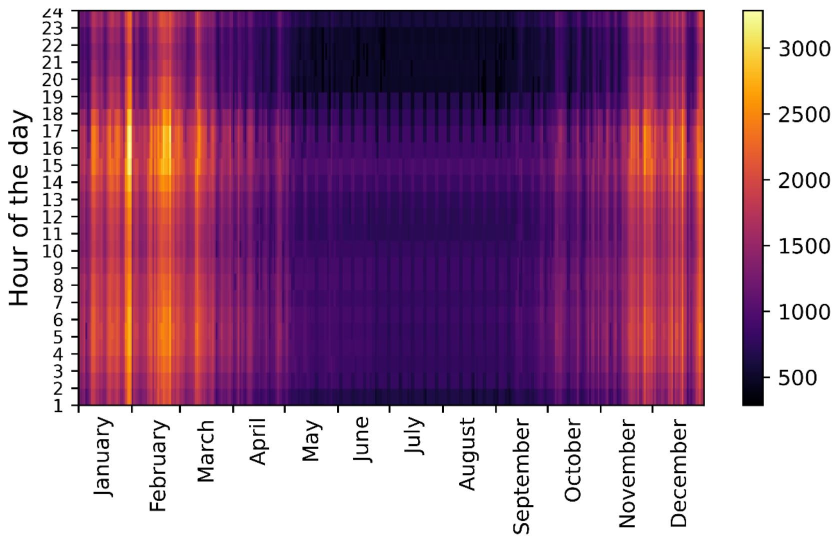


Figure 20. Colour-coded carpet plot showing the net electricity import for Ydalir in the reference project (with electric boiler) (51).

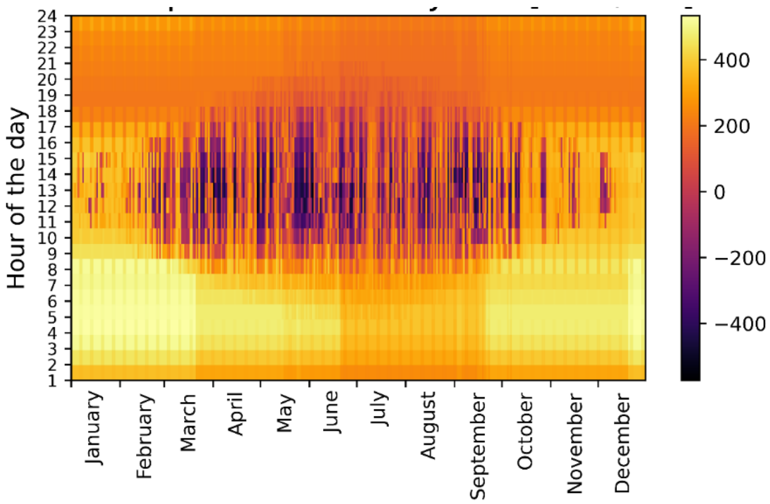


Figure 21. Colour-coded carpet plot showing the net electricity import for Ydalir as planned (with district heating and PV). Negative values indicate electricity export to the grid (51).

Table 21 Summary for calculating KPI ENE2.5

ENE2.5	**Colour-coded carpet plot**
Objective	To get a visual understanding of the energy flows between the neighbourhood and surrounding energy grid, and the energy use per energy carrier. This can help reduce the peak load and peak export of electricity and district heating to reduce the strain on the energy grid in the planning stage. By reducing the peaks in the energy grid, the neighbourhood can reduce the demand for grid investments and related emissions.
Description	The colour-coded carpet plot is a visualisation of the delivered and exported energies (like the net yearly load profile) per energy carrier. A color-coded carpet plot is a convenient graphical visualisation of the energy exchanged between the neighbourhood and the energy grids.
Method	IEA EBC Annex 67, Engineering practices in the ZEN research centre
Points available	1 point
ZEN KPI assessment	The point is awarded for documenting the colour-coded carpet plot for hourly (or sub-hourly) net energy use of electricity, district heating and fuels in Z and R over one year.
Best practice	- An energy efficient building body can reduce the demand for energy during the hours with the highest energy demand. - Using heat pumps and/or non-electric heating will reduce the electricity demand during the hours with the highest energy demand (compared to direct electric heating). - Solar panels reduce the demand for imported electricity. - Storage solutions (heating and electricity) can shift the demand for energy import at grid stress hours. - Optimal control can shift the demand for energy import at energy stress hours and create a flatter profile.

Power

A ZEN 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** through better balancing of variable renewable energy and better utilisation of existing energy infrastructure. Therefore, the ZEN definition has a strong investigates energy flows through energy grids (electricity and district heating). The KPIs in the power category refer solely to 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. All KPIs are calculated with an hourly or sub-hourly resolution. All power KPIs are assessed at the neighbourhood assessment boundary level.

Description of ZEN pilot area (Z) and reference project (R) with and without optimal control

The reference project (R) represents business-as-usual and is based on current building regulations (TEK) for new buildings (43) and relevant historical building regulations for existing buildings, while the ZEN pilot area (Z) is the representation of the area as built/as planned. KPIs are presented in this chapter under the assessment criteria 'load flexibility' to assess how well the neighbourhood exchanges energy in a flexible way. For these KPI, it is necessary to define two more scenarios/references. The first one is the ZEN pilot area but without optimised control (Z-nO). The second one is the reference project, but with optimised control (R-O). In these reference scenarios, the neighbourhood is constructed as in the ZEN pilot area (Z) and in the reference project (R), but the R-O does not provide load flexibility. By introducing these scenarios, it is possible to describe whether the differences in the exchange between the neighbourhood and the energy grids are caused by energy efficiency or flexible operation/optimised control, see Table 22.

Table 22 Description of ZEN pilot area (Z) and reference project (R) with and without optimal control.

	ZEN pilot area		**Reference project**	
Optimised control	Yes, optimised control	No optimised control	Yes, optimised control	No optimised control
Abbreviation	Z	Z-nO	R-O	R

Required documentation when calculating the power KPIs

Completion of the energy category's documentational requirements and KPIs is a prerequisite for the power category's KPIs. The documentational requirements for the power category build upon the documentational requirements and KPIs for the energy category. Table 23 lists required documentation when calculating the power KPIs.

Table 23. List of required documentation when calculating the power KPIs.

KPI	Description	Data type	Unit	Assess-ment level	Scenarios
POW3.1 Peak load	Peak load (import)	Peak value from net load duration curve	kWh/h*	N	Z and R
POW3.2 Peak export	Peak export	Peak value from net load duration curve	kWh/h*	N	Z and R
POW3.3 Energy stress	Energy stress	Net delivered energy during stress hours for the grid	kWh/year*	N	Z and R
POW3.4 Representative days	Representative days	Daily load profiles	kWh/h*	N	Z, Z-nO**, R, R-O**
POW3.5 Delivered energy difference	Delivered energy difference	Difference in delivered energy in scenarios Z and Z-nO and R and R-O	kWh/year*	N	Z, Z-nO**, R, R-O**
POW3.6 Operational cost difference	Operational costs difference	Difference in operational costs in scenarios Z and Z-nO and R and R-O	NOK/year*	N	Z, Z-nO**, R, R-O**
POW3.7 Energy stress difference	Energy stress difference	Difference in delivered energy in scenarios Z and Z-nO and R and R-O	kWh/year*	N	Z, Z-nO**, R, R-O**
POW3.8 Peak load difference	Peak load difference	Difference in delivered energy in scenarios Z and Z-nO and R and R-O	kWh/h*	N	Z, Z-nO**, R, R-O**

* For electricity and district heating
** Only for calculating the load flexibility KPIs (POW3.4 - POW3.8)

Assessment Criteria

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

Power performance: This assessment criterion assesses the power performance and strain of the neighbourhood on the electricity and district heating grid. The KPIs include POW3.1 – POW3.4. For all these KPIs, the performance is measured as a difference between the ZEN pilot area (Z) and reference project (R).

Load flexibility: This assessment criterion reflects whether the neighbourhood exchanges energy with the surrounding energy system (electric and district heating) in a flexible way. The KPIs include POW3.5 – POW3.8. The KPIs have been developed through work in FME ZEN, as evaluating the role of end-user flexibility and control is valuable for nZENs.

Energy flexibility is defined as the ability of a building or neighbourhood to manage its demand, storage, and local generation to respond to external signals, while safeguarding user needs and comfort (52). This results in load profiles (i.e., hourly, or sub-hourly, values of net energy demand) on the grids that deviate from typical ones. The methodology for calculating the load flexibility KPIs is based on the comparison of two scenarios; one flexible, where flexibility sources are activated to achieve a goal, in response to a driver, vs. a reference scenario that is insensitive to the driver. The load flexibility KPIs will reflect the difference in load profiles in the ZEN pilot area as built/as planned (Z), and the same area but where there is limited control and demand response (Z-nO), or in some cases between the reference project with and without optimal control (R and R-O) This is described in the schematic in Figure 22.

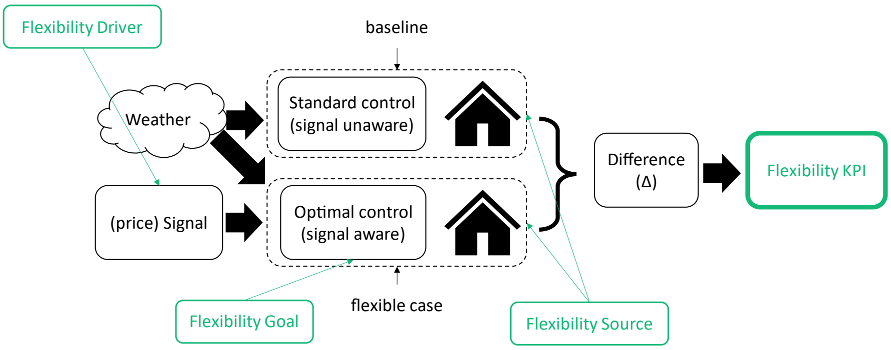


Figure 22 Schematics of the methodology for calculating the load flexibility KPIs (52).

Flexibility KPIs can be calculated for combinations of three elements: flexibility source, flexibility driver and flexibility goal. Figure 23 provides a visual summary of such combinations.

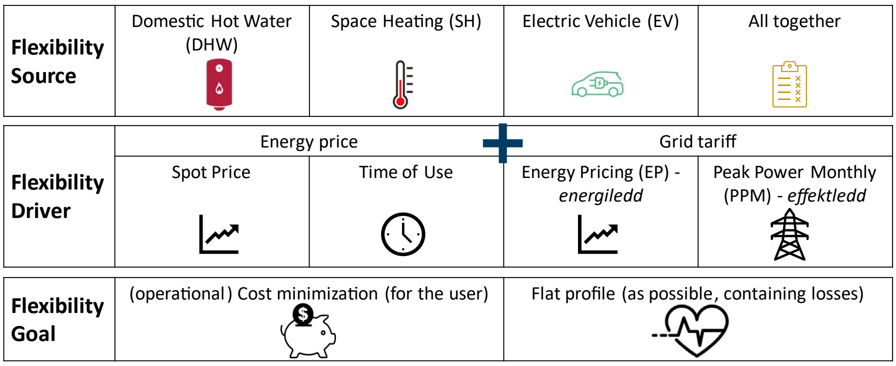


Figure 23 Visual summary of flexibility drivers and goals, in combination with different flexibility sources (52).

The KPIs under the assessment criterion 'Load flexibility' can be used to evaluate the effects of short-term load shifting[3] 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 aim of this assessment criterion is to assess short-term variations and short-term storage, both thermal and electric, because this is what usually are the options in a neighbourhood. With storage we mean both physical storage, such as hot water tanks and batteries (incl. those of 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 24 illustrates an

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

example of a single building, with PVs and battery, where the goal is to limit the net electricity export to the grid.

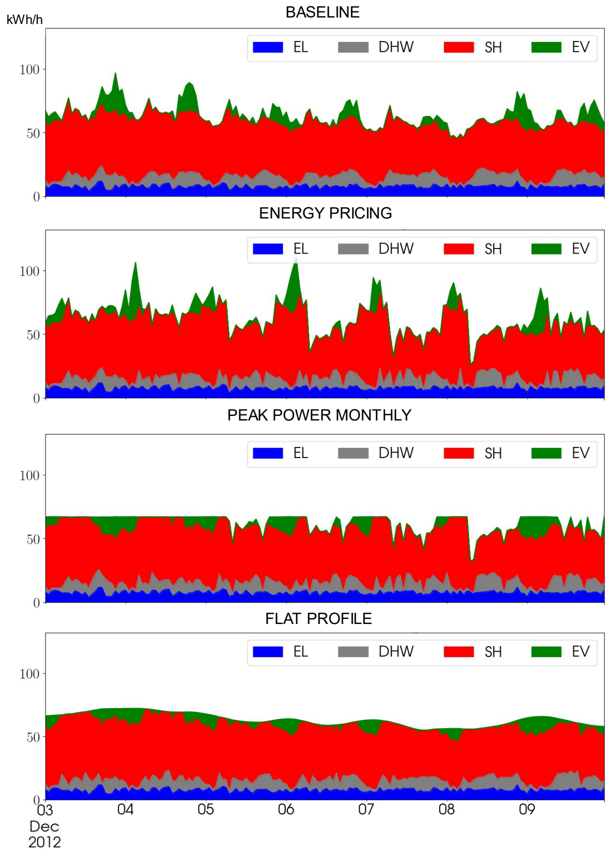


Figure 24 Apartment block with panel ovens, winter week. Baseline scenario (on top) and flexible scenarios with different flexibility drivers/goals. EL = electric specific; DHW = domestic hot water; SH = space heating; EV = electric vehicle (52).

POW3.1 Peak load

The peak load KPI and *POW3.2 Peak export* are simply the extreme values of the net duration curve as illustrated in Figure 15. The peak load KPI refers to the maximum positive hourly import load of electricity and district heating to the neighbourhoods during an operational year, see Table 24. The peak load should be calculated for the ZEN pilot area and the reference project.

Table 24. Summary for calculating KPI POW3.1.

POW3.1	**Peak load**
Objective	To reduce the peak load of electricity and district heating to reduce strain on the energy grid. By reducing the peaks in the energy grid, the neighbourhood can reduce the demand for grid investments and related GHG emissions.
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
Points available	6 points
ZEN KPI assessment	The KPI will be assessed on percentage (%) reduction in peak load in the ZEN pilot area compared to the reference area. The limit and target values will be further developed in future ZEN work.
Best practice	- An energy efficient building can reduce the demand for energy during the coldest hours of the year. - Using heat pumps and/or non-electric heating will reduce the electric peak load (compared to direct electric heating). - Solar panels reduce the demand for imported electricity. - Storage solutions (heating and electricity) can shift the demand for energy import at peak load hours. - Optimal control can shift the demand for energy import at peak load hours and create a flatter profile.

POW3.2 Peak export

The peak export KPI refers to the maximum net hourly export load of electricity (when the electricity production is higher than the electricity use) from the neighbourhood during an operational year, see Table 25. 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 25. Summary for calculating KPI POW3.2.

POW3.2	**Peak export**
Objective	The peak export should not exceed the peak load (import) and should not be the dimensioning factor for the electricity grid. By reducing the peaks in the energy grid, the neighbourhood can reduce the demand for grid investments and related GHG emissions.
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
Points available	2 points
ZEN KPI assessment	2 points are awarded if: Peak export of electricity < Peak load of electricity in the ZEN pilot area
Best practice	Storage solutions (electricity) and optimal control can increase the self-consumption by shifting electricity use to hours of electricity production.

POW3.3 Energy stress

The energy grid will experience a higher power demand during a few hours of the day, typically occurring in the early morning (7 - 9am) and late afternoon during workdays (4 - 6pm) in Norway, see Table 26. These hours are termed 'stress hours' and if the neighbourhood can reduce its power demand during these hours, then the energy stress may be reduced on the grid. In Figure 25, a ZEN pilot area is using optimised control to reduce electricity loads during stress hours. By reducing the stress on the energy grid, the neighbourhood can reduce the demand for grid investments and related GHG emissions.

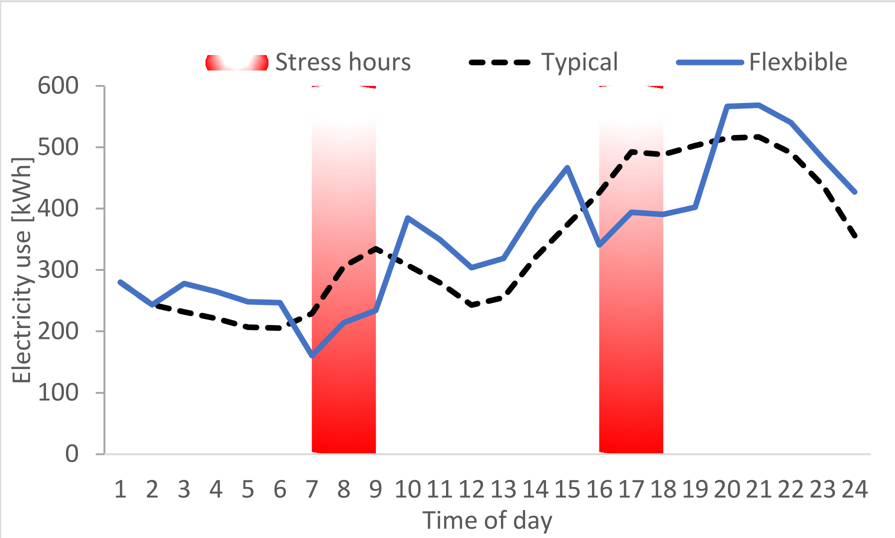


Figure 25 Alternative load profiles in a neighbourhood with (flexible) and without optimal control (typical) to reduce energy in the stress hours.

Table 26 Summary for calculating KPI POW3.3.

POW3.3	**Energy stress**
Objective	The energy grid will experience a higher power demand during a few hours of the day, typically in the morning and evening hours. These hours can be called 'stress hours' and if the neighbourhood can reduce its power demand during these hours, then energy stress may be reduced on the grid.
Description	The difference in energy use during hours that are predefined as stressful for the energy system, e.g., peak load hours for the grid, typically occurring in the early morning (7-9am) and late afternoon (4-6pm) during workdays in Norway when the hourly or sub-hourly load profile for electricity and district heating is calculated at the neighbourhood assessment level for the ZEN pilot area and reference project over a period of one year.
Method	IEA EBC Annex 67, Engineering practices in the ZEN research centre
Points available	6 points
ZEN KPI assessment	The KPI will be assessed on the percentage (%) reduction in delivered energy during stress hours in the ZEN pilot area compared to the delivered energy during stress hours in the reference project (R). The limit and target values will be further developed in future ZEN work.
Best practice	- An energy efficient building can reduce the demand for energy during the hours with the highest energy demand.

POW3.3	Energy stress
	- Using heat pumps and/or non-electric heating will reduce the electricity demand during the hours with the highest energy demand (compared to direct electric heating). - Solar panels reduce the demand for imported electricity. - Storage solutions (heating and electricity) can shift the demand for energy import at grid stress hours. - Optimal control can shift the demand for energy import at energy stress hours and create a flatter profile.

POW3.4 Representative days

Representative day charts show the average net import of electricity and district heating in a neighbourhood in different scenarios, see Table 27. They can be made as an average of the entire year or for different seasons and days separately. As an example, the representative daily profile for net delivered electricity (electricity use minus electricity production) on winter workdays for different scenarios in one of the pilots is shown in Figure 26. The figure shows the representative electricity use for the ZEN pilot with district heating (ZEN) and the reference area (R) with district heating and electric heating. The lines in the figure show the average winter workday net electricity profile, while the shaded area around these lines show the variation in electricity use (on winter workdays) from the 5^{th} - 95^{th} percentile interval.

The figure shows that the representative net delivered electricity on winter workdays have a morning peak and an afternoon peak. This is due to the high share of residential buildings in this pilot, where there is typically a morning peak caused by energy use before the residents leave for work, and the afternoon peak caused by cooking, lighting, equipment, charging of electric vehicles and heating (in the Reference EL-scenario). The reference area with electric heating shows a much higher electricity use during winter workdays compared to the other scenarios. This is due to the electricity being used for heating in this scenario. There is also a larger variation in daily electricity use in this scenario due to the link between electricity used for heating and the outdoor temperature. The pilot area and reference area with district heating have a similar representative electricity use profile on winter weekdays, but the net delivered electricity is lower in the ZEN scenario during the middle of the day due to electricity generation from PV. On some days, there is even export of electricity during winter workdays in the ZEN scenario.

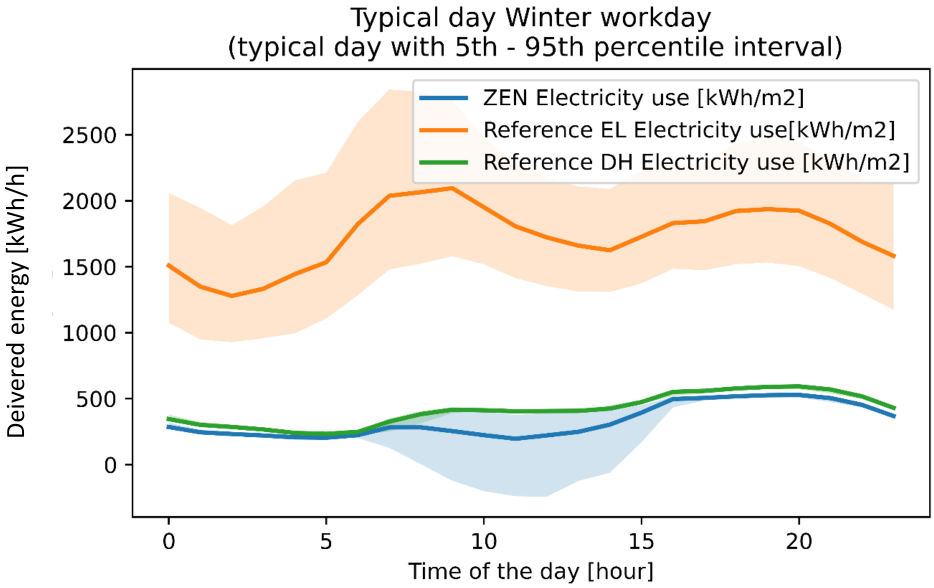


Figure 26. Representative net delivered electricity in one of the pilots on winter workdays.

Table 27. Summary for calculating KPI POW3.4.

POW3.4	**Representative day**
Objective	To get a better understanding of the energy flows between the energy grid and the neighbourhood.
Description	Representative daily load profiles for every hour of an average day of net import of electricity and district heating to the neighbourhood from the grid.
Method	IEA EBC Annex 67, Engineering practices in the ZEN research centre
Points available	2 points
ZEN KPI assessment	1 point for one graph for Z and R. 2 points for different seasons/weekdays for Z, R and/or Z-nO and R-O.
Best practice	- An energy efficient building can reduce the demand for energy during the coldest hours of the year. - Using heat pumps and/or non-electric heating will reduce the electric peak load (compared to direct electric heating). - Solar panels reduce the demand for imported electricity. - Storage solutions (heating and electricity) can shift the demand for energy import at peak load hours. - Optimal control can shift the demand for energy import at peak load hours and create a flatter profile.

POW3.5 Delivered energy difference

Delivered energy difference focuses on the difference in total energy use between the ZEN pilot area with/without optimal control (Z/Z-nO) and/or the reference project with/without optimal control (R/R-O). This allows a person to quantify explicitly the impact of load flexibility, see Table 28.

Table 28.Summary for calculating KPI POW3.5.

POW3.5	**Delivered energy difference**
Objective	The neighbourhood exchanges energy with the surrounding energy system in a flexible way that reduces the total energy use of the neighbourhood. Reducing the delivered energy can help reduce GHG emissions from *GHG1.4 Operational energy use (B6)*.
Description	The difference between energy use in the ZEN (Z) and reference (R) is calculated in *ENE2.2 Delivered energy*. This indicator refers to the difference between the ZEN pilot area with and without optimised control (Z and Z-nO). The difference in net delivered energy use when the hourly or sub-hourly load profile for electricity and district heating is calculated at the neighbourhood assessment level for the ZEN-pilot and reference project (Z) and the not-optimised ZEN pilot area (Z-no) over a period of one year.
Method	IEA EBC Annex 67, Engineering practices in the ZEN research centre
Points available	1 point
ZEN KPI assessment	The point is awarded for documenting the difference in energy use (kWh/year) for Z and Z-nO and/or R and R-O for electricity and district heating.
Best practice	- Storage solutions (heating and electricity) can shift the demand for energy import at peak load hours. - Optimal control can shift the demand for energy import at peak load hours and create a flatter profile.

POW3.6 Operational cost difference

Operational cost difference focuses on the difference in operational cost due to energy use between the ZEN pilot area with/without optimal control (Z/Z-nO) and/or the reference project with/without optimal control (R/R-O). This allows a person to quantify explicitly the impact of load flexibility, see Table 29.

Table 29 Summary for calculating KPI POW3.6.

POW3.6	**Operational costs difference**
Objective	The neighbourhood exchanges energy with the surrounding energy system in a flexible way that reduces the operational energy cost for the neighbourhood.
Description	The operational cost of the ZEN pilot area (Z) is calculated in *ECO6.2 Operating costs*. This indicator refers to the difference in operational energy cost between the ZEN pilot area with and without optimised control (Z and Z-nO). The difference operational cost due to energy use when the hourly or sub-hourly load profile is calculated at the building or neighbourhood assessment level for the ZEN pilot and reference project (Z) and the not-optimised ZEN pilot area (Z-no) over a period of one year.
Method	IEA EBC Annex 67, Engineering practices in the ZEN research centre
Points available	1 point
ZEN KPI assessment	The point is awarded for documenting the difference in cost (NOK/year) for Z and Z-nO and/or R and R-O for electricity and district heating.
Best practice	- Storage solutions (heating and electricity) can shift the demand for energy import until hours with lower energy costs and/or reduce energy use for some loads (load shedding).

POW3.6	Operational costs difference
	- Optimal control can shift/shed the demand for energy import at hours with high energy costs.

POW3.7 Energy stress difference

Energy stress difference looks into the difference of energy stress between the ZEN pilot area with/without optimal control (Z/Z-nO) and/or the reference project with/without optimal control (R/R-O). This allows a person to quantify explicitly the impact of load flexibility, see Table 30.

Table 30 Summary for calculating KPI POW3.7.

POW3.7	Energy stress difference
Objective	The neighbourhood exchanges energy with the surrounding energy system in a flexible way that reduce the energy use during hours that are predefined as stressful for the energy system, e.g., peak load hours for the grid, typically occurring in early morning and late afternoon during workdays, in Norway. By reducing the stress on the energy grid, the neighbourhood can reduce the demand for grid investments and related GHG emissions.
Description	The difference in energy stress between the ZEN pilot area (Z) and reference project (R) is calculated in *POW3.3 Energy stress.* This indicator refers to the difference in energy stress between the ZEN pilot area with and without optimised control (Z and Z-nO).The difference in energy use during hours that are predefined as stressful for the energy system, e.g., peak load hours for the grid, typically occurring in early morning and late afternoon during workdays, in Norway when the hourly or sub-hourly load profile for electricity and district heating is calculated at the neighbourhood assessment level for the ZEN pilot and reference project over a period of one year.
Method	IEA EBC Annex 67, Engineering practices in the ZEN research centre
Points available	1 point
ZEN KPI assessment	The point is awarded for documenting the difference in energy stress (kWh/year) for Z and Z-nO and/or R and R-O for electricity and district heating.
Best pactice	- Storage solutions (heating and electricity) can shift the demand for energy import at grid stress hours. - Optimal control can shift the demand for energy import at energy stress hours and create a flatter profile.

POW3.8 Peak load difference

Peak load difference focuses on the difference in peak load between the ZEN pilot area with/without optimal control (Z/Z-nO) and/or the reference project with/without optimal control (R/R-O). This allows a person to quantify explicitly the impact of load flexibility, see Table 31.

Table 31 Summary for calculating KPI POW3.8.

POW3.8	**Peak load difference**
Objective	The neighbourhood exchanges energy with the surrounding energy system in a flexible way that reduces the peak load of the neighbourhood (usually referring to imported energy but may apply also to exported energy). By reducing the stress on the energy grid, the neighbourhood can reduce the demand for grid investments and related GHG emissions.
Description	The difference in peak load between the ZEN pilot area (Z) and reference project (R) is calculated in *POW3.1 Peak load* and *POW3.2 Peak export.* This indicator refers to the difference in peak load between the ZEN pilot area with and without optimised control (Z and Z-nO). The %-difference in peak load (maximum of the peak import and peak export) when the hourly or sub-hourly load profile for electricity and district heating is calculated at the neighbourhood assessment level for the ZEN-pilot and reference project (Z) and the not-optimised ZEN pilot area (Z-no) over a period of one year.
Method	1 point
Points available	The point is awarded for documenting the difference in peak load for Z and Z-nO and/or R and R-O for electricity and district heating.
ZEN KPI assessment	The KPI will be assessed based on the percentage (%) reduction in peak load (kWh/h) in the ZEN pilot area (Z) compared to the peak load in the not-optimised ZEN pilot area (Z-nO)
Best practice	- Storage solutions (heating and electricity) can shift the demand for energy import at peak load hours. - Optimal control can shift the demand for energy import at peak load hours and create a flatter profile.

The load flexibility KPIs can be summarised in a graph which shows the effects of the flexibility on all the flexibility indicators together as shown in Figure 27. The example shows the flexibility indicators calculated for three different school buildings (one regular, one energy efficient and one very energy efficient). The example shows that while the operational cost difference (Δcost), energy stress difference (Δenergy stress) and peak load difference (Δpeak load) are reduced, the delivered energy difference (Δenergy) increases when optimal control is introduced.

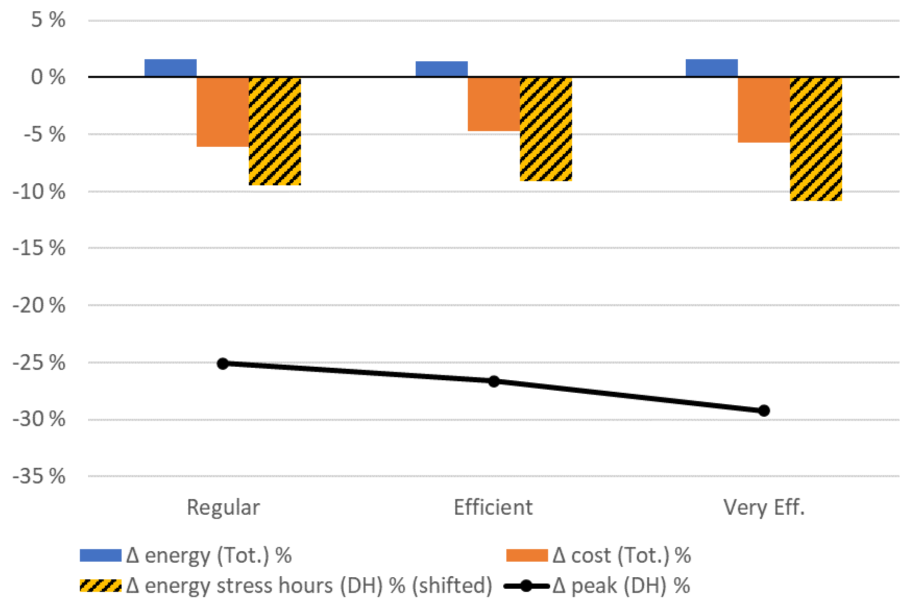


Figure 27 Example results on the energy flexibility indicators in three different school buildings.

Urban Form and Land Use

When planning a zero emission neighbourhood, each local context will have unique challenges and opportunities. Research has shown that some urban form and land use characteristics provide more decisive conditions for mitigating GHG emissions than others within the city boundary. According to the International Panel on Climate Change (IPCC) (53), compact urban development with high density and land use mix in combination with good access to amenities, walkable streets, and a sufficient share of green space, are of special importance for low energy use per capita, especially within the transport and building sector. Indirectly, these urban form characteristics also save valuable resources and enhance natural carbon uptake by increasing land use efficiency and open green space.

Urban form and land use refers to the spatial structure, land use patterns and the shape of buildings, street networks and open public space. The following KPIs for urban form and land use have been selected based on their influence on mitigating GHG emissions but also to their co-benefits concerning quality of life, climate adaption, biodiversity, health, and social equity. The urban form and land use KPIs are focused on locations within urban regions and may not translate well to neighbourhoods located outside of the urban boundary. Urban form and land use KPIs are valid for the neighbourhood assessment boundary level.

Assessment Criteria

The urban form and land use assessment criteria can be seen as a summary of the ZEN spatial indicators work and highlights the most fundamental aspects of urban form and land use (54–56). 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 geographic information system (GIS) software. The required background data are usually available from Norwegian municipalities in either the early planning phase (masterplan) or late planning phase (regulation plan). These KPIs are valid for the strategic planning phase. Basic knowledge in GIS is required for compiling the KPIs. The term 'plan area' is defined as the geographical system boundary of the ZEN pilot area and is used for all URB KPIs. The KPIs are grouped under four assessment criteria, namely: Density and land use mix, Building layout, Street network and Green open space.

Density and land use mix

The density and land use mix assessment criteria contains four KPIs, namely: URB4.1 Population density, URB4.2 Block density, URB4.3 Land use mix, and URB4.4 Access to a diversity of amenities.

URB4.1 Population density

High density of both residents and workplaces within walking distance increases service supply and provides better conditions for shared mobility, such as public transport and car sharing solutions that can contribute to lower GHG emissions from transport including the production of vehicles, see Table 32. Fewer cars per housing unit can also contribute to reduced GHG emissions from the building sector due to building less car parking spaces (57). Population density is calculated as the total of number of proposed residents and workplaces within the plan area together with surroundings within 1000 metres distance, see Figure 28. The value can either be calculated from a central location in the plan area or by the average for each block. Distance threshold should be within walking distance measured along convenient and safe routes (not air distance). If only the floor area of buildings (and not estimates of population) is known use 50 square metres gross floor area per person for residents and services and 20 square metres gross floor area for office space. The summary value for the plan area can either be calculated from a central location in the plan area or by the average for each building.

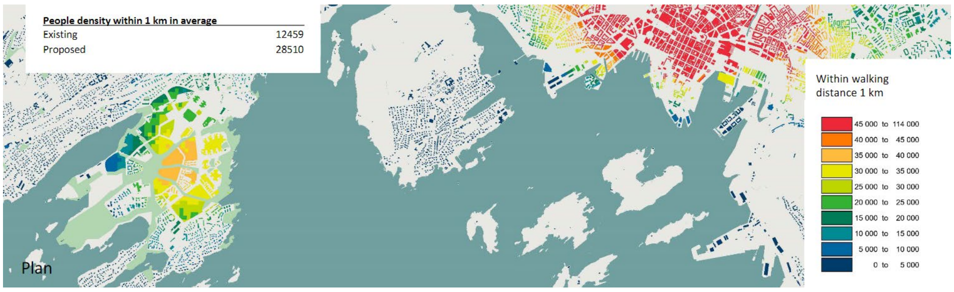


Figure 28. Map showing the proposed population density from the ZEN pilot area at Fornebu (56).

Table 32. Summary for calculating KPI URB4.1

URB4.1	**Population density**
Objective	To support public transport, provide a market for local services which are important for peoples' daily lives and well-being and to increase the potential for walking and cycling. Population density is also important for sharing economy services such as car sharing, smart charging, and smart grids.
Description	The total number of residents and workplaces within 1 km walking distance.
Method	GIS mapping with Place syntax tool (58).
Points available	2 points
ZEN KPI assessment	Points are awarded for the population density (residents + employees) within 1 km walking distance: 2 points: > 10 000 1 point: 5 000 – 10 000 0 points: < 5 000
Best practice	

URB4.2 Block density

High density at the block level provides efficient land use in combination with densification on hard surfaces which saves the need to exploit new green space or farmland. High block density and a balance of residential and office floor area provides conditions for smart energy solutions that reduce the per capita GHG emissions from the energy sector, see Table 33. High block density is a prerequisite for efficient district heating and cooling networks by smart thermal grids and provides an advantage for electrical grid balance, including electric public transport (53). Block density is calculated through the percentage of gross floor area divided by the plot area, see Figure 29 for an example. The percentage of gross floor area can be found in the plan proposal. If a plot area is not defined, the area can be defined as a space for construction of buildings separated from other plots or public spaces by the street pattern.

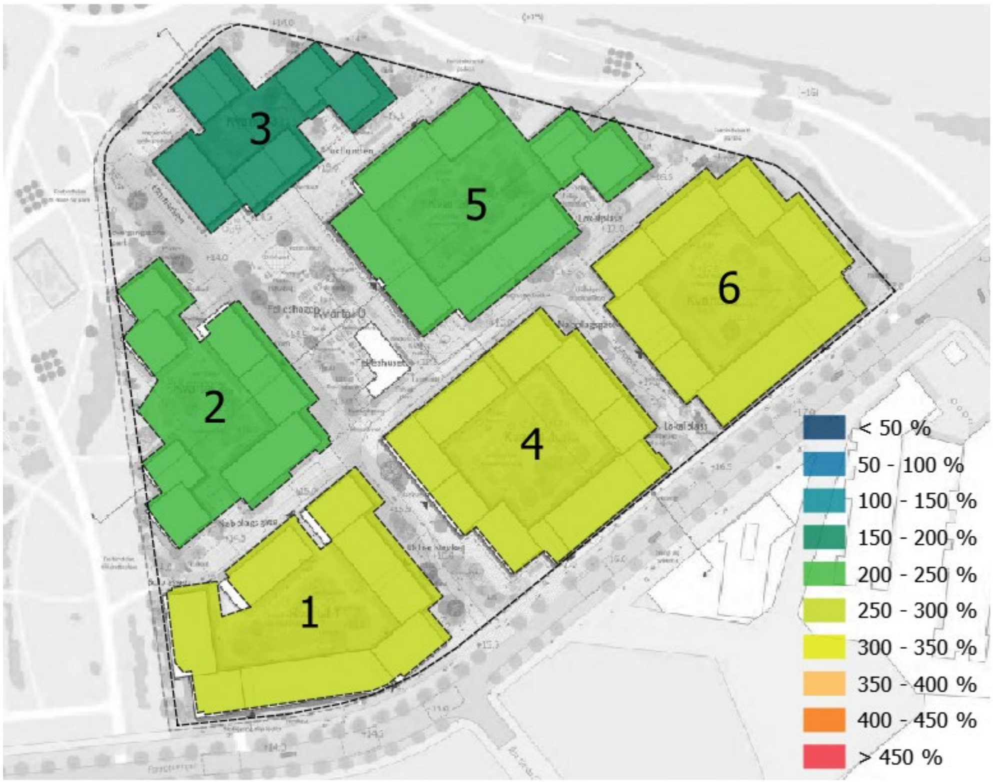


Figure 29. Map showing the calculated block density at Nansenløkka at the ZEN pilot area at Fornebu (59).

Table 33. Summary for calculating KPI URB4.2

URB4.2	Block density
Objective	To provide conditions for lower GHG emissions by saving green assets and reducing material consumption within buildings and infrastructure per capita. A certain density is necessary for both accessibility to a diversity of amenities and a customer base for these amenities.
Description	The allocation of points awarded are based on urban plots that include dwellings. Note that there is an important contrast between density and housing quality.
Method	GIS mapping.
Points available	1 point
ZEN KPI assessment	Points are awarded for block density: 1 point: 150 - 250 % 0 points: less than 150 or more than 250 %
Best practice	

URB4.3 Land use mix

Land use mix assesses the balance between residents and workers within the neighbourhood within 500 metres walking distance, see Table 35. The UN Habitat highlights the importance of a certain mix of residents and workers (60). A balance is important for co-use, level of service, social safety, and increased potential for sustainable transportation. A balance of 40 - 60 % can be considered very good, while a balance of less than 10 - 90 % is not good. Figure 30 shows the number of residents and workers within 500 metres walking distance from the ZEN pilot area at Fornebu, and Table 34 shows the share of residents and workers.

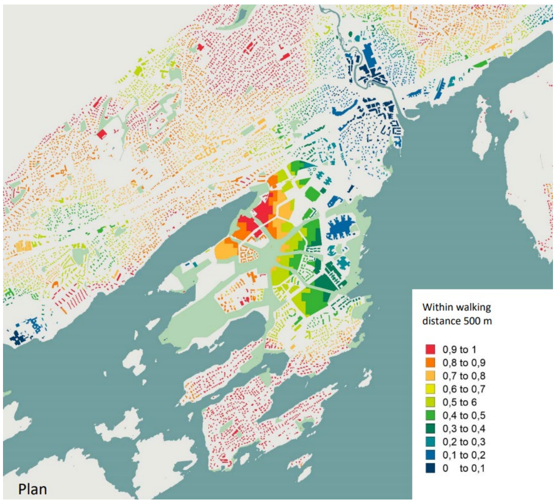


Figure 30. Map showing the land use mix within 500 metres walking distance from the ZEN pilot area at Fornebu (56).

Table 34. Existing and planned share of residents and workers within the ZEN pilot area at Fornebu (56).

Type of user	Existing		Planned	
	Amount	Share	Amount	Share
Residents	2 741	22%	13 685	48%
Workers	9 718	78%	14 825	52%
SUM	12 459	100%	28 510	100%

Table 35. Summary for calculating KPI URB4.3

URB4.3	Land use mix
Objective	To encourage a mix of residents and workers, it is important to facilitate for co-use, level and amount of service and amenities, social safety, and increased potential for sustainable transportation, which will in turn reduce GHG emissions from sharing services and transport. According to UN Habitat the share of non-resident gross floor area should preferably be between 40 and 60 % (60).
Description	Total number of residents and workers or share of gross floor area for residents within a 500 metre walking distance.
Method	GIS mapping with Place Syntax Tool (58). Calculated as the share of residents compared to the total number of residents and workplaces within 500 metres walking distance. The distance threshold should be calculated as the walking distance measured along convenient and safe routes (not air distance). The summary value for the plan area can either be calculated from a central location in the plan area or by the average for each building.
Points available	2 points
ZEN KPI assessment	Points are awarded for the balance between resident and workers:

URB4.3	**Land use mix**
	2 points: 40 - 60 % residents 1 point: 20 - 40 or 60 – 80 % residents 0 points: less than 20 or more than 80 % residents
Best practice	

<u>URB4.4 Access to a diversity of amenities</u>

The access to a diversity of amenities KPI categorises amenities into five groups: local public transport, fast regional transport, educational facilities, local service cluster and green open public spaces, see Table 37. Local public transport is defined as having at least one departure every 15 minutes during the daytime. Fast regional public transport is defined as transit on rails or BRT (bus rapid transport). Educational facilities are identified as secondary schools, primary schools, and nurseries. For the local service cluster, services are identified in the process guideline and are often located along a street or in a local centre. Services may include for example, grocery store, pharmacy, café or restaurant, health care or package pickup/post, and should include at least 3 types of local service. Green open public space is defined in *URB4.10 Share of green open space.* Access to local services is important for social equality and urban attractiveness. Figure 31 provides an example of how these urban attractions can be mapped within 1 km from the ZEN pilot area and Table 36 gives an example of the walking distances to each category of urban attractions. This KPI is to be assessed during the early planning phase, whilst *MOB5.1 Access to public transport* considers access to public transport in the implementation and use phases.

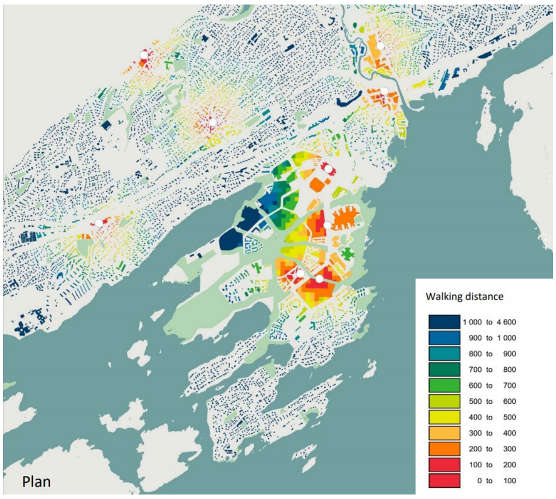


Figure 31. Closeness to local centre for the ZEN pilot area at Fornebu (56).

Table 36. Walking distances to each category of urban attraction, example taken from Fornebu (56).

Urban attraction	Walking distance – existing (metres)	Walking distance – planned (metres)
Local public transport	497	277
Fast regional public transport	2418	436
Educational facilities	1107	588
Local service cluster	924	433
Green open public space	158	105

Table 37. Summary for calculating KPI URB4.4

URB4.4	Access to a diversity of amenities
Objective	The access to a variety of amenities within walking distance has shown to be important for social equality and urban attractiveness (61) as well as for increasing the share of sustainable transport patterns (60) which will in turn decrease GHG emissions from transport.
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 2. fast regional public transport 3. Educational facilities 4. Local service cluster 5. Green open public space
Method	GIS mapping with Place Syntax Tool or other GIS applications that can measure walking distance (alternatively walking distance can be measured manually in Google Maps or other map services and reported in Table format) (58). GIS map showing facilities within 1 km walking distance.
Points available	2 points
ZEN KPI assessment	Points are awarded for the number of accessible facilities: 2 points: > 4 accessible categories 1 point: 3 accessible categories 0 points: 0 - 2 accessible categories
Best practice	

<u>Building layout</u>

The building layout assessment criteria contains three KPIs: URB4.5 Dwelling type, and URB4.7 Active frontages.

<u>URB4.5 Dwelling type</u>

The layout and use of buildings strongly influence life and living (62). Building types are closely related to plot dispositions which in turn influences sustainability, such as the amount of green space versus the number of concrete constructions and amount of private car driving, see Table 38. According to Naturskyddsföreningen, parking spaces in Sweden take more space than the actual living space (57). Figure 32 gives an example of calculating the share of detached and semi-detached houses.

Figure 32. Map showing the calculated share of detached and semi-detached houses at Nansenløkka at the ZEN pilot area at Fornebu (59).

Table 38. Summary for calculating KPI URB4.5

URB4.5	**Dwelling type**
Objective	Dwelling type influences floor area per person and the area of building envelope per floor area and thereby GHG emissions per capita during the construction and operation phases. A high share of detached houses increases the amount of private car driving.
Description	Share of detached and semi-detached houses of all dwelling units, including apartments.
Method	Count of detached and semi-detached houses divided by the total count of dwelling units, including apartments within the plan area
Points available	1 point
ZEN KPI assessment	Points are awarded for share of detached and semi-detached houses: 1 point: < 30 % 0 points: > 30 %
Best practice	- Optimisation of building floor area. - Prioritise multi-family homes over single-family buildings. - Shared space solutions for reducing the total floor area per dwelling. - Fewer parking spaces per housing unit or workplace.

URB4.6 Multifunctional building roofs

Building roofs can include building integrated renewable energy production, social spaces, and green spaces, see Table 39. Renewable energy production integrated into building roofs can include, but is not limited to, solar thermal collectors and photovoltaic systems. Social spaces are considered as shared spaces. Green roofs can mitigate climate emissions directly through carbon uptake and indirectly by inducing a cooling effect that reduces energy demand in buildings and energy demand for water treatment (53). Figure 33 shows the roof areas for social functions and green spaces at Nansenløkka, Fornebu.

Figure 33. Map showing the roof areas for social functions and green space at Nansenløkka at the ZEN pilot area at Fornebu (59).

Table 39. Summary for calculating KPI URB4.6

URB4.6	**Multifunctional building roofs**
Objective	The layout of roof areas can be designed for renewable energy production, carbon storage by plants, and/or providing outdoor areas for social activities and recreation.
Description	The share of building roof that is used for either energy production, social functions, or green space.
Method	Share of building roof for these purposes out of the total area of the building footprint.
Points available	1 point
ZEN KPI assessment	Points are awarded for share of building roof (total for all functions): 1 point: > 50% 0 points: < 50%
Best practice	- Plan for renewable energy production within the building roof - Plan for social functions - Plan for green spaces, see *URB4.11 Share of green open space, URB4.12 Share of green permeable area*

URB4.7 Active frontages

The building layout can support street life and social safety for pedestrians by facilitating active building frontages (63), see Table 41. To calculate active building frontages, each ground level building façade is defined within the categories A - E according to Table 40. This classification is based on entrance density, function mix and façade transparency. A function is defined as a type of dwelling, amenity, or office. Only facades towards main roads are mapped. A main road is defined as a major road with a large amount of traffic. A façade must fulfil all three requirements in to receive that category rating. Blind and passive facades are defined as facades with no entrances or windows. See Figure 34 for an example of how active frontages can be calculated.

Figure 34.Map showing the categorised building frontages at Bryggerikvartalet in Bodø (59).

Table 40. Categories of building frontages in terms of entrance density, function mix and façade transparency, adapted from (63).

Criteria for active building frontages		
Category A		
15 – 20 entrances per 100 m	> 3 types of function	No blind or passive facades
Category B		
10 – 14 entrances per 100 m	> 2 types of function	Few blind or passive facades (< 20 %)
Category C		
6 – 9 entrances per 100 m	> 1 type of function	Some blind or passive facades (< 40 %)
Category D		
2 – 5 entrances per 100 m	No mix of functions	Mostly blind or passive facades (> 80 %)
Category E		
0 – 2 entrances per 100 m	No mix of functions	100% Blind or passive facades

Table 41. Summary for calculating KPI URB4.7

URB4.7	**Active frontages**
Objective	Active building frontages at ground level with access from the street is important for providing conditions for URB4.3 Land use mix, URB4.4 Access to a diversity of amenities, the local economy, and socially safe and attractive streets.
Description	The share of active building frontages due to entrance density, function mix and facade transparency along main streets through or within the neighbourhood.
Method	GIS mapping or manually measured in Google Maps or other map services and reported in a Table format. Each façade line is defined within the categories A - E according to based on entrance density, function mix and façade transparency. Only facades towards main roads are mapped.
Points available	2 points
ZEN KPI assessment	Points are awarded for share of facades: 2 points: > 80% of facades in category A, B, or C 1 point: 40 - 80 of facades in category A, B, or C 0 points: < 40% of facades in category A, B, or C
Best practice	

Street network

The street network assessment criteria contain three KPIs, namely: URB4.8 Street connectivity, URB4.9 Street intersection density and URB4.10 Walkable and bikeable streets.

URB4.8 Street connectivity

The structure of street networks and how they support the perception of closeness and create potential for natural movement between neighbourhoods impact the long-term development of density and amenities patterns (64). Street connectivity, measures how well neighbourhoods are linked to each other based on sight lines along the street network, see Table 43. This indicator has a significant effect on social segregation (65), natural pedestrian movement (66) and perceived closeness within the urban fabric. A neighbourhood lacking well-connected streets to surrounding neighbourhoods can be considered a spatially segregated enclave. Figure 35 provides an example of a map showing the street network within the ZEN pilot area and shows the share of well-integrated streets.

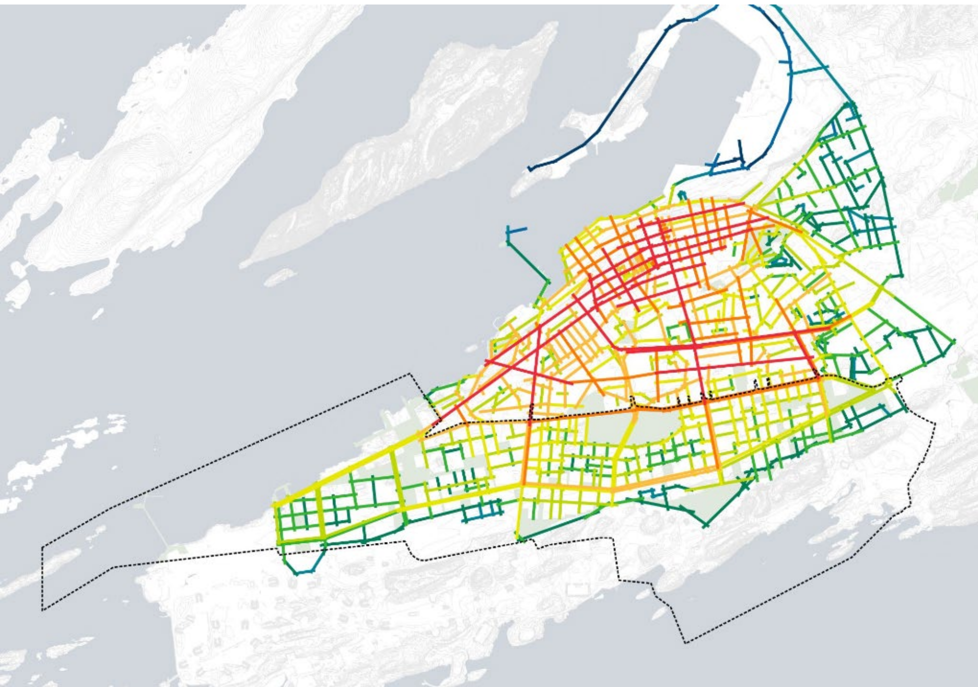


Figure 35. A map showing street network within the ZEN pilot area at Bodø (56)

Table 42. Share of the relevant surrounding neighbourhoods that are well connected to the plan area

Total number of relevant surrounding neighbourhoods	Number of relevant surrounding neighbourhoods that are well connected to the plan area
3	2

Table 43. Summary for calculating KPI URB4.8

URB4.8	**Street connectivity**
	To encourage walkability as well as social and economic exchange with surrounding neighbourhoods to increase the share of active mobility (see *MOB5.5 Mobility pattern*) and thereby reduce GHG emissions from GHG1.5 Operational transport (B8).
Description	Mapping to what extent the project is connected to the surrounding neighbourhoods by direct routes, particularly for walking and bicycling. Street connectivity assesses the distance to surrounding neighbourhoods as well as the number of streets that connect to the neighbourhood, see .Street connectivity is defined by the number of well-connected streets to surrounding neighbourhoods (along the neighbourhood district border). A well-connected street is characterised by visual overview and close walking distance from one local central place (could be a main street or square) to another local central place within a surrounding neighbourhood.
Method	Examine map and mark the routes that are continuous from central/well integrated streets within the plan area to central/well-integrated street(s) in surrounding neighbourhood within 1km air distance.
Points available	2 points

URB4.8	**Street connectivity**
ZEN KPI assessment	2 points: All relevant surrounding neighbourhoods are well connected to the plan area. 1 point: > 50% of the relevant surrounding neighbourhoods are well-connected to the plan area. 0 points: Relevant surrounding neighbourhoods are poorly connected to the plan area.
Best practice	

<u>URB4.9 Street intersection density</u>

Intersection density is also one of the most important characteristics for traffic safety when it comes to street design (67), see Table 44. A well-connected street network encourages walkability as well as social and economic exchange with surrounding neighbourhoods. In addition to spatial integration, street intersection density can support voluntary modal shifts to walking, cycling, and transit when street networks are transformed or extended (53). An example of calculating street intersection density is given in Figure 36.

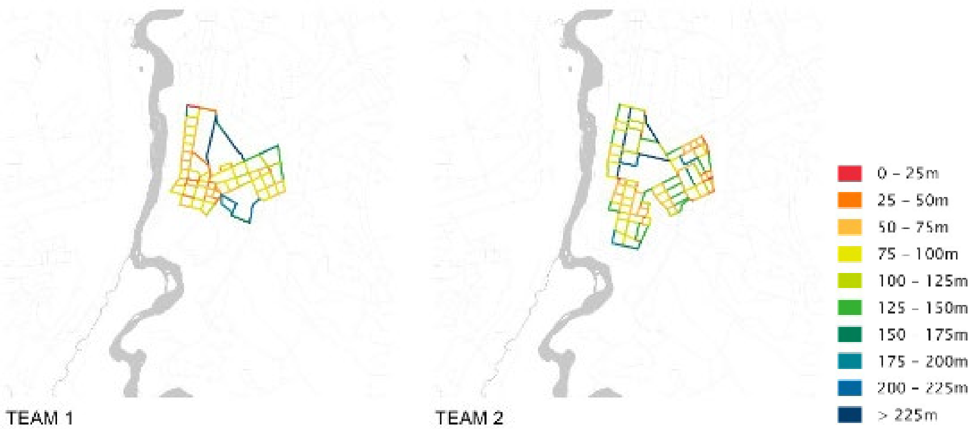


Figure 36. Calculated street intersection density for two plan proposals within the ZEN pilot area Sluppen (55).

Table 44. Summary for calculating KPI URB4.9

URB4.9	**Street intersection density**
Objective	To provide conditions that stimulate walking and cycling as well as increase traffic safety based on traffic calming effects. Intersection density is a measure of "network-grid-size" that influences origin-destination distances for multi-purpose trips and is therefore important for achieving neighbourhoods of short distances.
Description	Distance between pedestrian crossings along streets with vehicle traffic (not including pedestrian streets or walkways).
Method	Based on a map of the street network. Lengths between pedestrian traffic junctions are measured within the plan area and include the closest junction on all routes out of the plan area. Street intersection density is calculated as the measure of average street length between junctions for the plan area.
Points available	1 point

URB4.9	Street intersection density
ZEN KPI assessment	Points awarded for mean average distance between street intersections: 1 point: < 150 metres 0 points: > 150 metres
Best practice	- Allow for mixed traffic that is convenient for walking and cycling

URB4.10 Walkable and bikeable streets

Walkable and bikeable streets tend to be more common in compact urban developments with high levels of street connectivity due to higher pedestrian movements and better bicycle accessibility, see Table 46. Continuous routes of high quality for cycling characterise many of the best bicycle cities in the world (68). For supporting accessible and competitive public transport, street design should prioritise transit vehicles above private vehicle traffic. Streets that spatially prioritise walking, bicycling and transit are also more transport efficient since more people can move per hour in rush hour traffic than through streets prioritized for cars (69). Criteria for walkable and bikeable streets is listed in Table 45, and an example of walkable and bikeable streets for Nansenløkka, Fornebu is presented in Figure 37.

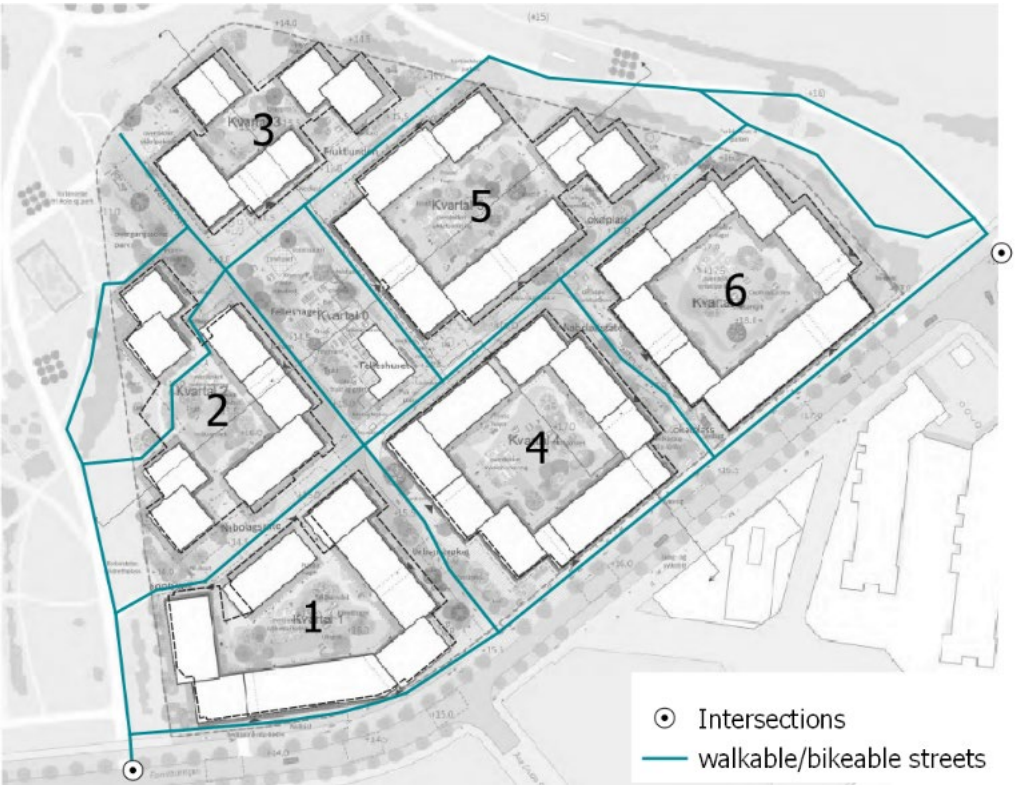


Figure 37. Walkable and bikeable streets at Nansenløkka, the ZEN pilot area at Fornebu (1).

Table 45. Criteria for walkable and bikeable streets (69).

Walkable street	**Walkable intersection**
Pedestrian street or low speed street prioritised for pedestrians (pedestrian street at same height as the road for vehicles).	Clearly prioritised street intersections for pedestrians. Traffic overview not obscured by obstacles.
Or	*Or*
Streets with a speed limit of 30 km/h or more: At least 2.5 metre wide pedestrian lane on a separate height level from vehicles and a marked border towards bicycle lanes.	Intersection with signal less than 4 meters wide. Traffic overview not obscured by obstacles.
Bikeable street	Bikeable intersection
Bicycles in mixed traffic on streets with maximum 30 km/h speed limit and less than 1 500 vehicles per day	Mixed traffic on streets with maximum 30 km/h speed limit and less than 1 500 vehicles per day. Traffic overview not obscured by obstacles.
Or	*Or*
Streets with a speed limit of 30 km/h or more: At least 2 metre wide cycle track clearly separated from vehicles, a marked border towards pedestrians and a minimum buffer of 1 metre towards parked cars.	Intersection with marked space for cyclists. Traffic overview not obscured by obstacles.
Street section space for pedestrian and bicyclists	
At least 50 % of the street section should be prioritised for pedestrians, cyclists, or public transport (tram or bus lane) or green space. If a street or an intersection contains more than one pedestrian or cycle lane (pavement) or one pedestrian or cycle crossing, then the lowest standard is mapped.	

Table 46. Summary for calculating KPI URB4.10

URB4.10	**Walkable and bikeable streets**
Objective	To provide conditions for more walking and cycling while at the same time increasing the potential for a more land use efficient transport system.
Description	Share of street network that is walkable and bikeable.
Method	Based on maps of the plan area, total lengths of all streets and share of streets being convenient and safe for walking and cycling based on the criteria listed in .
Points available	1 point
ZEN KPI assessment	Points awarded for walkable and bikeable streets: 1 point: 100 % of streets within the neighbourhood 0 points: < 100 % of streets within the neighbourhood
Best practice	Characteristics for walkable and bikeable streets (besides *URB4.9 Street intersection density*) include (69): - Measures to prevent high traffic speeds. - Wide pavements. - Wide and separate cycle tracks (if the vehicle traffic volume is high). - Safe intersections. - Provide separate bus lanes and/or protected bus stops.

Green open space

The green open space assessment criteria consists of three KPIs, namely: *URB4.11 Share of green open space, URB4.12 Share of green permeable area* and *URB4.13 Preserving and planting trees.*

URB4.11 Share of green open space

Beside carbon uptake, green infrastructure can also reduce mitigate climate emission by reducing energy need within the building sector (53). Green roofs have been shown to have beneficial effects in stormwater reduction and can also reduce building heating demands (53). If implemented at appropriate scales, green open spaces also have several co-benefits: Preserving and enhancing biodiversity, water quality and supply, air quality, soil fertility, food and wood security, livelihoods, resilience to droughts, heat stress, floods, and other natural disasters. Green open spaces also contribute to recreational qualities, air quality, ecosystem health and human well-being (53).

The share of green open public space is measured as the total ground surface land area within 500 metres air distance (clearly public qualitative green areas that are at least 0.2 hectares (2000m^2) in size), see Table 48. Green open public space is defined as a green outdoor area that is clearly public (physically and mentally accessible to all), permeable (where water can permeate though the soil) and larger than 0,2 hectare. Green spaces smaller than 0,2 hectares and green spaces with unclear boundaries (such as privately owned courtyards with unclear borders between private and publicly owned and managed green space) are not included. Schoolyards can be regarded as green open public space if they are accessible to all after school hours and have more than 50 % permeable green area. Green roofs and facades are not included. Figure 38 shows green open public space within 500 metres for each building within the ZEN pilot area and shows the average values of % green open public space for the existing situation and the planned situation for the ZEN pilot area.

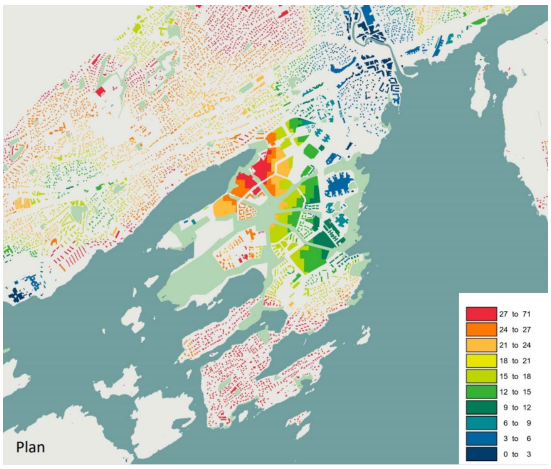


Figure 38. Green open public space within 500 metres for the ZEN pilot area at Fornebu (56).

Table 47. Share of green open public space within 500 meters air distance, average value for plan area

Type of space	Existing - Area (m^2)	Proposed - Area (m^2)
Share of green open public space	19%	20%

Table 48. Summary for calculating KPI URB4.11

URB4.11	**Share of green open public space**
Objective	Green and permeable open public space provide conditions for natural carbon uptake, climate adaption and provide co-benefits regarding people's health and well-being.
Description	The share of green open public space is measured by the share of all land area within the neighbourhood including a buffer area of 500 metres air distance from each building, see Table 49.
Method	Green open public space is calculated by the percentage share of green open public space within a buffer area of 500 meters air distance for each building/block within the neighbourhood. Green roofs and façades are not included in this KPI since these are already covered in .
Points available	2 points
ZEN KPI assessment	Points are awarded for the share of green open public space: 2 points: > 15% 1 point: 10 - 15% 0 points: < 10 %
Best practice	Green open public space includes various options, ranging from: - Moors and forests. - Parks. - Play areas.

URB4.12 Share of green permeable area

Green permeable areas contribute to carbon uptake and preservation and enhancement of biodiversity, water quality and supply, air quality, soil fertility, resilience to droughts, heat stress, floods and other natural disasters as well as contributing to ecosystem health and human wellbeing by air quality (53), see Table 49. Figure 39 gives an example of calculating green permeable area for Nansenløkka, Fornebu.

Figure 39. Green permeable area at Nansenløkka at the ZEN pilot area at Fornebu (59).

Table 49. Summary for calculating KPI URB4.12

URB4.12	Share of green permeable area
Objective	Green and permeable areas provide conditions for natural carbon uptake, climate adaption and provide co benefits on people's health and well-being.
Description	The share of green and permeable area, excluding artificially built-up surfaces with greenery such as green roofs but not limited to areas that are accessible for people, of the total plan area.
Method	GIS mapping or manually measured in Google Maps or other map services and reported in a Table format. Share of green permeable space within the plan area.
Points available	2 points
ZEN KPI assessment	Points are awarded for number of categories: 2 points: > 30% 1 point: 15- 30 % 0 point: < 15%
Best practice	

URB4.13 Preserving and planting trees

Preservation, management and extension of forests and parks is a key issue for cities looking to mitigate climate change due to the potential of trees to store large amounts of carbon on a small piece of land and doing so for a long period of time, see Table 50. Street trees have an especially positive impact on air quality, provide sun shelter and can help balance the urban climate. Street trees can also be used as a tactic for lowering vehicle speed (53). Figure 40 gives an example of reporting the number of trees at

Nansenløkka, Fornebu.

Figure 40. Number of trees at Nansenløkka at the ZEN pilot area at Fornebu (1).

Table 50. Summary for calculating KPI URB4.13

URB4.13	**Preserving and planting trees**
Objective	Trees enhance carbon uptake while providing a variety of co benefits such as air quality, balancing temperature, recreational values, biodiversity, and traffic calming at the same time.
Description	Planting of new trees and care of existing trees should be a central part of the project. An overall plan for preserving existing trees and instructions for planting of new trees.
Method	Mapping of existing trees in GIS or manually measured in Google Maps or other map services.
Points available	1 point
ZEN KPI assessment	Points are awarded for planned strategies for preserving existing and planting of new trees: 1 point: The project includes a plan for preserving existing trees and instructions for planting of new trees 0 points: No plan for preserving existing trees and planting of new trees
Best practice	- Preserve existing trees - Plant native trees

Mobility

Travel behaviour related to a project is the combined result of a range of factors, some of which can be captured in calculations/assessments in the planning phases of a project, and some which cannot. For instance: Demographics of the residents, e.g., in terms of age/occupation, household composition (e.g., with young children) affect the number and types of necessary daily out-of-home activities to be carried out, while the location and distance between residences and the activity-related destinations, combined with the available and realistic travel alternatives for these relations, form the basis for the residents' day-to-day choices of travel behaviour. To add to the complexity, recent development in technology provides a substantial share of the working population with the option to work from home on an occasional or regular basis. Furthermore, climate and topography, car ownership and quality of transport services available vary between regions and urban areas. In order to capture these factors and provide a project-specific baseline required to assess the effects of mobility-related ZEN measures, the following KPIs within the Mobility category should be based on specific project properties, and combined with – if possible – data on travel behaviour representing local conditions (e.g., local samples from the National Travel Survey (NRVU) see ZEN Memo no. 37 (70)), rather than on data describing national averages.

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. Mobility KPIs will be assessed at the neighbourhood assessment boundary level and do not include transport within buildings (e.g., lifts and escalators). Air transport and sea shipping 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., weather) are not explicitly included, but can to some degree be inherent in area-specific travel survey data used for the calculating KPIs. It should be noted that the basic conditions for urban form and land use that relate to sustainable transport patterns and smart mobility systems are addressed within the urban form category.

Assessment Criteria

The mobility category is split into three assessment criteria, namely 'access', 'travel behaviour' and 'logistics'. The access assessment criteria include *MOB5.1 Access to public transport, MOB5.2 Travel time ratio, MOB5.3 Parking facilities* and *MOB5.4 Vehicle ownership.* The travel behaviour assessment criteria include *MOB5.5 Mobility pattern* and *MOB5.6 Passenger and vehicle mileage* whilst the logistics assessment criteria include *MOB5.7 Freight and utility transport.* Results from the process guideline on demographic analyses for parameters such as total number of inhabitants, age distribution and household size should be used as a starting point for the calculation of *MOB5.4 Vehicle ownership, MOB5.5 Mobility pattern* and *MOB5.6 Passenger and vehicle mileage.*

<u>MOB5.1 Access to public transport</u>

Access to public transport considers links to existing and planned transport nodes (such as trains, buses, trams, or metro), as well as links to local city centres, see Table 52. 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 dwellings 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 poor to very good. In an early strategic planning phase, access to public transport can be based on the existing public transport services in the proposed plan area, and distances can be calculated from an estimated centre of gravity within the plan area. The results from the early planning phase can also be used in *URB4.4 Access to a diversity of amenities*. For the implementation and use phases, local NRVU data can be used directly, if available for the ZEN pilot area. If such data is not available, then the procedure described below 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 (NRVU 2018/19 key report (71)), combining the number of departures per hour on weekdays and the distance from home to the station or stop normally used, see . To follow is an explanation of the five-point scale:

1. *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.
2. *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
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. *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.
5. *Very good access:* At least 4 departures per hour and less than 1 km to the station or stop.

Table 51. Access to public transport

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

Table 52. Summary for calculating KPI MOB5.1.

MOB5.1	**Access to public transport**
Objective	To facilitate frequent and easily accessible public transport, as a climate-efficient transport choice in the ZEN pilot area and reduce GHG emissions from *GHG1.5 Operational transport (B8).*
Description	A qualitative variable is calculated based on public transport access on a five-point scale from very poor to very good, based on the distance from the neighbourhood to the station or stop normally used, and frequency of departures from the station or stop.
Method	BREEAM Communities, NRVU
Points available	3 points
ZEN KPI assessment	See Table 51

MOB5.1	**Access to public transport**
Best practice	• Project located within short distance to stops with high-frequency public transport services. • Construction of new stop(s) with high-frequency public transport services close to neighbourhood.

<u>MOB5.2 Travel time ratio</u>

This KPI considers the competitive relationship between private motorised, public transport and active transport options for door-to-door movements between the ZEN pilot area and e.g., the city centre and/or closer local centres or public transport hubs., as demonstrated in Table 53 and Figure 41.

Start ZVB****	Light Rail stop (Birkelandsskiftet)	Kokstad (Kokstaddalen)	Sandsli (Sandslivegen)	Bergen city centre (Byparken)
Car*	**1,0** 11 min	**1,0** 12 min	**1,0** 13 min	**1,0** 29 min
Publ.transp. Basis**	**1,1** 12 min	**1,9** 23 min 1 change	**1,5** 19 min 1 change	**1,7** 49 min 1 change
Publ.transp. ZVB***	**1,1** 12 min	**1,4** 17 min	**1,3** 17 min	**1,7** 49 min 1 change
Bicycles*	**0,8** 9 min	**1,1** 13 min	**1,2** 16 min	**2,1** 60 min
Walk*	**2,8** 31 min	**3,8** 46 min	**4,4** 57 min	-

** Travel times for car, bicycle and walk from bus stop Kartveitskiftet are fetched from Google Maps.*
*** Travel times for Public transport Basis from bus stop Kartveitskiftet are fetched from Skyss.no.*
**** Travel times for Public transport ZVB, with shuttlebuss to/from ZVB, are based on Public transport Basis, adjusted for feeder time and that there will be no need for change en-route to Kokstad and Sandsli. Travel times to Kokstad og Sandsli assumes separate lines/departures for the respective destinations.*
***** Access time from ZVB to bus stop Kartveitskiftet are fetched from Google Maps, and are estimated to 7 minutes for car, Public transport Basis, Public transport ZVB and walk, and 2 minutes for bicycle.*

Figure 41. Estimated travel times and travel time ratios (in bold) for car vs. respectively public transport, bicycle and walk, for ZEN ZVB (70).

Travel time information can be obtained from travel planners such as EnTur and the equivalent offered by various local public transport companies, possibly in combination with information from map-based services such as Google Maps. 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. The KPI should primarily be based on travel times to city centre during morning rush hours. The travel time ratio is calculated for the implementation and use phases, whereby a low ratio factor is desirable, and by using the following formula:

$$\text{travel time}_{\text{public}} \,/\, \text{travel time}_{\text{private motorized}} \qquad [3]$$

$$\text{travel time}_{\text{active}} \,/\, \text{travel time}_{\text{private motorized}} \qquad [4]$$

Table 53. Summary for calculating KPI MOB5.2

MOB5.2	**Travel time ratio**
Objective	To increase the ratio of public and active transport over private motorized transport to reduce GHG emissions relating to *GHG1.5 Operational transport (B8).*
Description	The KPI considers the competition between active modes (bicycle most relevant), public transport, and the private car in an everyday situation with time constraints.

MOB5.2	Travel time ratio
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 services such as Google Maps. The KPI is calculated using formula [3] and [4].
Points available	3 Points
ZEN KPI assessment	Target values are based on ratio factors and will be developed in the next version of the ZEN guideline report.
Best practice	• The shorter the overall distance, the more favourable the conditions are expected to be for active modes (bicycle most relevant) to compete with travel times by private motorised options. • A combination of short distances to public transport stops, high frequency, and high speed for the public transport service, with no need for change of vehicle on route, provides the most favourable conditions for public transport to be able to compete with private motorized vehicles in terms of travel time. • Locating parking spaces for private motorised vehicles at a distance from dwellings, will add to the door-to-door travel time for private motorized options, and hence affect the travel time ratios in a desired direction from a ZEN perspective.

MOB5.3 Parking facilities

This KPI considers the physical facilitation of a resident's vehicle ownership or driving a car in, to and from a neighbourhood, in terms of access to a parking space for the vehicle when not in use, see Table 54. The municipality's parking norm specifies local regulations on how many parking spaces should and can be established for residents or workers and may act as a reference value. In areas with low parking capacity, and/or high costs associated with parking, this may incur restrictions on residents' ability to own a car.

Parking options can be specified as the number of parking spaces available per unit, and type of parking spaces available (handicap, guest, private, shared, car, or bike parking space). 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 safe 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 54. Summary for calculating KPI MOB 5.3

MOB5.3	Parking facilities
Objective	To reduce private vehicle ownership and facilitate for the transition from fossil-fuel to electric private mobility, as well as encourage more active forms of mobility (electric/manual bicycles).
Description	Parking options can be specified as the number of parking spaces available per building unit.
Method	Documentation of the parking norm and planned parking facilities.
Points available	3 points

MOB5.3	**Parking facilities**
ZEN KPI assessment	Target values are based on the percentage reduction in the number of parking spaces compared to parking norms (reference), percentage of parking spaces for electric vehicles and safe parking facilities for bicycle parking. To be developed in the next version of the ZEN guideline report.
Best practice	- Avoid building underground parking facilities for private cars, since underground constructions typically have higher GHG emissions from the materials used in groundworks and foundations. - Reduce the amount of private vehicle parking spaces. Facilitate for *URB4.4 Access to a diversity of amenities, MOB5.1 Access to public transport* and *MOB5.2 Travel time ratio* so that public and active mobility are viable alternatives. - Install electric charging points for cars and bicycles. - Supply safe bicycle parking facilities.

MOB5.4 Vehicle ownership

Vehicle ownership is an important factor for both the extent of travel activity and the use of travel modes, see Table 55. 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 hybrid variants) for the vehicle fleet. In NRVU, vehicle ownership is defined at a household level. 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 55. Summary for calculating KPI MOB 5.4

MOB5.4	**Vehicle ownership**
Objective	To reduce the user's need for private vehicle ownership, which will in turn increase public and active modes of transport and reduce GHG emissions from *GHG1.5 Operational transport (B8).*
Description	The KPI describes user's access to private vehicles. The KPI can be expressed as an average number of privately owned vehicles per household, and/or distribution of households on level with vehicle ownership, from zero to multiple vehicles. The KPI can be further split into categories based on type of energy carrier (e.g., fossil (diesel, petrol), low emission (HVO) and zero emission (electric, hydrogen)).
Method	NRVU
Points available	3 points
ZEN KPI assessment	Points are awarded for the reduction in ratio of cars per household and increase in percentage of cars that are zero- or low emission. To be developed in the next version of the ZEN guideline report.
Best practice	Projects encouraging high share of no-car households and high share of zero-emission vehicles among privately owned vehicles.

MOB5.5 Mobility pattern

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), see Table 56. NRVU can be used directly or in combination with information about *MOB5.3 Parking facilities* and *MOB5.4 Vehicle 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/person/day; number of trips/person/day by mode of transport, and % share of trips by each mode of transport. An example of the estimated distribution of trips according to transport mode, reference and ZEN scenario is presented in Figure 42.

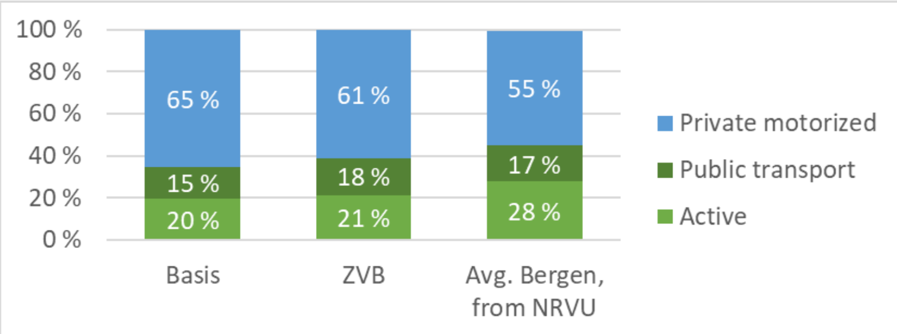


Figure 42. Estimated distribution of trips according to transport mode, reference and ZEN scenario for project, compared to the average in Bergen from NVRU (70).

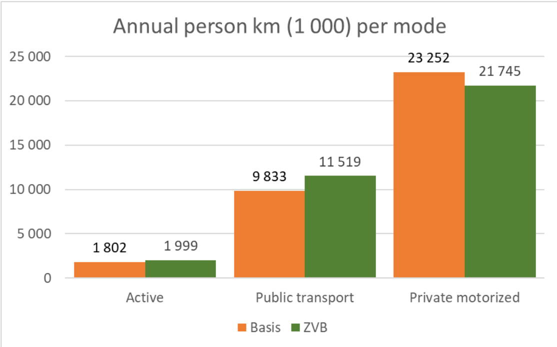
The scope of trips is limited to everyday journeys and does not include vacation or leisure travel. The mobility pattern is calculated for the strategic planning phase and implementation phase and is used as an input for calculating *MOB5.6 Passenger and vehicle mileage* and the process guideline. In the use phase, actual data is used.

Table 56. Summary for calculating KPI MOB5.5

MOB5.5	**Mobility pattern**
Objective	To increase the share of public and active transport and reduce GHG emissions related to *GHG1.5 Operational transport (B8).*
Description	Assessment includes 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 results can be further split into categories based on type of energy carrier (e.g., fossil (diesel, petrol), low emission (HVO) and zero emission (electric, hydrogen)).
Method	NRVU
Points available	3 points
ZEN KPI assessment	Target values for percentage of public, private and active transport. To be developed in the next version of the ZEN guideline report.
Best practice	High share of trips using active modes of zero- or low emission travel alternatives.

MOB5.6 Passenger and vehicle mileage

The calculated trip production and distribution of transport alternatives in *MOB5.5 Mobility pattern* is used together with information about the average distance for the specific combinations of trip purpose and mode of travel for daily travels to calculate the total annual mileage for passengers (person km/year) and private motorised vehicles (vehicle km/year) for the neighbourhood users, see Table 57.



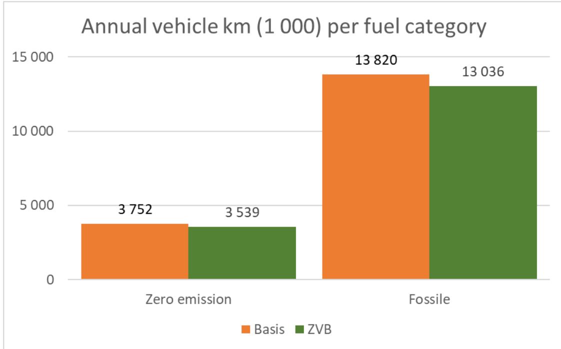


Figure 43. Estimated annual passenger kms by mode (left) and estimated annual private vehicle kms by category energy carrier (right), Basis and ZEN scenario for project (70).

An example of estimated resulting passenger and vehicle mileage is given in Figure 43. Trip lengths my mode can be fetched from NRVU. Vehicle mileage for cars can be split into mileage for fossil (diesel, petrol), low emission (HVO) and zero emission (electric, hydrogen) energy carriers respectively, based on (local) data from the NRVU. The results from this KPI can be used in *GHG1.5 Operational transport (B8)* and the process guideline.

Table 57. Summary for calculating KPI MOB5.6

MOB5.6	**Passenger and vehicle mileage**
Objective	To calculate the total annual mileage for passengers and vehicles, and the vehicle mileage with fossil (diesel, petrol), low emission (HVO) and zero emission (electric, hydrogen) energy carriers respectively.
Description	The KPI can be expressed as total annual mileage for passengers (person km/year) and private motorised vehicles (vehicle km/year) across the neighbourhood users, with a further split of vehicle mileage into mileage for fossil fuels and zero-emission alternatives respectively. The results from this KPI can be used in *GHG1.5 Operational transport (B8).*
Method	NRVU
Points available	3 points
ZEN KPI assessment	Target values for percentage of emission free passenger mileage (pkm) and emission free vehicle mileage (tkm). To be developed in the next version of the ZEN guideline report.
Best practice	Low number of passenger- and vehicle kms conducted using fossil fuels.

<u>MOB5.7 Freight and utility transport</u>

This KPI will be developed in the next version of the ZEN definition guideline and may consider waste transport, centralised package delivery terminals (e.g., post i butikken, matkasse), home office and shared facilities, see Table 58.

Table 58. Summary for calculating KPI MOB5.7

MOB4.7	**Freight and utility transport**
Objective	
Description	
Method	
Points available	2 points
ZEN KPI assessment	
Best practice	

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 will most likely be offset by lower operational costs during the operational phase. Economy KPIs are valid for both the building and neighbourhood assessment boundary level. Economy KPIs are therefore important and relevant as they are included in evaluation frameworks in neighbourhood approaches, such as Sustainable Positive Energy Neighbourhoods (SPENs) (72) and are being developed in research networks such as IEA EBC Annex 83 Positive Energy Districts (2020-2024) Subtask C (73) and COST PED EU NET (2020-2024) (74).

Assessment Criteria

The economy category comprises of two assessment criteria, namely life cycle costs (LCC) and cost benefit. LCC consists of two KPIs, namely *ECO 6.1 Capital costs* and *ECO6.2 Operating costs*, whilst cost benefit consists of one KPI, namely *ECO6.3 Overall performance.* It is recognised that LCC calculations provide a snapshot of costs at that given point in time, and that costs are sensitive to both fluctuating prices and inflation. The goal of the ZEN economy KPIs is to assess the affordability of different GHG emission reduction measures in relation to a reference project (R) to achieve nZEN.

<u>Life cycle costs</u>

LCC is an economic evaluation methodology which is a compilation and assessment of 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: 2013 Life cycle costs for construction works – Principles and classification* (75). *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 is 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 (76). Continual monitoring and optimisation of LCC should continue throughout the project's life cycle.

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 (77)) can also be used as reference values. LCC at the building and neighbourhood assessment boundary levels shall include as a minimum '1 Acquisition and residual costs' and '5 Supply costs: 51 Energy' from Table 2 of Cost classifications in *NS 3454: 2013* (75).

The reporting units for LCC are aligned with the reporting units in the chapter on *GHG Emissions* and are as follows; Total Norwegian kroner, 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/m² PA/yr) for infrastructure whereby the analysis period is 60 years and the calculation interest rate is 4%. The time period in which LCC calculations are carried out shall be stated.

Cost benefit analysis

The cost benefit assessment criteria are useful to allow ZEN partners to weigh the costs and benefits of implementing zero emission strategies or measures to reach the ZEN aim of reducing direct and indirect GHG emissions towards zero. Such nZEN measures that may be assessed in a cost-benefit analysis between the reference project (R) and ZEN project (Z) include, amongst other measures, choice of energy system, choice of construction method and construction materials (see examples of nZEN measures in the best practice section of the KPI tables for the other ZEN KPIs). The cost benefit analysis can also consider the change in cost and payback times for GHG emission reduction measures or the cost of GHG emissions saved.

ECO 6.1 Capital costs

This KPI captures capital costs calculated according to *NS 3454: 2013* (75), see Table 60. 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 GHG emissions of the ZEN pilot area. Capital costs are seen from the developer's perspective, and shall be calculated according to *NS 3453: 2016 Specification of costs in building projects*, see Table 59 (78). *NS 3453: 2016* is aligned with *NS 3451: 2022 Table of building elements used* in the LCA calculations for ZEN GHG KPIs. It is expected that there will be a higher investment in more energy-efficient and zero emission buildings and infrastructure. This KPI will be assessed at both the building (02 Building) and neighbourhood level (07 Outdoors) and will ascertain costs associated with, amongst other things, the energy system (03 Heating, ventilation, and sanitation and 04 Electric power) and material procurement. Discount agreements between contractors and suppliers are not included.

Table 59. Specification of construction costs NS 3453:2016 (78)

	Type of cost	**Reference Project (R)**	**ZEN project (Z)**
01	Shared costs		
02	Building		
03	Heat, ventilation, and sanitation		
04	Electric power		
05	Telecommunications and automation		
06	Other installatinos		
01 – 06	Building cost		
07	Outdoors		
01 – 07	Contractor cost		
08	General costs		
01 – 08	Construction cost		
09	Special costs		
10	Value added tax (VAT)		
01 – 10	Base cost		
11	Expected addition (incl. VAT)		
01 – 11	Project cost		
12	Uncertainty provision (incl. VAT)		

	Type of cost	Reference Project (R)	ZEN project (Z)
01 – 12	Cost framework		
13	Price regulation (incl. VAT)		
01 – 13	TOTAL		

Table 60. 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 captures 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 GHG emissions of the ZEN pilot area.
Method	Capital costs are calculated according to *NS 3454: 2013 Life cycle costs for construction works – Principles and classification* (75) and *NS 3453:2016 Specification of costs in building projects*, see Table 59. Results are reported in terms of NOK and NOK/m^{2GFA}. As a minimum, all buildings and energy systems within the neighbourhood should be included. The reference project energy system can be based on the reference project developed in the Energy category. Existing areas will have no capital costs, unless changes are being made to the existing area, then the costs associated with the changes being made are to be included.
Points available	6 points
ZEN KPI assessment	The limit and target values will be further developed in future ZEN work.
Best practice	

<u>ECO6.2 Operating costs</u>

This KPI captures annual operating costs, relating to energy use, see Table 61. Operating costs are seen from the building owner's perspective. This KPI will be assessed at both the building and neighbourhood level.

Table 61. 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 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 captures these operational costs.

ECO 6.2	Operating costs
Description	Operating costs refer to capital-related annual costs for those assets or items purchased or implemented for improving GHG emissions of the neighbourhood.
Method	Operating costs are calculated according to *NS 3454: 2013 Life cycle costs for construction works – Principles and classification* (75). Results are reported in terms of NOK and NOK/m^{2GFA}/yr. The reference project energy system can be based on the reference project developed in the Energy category. Existing areas can use current operating costs as a reference. Planned changes to the existing area shall be included in the ZEN project.
Points available	6 points
ZEN KPI assessment	The limit and target values will be further developed in future ZEN work.
Best practice	

ECO6.3 Overall performance

This KPI outlines 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, see Table 62. This set of indicators summarises both the *ECO 6.1 Capital costs* and *ECO6.2 Operating costs* in terms of:

- ***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 DIGDIR's guide for public buildings (79).
- ***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, which means 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.
- ***Cost of GHG emissions saved***: To be further developed in future ZEN work.

Table 62. 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 LCC.
Method	Calculate the net present value, annual cost, payback period and cost of GHG emissions saved based on the results from *ECO 6.1 Capital costs* and *ECO6.2 Operating costs.*
Points available	8 points

ECO 6.3	Overall performance
ZEN KPI assessment	The limit and target values will be further developed in future ZEN work.
Best practice	

Limitations and Further Work

This is the third version of the ZEN definition guideline report. It builds upon the ZEN definition report and ZEN definition guideline report series 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 scope for further work, which will be covered in future editions of the ZEN definition guideline report. During the next period, the ZEN definition guideline working group will complete the following activities:

- **Testing and evaluation of assessment criteria and KPIs in all ZEN pilot projects**: All ZEN pilot areas shall select ZEN assessment criteria and KPIs to be tested and evaluated. Knowledge gained from this testing shall be used to evaluate reference values 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 the further development of setting limit and target values after testing and evaluating assessment criteria and KPIs in pilot project against reference projects and reference values.
- **ZEN KPI tool**
    - **Data collection and documentation**: Develop a transparent ZEN KPI tool for data collection, monitoring, evaluation, and documentation.

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Appendix A: 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>

<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>60 Other installation, general</td><td colspan="10" rowspan="9"></td><td rowspan="9"></td><td colspan="6" rowspan="9"></td></tr>
<tr><td>61 Prefabricated unit</td></tr>
<tr><td>62 Passenger and goods transport</td></tr>
<tr><td>63 Transport facilities for small goods</td></tr>
<tr><td>64 Stage equipment</td></tr>
<tr><td>65 Waste and vacuum cleaning</td></tr>
<tr><td>66 Fixed furniture</td></tr>
<tr><td>67 Loose furniture</td></tr>
<tr><td>69 Other</td></tr>
<tr><td>7 Outdoor, general</td><td colspan="10" rowspan="10">Level 3: Infrastructure</td><td rowspan="10"></td><td colspan="6" rowspan="10">Level 3: Infrastructure</td></tr>
<tr><td>71 Adapted terrain</td></tr>
<tr><td>72 Outdoor construction</td></tr>
<tr><td>73 Outdoor heating, ventilation and sanitation</td></tr>
<tr><td>74 Outdoor electric power</td></tr>
<tr><td>75 Outdoor tele and automation</td></tr>
<tr><td>76 Roads and courtyards</td></tr>
<tr><td>77 Parks and gardens</td></tr>
<tr><td>78 Outdoor infrastructure</td></tr>
<tr><td>79 Other</td></tr>
<tr><td>Total</td><td colspan="17">Level 4: Neighbourhood</td></tr>
<tr><td>Biogenic carbon</td><td colspan="17">To be reported separately for each life cycle module where the carbon sequestration or release occurs and separately from the rest of the results.</td></tr>
<tr><td>LULUC</td><td colspan="17"></td></tr>
</table>

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