Research Centre on
ZERO EMISSION
NEIGHBOURHOODS
IN SMART CITIES

NTNU SINTEF

THE ZEN DEFINITION – A GUIDELINE FOR THE ZEN PILOT AREAS

VERSION 1.0

ZEN REPORT No. 11 – 2018

Wiik, Fufa, Baer, Sartori and Andresen | SINTEF / NTNU

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ZEN Report No. 11

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Keywords: GHG Emissions, Energy, Power, Mobility, Economy, Spatial qualities
ISBN 978-82-536-1608-7

Norwegian University of Science and Technology (NTNU) | www.ntnu.no
SINTEF Building and Infrastructure | www.sintef.no

https://fmezen.no

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 optimising local energy systems and their interaction with the larger system;
- Create and manage a series of neighbourhood-scale living labs, which will act as innovation hubs and a testing ground for the solutions developed in the ZEN Research Centre. The pilot projects are Furuset in Oslo, Fornebu in Bærum, 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 for eight years (2017-2024), and the budget is approximately 380 million Norwegian kroners, 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 includes the names of the authors that have contributed the most to the various fields:

GHG Emissions: Marianne Kjendseth Wiik (SINTEF) and Selamawit Mamo Fufa (SINTEF).
Energy: Igor Sartori (SINTEF) and Inger Andresen (NTNU).
Power/Load: Igor Sartori and Inger Andresen.
Mobility: Selamawit Mamo Fufa, Michael Klinski (SINTEF) and Daniela Baer (SINTEF).
Economy: Selamawit Mamo Fufa, Michael Klinski and Marianne Kjendseth Wiik.
Spatial Qualities: Daniela Baer, Brita Fladvad Nielsen (NTNU), and Taru Uusinoka (NTNU).

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

Sammendrag

Hensikten med denne rapporten er å gi en veiledning til hvordan de ulike vurderingskriteriene og nøkkelindikatorene i ZEN definisjonen (klimagassutslipp, energi, effekt, mobilitet, økonomi, og stedskvaliteter) kan vurderes og følges opp i ZEN pilotprosjekter. Rapporten gir en beskrivelse av relevante evalueringsmetoder, og gir en oversikt over data som er nødvendig for å gjøre evalueringene. Videre gir rapporten en kort beskrivelse av pilotområdene i ZEN, med tilhørende hovedutfordringer. Målgruppen for veilederen er aktører som er involvert i planlegging og utvikling av ZEN pilotområder, samt andre som er interessert i dette området. Denne første versjonen av en veileder for ZEN pilotområder viser også begrensninger og utfordringer mht. til videre arbeid, som vil bli adressert i fremtidige utgaver av rapporten.

Abstract

The objective of this report is to provide a guideline for how the assessment criteria and key performance indicators (KPIs) covered under each category of the ZEN definition (GHG emissions, energy, power/load, mobility, economy and spatial qualities) may be assessed and followed up in ZEN pilot projects. The guidelines explain relevant evaluation methodologies, focusing on what types of data that could be used to access the criteria and KPIs, how these data could be collected, and how the fulfilment of the KPIs could be documented. Furthermore, the guidelines illustrate briefly the ZEN pilot projects and main challenges identified in their development. The target group of the ZEN definition guideline is the different actors involved in ZEN pilot projects and other interested parties in the field. This first version of the ZEN guideline report highlights the limitations and scope for further work, which will be addressed in future editions of the ZEN definition report.

Contents

1 Introduction

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

To reach this goal, there is a need for the following:

1. A clear definition of the goal, i.e. what is a zero emission neighbourhood
2. Key performance indicators, which will help to plan and design the neighbourhood and to monitor its actual performance,
3. Tools to monitor the performance of a planned or existing neighbourhood with different ambition levels (equivalent to the ZEB tool),
4. A guideline for how the definition of ZEN and its KPIs could be assessed and implemented into the planning, design, construction, and operational phases of planned and existing neighbourhoods (ZEN pilot projects).

This guideline focuses on the 4th point.

The ZEN Centre is organized in six work packages (WP) (Figure 1.1). The ZEN definition and the related KPIs are developed in WP 1 and are published in a separate report [1]. The aim of the ZEN definition guideline developed under WP6 is to describe the KPIs in more detail and deliver first ideas on how the categories of the ZEN definition could be assessed and followed up in the pilot projects. This will include a suggestion of how to collect data and how to document KPI results.

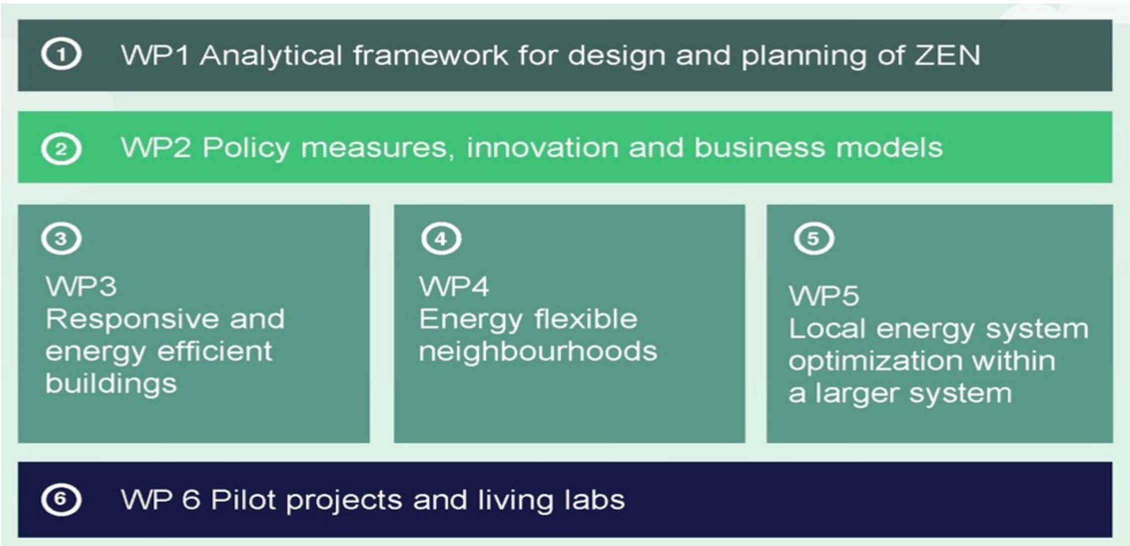


Figure 1.1. Work packages within the ZEN Centre

1.1 Sustainability assessment of neighbourhoods

An overview of existing neighbourhood sustainability assessment tools can be found in Table 1.1 [2], while an overview of the most prominent neighbourhood sustainability assessment schemes and assessment criteria is given in Table 1.2. A comprehensive review of the 'state of the art' of multi criteria/scale tools, human computer interfaces (HCI), and emerging technologies for use in the development of the different tools are included in a report from ZEN Work Package 1 (in progress). In Work Package 1, promising tools and technologies will be evaluated and compared to assess the potential for integration in the development of the ZEN toolbox for use in selected ZEN pilots. A guideline for the application of the tools will be incorporated in future editions of the ZEN definition guideline report.

Table 1.1. An overview of existing neighbourhood sustainability assessment tools [2].

Neighbourhood sustainability assessment tool	**Country of Origin**	**Developers**
LEED-ND	US	USGBC, CNU, NRDC
Enterprise Green Community	US	Enterprise Partners
Green Land Development	US	Home innovation research labs
BREEAM Communities	UK	Building Research Establishment
One Planet Communities	UK	BioRegional
CASBEE-UD	Japan	Japan Green Building Council
EarthCraft Communities (ECC)	US	Greater Atlanta Home Builders Association
DGNB for Urban Development	Germany	German Sustainable Building Council
Green Star Communities	Australia	Green Building Council of Australia
GSAS for Districts	Qatar	Gulf Organization for Research and Development
Green Mark for Districts	Singapore	Building and Construction Authority
GBI Township	Malaysia	Malaysian Institute of Architects, Association of Consulting Engineers Malaysia
Neighbourhood Sustainability Framework	New Zealand	Beacon Pathway
HQE2R	France	CSTB
ECOCITY	EU	EU Research project
Green Townships	India	Indian Green Building Council
Aqua for Neighbourhoods	Brazil	Vanzolini Foundation, Certivea, HQE
Pearl Community for Estidama	UAE	Abu Dhabi Urban Planning Council
BEAM Plus Neighbourhood	Hong Kong	Hong Kong Green Building Council
EnviroDevelopment	Australia	Urban Development Institute of Australia
BERDE for Clustered Developments	Philippines	Philippine Green Buildings Council

Table 1.2. Assessment criteria in existing neighbourhood sustainability assessment tools [2]. The percentages signify the weight of the different categories in the overall assessment.

CATEGORY	CRITERIA	LEED-ND	BREEAM-communities	DGNB-NSQ	CASBEE-UD	Pearl Community
Location and site selection		18%	4%	3%	0%	1%
Transportation	Connectivity to public transportation, connectivity to bike lane, pedestrian friendliness, private car, parking etc.	6%	11%	9%	7%	4%
Infrastructure and design	Design principles, mixed use, compact development, green infrastructures, heat island	34%	14%	31%	30%	25%
	Innovation	5%	0%	0%	0%	1%
Environment, ecology and resource efficiency	Water Energy Materials, resource conservation, waste management, Biodiversity, nature and microclimates	3% 5% 2% 5%	4% 4% 8% 15%	2% 6% 5% 11%	4% 11% 6% 21%	23% 15% 14% 9%
Social-cultural quality	Safety, well-being, quality of life, sound emission, affordable housing, inclusive communities, social networks and infrastructure, heritage	17%	16%	12%	19%	6%
Economic quality	Local economy, employment and local jobs, business, investments.	5%	15%	15%	1%	0%
Institutional		0%	9%	6%	1%	1%

1.2 Experiences from the research centre on zero emission buildings

From 2008 to 2016, the research centre for Zero Emission Buildings (ZEB Research Centre) was operational. The ZEB Research Centre developed a Norwegian ZEB definition, and a Norwegian ZEB definition guideline for assessing GHG emissions relating to zero emission buildings [3-5]. The Norwegian ZEB definition guideline considers a range of ZEB ambition levels, from ZEB-O÷EQ to ZEB-COMPLETE:

1. **ZEB-O÷EQ:** Emissions related to all energy use for operation "O", except energy use for equipment and appliances (EQ), shall be compensated for with renewable energy generation. The definition of O÷EQ therefore includes operational energy use, except energy use for equipment and appliances (B6*), as outlined in NS-EN 15978: 2011 [6].

2. ZEB-O: Emissions related to all operational energy "O" shall be compensated for with renewable energy generation. The O includes all operational energy use (B6), according to NS-EN 15978: 2011 [6].
3. ZEB-OM: Emissions related to all operational energy "O" plus embodied emissions from materials "M" shall be compensated for with renewable energy generation. The M includes the product phase of materials (A1 – A3) and scenarios for the replacement phase (B4), according to NS-EN 15978: 2011 [6]. Note that B4 in ZEB-OM considers only scenarios related to the production of materials used for replacement. The transportation (A4), installation (A5), and end of life processes for replaced materials are not included in B4.
4. ZEB-COM: This is the same as ZEB-OM, but also takes into account emissions relating to the construction "C" phase. The phases included in C are transport of materials and products to the building site (A4) and construction installation processes (A5), according to NS-EN 15978: 2011 [6]. Note that B4 in ZEB-COM is expanded to include the transportation (A4) and installation process (A5) of replaced materials. The end of life processes of replaced materials is not included in B4.
5. ZEB-COME: This is the same as ZEB-COM, but also takes into account emissions relating to the end of life "E" phase. The end of life phase includes deconstruction/demolition (C1), transport (C2), waste processing (C3), and disposal (C4), according to NS-EN15978: 2011 [6]. Similarly, the end of life processes of replaced materials in B4 are to be included and taken to an end of waste state.
6. ZEB-COMPLETE: Emissions related to a complete lifecycle emission analysis have to be compensated for, namely all phases: product stage (A1 - A3), construction process stage (A4 – A5), use stage (B1 – B7), and end of life stage (C1 - C4). If relevant and available, benefits and loads beyond the system boundary (D) can be included as additional information, according to NS-EN15978: 2011 [6].

A simplified illustration of the ZEB emission balance is shown in Figure 1.2. The ZEB methodology was used in seven pilot building projects developed in the ZEB Research Centre, as well as in two concept studies, namely:

A single-family house concept building [7, 8], the Multikomfort house in Larvik [9], the Living Laboratory in Trondheim [10-12], an office concept building [13, 14], Powerhouse Kjørbo in Sandvika [15-17], the administration and educational building at Campus Evenstad [18, 19], the Visund office building at Haakonsvern, Bergen, five dwellings at Skarpnes, Arendal, and Heimdal high school in Trondheim [20]. These buildings cover a range of typologies (residential, office, and school buildings). An overview of the ZEB emission balance for some of ZEB buildings is shown in Figure 1.3.

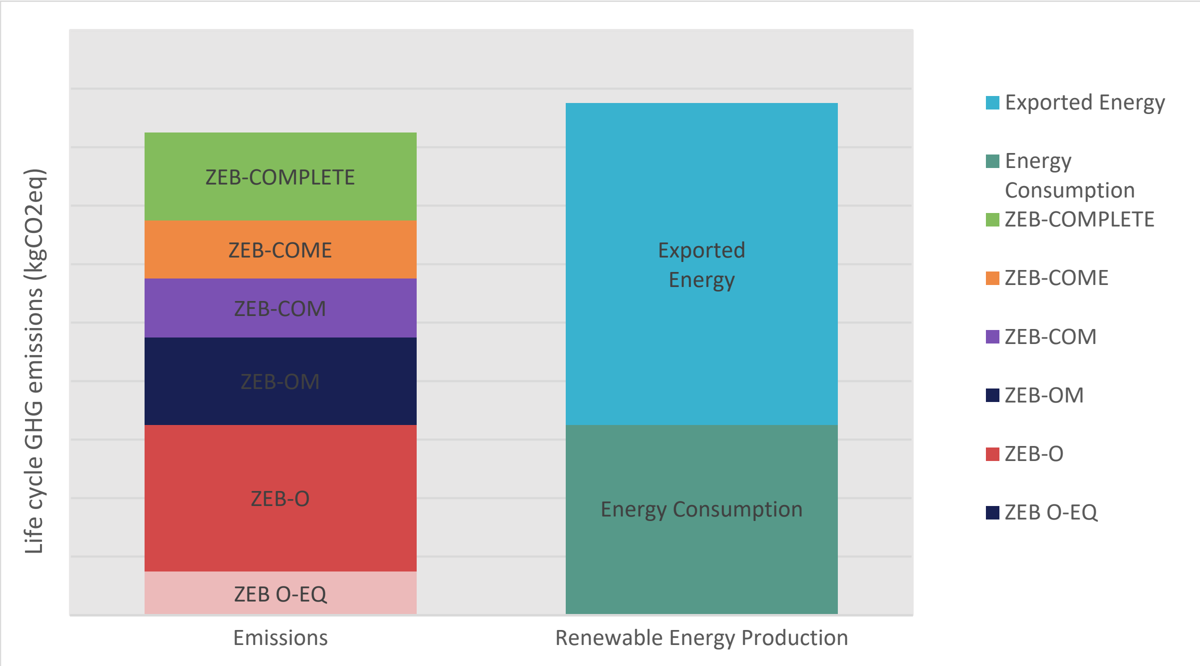


Figure 1.2. Compensation of emissions from operational energy use (O), materials (M), construction (C), end-of-life (E), and the use phase (PLET) in zero emission buildings (ZEB) from local, renewable energy generation [4].

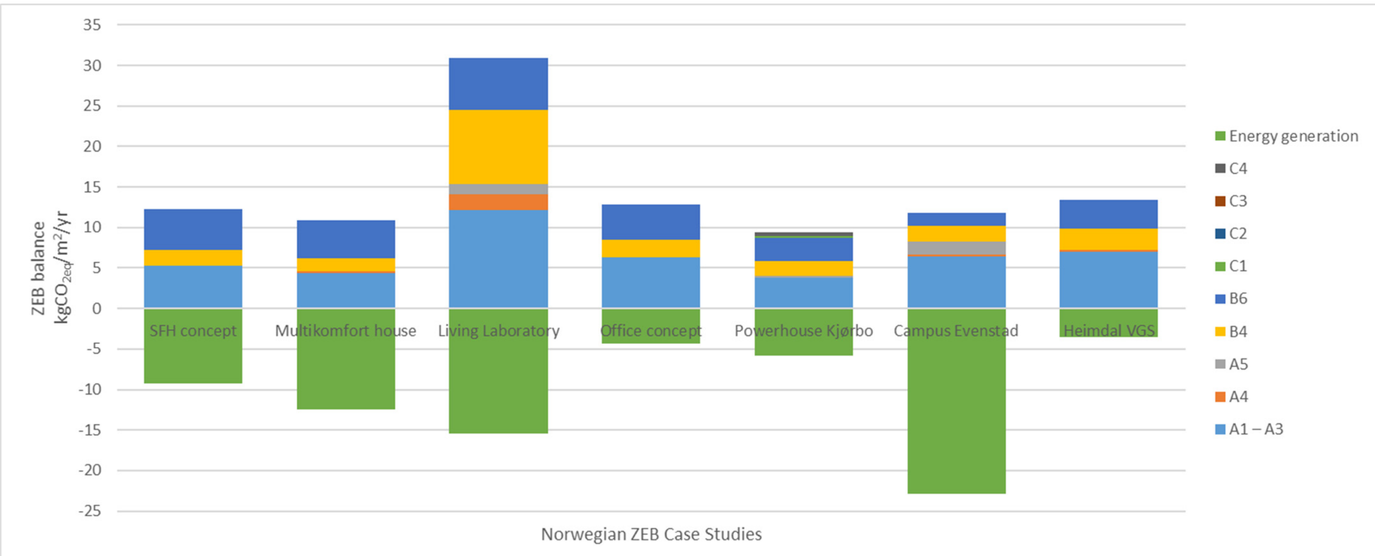


Figure 1.3. ZEB balance for each ZEB building per life cycle module [21].

The method and experiences from the Norwegian ZEB Research Centre are an important development for the field of GHG emission calculations of buildings in Norway [21]. Lessons learnt from the Norwegian ZEB Research Centre on methodological choices have been incorporated into NS 3720 'Method for GHG calculations for buildings'. Ambition level definition and lessons learnt on GHG emission reduction measures (such as design and material choices) will be transferred to the ZEN Research Centre. In the ZEN Centre's definition report, it is stated that a zero emission neighbourhood should have a defined ambition level with respect to which life cycle modules and building and infrastructure elements to include. For the time being, it is up to the owner of a ZEN project to unambiguously define ambition level in accordance with the modulus principle of NS-EN 15978 and NS 3720. In the ZEN Centre, further work will be carried out to clarify ambition level definition, what should be the recommended minimum ambition level for ZEN pilot projects, and how to calculate GHG emission gains from local renewable energy production [1].

1.3 The ZEN definition guideline report

This report is a first draft for discussion and further development of the criteria and guidelines. The guidelines described in this report follows up the ZEN definition report. From the very start, it has been important to involve ZEN partners and stakeholders to participate in the formation of the ZEN definition. This has been achieved through workshops and discussions parallel to the development of the ZEN definition. The ZEN guideline has been developed in parallel with the ZEN definition work. A description of the main process used to develop the ZEN Research Centre's definition of a zero emission neighbourhood is given in Appendix 1.

Over the duration of the ZEN Centre, a ZEN design and planning toolbox will be developed (Figure 1.4). This toolbox is developed to help plan, design, and visualise the performance of ZEN pilot projects in various project phases.

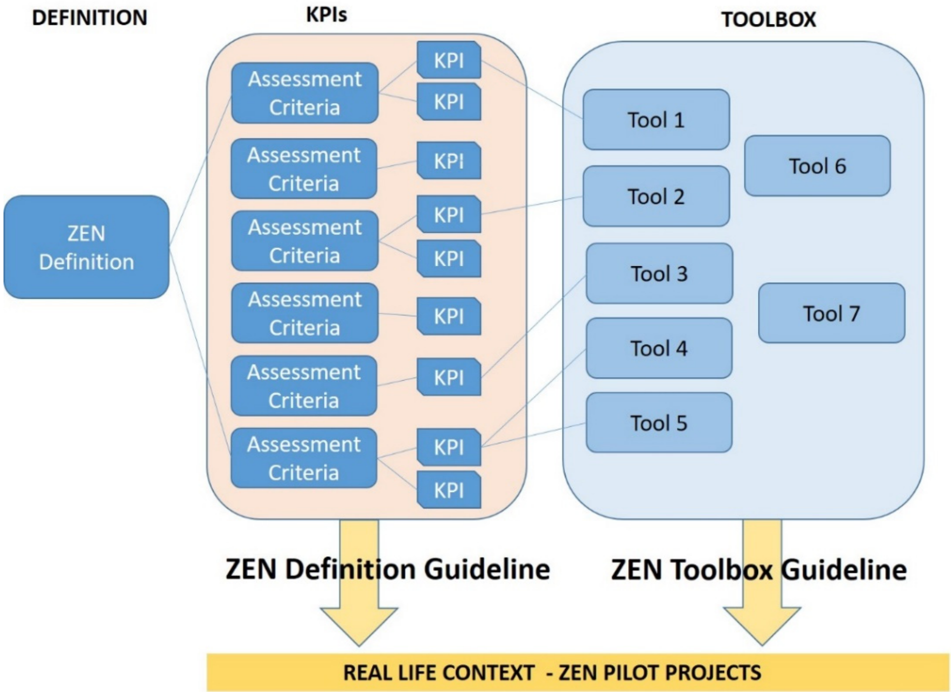


Figure 1.4. The relationship between ZEN definition, ZEN definition guideline, ZEN toolbox, and ZEN toolbox guideline.

Future work will focus on how tools can be used to plan, design, analyse, monitor, and visualise the criteria and KPIs at different project phases and engage stakeholders responsible for delivering data on KPIs (Figure 1.5). This assessment must be done regarding the different phases for ZEN development and the scopes covered by a ZEN development.

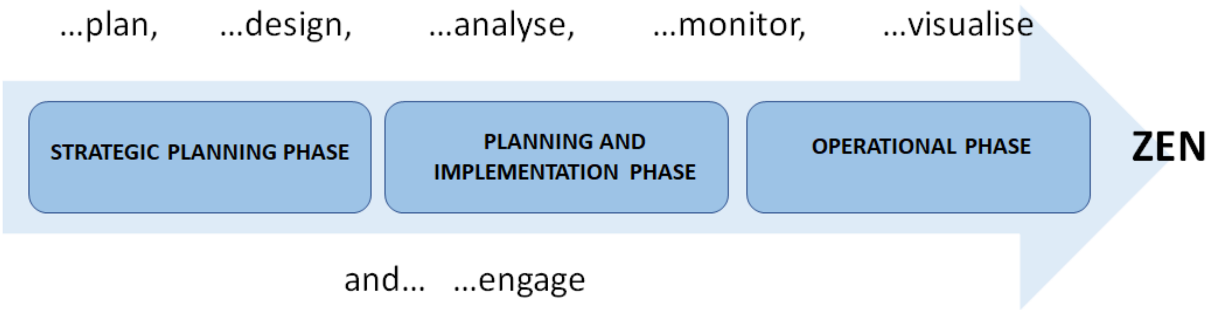


Figure 1.5. Use of tools during different project phases.

To follow, **Chapter 2** presents an overview of existing neighbourhood assessment tools as well as a summary of ZEB ambition levels. This is to highlight the new approach that the ZEN Centre is taking compared to existing neighbourhood assessment schemes. On the other hand, the ZEB ambition levels are presented to show an example of how ambition levels of GHG emissions of buildings have been applied previously.

Chapter 3 presents the different categories of the ZEN definition with their assessment criteria and KPIs. This includes detailed descriptions of the assessment criteria and KPIs and first guidelines on how to assess and document them.

Chapter 4 provides a general overview of ZEN pilot projects, the differences between different pilot projects, and the main challenges identified in their development.

Chapter 5 presents an overview of the limitations of the ZEN definition guideline report and the scope for further work on the ZEN definition guideline.

2 Definitons

2.1 Definition of ZEN

The Zero Emission Neighbourhood definition is being developed under a separate work task within the ZEN Research Centre, and the definition work will be an ongoing process throughout the programme period (2017 – 2025), as different specifications and solutions in the different work packages and pilot projects are tested and evaluated. The following ZEN definition was formulated for the first version of the ZEN definition report [1]:

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

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

Footnotes:

1) Buildings can be of different types, e.g. new, existing, retrofitted or a combination. Infrastructure includes grids and technologies for supply, generation, storage and export of electricity and heat. Infrastructure may also include grids and technologies for water, sewage, waste, mobility, and ICT.
2) The area has a defined physical boundary to external grids (electricity and heat, and if included, water, sewage, waste, mobility, and ICT). However, the system boundary for analysis of energy facilities serving the neighbourhood is not necessarily the same as the geographical area.
3) The analysis period is normally 60 years into the future, assuming 60 years service life of buildings and 100 years service life of infrastructure and relevant service life for components that will be replaced.
4) The standard NS-EN 15978 "Sustainability of construction works - Assessment of environmental performance of buildings - Calculation method" and the proposed new standard NS 3720 "Methods for greenhouse gas calculations for buildings", defines a set of life cycle modules; material production (A1-A3), construction (A4-A5), operation (B1-B7 in NS-EN 15978 and B1-B8 in NS 3720), end-of-life (C1-C4), and benefits and loads beyond the system boundary (D). NS 3451 "Table of building elements" provides a structured nomenclature checklist of building elements which can be used to define the physical system boundary. A given zero emission neighbourhood should have a defined ambition level with respect to which of these life cycle modules to include, and which building and infrastructure elements to include. It is up to the owner of a ZEN project to decide such an ambition level, but this should be unambiguously defined according to the modulus principle of NS-EN 15978 and NS 3720. In the FME-ZEN Centre, further work is carried out to clarify what should be the recommended minimum ambition level for ZEN pilot projects. Further work is done to clarify how to calculate CO2 emission gains from local renewable energy production, and the FME-ZEN does not currently bind to the method of emission calculations in NS-EN 15978 and NS 3720.Flexibility should facilitate the transition to a decarbonized energy system**,** low peak load capacity requirements in external grids and flexible energy exchanges with facilities in the surrounding area.
5) Flexibility should facilitate the transition to a decarbonized energy system and reduction of power and heat capacity requirements.

2.2 What makes up a neighbourhood?

A neighbourhood is characterized by a combination of geographic (place-oriented) and social (people-oriented) components. However, the spatial boundaries of a neighbourhood cannot always be clearly defined. It may be a territorially defined administrative unit of a city, an area of study/application whose demarcation is made from a contextual perspective, or an area within which the residents identify themselves and develop a sense of responsibility [22]. Within the ZEN Research Centre, a topic for discussion is how to demarcate spatial boundaries suitable for each category identified in the ZEN definition, such as emissions, energy, power/load, economy, mobility, and spatial qualities.

Previous research has shown that several different characteristics can be used to describe and set the boundaries of a neighbourhood [23], such as:

- Structural characteristics of the residential and non-residential buildings: type, scale, materials, design, state of repair, density, landscaping, etc.
- Infrastructural characteristics: roads, sidewalks, streetscaping, utility services, etc.
- Demographic characteristics of the resident population: age distribution, family composition, racial, ethnic, and religious types, etc.
- Class status characteristics of the resident population: income, occupation, education, composition, etc.
- Tax/public service characteristics: safety, public schools, public administration, parks and recreation.
- Environmental characteristics: land, air, water and noise pollution, topographical features, views, etc.
- Proximity characteristics: access to major destinations of employment, entertainment, shopping, etc.
- Political characteristics: the degree to which local political networks are mobilized, residents exert influence in local affairs through spatially rooted channels or elected representatives.
- Social-interactive characteristics: local friend and kin networks, degree of inter-household familiarity, type, and quality of interpersonal associations, residents' perceived commonality, participation in locally based voluntary associations, strength of socialization, and social control forces, etc.
- Sentimental characteristics: residents' sense of identification with place, historical significance of buildings or district, etc.
- Functionality: residential, offices, commercial, industry, schools, hospitals, mixed-use etc.

Nevertheless, neighbourhoods are mainly understood in a geographical context, as a group of buildings within a defined proximity to each other [24], while other studies put buildings as the immediate spatial connection to the urban block level [25]. This means that a neighbourhood consists of more than just buildings. Figure 2.1 shows how the neighbourhood can be understood in a framework of different spatial levels, with the neighbourhood at the meso level between the city (macro level) and building levels (micro level) [24]. The neighbourhood level itself may be divided into several spatial elements. Gothenburg city planning department divides the neighbourhood into public space, street space, and blocks (consisting of buildings and courtyards) as shown in Figure 2.2 [26].

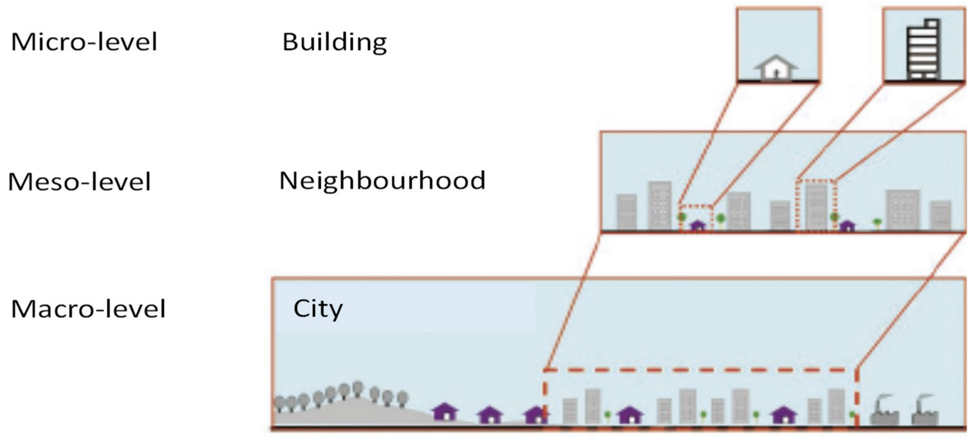


Figure 2.1. Identification of the neighbourhood, illustration based on CASBEE [24].

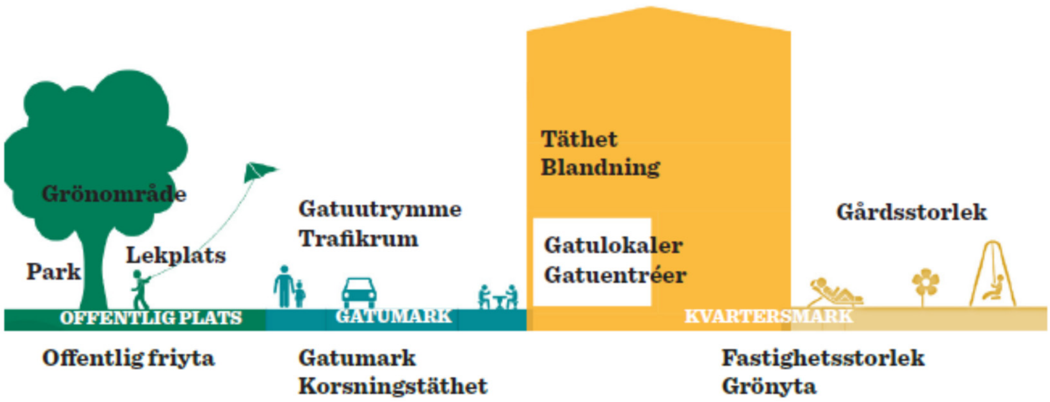


Figure 2.2. Identification of the neighbourhood, illustration from Gothenburg city planning department [26].

In the ZEN Research Centre, a neighbourhood is defined as a group of interconnected buildings (which can be of different types, e.g. new, existing, retrofitted, or a combination) with associated infrastructure (which includes grids and technologies for supply, generation, storage, and export of electricity and heat, and may also include grids and technologies for water, sewage, waste, mobility, and ICT), located within a confined geographical area. The area has a defined physical boundary to external grids (electricity and heat, and if included, water, sewage, waste, mobility, and ICT). However, the system boundary for analysis of energy facilities serving the neighbourhood is not necessarily the same as the geographical area. The system boundary for each ZEN pilot area is also dependent on the case and may vary accordingly.

2.3 Assessment criteria and key performance indicators

In the ZEN Research Centre's definition report, assessment criteria and key performance indicators are given. While we divide the ZEN definition into seven categories (GHG emissions, energy, power/load, mobility, economy, and spatial qualities), each of these categories is divided into several assessment criteria. The assessment criteria are then divided into several key performance indicators (KPIs) (see Figure 2.3).

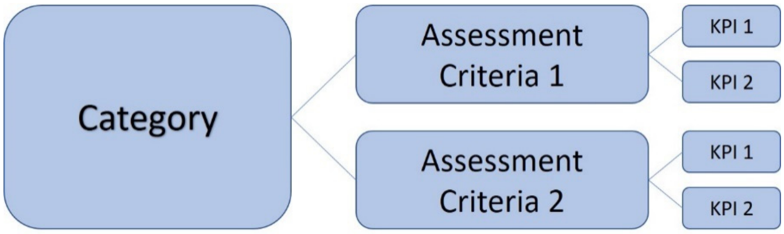


Figure 2.3. System of category, assessment criteria, and KPIs within the ZEN definition guideline.

Assessment Criteria are requirements that name different aspects within a category which are important to assess the performance of a neighbourhood within the category. Assessment criteria may be interconnected (that means the fulfilment of one criterion depends upon the fulfilment of another). Each assessment criterion is assessed by one or several KPIs.

Key performance indicators (KPI) are sets of quantifiable performance measurements that define sets of values based on measured data from a project, making it easier to measure and track the neighbourhood's performance over time and against other similar projects [27]. Having a KPI does not mean that there must be a target, or value that has to be reached. Those would be "requirements", "benchmarks", or "ambition levels".

ZEN assessment criteria and KPIs are described in detail under Chapter 3.

Translation of some of the main terminology
used in the ZEN definition guideline from English to Norwegian

Zero emission neighbourhood – Nullutslippsområde
Assessment criteria – Vurderingskriterier
Key Performance Indicator – Nøkkelindikatorer

2.4 Pilot projects

In the context of the ZEN Research Centre, pilot projects are geographically limited (primarily urban) areas in Norway where new solutions for the construction, operation, and use of buildings are tested to cut the total greenhouse gas emissions to zero on a neighbourhood scale. ZEN pilot projects will function as role models, inspiring others to build zero emission neighbourhoods and offering explanations about how the best possible results can be achieved. It is acknowledged that various stakeholders will have different influences on the ZEN pilot area at different times during the development of the area. In all, nine ZEN pilot areas are included in the ZEN Research Centre, namely:

- Ydalir, Elverum
- Furuset, Oslo
- Campus Evenstad
- Lø, Steinkjer (former NRK site)

- Knowledge Axis, with NTNU Campus
- Knowledge Axis, withSluppen, Trondheim
- Zero Village Bergen
- Nyby, Bodø
- Fornebu, Bærum

More details on the ZEN pilot areas can be found in Chapter 4 of this report.

2.5 Project phases

During its lifetime, a neighbourhood will go through many project phases. So far, we have limited the number of project phases to be assessed in the ZEN Research Centre to six phases [28]. These project phases include the following:

1. Planning phase
2. Brief and preparation phase
3. Early design phase
4. Detailed design phase
5. Construction phase
6. Operational phase

The project phases are depicted in Figure 2.4. NB: The implementation phase consists of the brief and preparation phase, the early design phase, the detailed design phase and the construction phase.

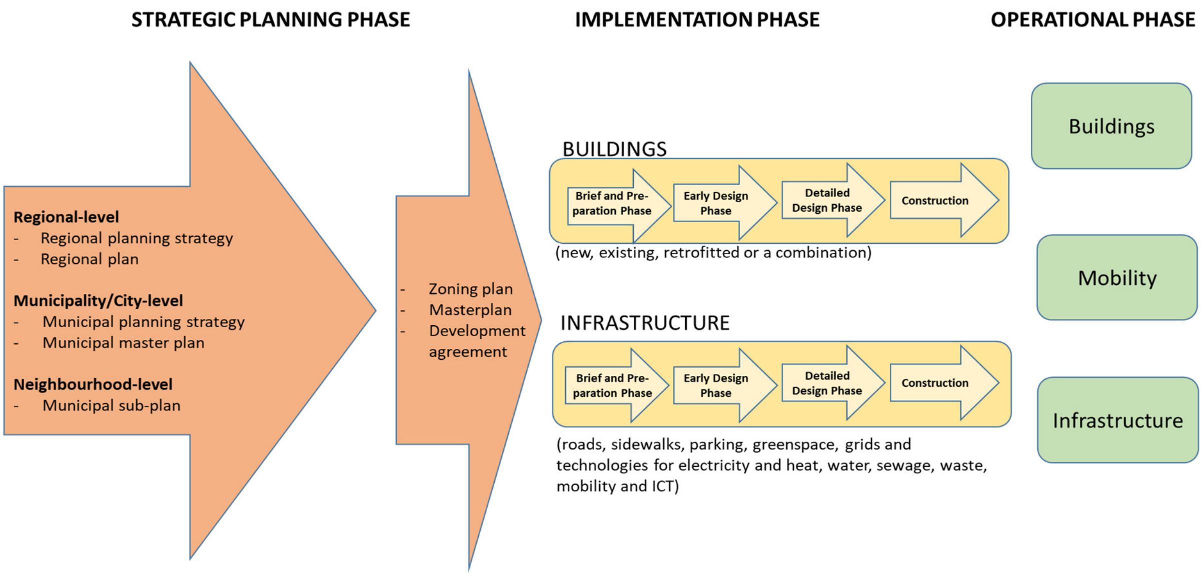


Figure 2.4. Project phases (illustration, Daniela Baer).

In addition, there will be a reference project for each ZEN pilot project that will act as a base case for comparison. More details on reference projects can be found in Chapter 3 of this report, which explains the operationalisation of the ZEN definition key performance indicators and assessment criteria. A Norwegian translation of project phases can be found in the blue text box. It should be noted that the project phases outlined above are part of a fluid process, and there may be some degree of overlap between the different phases.

Translation of some of the main terminology used in the ZEN definition guideline from English to Norwegian

Phase of development - Utbyggingstrinn
Project phases - Prosjektfaser
Planning phase – Planleggingsfase
Brief and preparation phase - Programmering
Early design phase - Skisseprosjekt/forprosjekt
Detailed design phase – Detaljprosjekt
Construction phase - Byggefase
Operational phase - Driftsfase
Reference project - Referanseprosjekt

PLANNING PHASE

The planning phases are divided into a strategic planning phase on the regional and municipal level, while the planning and implementation phase consists of planning on the neighbourhood level as e.g. the zoning plan [29]:

Regional
- Regional planning strategy
- Regional plan

Municipal
- Planning Programm
- Municipal planning strategy
- Municipal master plan
- Municipal sub-plan

Neighbourhood
- Zoning plan
- Masterplan
- Development agreement

A Norwegian translation of these planning phases can be found in the blue text box.

Translation of some of the main terminology used in the ZEN definition guideline from English to Norwegian

Regional planning strategy – Regional planstrategi
Regional plan – Regional plan
Municipal planning strategy – Kommunal planstrategi
Municipal master plan – Kommuneplan
(with social elements – med samfunnsdel)
(with land use element – med arealdel)
Municipal sub-plan (topical plan) – Kommunedelplan (temaplan)
Planning program – Planprogram
Zoning plan – Reguleringsplan
Development agreement - Utbyggingsavtale

The **regional planning strategy** is developed on a regional basis. The county council and various municipalities are involved in the process. The aim is to identify regional planning needs during the county council period, including how to monitor ongoing and new regional plan tasks. These needs are addressed through regional plans, inter-municipal planning cooperation, and municipal planning.

Regional plans are defined in the regional plan strategy and are the priority areas for cooperation within the county. They can apply to the entire county (for example, today's county plans), to parts of the county, or they may take up more delimited topics for all or a part of the county [30].

The **municipal planning strategy** is an aid for the municipal council to clarify which planning tasks the municipality will prioritize during the parliamentary term to meet the municipality's needs. An important aim is to strengthen the political management of which planning tasks should be prioritized. The municipal planning strategy provides a systematic assessment of the municipality's planning needs so that the municipality can better meet the current challenges. [31].

Planning at the level of the **municipal master plan** is aligned with the planning strategies and plans at the regional level. The municipal plan is comparable with the regional plan, but with a focus on the municipality level. The municipal master plan can also be broken down into further **municipal sub-plans** on a smaller geographical scale, such as a neighbourhood plan or a topical plan. The ZEN pilot projects of Sluppen and Bodø will for e.g. develop municipal sub-plans for the ZEN pilot projects during 2018/2019.

A **planning program** is a 'recipe' for further planning and must be provided from the municipality for regional and municipal plans, which can have significant effects on the environment and society. The plan shall explain the purpose of the planning work, the planning process with time limits and participants, the program for participation, especially in relation to groups that are thought to be particularly affected, which options will be considered, and the need for investigations [31].

More detailed land use planning is provided within the **zoning plan**. The zoning plan describes the provisions for the use, protection, and design of a defined geographical level, mostly areas and physical surroundings. Zoning plans are adopted by the municipal council but may be prepared by both public and, in some cases, private parties [31].

A **development agreement** is an agreement between municipalities and developers or landowners about the development of an area, in accordance with Chapter 17 of the Norwegian Planning and Building Act. The distribution of development costs for technical and green infrastructure is often regulated in the development agreement, but other aspects of the development of an area could also be described here [34].

IMPLEMENTATION PHASE

The **brief and preparation phase** is characterized by developing project objectives, outcomes, aspirations, and the project budget [28]. The main stakeholders and forms of contract are identified. These details are formalized in the project brief. This phase may also include a range of feasibility studies and collection of site information. Feasibility studies may include programming, a description of specific site features, expectations related to function, an overview of the users and their needs, space requirements, building design requirements, contractual arrangements, and procurement of important documents such as the zoning plan.

The **early design phase** includes developing the project brief into the project outline *[skisseprosjekt]* and the continuation of the feasibility studies from the brief and preparation phase in the form of preliminary studies *[forprosjekt]*. The project outline develops the physical and functional concept in dialog with the municipality. The preliminary studies involve the development and selection of technical, functional, and physical structures. This may also include applying for building and/or planning permission, and should ideally take place after the client has had time to review the preliminary studies so that any necessary adjustments can be incorporated into the application.

The **detailed design phase** covers the detailed design and planning *[detaljprosjekt]*. This typically includes preparation of the main drawings, building details, and tender documents ready for tender, as well as procurement of contractors and applying for any building permits required. The detailed design phase also involves selecting products and clarifying aspects of the design and planning to stakeholders.

The **construction phase** covers the execution of the construction and includes the follow up of building works at the construction site. The construction phase may experience changes from the detailed design phase due to (amongst other things) unforeseen site conditions or limited availability of construction materials or services. The construction phase comes to an end once the construction is ready for takeover by its users. This includes the approval of completed construction works, documentation of finished solutions with drawings, operating, and maintenance instructions, as well as a certificate of completion.

OPERATIONAL PHASE

The operational phase is perhaps the longest project phase and covers the operation of a ZEN pilot area by its users. This phase includes (amongst other things) use, maintenance, repair, replacement, and refurbishment, as well as operational energy, water, and transport use of the ZEN pilot area.

2.6 Phases of development

It is possible, and even likely, for one neighbourhood to experience multiple project phases simultaneously. For example, Phase 1 may consist of establishing neighbourhood infrastructure, Phase 2 may consist of constructing public buildings (e.g. nursery schools, schools, and doctor surgeries, etc.). Phase 3 may consist of building apartment blocks, Phase 4 may consist of building detached housing, while Phase 5 may consist of outdoor landscaping and street furniture.

It is recommended that each ZEN pilot area is classified according to the various planned phases of development. Each development phase will go through the same project phases, but at different times. Therefore, the ZEN partners can ensure that each phase of the development is properly documented for each project phase, and that the project data for each phase of the development and project phase is compiled to represent the whole neighbourhood area.

It may also be a good idea to show these phases of development against a time horizon, as each ZEN pilot area has a different time perspective. For example, NRK Steinkjer has a time horizon of approximately 3 years, Ydalir in Elverum need at least a 10-year time horizon, while the 'New City – New Airport' project in Bodø has a long-term time horizon of over 80 years. All the ZEN pilot areas will exist after the research centre comes to an end in 8 years' time, and will require a robust methodology for measurement and management after the end of the ZEN research centre.

2.7 Reference project and reference values

The reference project is a project that represents the zero emission neighbourhood if it was designed and built according to today's standards instead of being designed, built and managed to reduce GHG emissions towards zero within its lifecycle. The purpose of the reference project is to act as a benchmark with reference values to document how much a ZEN pilot area has managed to reduce its total life cycle GHG emissions towards zero. The reference project will use reference values based on today's technical standards. For example, the reference project will use building energy requirements from the current building code (TEK17) to ascertain how much energy different buildings within the neighbourhood would use if they were not designed within the ZEN framework. A ZEN pilot area can then track how much it has been able to reduce energy demands compared to these reference values.

A reference project and reference values should be established for each ZEN pilot area. The reference project and reference values will be used to measure and track the performance of individual key performance indicators and assessment criteria. Consequently, milestones for reductions (i.e. GHG emissions, energy, power/load and cost) and improvements (i.e. mobility, spatial qualities and innovation) may be established. For example, a ZEN pilot area may achieve a 70% reduction in total GHG emissions in the detailed design phase compared to the reference project.

The reference project will be used as a base case or 'business as usual' (BAU) for documenting and comparing the ZEN pilot areas, as well as comparing the ZEN pilot area to other, similar neighbourhoods being built according to current practice, current technology, and Norwegian building regulations (TEK17). The reference project will typically not include any zero emission strategies. In the case of existing areas, the reference project should be developed according to current conditions or 'business as usual'. In the case of new developments, the reference project should be developed according to today's standard practice. The reference project should be tailored to each ZEN pilot area, since each ZEN pilot area is unique, and subject to different conditions and prerequisites. The reference project should also reflect reality, and is thus a live snapshot of current practice, which will naturally change over the duration of the ZEN Research Centre as building regulations are tightened with regard to maximum energy demands and other environmental requirements.

The reference project may be amended or revised before progressing to a new project phase and should be adjusted according to the actual developments in the project. For example, if the ZEN pilot area increases its heated floor area (BRA) of residential buildings from 10 000 m^2 to 15 000 m^2 from the planning to early design phases, then this should be reflected in the reference project at the planning stage and the reference project at the early design phase to reflect this increase in area usage. A Norwegian translation of reference project and values can be found in the blue text box.

Translation of some of the main terminology
used in the ZEN definition guideline from English to Norwegian

Reference project - Referanseprosjekt
Reference values - Referanseverdi

3 ZEN definition categories

The ZEN definition key performance indicators (KPI) and assessment criteria are grouped into seven categories [1]:

- GHG Emissions
- Energy
- Power/load
- Mobility
- Economy
- Spatial qualities
- Innovation (will be described in subsequent versions of the guideline report)

The ZEN definition report outlines the central ZEN definition, assessment criteria, and key performance indicators (KPIs) used in the ZEN Research Centre (Figure 3.1). To follow is a more detailed guideline explaining the use of the assessment criteria and KPIs in the ZEN pilot areas. Additional KPIs and assessment criteria being considered are outlined in Appendix A of the ZEN definition report [1].

Category	Assessment criteria	Key performance indicators (KPIs)
GHG emission	• Total GHG emissions • GHG emission reduction	• Total GHG emissions in tCO_{2eq}; tCO_{2eq}/m^2 heated floor area (BRA)/yr; $kgCO_{2eq}/m^2$ outdoor space (BAU)/yr; tCO_{2eq}/capita • % reduction compared to a base case
Energy	• Energy efficiency in buildings • Energy carriers	• Net energy need in kWh/m²BRA/yr; Gross energy need in kWh/m² BRA/yr; Total energy need in kWh/m² BRA/yr • Energy use in kWh/yr; Energy generation in kWh/yr; Delivered energy in kWh/yr; Exported energy in kWh/yr; Self-consumption in %; Self-generation in %; Colour coded carpet plot in kWh/yr
Power/Load	• Power/load performance • Power/load Flexibility	• Net load yearly profile in kWh; Net load duration curve in kWh; Peak load in kWh; Peak export in kWh; Utilisation factor in % • Daily net load profile in kWh
Mobility	• Mode of transport • Access to public transport	• % share • Meters; Frequency
Economy	• Life cycle cost (LCC)	• NOK; NOK/m² heated floor area (BRA)/yr; NOK/m² outdoor space (BAU)/yr; NOK/capita
Spatial qualities	• Demographic needs and consultation plan • Delivery and proximity to amenities • Public Space	• Qualitative • No. of amenities; Meters (distance from buildings) • Qualitative

Figure 3.1 ZEN assessment criteria and KPIs covered in ZEN definition guideline.

A Norwegian translation of the ZEN definition categories can be found in the blue text box.

Translation of some of the main terminology
used in the ZEN definition guideline from English to Norwegian

Category – Kategori
GHG Emissions – Klimagassutslipp
Energy – Energi
Power - Effekt
Mobility – Mobilitet
Economy – Økonomi
Spatial qualities – Stedskvaliteter
Innovation – Innovasjon

3.1 GHG emissions

Assessment criteria and KPI

The GHG emissions category is split into two assessment criteria, namely 'total GHG emissions' and 'GHG emission reduction'. These assessment criteria are relevant for all ZEN partners and stakeholders and are to be implemented during all project phases. An overview of the assessment criteria and KPIs for the GHG emissions category can be found in Table 3.1. All key performance indicators in the GHG emission category are to be calculated and presented using NS 3451: 'Table of Building Elements' to at least a 2-digit level [33], and using the life cycle modularity principle according to NS-EN 15978 [34] and NS 3720 [35]. An overview of this reporting matrix can be found in Table 3.2. A Norwegian translation of some of the most important terms in the GHG emissions category can be found in the blue text box.

Table 3.1. An overview of assessment criteria and KPIs for the GHG emissions category.

Assessment criteria and KPI	Unit	Strategic planning	Brief and preparation	Early design phase	Detailed design phase	Construction phase	Operational phase
Total GHG emissions	tCO_{2eq} $kgCO_{2eq}/m^2$ heated floor area (BRA)/yr $kgCO_{2eq}/m^2$ outdoor space (BAU)/yr $kgCO_{2eq}$/capita	x	x	x	x	x	x
GHG emission reduction	% reduction compared to a base case	x	x	x	x	x	x

Translation of some of the main terminology
used in the ZEN definition guideline from English to Norwegian

GHG emissions - Klimagassutslipp
Total GHG emissions - Totale klimagassutslipp
GHG emission reduction - Reduksjon i klimagassutslipp
Table of building elements - Bygningsdeltabell
Life cycle module - Livssyklusmodul

Total GHG emissions

The total GHG emissions assessment critiera in the GHG emission category is to be calculated and presented in terms of the functional units listed in Table 3.1, using NS 3451:' Table of Building Elements' to at least a 2-digit level [33], and using the life cycle modularity principle according to NS-EN 15978 [34] and NS 3720 [35]. An overview of this reporting matrix can be found in Table 3.2. The building assessment boundary corresponds to building elements 20-69 in NS 3451 (indicated by a light blue background in Table 3.2), while the neighbourhood assessment boundary includes building elements 70-79 (indicated by a light orange background in Table 3.2). It will also be important to describe the different types of buildings within a ZEN pilot area according to NS 3457-3 [36] to at least a 2-digit level and to group total GHG emissions per building type and per building element 20-69.

Table 3.2. Reporting matrix for total GHG emissions.

	A1-A3: Product stage	A4: Transport to site	A5: Installation	B1: Use	B2: Maintenance	B3: Repair	B4: Replacement	B5: Refurbishment	B6: Operational energy use	B7: Operational water use	B8: Operational transport use	C1: Deconstruction	C2: Transport to end of life	C3: Waste processing	C4: Disposal	D: Reuse, recovery and recycling	Total
20 Building, general																	
21 Groundwork and foundations																	
22 Superstructure																	
23 Outer walls (incl. green walls)																	
24 Inner walls																	
25 Floor structure																	
26 Outer roof (incl. green roofs)																	
27 Fixed inventory																	
28 Stairs and balconies																	
29 Other																	
30 Heating, ventilation and sanitation, general																	
31 Sanitary																	
32 Heating																	
33 Fire safety																	
34 Gas and air pressure																	
35 Process cooling																	
36 Ventilation and air conditioning																	
37 Comfort cooling																	
38 Water treatment																	
39 Other																	
40 Electric power, general																	
41 Basic installation for electric power																	
42 High voltage power																	

	A1-A3: Product stage	A4: Transport to site	A5: Installation	B1: Use	B2: Maintenance	B3: Repair	B4: Replacement	B5: Refurbishment	B6: Operational energy use	B7: Operational water use	B8: Operational transport use	C1: Deconstruction	C2: Transport to end of life	C3: Waste processing	C4: Disposal	D: Reuse, recovery and recycling	Total
43 Low voltage power																	
44 Lighting																	
45 Electric heating																	
46 Standby power																	
49 Other																	
50 Tele. and Automation																	
51 Basic installation																	
52 Integrated communication																	
53 Telephone and paging																	
54 Alarm and signal																	
55 Sound and picture																	
56 Automation																	
57 Instrumen-tation																	
59 Other																	
60 Other installation, general																	
61 Prefabricated unit																	
62 Passenger and goods transport																	
63 Transport facilities for small goods																	
64 Stage equipment																	
65 Waste and vacuum cleaning																	
66 Fixed furniture																	
67 Loose furniture																	
69 Other																	
7 Outdoor, general																	

	A1-A3: Product stage	A4: Transport to site	A5: Installation	B1: Use	B2: Maintenance	B3: Repair	B4: Replacement	B5: Refurbishment	B6: Operational energy use	B7: Operational water use	B8: Operational transport use	C1: Deconstruction	C2: Transport to end of life	C3: Waste processing	C4: Disposal	D: Reuse, recovery and recycling	Total
71 Adapted terrain																	
72 Outdoor construction																	
73 Outdoor heating, ventilation and sanitation																	
74 Outdoor electric power																	
75 Outdoor tele. and automation																	
76 Roads and courtyards																	
77 Parks and gardens (incl. blue-green infrastructure)																	
78 Outdoor infrastructure																	
79 Other																	
Total																	

All GHG emission calculations should be carried out according to the life cycle assessment methodology as described in ISO 14040 [37] and the Intergovernmental Panel for Climate Change's global warming potential 100-year methodology [38, 39]. 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 [40] and NS-EN 16485 [41]. Similarly, carbonation of concrete should be calculated according to NS-EN 16757 [42]. Further details on the LCA methodology to be used in the ZEN Research Centre can be found in the ZEN LCA report [43].

Functional unit

A functional unit is defined in ISO 14040 as the 'quantified performance of a product system for use as a reference unit' [37]. In this case, the product system is the ZEN pilot area, and the following reference units have so far been agreed upon by ZEN partners:

1. tCO_{2eq}
2. $kgCO_{2eq}/m^2$ heated floor area (BRA)/yr
3. $kgCO_{2eq}/m^2$ outdoor space (BAU)/yr
4. $kgCO_{2eq}$/ capita

The first functional unit measures total GHG emissions in terms of tonnes of carbon dioxide equivalents (tCO_{2eq}) according to the Intergovernmental Panel for Climate Change's global warming potential 100-year methodology [38, 39]. The second and third functional units require a bit more interpretation. For buildings, the area (m^2) is defined according to NS 3940 [44] and corresponds to heated floor area (BRA), as demonstrated in Figure 3.1. This functional unit is valid for the building assessment boundary level.

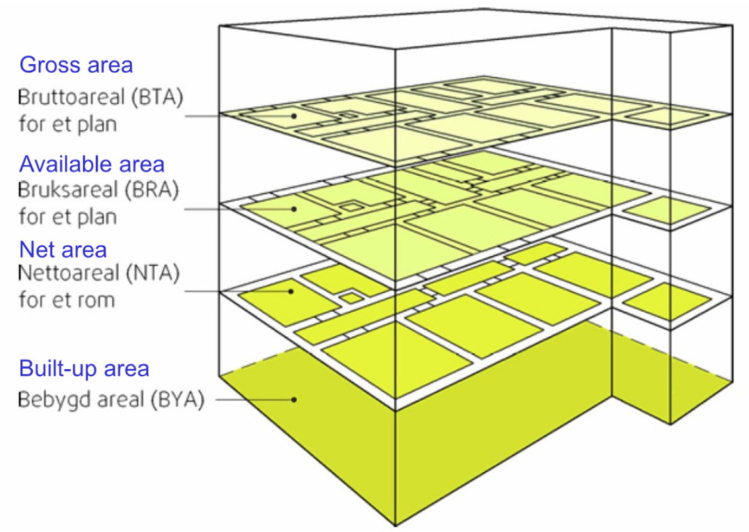


Figure 3.1: Building areas according to NS 3940 [44].

For the third functional unit, outdoor area is described in TEK17 § 5-6 as Minimum outdoor area (MUA) and in § 8-3 about outdoor area and corresponds to outdoor space (BAU) or bolig/friområde (BF)[1]. This functional unit is valid for the neighbourhood assessment boundary level.

The analysis period is set to 60 years for the service life of buildings, and 100 years for the service life of infrastructureThis means that two results will be provided in terms of $kgCO_{2eq}/m^2/yr$; one for the building assessment boundary level and one for the neighbourhood assessment boundary level. The definition of $kgCO_{2eq}$/capita will be determined in subsequent versions of the guideline report.

To follow is a summary of the main data sources for inventory data and emission factors for materials, construction, transport, energy, and end of life.

<u>Materials</u>

Material quantities can be obtained from architect's and planner's drawings, from building information modelling (BIM), and from city information modelling (CIM). Material quantities can also be checked

[1] There is no common definition nor requirement for the minimum outdoor area or how it will be calculated in TEK 17. The municipality may make planning regulations for outdoor areas for the municipal master plan with land use elements and the zoning plan. For housing, schools, kindergartens, and other buildings where it is necessary to set aside a minimum outdoor space, the plan should state the minimum outdoor space including play area. MUA is given in m^2 whole numbers per unit housing, school pupil, or kindergarten child, etc. All area of the site which is not dedicated to buildings, driving, or parking is suitable as outdoor area (TEK 17).

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.

Environmental product declarations (EPDs) developed according to ISO 21930, ISO 14040, ISO 14025 and NS-EN 15804 [37, 45-48] are good sources of specific emission data for construction products. When EPD data are not available, generic emission factors can be ascertained from life cycle inventory databases such as Ecoinvent [49]. 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 should not be older than five years, and generic data should not be older than ten years.

The SINTEF design guidelines *(Byggforskserien)* can be used to develop realistic scenarios for installation, repair, maintenance, replacement, and refurbishment of components; while the SINTEF design guideline for replacement and maintenance intervals for building parts *(Bks 700.320 intervaller for vedlikehold og utskiftninger av bygningsdeler)* [50] can be used to ascertain reference service lifetimes of construction components. Installation manuals and product data sheets from product manufacturers can also be used to create realistic scenarios for transport to site and for installation.

Construction

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 3.2. It includes additional materials such as glue, screws, and tape for installing construction products, transport of materials, construction machinery and personnel to the construction site, transport of waste (including packaging) to waste treatment, and its disposal, energy use (e.g. building heating and drying during the construction phase, energy use in the construction offices), internal transport, storage, temporary works, as well as the operation of construction machinery on site. Water use and demolition works are excluded from the system boundaries. This system boundary is also in accordance with EN 15978, EN 15804, and NS 3720 [6, 35, 45].

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 sent by the contractor to the local authorities. Waste treatment scenarios can be developed according to current waste treatment practices [51].

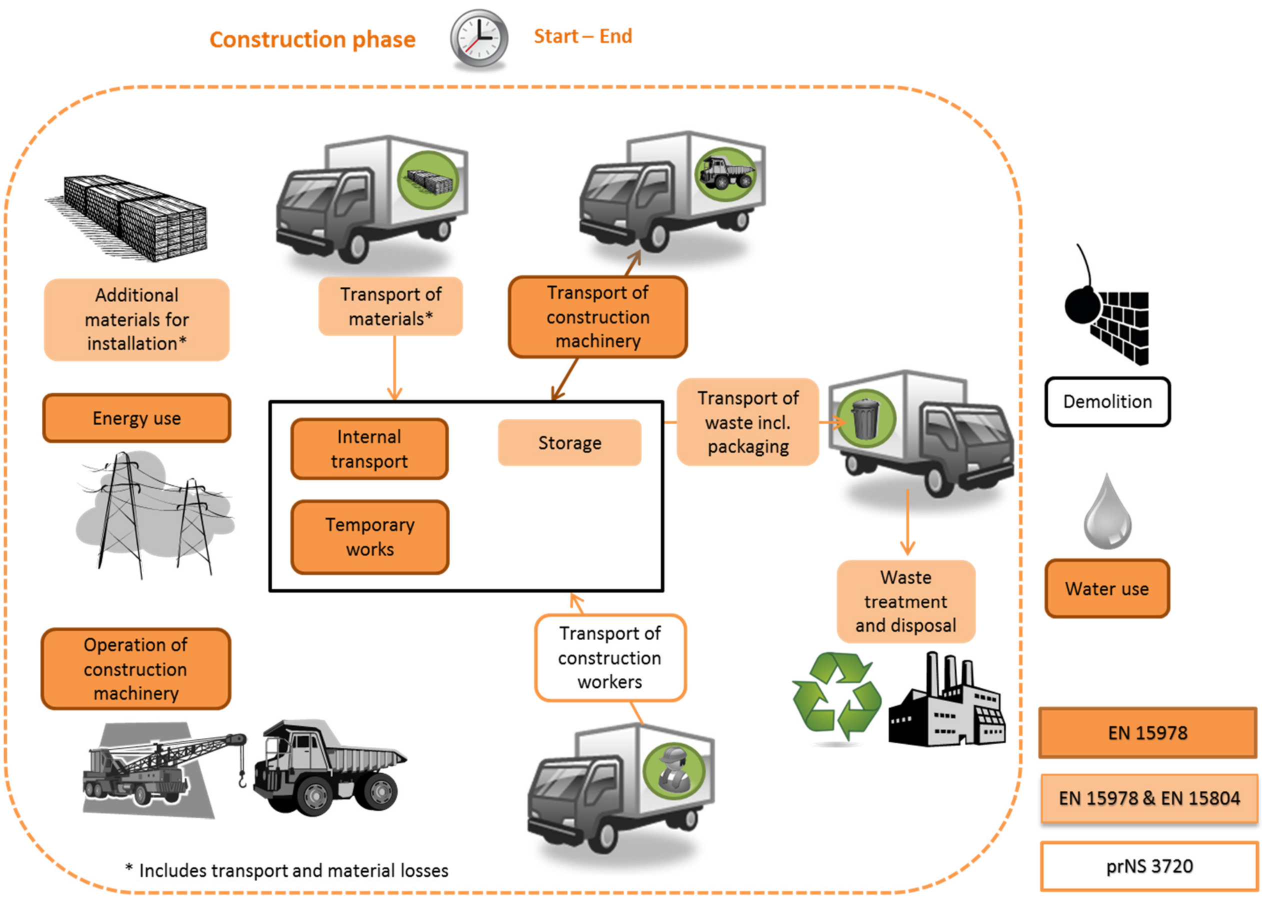


Figure 3.2: Overview of the system boundary for the construction phase, adapted from [19, 52].

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. If this is the case, generic emission factors from a life cycle inventory database (such as Ecoinvent) may be used. Transport emission factors for goods and person transport from NS-EN 16258 [53] may be used in emission calculations. 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.

Transport

KPI results from the mobility category chapter (see Chapter 3.6) can be used as a direct input for inventory data in life cycle module B8: transport in use. This data includes modes of transport, frequency, fuel types, distances travelled, and capacity utilization (amount of people transported per mode of transport). A detailed explanation of the methodology used for calculating emissions from transport in the use phase, can be found in NS 3720 [35].

Transport emission factors for goods and person transport from NS-EN 16258 [53] may be used in emission calculations. 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.

Energy for operation

KPI results from the energy category chapter (see Chapter 3.2) on delivered and exported energy (kWh/m^2) at both the building and neighbourhood assessment boundary level can be used as a direct input for inventory data in life cycle module B6: operational energy use. These results can then be multiplied by the corresponding emission factors for the various energy carriers used in the ZEN pilot area. The authors acknowledge that specific emission factors for different energy carriers is a much-debated topic, and further discussion on this falls outside the scope of this report. However, over the coming years, the LCA working group in the ZEN Research Centre will investigate the system boundaries, cut off points, and temporal resolution of emission factors used for different energy carriers.

Since most district heating companies are operating local distribution networks, average emission factors for district heating are typically not representative of the distribution network and should not be used in GHG emission calculations for the ZEN pilot areas. Furthermore, the allocation of emissions from, for example waste incineration, also need to be resolved. These issues will be addressed as part of the ongoing work of the LCA working group in the ZEN Research centre. However, as a starting point, Norsk Fjernvarme has developed an online tool that shows the district heating energy mix for different companies and regions in Norway [54]. This may be used as a starting point for developing specific emission factors for district heating in Norway.

End of life

If no other data are available, then the life cycle inventory for deconstruction (life cycle module C1) may be based on the life cycle inventory for installation (life cycle module A5), as it may be assumed that the same amount of materials, work force, and energy is required to deconstruct a product as is required to install it.

The life cycle inventory for transport to waste treatment (life cycle module C2) may be extracted from the amount of construction materials used in the production phase, combined with the transport to waste treatment scenario described in EPDs. Transport emission factors for goods and person transport from NS-EN 16258 [53] may be used in emission calculations. 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.

The life cycle inventories for waste treatment and disposal may also be extracted from the amount of construction materials used in the production phase, and combined with waste treatment and disposal scenarios developed according to current waste treatment and disposal practices [51].

GHG emission reduction

The assessment criteria 'GHG emission reduction' is based on the total reduction of GHG emissions compared to a base case or reference project, see Figure 3.3. This approach has been favoured by ZEN partners over the ZEB GHG emission balance approach [3-5] since it tracks the reduction of GHG emissions towards zero over the ZEN pilot area's life cycle and is most in line with the ZEN Research

Centre's ambition of reducing GHG emissions towards zero. This approach is also more in line with the Futurebuilt 50|50 project and klimagassregnskap.no way of thinking [61, 62], as demonstrated in Figure 3.4. The Futurebuilt 50|50 project aims to reduce GHG emissions relating to transport, materials, and energy in 50 Norwegian pilot buildings [61].

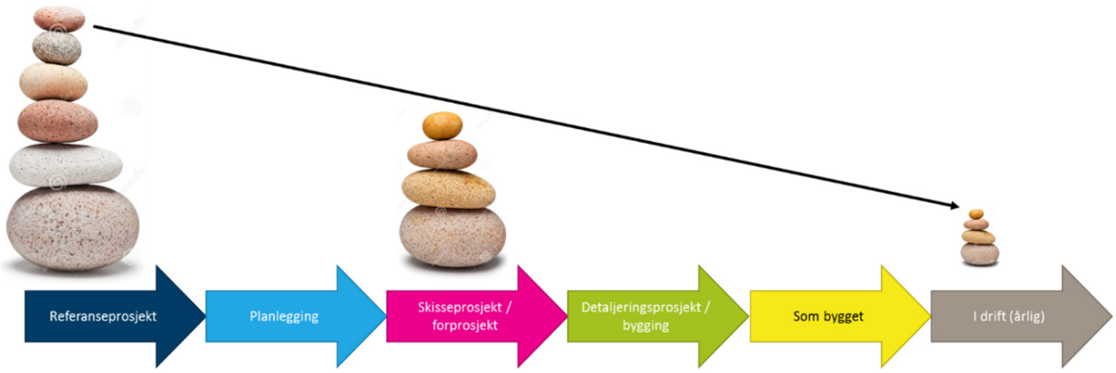


Figure 3.3. Illustration of the KPI for GHG emission reduction in the ZEN pilot areas.

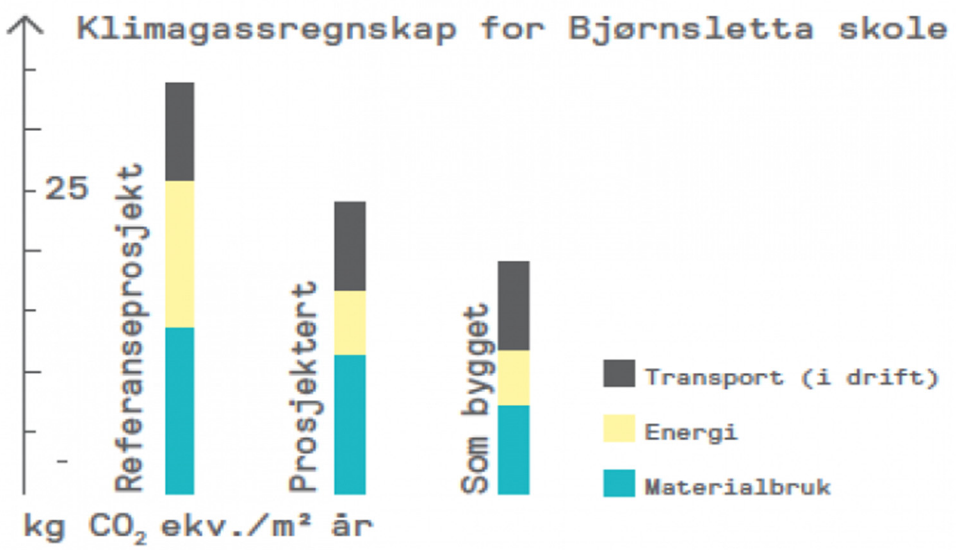


Figure 3.4. Example from Bjørnsletta school, Source: Futurebuilt.

The GHG emission reduction assessment critiera can be shown both graphically and as a percentage reduction, once the matrix for total GHG emission results has been filled out for the reference project and one or more project phases. Consequently, ambition levels for GHG emission reductions can be established. For example, a ZEN pilot area may achieve a 50% reduction in total GHG emissions in the detailed design phase compared to the reference project.

GHG emission reduction measures

As a starting point, some established emission reduction measures have been identified in [57, 58] and include the following:

1. Reduce the consumption of materials, energy, waste, water, and transport.
2. Reuse, recycle, and share.

3. Choose materials, energy, and transport with low GHG emissions.
4. Choose durable, locally produced materials, energy, and transport.
5. Encourage a circular economy for construction waste, household waste, water consumption, and recycled water.

Reference project and reference values

The following is a suggestion of how a reference project and reference values can be established for materials, construction, transport, energy, and end of life GHG emissions.

Materials

The reference project may be based on pre-accepted construction details from SINTEF design guidelines and should fulfil minimum building regulations (e.g. TEK17) for different building envelopes [59]. Ideally, emission factors which are geographically and temporally representative of the ZEN pilot area should be used. For example, Norwegian EPDs can be used for building materials and components.

Construction

Reference projects and reference values for the construction phase still need to be developed, since measuring GHG emissions from the construction site is a relatively new field. However, the contractor can help estimate and quantify the construction activities likely to take place.

Transport

Reference projects and reference values may be based on national averages from the Norwegian travel habit survey (reisevaneundersøkelse – RVU) [60] or may be based on existing transport connections to the ZEN pilot area.

Energy for operation

The reference project should follow the guidance given in the energy category chapter (chapter 3.2) and be based on minimum building regulations (e.g. TEK17) for different building typologies [59]. Reference values for emission factors for different energy carriers may also be established by the LCA working group in the ZEN Research Centre.

End of life

Typically, end-of-life scenarios are developed to represent today's current practice, despite taking place 60 to 100 years in the future. This is done to remove uncertainty from GHG emission results. If this approach is used in the ZEN Research Centre, then GHG emission results during the end of life phase from different project phases will be the same as in the reference project, thus showing no improvement or reduction in GHG emissions during the end of life phase. It is also unlikely that any ZEN pilot area will experience the end of life phase during the eight years that the ZEN Research

Centre is operational. However, that does not mean that a ZEN pilot area cannot plan for the end of life phase. Therefore, any GHG emission reduction measures or strategies for the end-of-life phase must be clearly documented, a plan must be in place to warrant that these measures will be carried out in 60 to 100 years' time, and the measures must be quantifiable.

3.2 Energy

Assessment criteria

The energy category is split into two assessment criteria, namely 'energy efficiency in buildings' and 'energy carriers'. Both assessment criteria have a series of KPIs. The energy efficiency in buildings criterion includes net and gross (thermal) energy and total (thermal + electric specific) energy need, while the ‘energy carriers' criterion includes energy use, energy generation, delivered energy, exported energy, self-consumption, self-generation, and colour coded carpet plots. The terms energy use, energy generation, delivered energy, and exported energy are in accordance with the ISO 52000 standard [61]. These KPIs are relevant for municipalities, building owners and operators, contractors, architects, engineering consultants, energy companies, and authorities. The KPIs for the energy category are to be implemented during the early design, detailed design, construction, and operational phases. An overview of the assessment criteria and KPIs for the energy category can be found in Table 3.3. All key performance indicators in the energy category are to be calculated with an hourly resolution for each project phase. A Norwegian translation of some of the most important terms in the energy category can be found in the blue text box.

Table 3.3. An overview of assessment criteria and KPIs for the energy category.

<table>
<tr><th>Assessment criteria and KPIs</th><th>Unit</th><th>Strategic planning phases</th><th>Brief and preparation</th><th>Early design phase</th><th>Detailed design phase</th><th>Construction phase</th><th>Operational phase</th></tr>
<tr><td>Energy efficiency in buildings</td><td>Annual totals</td><td rowspan="12">X</td><td rowspan="12">X</td><td rowspan="12">X</td><td rowspan="12">X</td><td rowspan="12">X</td><td rowspan="12">X</td></tr>
<tr><td>- Net energy need</td><td>kWh/m^{2}BRA</td></tr>
<tr><td>- Gross energy need</td><td>kWh/m^2 BRA</td></tr>
<tr><td>- Total energy need</td><td>kWh/m^2 BRA</td></tr>
<tr><td>Energy carriers</td><td>Annual totals
Monthly profiles</td></tr>
<tr><td>- Energy use</td><td>kWh</td></tr>
<tr><td>- Energy generation</td><td>kWh</td></tr>
<tr><td>- Delivered energy</td><td>kWh</td></tr>
<tr><td>- Exported energy</td><td>kWh</td></tr>
<tr><td>- Self-consumption</td><td>%</td></tr>
<tr><td>- Self-generation</td><td>%</td></tr>
<tr><td>- Color coded carpet plot</td><td>kWh</td></tr>
</table>

Note 1: the number of KPIs under the assessment criteria 'energy efficiency in buildings' appear to be three, but it is actually just one table of energy needs arranged per energy service provided. Furthermore, thermal net energy needs are not directly measurable and are therefore more suitable to be used in calculations/simulations of new buildings. Thermal gross energy need is measurable, though it requires sub metering (additional metering beyond the main/smart meter).

Note 2: the KPIs under the assessment criteria 'energy carriers' are not all independent. Delivered and exported energy are the two fundamental ones, and those are normally measured. The colour coded carpet plots are just a visualization of these two quantities. Energy use and generation are not always known from measurements, since they require sub-metering. Self-consumption and self-generation are indicators resulting from mathematical re-elaboration of energy use and generation, using hourly values.

Note 3: as an intermediate step, it may be worth calculating all the KPIs under the assessment critiera 'energy carriers' also on the building(s) boundary level. The available national and international norms only apply to the building(s) boundary level, so it would be straightforward to take this step first and calculate the KPIs. Thereafter, the calculations can be extended to the neighbourhood boundary level in order to produce the final KPIs. This would make it possible to distinguish clearly between the effect of measures within buildings and between buildings.

Translation of some of the main terminology
used in the ZEN definition guideline from English to Norwegian

Energy need – Energibehov
Net – Netto
Gross - Brutto
Energy carrier – Energibærer
Energy use – Energibruk
Energy generation – Energiproduksjon
Delivered energy – Levert energi
Self-consumption – Egenbruk

Energy efficiency in buildings: energy needs

The KPIs under the 'energy efficiency in buildings' assessment criterion are calculated at the building assessment boundary level, which must be harmonized between ISO 52000 and NS 3031 [61, 62]. This typically includes building energy use for heating, cooling, ventilation, domestic hot water, de-/humidification, and lighting and may include plug loads.

Net and gross energy needs are calculated according to NS/TS 3031 and are presented in terms of total energy needs and split per energy service, see Table 3.4 [62]. Specific energy need is calculated per kWh of m^2 heated floor area (BRA) per year (kWh/m^2/yr). The difference between net and gross energy needs is that the latter includes losses from the heating and cooling distribution system, as well as the storage system inside buildings. Net energy need is for example useful for checking compliance with the passive house definition [63, 64], while gross energy need is useful as a starting point for the design of heating and cooling supply systems.

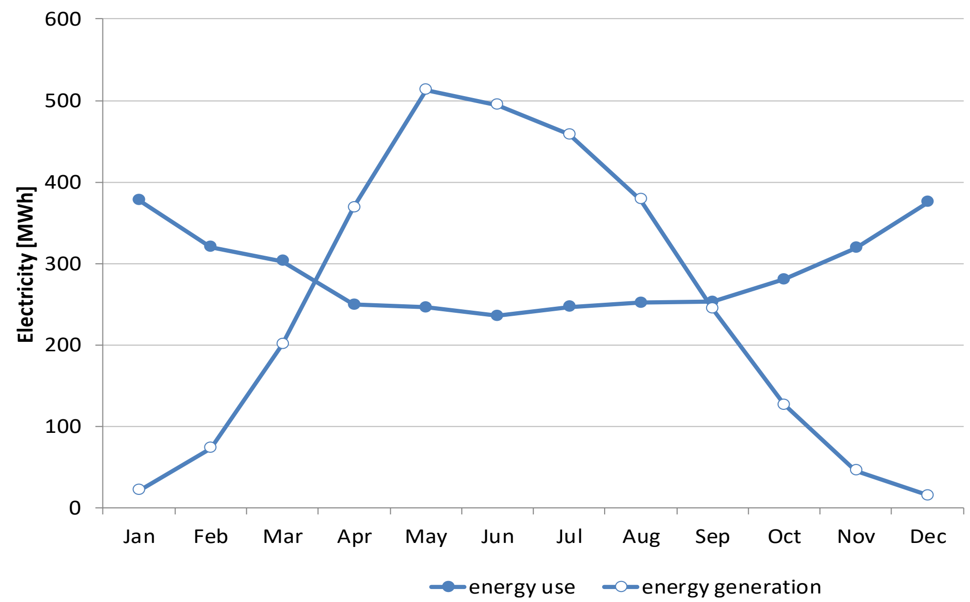
Table 3.4. A table showing the net energy need for different building services [62].

Energy Service			**Energy need (kWh/yr)**	**Specific energy need (kWh/m^2/yr)**
Thermal energy need	1a	Room heating		
	1b	Ventilation heating		
	2	Hot water		
	3a	Room cooling		
	3b	Ventilation cooling		
Total thermal energy need (sum of 1-3)				
Electric energy need	4a	Fans		
	4b	Pumps		
	5	Lighting		
	6	Technical equipment		
Total electric energy need (sum of 4-6)				
Total energy need (sum 1-6)				
Other energy need				-

Energy carriers: use, generation, delivered and exported

The KPIs under the 'energy carriers' assessment criterion are calculated at the neighbourhood assessment boundary level, which 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 is also considered. In other words, the neighbourhood assessment boundary includes, in principle, all energy flows within the neighbourhood.

Energy use, energy generation, delivered energy, and exported energy are calculated per energy carrier, according to NS/TS 3031 [62]. For energy carriers, energy use and energy generation can be compared on a graph showing their monthly values. This gives a visual impression of the seasonal mismatch between the two quantities, see Figure 3.5 However, delivered and exported energy (as well as self-consumption and self-generation) should be calculated on an hourly mismatch between energy use and energy generation. The annual totals for delivered and exported energy can be reported in a table format, such as in Table 3.5.



mismatch factors	
monthly	hourly
self-generation	
57 %	29 %
self-consumption	
67 %	34 %

Figure 3.5. A graph showing monthly energy use and energy generation profiles.

Table 3.5. A table showing delivered and exported energy per energy carrier [62].

Energy carrier			Delivered and exported energy (kWh)
Delivered energy	1	Delivered electricity	
	2	Delivered oil (fossil)	
	3	Delivered gas (fossil)	
	4	Delivered biofuel	
	5	Delivered district heating	
	6	Delivered district cooling	
	7	Other delivered energy carriers	
Total delivered energy (sum of 1-7)			
Exported energy	8	Self-generated electricity for export	
	9	Exported heat to district heating	
	10	Exported cooling to district cooling	
Total exported energy (sum of 8-10)			
Total net delivered energy (sum of 1-10)			

Local storage systems, both electric (including the batteries of electric vehicles) and thermal, may already be in place or under evaluation during the design phase. This would affect all the KPIs under the 'energy carriers' assessment criteria. 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 two sub-categories: one with and one without the storage system.

Energy carriers: self-consumption and self-generation

The self-consumption and self-generation key performance indicators tell us about the mismatch between energy generated locally and energy used in the neighbourhood. The calculation is typically carried out in two steps.

First, energy use and energy generation are considered separately, i.e. without considering their interaction. It may be useful to plot a graph of the monthly values of these quantities, such as in Figure 3.7. Second, the interaction between energy use and generation is considered on an hourly basis, and the overall result over the year is expressed numerically in terms of the two indicators self-consumption and self-generation. In literature, the same concepts are presented with different names. For example, in [65] these are called ‘self-consumption’ and ‘self-sufficiency’, respectively; while in [66] 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).

The two indicators express two complementary aspects of the interaction between energy use and generation. This can be better explained with reference to a graph showing daily profiles, such as in Figure 3.6, where electricity is considered, and PV is assumed as local generation in a single building [65]. 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 utilized directly within the building.

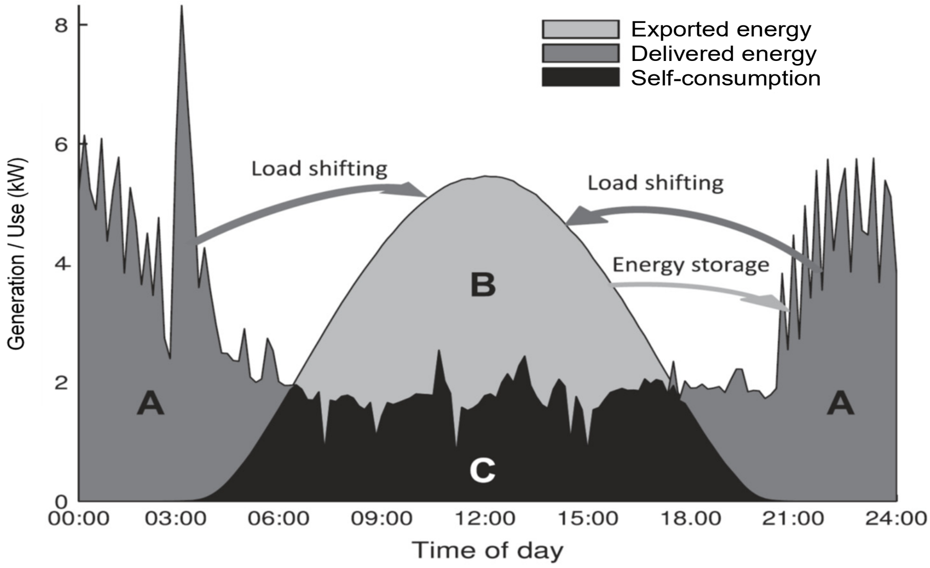


Figure 3.6. A schematic outline of the daily energy use (A + C), energy generation (B + C), and self-consumption (C) in a building with on-site PV. It also indicates the function of the two main options (load shifting and energy storage) for increasing self-consumption. Source: adapted from [65].

The self-consumption KPI is 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;

$$\text{Self-consumption} = \frac{C}{B + C}$$

$$\text{Self-generation} = \frac{C}{A + C}$$

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 [65] and [66].

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 demand (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 the use of local storage.

Energy carriers: colour coded carpet plot

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 net export, 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 *x*-axis, and 365 days of the year on the *y*-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 Figures 3.7 and 3.8.

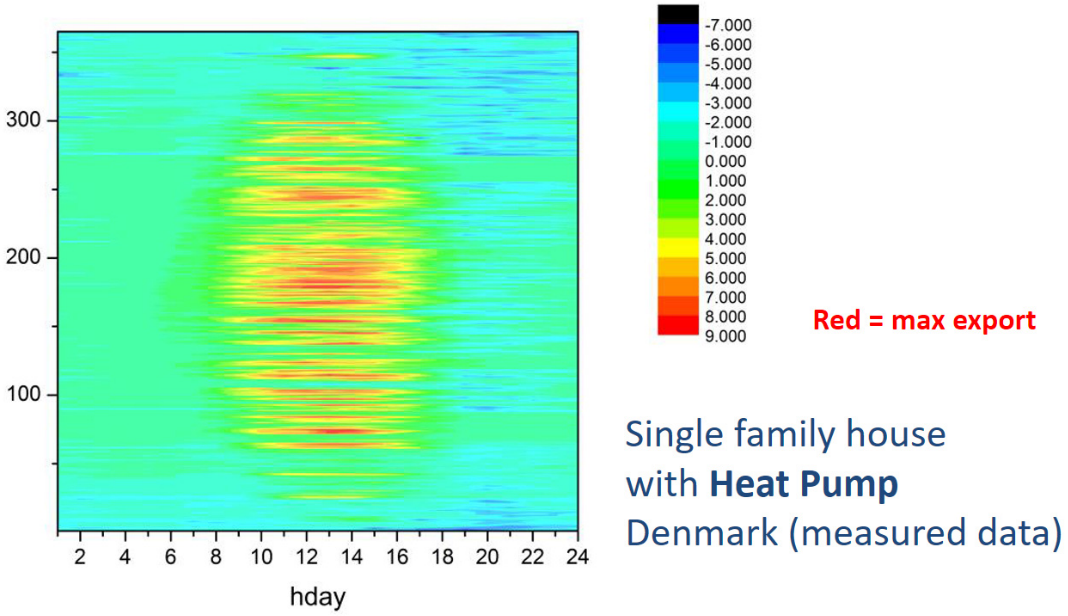


Figure 3.7. An all-electric single-family house with heat pump and PV. Monitored data from a house in Denmark. Source: [67]

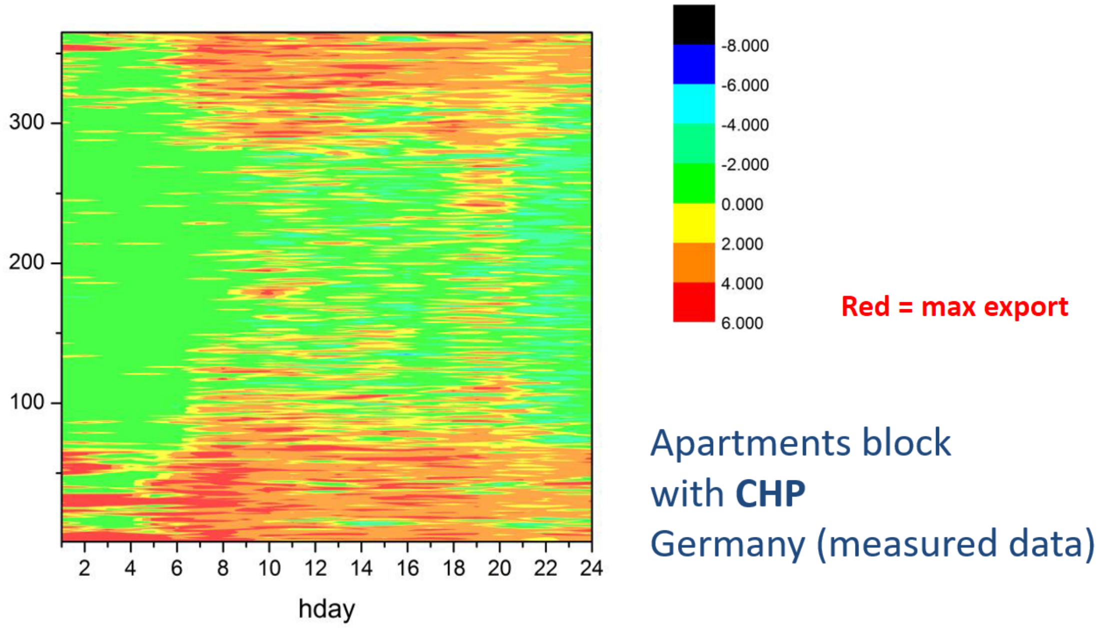


Figure 3.8. Apartment blocks with combined heat and power (CHP) unit and PV. Monitored data from a building in Germany. Source: [67]

Reference project and reference values

The reference values in the business as usual (BAU) scenario should be based on today's standards (TEK17) [59]. The level of detail and the source of data may differ according to the different project phases. For example, simulation tools used in the design phases can be substituted by monitoring data in the operational phase, while design parameters, e.g. air tightness, may be substituted by measured values in the construction phase.

3.3 Power / Load

Assessment criteria and KPI

The power/load category is split into two assessment criteria, namely 'power/load performance' and 'power/load flexibility'. Both assessment criteria have a series of KPIs. The power performance assessment criteria includes net load yearly profile, net load duration curve, peak load, peak export and utilization factor; while the power flexibility assessment criteria includes net load daily profile and possibly other KPIs not yet defined. These KPIs are relevant for municipalities, building operators, contractors, engineering consultants, energy companies, IT companies, and authorities. The KPIs for the power/load category are to be implemented during the early design, detailed design, construction, and operational phases. An overview of the KPI for the power/load category can be found in Table 3.6. All key performance indicators in the power/load category are to be calculated with hourly or sub-hourly resolutions for each project phase. A Norwegian translation of some of the most important terms in the power/loadcategory can be found in the blue text box.

Table 3.6. An overview of assessment criteria and KPIs for the power/load category.

Assessment criteria and KPIs	**Unit**	**Strategic planning phases**	**Brief and preparation**	**Early design phase**	**Detailed design phase**	**Construction phase**	**Operational phase**
Power/load performance	Hourly values Yearly profiles	X	X	X	X	X	X
- Net load yearly profile	kW						
- Net load duration curve	kW						
- Peak load	kW						
- Peak export	kW						
- Utilization factor	%						
Power/load flexibility	Hourly values Daily profiles						
- Daily net load profile	kW						

Note 1: in the assessment criteria 'power/load performance' (or 'load performance') the KPIs peak load, peak export, and utilisation factor are just values extracted from the KPI net load duration curve.

Note 2: the KPI 'daily net load profile' could as well go under the assessment criteria 'power/load performance'. The assessment criteria 'power/load flexibility' (or 'load flexibility') would contain KPIs that have been discussed at the WP workshop in March 2018 and will be introduced in the second version of this ZEN definition guideline.

Note 3: it may be useful to calculate all the power/load KPIs also on the energy needs (at least thermal needs), not only on the energy carriers. This would give useful information in the early design phase, when it the energy system/energy carriers still need to be designed.

Translation of some of the main terminology
used in the ZEN definition guideline from English to Norwegian

Power/load – Effekt
Duration curve - Varighetskurve
Peak load – Spisslast
Peak export – Spisseksport
Utilization factor – Utnyttingsfaktor
Load profile - Lastprofil

Power/load performance: net load yearly profile and duration curve

The net load yearly 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.

As with the carpet plots, it is necessary to see the delivered and exported quantities of an energy carrier as two sides of the same variable. Figure 3.9 shows an example of a graph where delivered electricity is assigned a positive value and export a negative value. The two graphs, for the net load yearly profile and the duration curve, can be superimposed and visualized within the same figure, as shown in Figure 3.9.

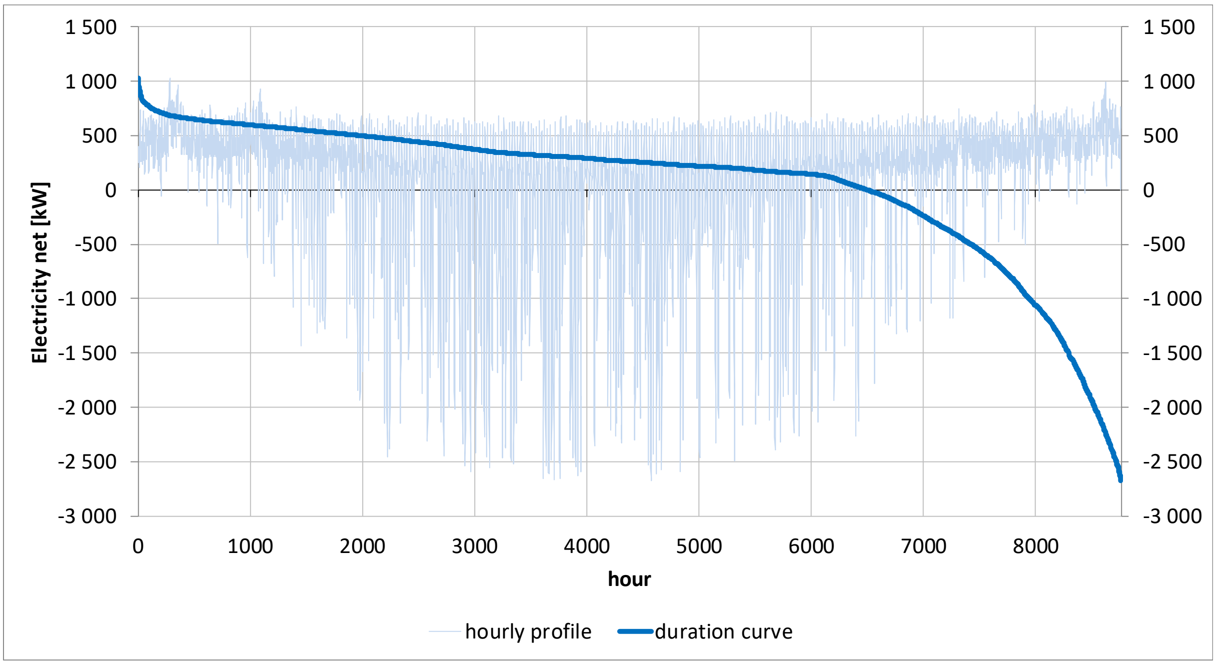


Figure 3.9. An example of a net load duration curve.

The value of the net load yearly profile is to give an illustration of the energy flows throughout the year, much as the color-coded carpet plot. On the other hand, the value of the net load duration curve is to provide useful information for the design 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.

Power/load performance: peak load and peak export

The peak load KPI and the peak export KPI are simply extreme values of the net duration curve. The maximum positive value is the peak load, while the maximum negative value is the peak export. If there is no net export, then the peak export is equal to zero. This is shown in Figure 3.10. It should be noted that the area under the net load duration curve represents net delivered energy. That means that the area under the positive part of the duration curve is equal to annual delivered energy, while the area 'under' (graphically above) the negative part of the duration curve is equal to annual exported energy.

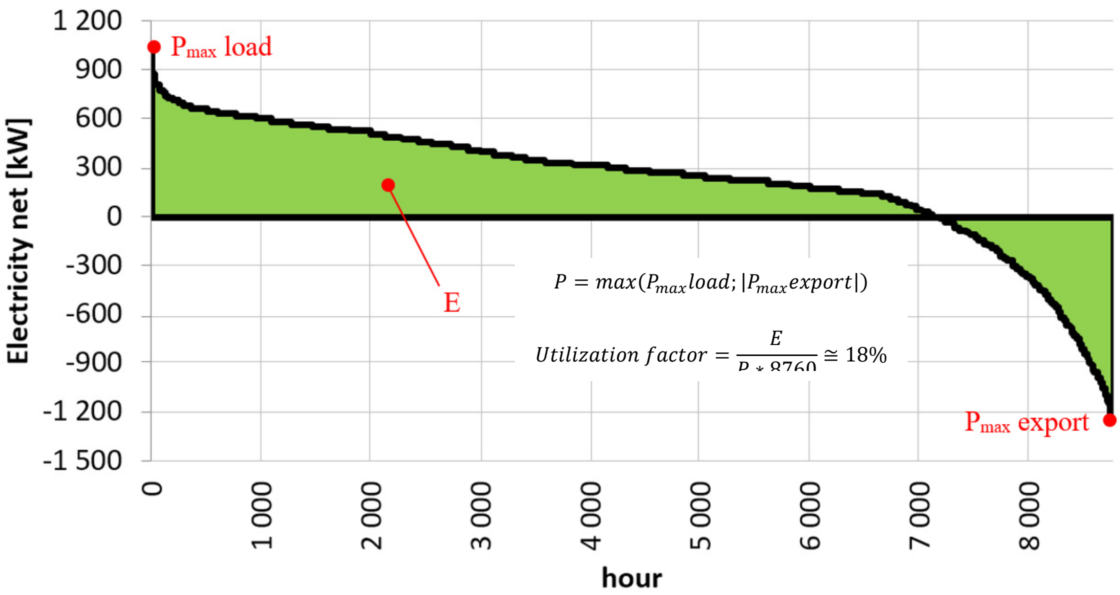


Figure 3.10. A graph showing the net load duration curve.

Power/load performance: utilisation factor

The utilization factor shows how much of the maximum grid connection capacity is required by the neighbourhood. The formulae in Figure 3.10 shows how to calculate the utilization factor. The area under the whole net duration curve, E, is the sum of annual delivered and exported energy, each taken with a positive sign. The maximum grid connection capacity, P, is given by the highest point between peak load and peak export, when both are taken with a positive sign. One may imagine graphically building a rectangle that has the 8760 hours as a base and P as the height. The ratio between E and the area of this rectangle is the utilization factor.

Net load profiles with relatively high peaks (either peak load or peak export) and relatively low average values, will have low utilization factors. Reducing the maximum peak does, in general, increase the utilization factor. On the other hand, also increasing the average value, e.g. increasing net energy use, will give a higher utilization factor. Therefore, an increase in the utilization factor is not necessarily a good thing and should not be set as a target per se.

Power/load flexibility: net load daily profile

The net load yearly profile and duration curve are calculated or measured on the neighbourhood assessment boundary level, for each energy carrier, with hourly or sub-hourly resolutions. As with the yearly profiles, the objective is to map out the net flow of an energy carrier delivered to and/or exported from a neighbourhood. However, the focus is on the daily profile for a few typical days during a year, e.g. summer, winter, spring and autumn, coldest days. The net load daily profile may also distinguish between weekdays and weekends. For this reason, it may be desirable to have a sub-hourly resolution for this KPI, even if an hourly resolution has been used for all other KPIs.

The value of the net load daily profiles is once again that of an immediate visual impression when comparing two alternatives. This KPI is useful to evaluate the effects of short term load shifting[2] and storage solutions, and their effectiveness in responding to signals from smart energy grids. Such signals might be price signals, information on the CO_2 content of energy produced at different hours throughout a day, as well as information on grid congestion problems, e.g. peak load hours in the (distribution) grid.

The focus of this KPI is on short-term variations and short-term storage, both thermal and electric, because this is what is usually available in a neighbourhood. With storage we mean both physical storage, such as hot water tanks and batteries (incl. those of electric vehicles) and virtual storage, such as changing the heating pattern of a building to serve other purposes (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 3.11 illustrates an example of a single building, with PV and battery, where the goal is to limit the net electricity export to the grid.

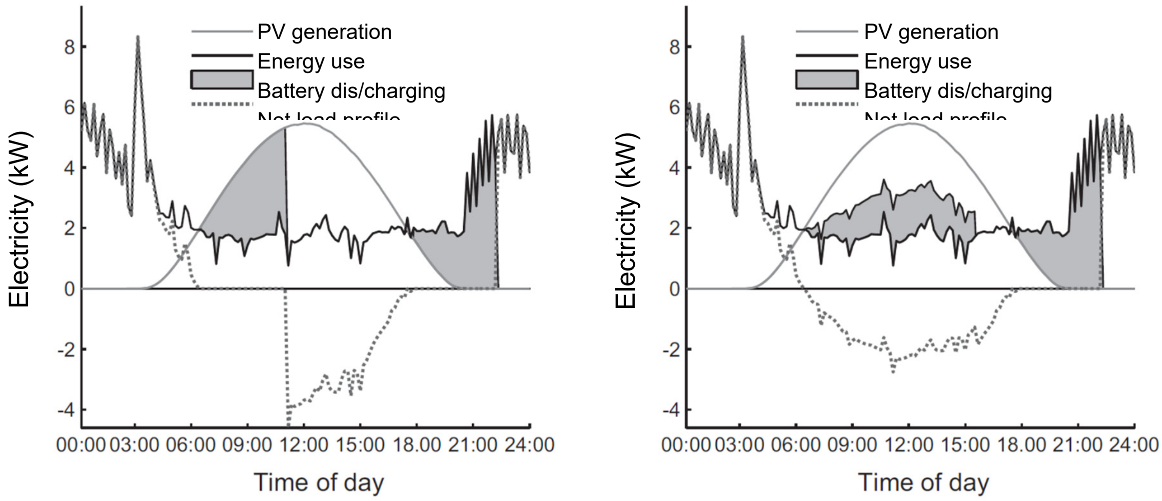


Figure 3.11. Example of electricity net load daily profile (dotted line), with a PV-battery system with different rates of charging. On the left, 100% of the surplus PV power is stored until the battery is fully charged. On the right, charging is limited to 40% of the surplus PV power, thus lowering the peak export power. The total battery capacity is the same in both cases. Source: adapted from [65].

Reference project and reference values

The reference values in the business as usual (BAU) scenario should be based on today's standards (TEK17) and/or best available information of typical use and generation profiles. The level of detail and the source of data may differ for different project phases. For example, simulation tools in design phases can be substituted by monitoring data in the operational phase.

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

3.4 Mobility

Assessment criteria and KPI

The mobility category is split into two assessment criteria, namely 'mode of transport' and 'access to public transport'. The KPIs and assessment criteria for the mobility category are mostly based on BREEAM Communities (TM 01 and TM 04) [68], as it was a wish from the ZEN partners to use criteria from BREEAM as a starting point for ZEN. These KPIs will be assessed at the neighbourhood level and do not include transport within buildings (e.g. lifts and escalators). The KPIs for the mobility category are to be implemented during the planning, detailed design, and operational phases. An overview of the KPIs for the mobility category can be found in Table 3.7. Air transport and sea shipping are excluded. Factors which have significant effect on travel behaviour, such as socio-economic (e.g. income, occupation), demographic (e.g. gender, age), travel preferences and attitudes, and other contextual factors (e.g. parking availability, weather) are addressed under the spatial qualities' category (Chapter 3.7).

Table 3.7. An overview of assessment criteria and KPIs for the mobility category.

Assessment criteria and KPI	**Unit**	**Strategic planning phases**	**Brief and preparation phase**	**Early design phase**	**Detailed design phase**	**Construction phase**	**Operational phase**
Mode of transport	% share	x			x		x
Access to public transport	meters	x			x		x

A Norwegian translation of some of the most important terms in the mobility category can be found in the blue text box.

Translation of some of the main terminology
used in the ZEN definition guideline from English to Norwegian

Mobility - Mobilitet
Mode of transport - Transportmåte
Access to public transport - Tilgjengelighet til kollektivtransport

Mode of transport

Mode of transport describes the percentage share of 'green' transport modes available in the ZEN pilot area, as well as the number of trips and the distances travelled by different modes of transport. Modal choice can depend on the purpose of the travel (e.g. work-related, for services, leisure), travel distance (e.g. shorter distances to city centre increase walking and cycling), and travel time. It can be done by using one (e.g. bicycle) or by combining different means of transport (e.g. walk-bus-walk). The percentage share of modal share can be evaluated using:

- Percentage share of travels by transport mode such as walking, cycling, public transport, and/or by private car.
- Percentage share of vehicles with alternative fuels, such as diesel vehicles, petrol vehicles, HVO biofuel vehicles, electric vehicles, battery electric vehicles, plug-in hybrid electric vehicles, etc.
- Average load factor (occupancy rate) of mode of transport to identify transport sharing, such as car sharing, carpooling, hire and ridesharing services, bike sharing
- Distance driven by mode of transport

The results from this KPI can be used in life cycle module B8 – transport in the operational phase, for GHG emission calculations in the emissions category [35]. The GHG emission calculation can be performed following the methodology and background emission factors given in NS 3720 [35].

The Norwegian travel survey (reisevaneundersøkelse (RVU) in Norwegian) can be used as an initial source of information for annual data that need to be assessed and adapted to the pilot areas [60]. Furthermore, it may be beneficial to use data from models for estimation of residents' transport demand and mode. Such models will e.g. be developed within the ongoing research project EE Settlement – Embodied Energy, Costs and Traffic in Different Settlement Patterns, where SINTEF Building and Infrastructure is involved.

Access to public transport

The aim of the access to public transport assessment critiera is to ensure the availability of frequent and convenient public transport, as a low-carbon choice, within the ZEN pilot area. Access to public transport includes links to existing and planned public transport nodes (such as train, bus, tram, or metro) as well as links to local city centres, distance travelled to/from station/stop, service frequency, and travel time. In BREEAM Communities, a local centre is defined as any community focal point including local shops, community facilities, a major transport node, (i.e. a railway, bus station), or another type of significant non-leisure related meeting place. Better accessibility of public transport, shorter walking distance to/from station/stop, and availability of frequent public transport may contribute to reducing travelled distances. The distance from a building within the ZEN pilot area to the nearest transport node, as well as the frequency of transport at peak hours (between 08:00-19:00) and off-peak hours (between 19:00 – 08:00) in urban and rural areas, as given in BREEAM Communities technical manual, can be used as a reference (7).

Reference values

Data from sources such as KOSTRA (municipality-state-reporting system, https://www.ssb.no/offentlig-sektor/kostra/), Statistics Norway (www.ssb.no), and TØI’s national travel surveys (www.toi.no/rvu/), can be used as a reference value.

3.5 Economy

Assessment criteria and KPI

The economy category has one assessment criteria, namely life cycle costs (LCC). The assessment criteria for the economy category is useful in all project phases. LCC in early project stages is used for studying the consequences of the performance requirements before any decisions are made. In the early stage of a project, LCC forecasting may use 'benchmark costs' based on historical costs of previous projects. As design evolves and more detailed information becomes available, benchmarks should be substituted with project-specific estimated costs. The early preparation and design phases have the greatest potential to influence the post - construction 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 can be taken [69]. Continual monitoring and optimization of LCC should continue throughout the project life cycle.

An overview of the KPI for the economy category can be found in Table 3.8. A Norwegian translation of some of the most important terms in the economy category can be found in the blue text box.

Table 3.8. An overview of assessment criteria and KPIs for the economy category.

Assessment criteria and KPI	**Unit**	**Strategic planning phases**	**Brief and preparation**	**Early design phase**	**Detailed design phase**	**Construction phase**	**Operational phase**
Life cycle cost (LCC)	NOK NOK/m^2heated floor area (BRA)/yr NOK/m^2 outdoor space (BAU)/yr NOK/capita	x	x	x	x	x	x

Translation of some of the main terminology
used in the ZEN definition guideline from English to Norwegian

Life cycle cost - Livsløpskostnader
Capital costs - Kapitalkostnader (k)
Management costs - Forvaltningskostnader (F)
Operation and maintenance costs - Drifts (D)- og vedlikeholdskostnader (V)
Replacement and development costs - Utskiftings- og utviklingskostnader (U)
Management, operation, maintenance, and development costs - Forvaltning, drift, vedlikehold og utviklingskostnader (FDVU)
Consumption costs - Forsyningskostnader
Cleaning costs - Renholdskostnader
Service and support costs - Service/Støttekostnad
Net present value - Nåverdi
Annual cost – Årskostnad
Discount rate - Kalkulasjonsrente
Real cost - Fast kroneverdi
Nominal cost - Nominelle kostnader
Payback period - Nedbetalingstid
Internal rate of return - Internrente

Life cycle cost (LCC)

Life cycle costing (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. LCC should be calculated according to NS 3454 Life cycle costs for construction works - Principles and classification [70], NS-EN 16627 Sustainability of construction works - Assessment of economic performance of buildings - Calculation methods [71], and ISO 15686-5 Building and construction assets - service life planning Part 5: Life-cycle costing [69]. However, NS 3453 and ISO 15686-5 use different terms in the LCC definition. In ISO 15686-5, "whole life costing" (WLC) is defined as it is equivalent to LCC plus external cost, even though it is admitted that sometimes all terms are used interchangeably. ISO 15686-5 states that LCC should be used to describe a limited analysis of a few components, while WLC should be considered as a broader term which covers a wide range of analyses. The Norwegian Standard NS 3454 defines LCC as including both original costs and cost incurred throughout the whole functional lifetime. Thus, LCC analysis and description given in NS 3454 has been followed, as it is a well-used method in Norwegian construction projects.

An overview of the ZEN reporting format for life cycle costs can be found in Table 3.9. For ZEN partners, it is important to harmonize the ZEN LCC methodology in the economy category with the ZEN LCA methodology in the emissions category. This will save both time and resources. Therefore, NS 3451: Table of Building Elements is used, to at least a two digit level, to help structure life cycle costing calculations, whereby building elements 20 – 69 correspond to the building assessment boundary and 70 – 79 correspond to the neighbourhood assessment boundary [33]. LCC related to these building and neighbourhood assessment boundary are then broken down into the following categories [70]:

- Capital and residual costs
- Management costs
- Operating and maintenance costs
- Replacement and development costs
- Consumption costs
- Cleaning costs (include costs related to cleaning activities)

Life cycle costs are to be reported in terms of total Norwegian kroner (NOK), in terms of Norwegian kroner per square meter heated floor area (BRA) per year (NOK/m^2/yr), Norwegian kroner per square meter of outdoor space (BAU) per year (NOK/m^2/yr), and Norwegian kroner per capita (NOK/capita). The definition of NOK/capita will be determined in subsequent versions of the guideline report. Life cycle costing should be completed as early as possible in the design process to maximise the outcome and ensure opportunities to positively influence the project can be taken.

Table 3.9. Matrix for documenting life cycle costs [70].

NS 3454		NS 3451					
Category	Sub-categories	**2 Building**	**3 Heating, ventilation and sanitation**	**4 Electric power**	**5 Tele. and automation**	**6 Other installation**	**7 Outdoor**
1 Capital and residual costs	11 Project cost						
	14 Residual cost						
2 Management costs	21 Taxes and fees						
	22 Insurance						
	23 Administration and management						
3 Operation and maintenance costs	31 Operation						
	32 Maintenance						
	33 Reparation of damage						
4 Replacement and development costs	41 Replacement						
	42 Developments and upgrading						
5 Consumption cost	51 Energy						
	52 Water and sewage						
	53 Waste handling						
6 Cleaning cost	61 Regular cleaning						
	62 Periodic cleaning						
	63 Extraordinary cleaning						
	64 Cleaning related task						

Economic evaluation methods for LCC

NS 3454 defines the life time costs as the net present value (NPV) of the LCC and the annual costs as the annuity of the LCC (Figure 3.12).

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. Future costs are converted to present value by use of the real discount rate. Different discount rates may apply depending on whether nominal costs or real costs are being discounted. Real costs are costs expressed as a value at the base data, including estimated changes in price due to forecast changes in efficiency and technology, excluding general price inflation or deflation (increase or decrease in price levels). Nominal costs are expected price that will be paid when a cost is due to be paid, including estimated changes in price due to, for example, forecasting change in efficiency, inflation or deflation, and technology. The nominal cost should be calculated by multiplying the real cost by the inflation/deflation factor. 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 Difi's guide for public buildings [73].

Annual cost (AC) or annual equivalent value (AEV): is a uniform annual amount equivalent to the project net costs, taking into account 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 (Figure 3.12). The annual equivalent value is the regular annual cost that when discounted equals NPV of the investment. The same principle can be applied to GHG emissions ($kgCO_{2eq}/m^2/yr$) in the emission category.

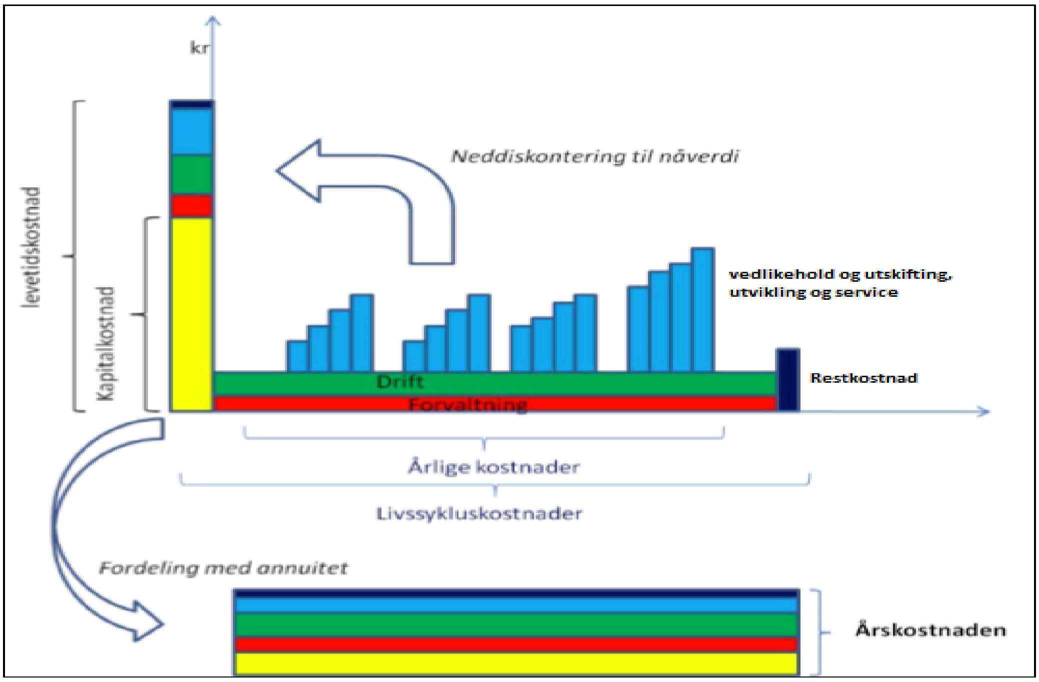

Figure 3.12. Annual cost model (adapted from [72])

Payback period: is the time it takes to cover investment costs and is considered as an additional criterion used to assess the time period during which an investment is at risk. It is calculated as the number of years elapsed before the NPV of the cumulative returns exceeds the initial investment. Simple payback takes real (non-discounted) values, while discounted payback uses present (discounted) value. The costs and savings occurred after payback has been reached, are not considered.

Internal rate of return (IRR): is the compound rate of interest that makes costs equal to benefits when cash flows are reinvested at a specified interest rate. IRR defines the discount rate that produces a NPV of zero (or the rate at which the costs equal the benefits of the investment). IRR enables the evaluation of the feasibility of an investment or comparison between possible different investments.

Net savings (NS): is the difference between the present worth of income generated by an investment and the amount invested. It is expressed in values (discounted) and unit of currency.

Reference values

Using LCC as part of decision making requires good accessibility to reliable input data, starting with generic information (statistic, key numbers) 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 [74]) can also be used as reference values.

3.6 Spatial qualities

Introduction

The spatial qualities category covers different features of the built environment that can affect, directly or indirectly, the appeal of a neighbourhood. It is important to pay attention to the different qualities of urban space, since it affects whether people living and working in the neighbourhood are willing and motivated to stay and use the neighbourhood. If the living conditions are perceived as bad, users would seek to satisfy their needs elsewhere, outside of their own neighbourhood. This leads to increased travel needs, which in turn leads to higher GHG emissions. Essentially, the core of city planning is to create good neighbourhoods for citizens to live, work, and play in.

Aim

The aim of the spatial qualities' category is to provide assessment criteria and KPIs for spatial qualities in a neighbourhood that are in line with the users' demands and that create good places to live and thereby encourage an environmentally friendly lifestyle with a low carbon footprint.

Definition

Within this report, we see spatial qualities as qualities of a neighbourhood perceived by its users and influenced by spatial elements of the neighbourhood. A spatial quality may for example be walkability, which is provided by amenities located within walking distance, together with an appealing public space which invites for usage.

Spatial qualities are linked to the spatial dimension of a place. The neighbourhood is a spatial dimension which is a part of the nexus between the city (macro level) and single components of the built environment of a neighbourhood, such as buildings (micro level) (Figure 3.13).

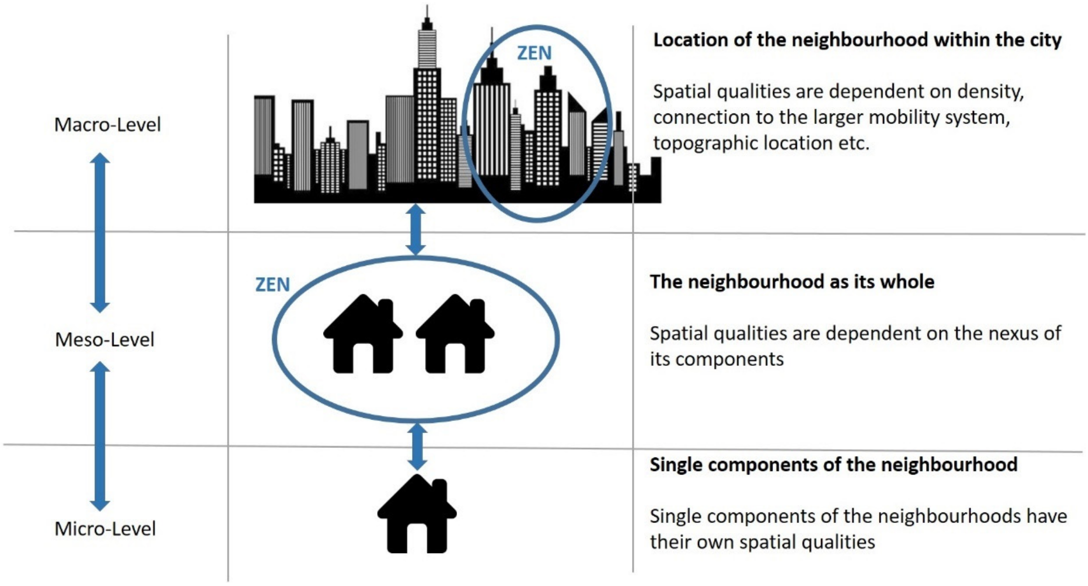

Figure. 3.13. Spatial dimensions of spatial qualities, illustration D. Baer

The spatial qualities provided at the neighbourhood level are influenced by two other spatial layers. The location within the city/larger region (Macro-level) and the design of the buildings (Micro-level). As the ZEN Centre focuses on the neighbourhood level, we have chosen three criteria important for providing good spatial qualities at the neighbourhood level.

Selection of assessment criteria and KPI

The ZEN pilot area must consider three aspects when assessing spatial qualities criteria at the neighbourhood level to encourage a low-carbon footprint lifestyle::

First, to ensure that the development is in line with the demands of its users and thereby provides appropriate spatial qualities. The criterion 'demographic needs and consultation plan' makes sure that the crucial stakeholders for the neighbourhood development are identified and consulted in the planning, construction, and operational phases of the neighbourhood.

Secondly, the neighbourhood must provide appropriate amenities. Based on the consultation of the users, the criterion 'delivery and proximity to amenities' aims to ensure that the desired amenities are provided within walking distances for the users of the neighbourhood. Mixed land use has several good implications, as UN Habitat states: "*The purpose of mixed land-use is to create local jobs, promote the local economy, reduce car dependency, encourage pedestrian and cyclist traffic, reduce landscape fragmentation, provide closer public services, and support mixed communities*" [75].

Thirdly, the neighbourhood must provide an appealing public space which encourages use. The criterion Public space focus on the use of nearby amenities by providing an appropriate open space that encourages social interaction and sustainable mobility behaviour with focus on walkability.

Assessment criteria and KPI

The spatial qualities category is split into three assessment criteria, namely 'delivery and proximity to amenities', 'public space', and 'demographic needs and consultation plan'. The selected assessment criteria are mainly based on BREEAM Communities [76]. Other resources, such as the UN Habitat principles for sustainable neighbourhood planning [75] and the public life analysis [*Bylivsundersøkelse]* in Oslo [77], were used to support the development of appropriate assessment criteria and KPIs.

An overview of the assessment criteria and KPIs for the spatial qualities' category can be found in Table 3.10. A Norwegian translation of some of the most important terms in the economy category can be found in the blue text box.

Table 3.10. An overview of the assessment criteria and KPIs for the spatial qualities' category.

Assessment criteria and KPI	**Unit**	**Strategic Planning phase**	**Planning phase**	**Brief and preparation**	**Early design phase**	**Detailed design phase**	**Construction phase**	**Operational phase**
Demographic needs and consultation plan - Demographic analysis - Stakeholder analysis - Needs assessment - Consultation plan	qualitative	x	x	x	x	x	x	x
Delivery and proximity to amenities - Delivery of amenities - Proximity to amenities - Localisation of amenities	No. of amenities, Meters (distance from buildings)	x	x	x	x	x	x	X
Public Space	qualitative	x	x	X	x	x	x	x

Translation of some of the main terminology used in the ZEN definition guideline – from English to Norwegian

Spatial Qualities – Stedskvaliteter
Public Space – Offentlig rom
Amenities – Fasiliteter
Community – Lokalsamfunnet
Inclusive Design – Universell utforming
Co-location – Sambruk
Multiple use of spaces and amenities -Flerbruk
Community management – Velforening
Public Space Analysis - Bylivsundersøkelse

Demographic needs and consultation plan

This assessment criteria ensures 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, the quality and acceptability of the development throughout the design and construction processes, are ensured.

The assessment criterion consists of four different KPIs[3]:

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

Data to describe the demographic profile for the neighbourhood should be available from the local authorities. The demographic profile should include information about age, gender, cultural background, household size, values, tenure, and change, population projections, headship rates, the ageing population, children and young people, employment (sectors, incomes, businesses, unemployment), education, skills, and training and health [76].

The second KPI will involve a **stakeholder analysis** to identify the neighbourhoods' users and stakeholders that are important to include in the ZEN pilot area. The following list consists of potential

[3] The KPIs specified in this criterion, may, strictly speaking, not be defined as KPIs, as they are activities to be carried out in the planning of ZEN. We have, however, chosen to call them KPIs, to be able to count them in a similar manner to the KPIs under the other criteria. They will however, just have a value of either 0 (not carried out) or 1 (carried out).

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

The third KPI will involve a **needs assessment** to provide information about the needs and requirements of the users of the neighbourhood regarding the delivery of amenities and the design of public space. Consideration should be given to how the demographics of the community will change over the life time of the development as it is important to plan and design for adaptability and flexibility. The following aspects should be considered in the needs assessment [76]:
- community buildings/local meeting places,
- dwellings, including affordable homes and mix of tenure,
- education and library services,
- green space,
- leisure facilities (free and priced) and other sports facilities (e.g. tennis courts, football fields, swimming pools, etc.),
- health and social care services such as pharmacy, medical centre, and GP surgery,
- shops and/or farmer's markets selling food and fresh groceries,
- community gardens or places growing fresh fruit and vegetables,
- children's playground and facilities (nursery/crèche),
- communication services such as public internet access, post box, and postal facility,
- bank and/or cash machine,
- community house,
- places of religious worship (incl. parish halls), etc.

As a fourth KPI, a **consultation plan** should be developed to ensure the inclusion of the users' needs in the ZEN development process. The aim of the consultation plan is to ensure that the needs, ideas, and knowledge of the community are used to improve the quality and acceptability of the development throughout the design and construction processes and into the use phase.

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

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

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

- Inclusion of different stakeholders in design reviews of plans for delivery of amenities, public space, local parking, landscaping, community management [velforening], 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/heritage value).
- Accountability: The consultation plan is completed by people who are trained in human centred and/or participatory design processes. Accountability means that the input from users are handled in an open manner and decisions regarding what is implemented of users' ideas and needs are openly discussed. The 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 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' viewpoint (such as cleaners, food distributors, healthcare assistants, etc.).
- Opportunities for shared use of facilities and infrastructure with the existing or adjacent community.

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

- the consultation exercise has a clearly communicated purpose,

- participants understand how their views will be used in plans for the development,
- expectations are set as to which options are open for discussion and revision,
- reasonable advance notice is given to potential participants of the consultation exercise,
- efforts are made to include hard-to-reach groups,
- specific attention must be taken to ensure a clear language and no use of discipline specific wording,
- the consultation is facilitated by a person or organization that is independent from the project owner.

The development of a consultation plan is mandatory, and the following table lists potential assessment aspects.

Table 3.11. Assessment of 'Demographic needs and Consultation plan'

Assessment Aspect
A stakeholder analysis has been conducted including marginalised groups.
A demographic analysis has been conducted to identify a sample of end-users.
The needs of the users of the neighbourhood regarding the delivery of amenities and public space have been identified through an inclusive and open process.
The needs and solutions proposed in the consultation plan are openly shared and used as guiding principles in the concept development.
A consultation plan is developed in a collaborative manner and scenarios are well known to decision makers and citizens.
The consultation is based on a facilitated community consultation method and conducted by a person or institution independent of the implementing stakeholders or authorities.
The needs identified in the consultation plan are in implementation at the same time as the first buildings are being constructed.
The citizen representatives involved in the consultation plan have a way to evaluate and provide input on the implementation and final design.
The participants in the consultation plan are involved in the final implementation stages.

Data for the assessment criteria are generated based on information from the project owner or local authorities.

The KPI assessment should be documented by providing:
- A copy of the stakeholder analysis.
- A copy of the demographic analysis.
- A copy of the need's assessment report.
- A copy of the consultation plan (planning phase).
- Evidence on how the consultation plan has guided the implementation (from brief and early design phase to operational phase) of the ZEN pilot area
- Documentation showing the output of the facilitated community consultation exercise.

Delivery and Proximity to amenities

This criterion covers the delivery of amenities within the neighbourhood and the proximity of the amenities to the users of the neighbourhood. Amenities in a neighbourhood are important for providing a sense of liveability for residents and users of the neighbourhood, and they play a key role in the perception of quality of urban life [78]. When asked about their thoughts about urban amenities, interviewed citizens in a research study in Auckland described them as *"all the services and infrastructure they used in their daily lives"* [79]. Amenities can thereby be defined as facilities that contribute to the urban living experience of residents. On the neighbourhood scale, they are divided into public amenities provided by the municipality, such as parks, public squares, and recreational facilities, and commercial amenities, such as cafés, restaurants, and retail. Besides that, there are amenities provided by other organisations, such as the local community, sport clubs, and voluntary organizations. This may also include community gardens or social events, which also play an important role in relation to quality of life.

The assessment criteria 'delivery and proximity to amenities' is divided into three KPIs: delivery for amenities, proximity to amenities, and localisation of amenities. These are described in more detail beneath.

Delivery of Amenities
Delivery of amenities is measured o ensure that appropriate amenities are delivered on behalf of the inhabitants' and users' needs within the neighbourhood. The amenities preferred by locals have to be identified at an early stage of development. The criterion 'demographic needs and consultation plan' provides the identification of users' needs during the needs assessment.
In order to provide a good place to live in the ZEN pilot area, it is important to provide as many useful amenities as possible within the neighbourhood, and to ensure that desired amenities located outside the neighbourhood can be easily reached by public transportation.
The delivery of amenities is assessed by the number of delivered amenities in relation to the desired amenities by the neighbourhood users.

Proximity to Amenities
Secondly, the proximity to the delivered amenities is an important factor to assess. It is important to ensure that non-motorised users have the chance to access amenities easily. Research shows a decrease in car use as shorter the distance between home and amenities is [80]. The delivery of amenities within a walkable distance is thereby an important factor to promote walking within the neighbourhood. Within BREEAM Communities [76], walking distance is defined as up to 650 m for inner urban areas. One methodology to assess the proximity to amenities is described in the master thesis of Marianne Gro Lindau at NTNU [81]. She describes how proximity can be assessed from the existing buildings in a neighbourhood based on the existing pedestrian network in a GIS analysis. Such a methodology could be used to assess proximity in ZEN pilot projects. It is important to mention that the system boundary of the neighbourhood must be extended with regard to the assessment of the amenities criterion. This is because some of the amenities may be located outside of the neighbourhood boundary, but still within walking distance from the buildings located within the geographical boundary of the neighbourhood. The neighbourhood boundary thus has to be expanded for this analysis, to cover the area within walking distance from buildings located within the neighbourhood.

Localisation of Amenities
Whilst the first two aspects ensure that the desired amenities are provided for within the neighbourhood and are accessible to users, little is said about the location of amenities within the neighbourhood. The synergy of amenities is an important factor when providing spatial qualities for the neighbourhood. The **synergy** of different amenities in close proximity to each other or within a building helps to reduce the demand for space. For example, common facilities, such as restrooms, kitchens, meeting rooms, or parking facilities, can be shared. This reduces the demand for space and directly reduces emissions, as less area is built.
The synergy of amenities helps as well to limit the volume of traffic, as more amenities can be frequented at one common place. Examples include post offices located within supermarkets, or a cafés located within libraries. The synergy of amenities also contributes to the vitality of a place, as more people are using the place.

The **multiple use of space** for the delivery of amenities at different times of the day can also help to reduce the demand for space. Multiple use spaces can be outdoors, such as, for example public spaces used for different kinds of public events. Multiple use spaces can also be located within buildings, for example if school facilities are used for community activities, such as sport events or flea markets, in the evenings or weekends.

A close localisation of different land uses helps as well to reduce peak loads on energy systems, as the different land uses have different timeslots for energy use. For example, a school has its highest demand during daytime, while a retirement home has its peak demand in the evening and early morning. Together, they have a more evenly distributed consumption pattern that may make better use of locally available renewable energy.

Data for the assessment of criteria may be generated from different sources. Desired amenities are documented within the 'demographic needs and consultation plan' assessment criteria. Data about the realised amenities within the neighbourhood could be provided by the municipality for public amenities and the chamber of commerce for private amenities.
Data for the assessment of proximity of amenitiescan also be generated from different sources. The department of city development and the geo-data department could provide data about the built environment of the neighbourhood with focus on the planned and realized buildings.

The **analysis** of delivered amenities and proximity of amenities can be generated with the help of a geographic information system (GIS), which is in common use in municipalities and private entities.

The **documentation** of assessment criteria can be presented as:
- a document describing the process of assessment and the results,
- an analysis sheet showing the ratio of delivered amenities to local supply requirements and/or desired amenities,
- an analysis sheet showing the number of amenities located within walking distance.

We recommend visualising the results of the GIS analysis to better understand the relationship between distances and amenities, especially when the geographical boundary of the neighbourhood has been extended for the analysis.

Public space

Public space is one of the key dimensions of spatial qualities. The underlying reason for choosing public space as one of the assessment criteria within spatial qualities, is that by promoting it we also 'encourage social interaction by creating comfortable and vibrant spaces' [82]. This goes well together with the UN Habitat strategy for sustainable neighbourhood, that, guided by its five principles aims to 'foster sustainable urban development by creating liveable and efficient neighbourhoods' [75]. This approach also goes hand in hand with one of the principles of Gehl, emphasising that the planning processes should prioritise public life and public spaces before considering the buildings [82].
By creating attractive public spaces, planners and decision-makers can encourage people to stay in the neighbourhood. This has an indirect influence on environmental sustainability.

To define public space, we utilise the same definition as in BREEAM Communities [76]:

> *'all those parts of the built and natural environment where the public has free access. It encompasses: all the streets, squares and other rights of way, whether predominantly in residential, commercial or community/civic uses; the open spaces and parks; and the 'public/private' spaces where public access is unrestricted (at least during daylight hours). It includes the interfaces with key internal and external and private spaces to which the public normally has free access.*"

Figure 2.2 in Chapter 2 illustrates public space in a neighbourhood.

The following elements are important to consider when planning for good public spaces [76, 82]:

- universal design
- usability for several user groups
- providing different elements, such as benches and playground equipment that encourages use of the public space
- shared space, where different transportation forms are treated equally, and safe circulation of all users is ensured
- attractive transitions areas between public space and buildings (ground floor use of buildings for cafes etc., façade design, etc.)
- use of local materials
- preservation of landmarks and historical elements
- lighting
- green-blue infrastructure
- human-scale orientation of elements and buildings

Figure 3.14 gives a good overview of the key attributes and intangibles needed to create a liveable neighbourhood.

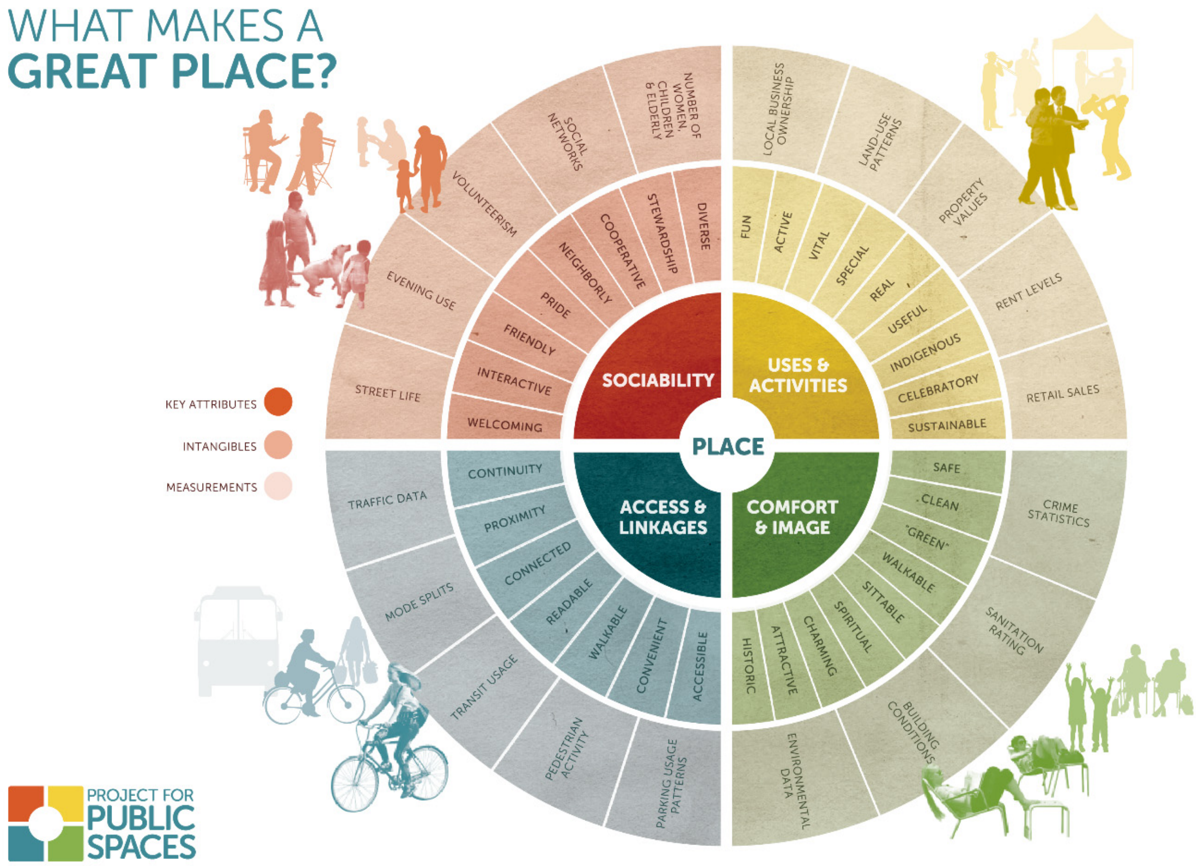

Figure 3.14. Key attributes, intangibles, and measurements of liveable places. Illustration by Project for Public Spaces [83]

Public space analyses were already adapted from Oslo and Bergen, based on a methodology developed of Gehl Architects, and consisting of two parts, an analysis part and a recommendation part [79, 85]. The analysis follows the development of public space and helps to evaluate applied measurements as well as give recommendations for further development. The analysis qualitative and quantitative data and methods, such as pedestrian counts, registrations of usage of public space, registration of age and gender of users, and a survey of the users. The analysis uses a triangular approach to assess public spaces.

Table 3.12. provides twelve spatial quality criteria for public spaces that can be divided into three different aspects: protection, comfort, and enjoyment. Experience shows that public spaces that take these aspects into account are used more frequently [82]. The twelve quality criteria can be used as a basis for analysing the different features of the public space and for developing strategies.

Table 3.12. Twelve quality criteria for public space. Adapted from Gehl Architects [82].

PROTECTION	**Protection against traffic** - Separation of different traffic modes - Protection for pedestrian	**Protection related to microclimate** - Wind - Precipitation - Sun - Shade - Temperature - Pollution	**Protection against crime and violence** - Good lighting - Mix use of ground floor day and night - Lively public spaces
COMFORT	**Opportunities to walk** - Good quality surfaces - Mix use of ground floor - Maintenance - Enough space for walking - No obstacles	**Opportunities to stand and stay** - Supports for standing - Edge effects, such as attractive zones for standing	**Opportunities to sit** - Good view, sun, people to observe - Benches - Secondary seating - Microclimate
	Opportunities to see - Something to observe, interesting views - Good lighting	**Opportunities to talk and listen** - Low noise levels	**Opportunities to play and exercise** - Different seasons - Different age groups
ENJOYMENT	**Scale** - Buildings and public spaces are in human scale	**Pleasure and enjoyment of the environment** - Microclimate	**Aesthetic qualities/ positive impression** - Blue-green infrastructure - Good materials - Maintenance in different seasons

4 ZEN Pilot projects

Nine pilot projects will be developed within the ZEN Research Centre. This includes Ydalir in Elverum, Furuset in Oslo, Fornebu in Bærum, Campus Evenstad in Hedmark, NRK site in Steinkjer, the knowledge axis at NTNU in Trondheim, the NTNU Campus at Sluppen, Zero Village Bergen, and the 'New airport – new city' in Bodø (Figure 4.1 and Table 4.1).

Figure 4.1. Location (left) and illustration (right) of the ZEN pilot projects. (Credits for illustration and pictures from left to right are as follows: Baer/Andresen, tegn3, a-lab, Bodø Municipality, Kjeldsberg Eiendom, Koht Arkitekter, Steinkjer Avisa, Snøhetta/Mir, Statsbygg, Wilhelm Joys Andersen).

Table 4.1. The ZEN pilot projects at a glance [84].

Pilot areas	City population (1.1.17)	Project owner	Area (m^2)	Planned/Existing function	Construction planned	Phase
Ydalir, Elverum	14 877	Public	430 000	Residential area with a school and nursery school	New construction: 1 000 dwellings (ca. 100 000 m^2), a school (under construction) and a nursery school	Implementation
Furuset, Oslo	666 759	Public	870 000	Multifunctional sub centre with 1 400 dwellings and 3 800 inhabitants, 213 100 m^2 existing building stock	Retro-fitting/upgrading and new construction: 1 700 – 2 300 dwellings and 2 000 – 3 400 work places (up to 160000 m^2)	Implementation and Operation
Sluppen, Trondheim	190 464	Public	275 000	Multifunctional sub centre with a mobility hub (planned)	Retro-fitting and new construction	Planning and Operation
Campus Evenstad	2 530 (municipality)	Public	61 000	University campus	Building stock in use: 10 000 $m^{2,}$ no further construction planned	Operation
Lø, former NRK site, Steinkjer	12 744	Public	11 113	Nursery school and dwellings (planned)	Re-use of existing building stock and new construction of 10-12 dwellings	Planning
NTNU Campus	190 464	Public	339 031	University campus	Retrofit and new construction (136 000 m^2)	Planning
Zero Village Bergen	252 772	Private	378 000	Residential area with a nursery school and additional services (planned)	720 new dwellings (92 000 m^2)	Planning
New City – New Airport, Bodø	51 002	Public	3 400 000	Multifunctional city centre extension with residential and business areas (planned)	Re-use and new construction: 2 800 dwellings in the first construction stage	Planning
Fornebu, Bærum	124 008	Public	3 400 000	Multifunctional centre, ca. 265 000 m^2 existing building stock	New construction: 3 700 dwellings, 2 600 are built and in operation	Planning and Operation

There are several differences identified between the ZEN pilot projects:

- The ZEN pilot areas comprise of both new developments and existing neighbourhoods.
- The ZEN pilot areas vary in size, from a small university campus (Campus Evenstad) to a large neighbourhood development ('New City – New Airport' in Bodø).
- Each ZEN pilot area is at a different phase of development, from the early planning phase to the operational phase.
- Each ZEN pilot area has different functional requirements and building typologies: e.g. residential, school, office, commercial, university campus, etc.
- Each ZEN pilot area has different stakeholders and users.
- Each ZEN pilot area has a different public/private energy network.
- Each ZEN pilot area will develop its own architecture concerning aesthetics and material choices.
- Each ZEN pilot area is placed in a different geographical context with different transport links, and a different climate, etc.

Furthermore, ten main challenges have been identified through interviews with central stakeholders and the study of relevant documents [85]:

- ***Project organisation and management***: How to ensure a continuation in process management given the long timeframe of the projects. How to ensure commitment to ZEN goals among all participants (different landowners, public and private developers, contractors, end users, etc.). How to implement new interdisciplinary ways of working.
- ***Lack of knowledge***. There is limited knowledge about how to plan, develop, construct, and operate a ZEN area.
- ***Legislation***. Current codes and regulations are not adapted to ZEN innovationsolutions, especially with respect to the exchange of energy between buildings.
- ***Goal conflicts***. How to handle conflicting interests of different stakeholders, i.e. developers, municipalities, citizens, etc.
- ***Time and cost restrictions***. Even though the projects have long timeframes, the projects are still subject to limited time and resources, which makes it demanding to take into account the added complexity of ZEN projects.
- ***New energy technologies***: How to select, design, and integrate the most suitable energy supply systems with the lowest possible carbon footprint and life cycle costs. Lack of methods, tools and data.
- ***System boundaries***: What emissions should be included in the calculations and how. What is the needed level of detail? How to consider energy plants located outside the development area.
- ***Risks and uncertainties***. How to handle risks given the large uncertainties (long timeframe) of the developments. Change in boundary conditions (e.g. regulations and incentives), new technologies developments, etc. Uncertainties about the costs and performance of ZEN solutions.
- ***Flexibility***. How to plan the infrastructure to allow for flexibility and adaptation to future developments in technology, legal frameworks and use.
- ***Transferability***: How to transfer knowledge and solutions developed in the pilot project to other neighbourhood developments.

A detailed description of pilot projects with regard to their measures, status, challenges and risks, the stakeholders involved, and the characteristics of the locality is available in the, ZEN pilot projects – plans and challenges report [85].

5 Limitations and further work

This is a first version of the ZEN definition guideline. It builds uponthe ZEN definition report and provides more detailed descriptions of the 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 projects. This first version of the ZEN definition guideline has highlighted the limitations and scope for further work, which will be covered in future editions of the ZEN definition report.

During the next two-year period, the ZEN definition guideline working group suggest taking on the following activities:

- **Testing and evaluation of assessment criteria and KPIs in ZEN pilot projects**: Check with the ZEN pilot areas which indicators they already use, and test and evaluate the performance of the criteria and KPIs. KPIs and criteria for the innovation category will also be further developed and incorporated in the forthcoming guideline reports. Furthermore, evaluate the need for revising existing criteria and KPIs or incorporating additional assessment criteria and KPIs outlined in Appendix A of the ZEN definition report or additional new ones.
- **Further development of spatial quality category:** The expert group on spatial qualities is planning to widen the category of spatial qualities with additional assessment criteria and KPIs. At the time of writing, the following indicators are planned to be integrated in a first step: mixed use, density, share of residents, integration with surrounding neighbourhoods.
- **Data collection and documentation**: Develop a transparent system for data collection, monitoring, evaluation, and documentation, including the type and availability of data, who should assess the data, in which quality (including source and age of data) and regularity.
- **Tools**: ZEN pilot projects need tools which enable them to assess, analyse, monitor, and visualise assessment criteria and KPIs and engage relevant stakeholders in different phases. In future editions of the ZEN definition report, a guidance for the selected tools and how to use them in pilot projects is needed.
- **Reference/case projects**: In this ZEN definition guideline report, basic background information used for developing reference projects and reference values are incorporated. In future editions of the ZEN definition report, reference projects/values should be developed that can be used as benchmarks to evaluate and document how much a ZEN pilot area has managed to reduce its total life cycle GHG emissions towards zero.
- **Ambition level**: In future editions of the ZEN definition report, a guideline for ZEN ambition level definition and recommendation for minimum ambition level requirements for ZEN pilot projects should be developed.
- **Multi-criteria analysis**: In this guideline report, the assessment criteria and KPIs are described separately. A methodology for multi-criteria analysis approach for evaluating, measuring, and reporting the interconnection between criteria and KPI results under each category will be developed.
- **Verification**: Verification and documentation of the results should be performed. Each pilot ZEN area has a dedicated ZEN advisor to follow the progress of the KPIs. A ZEN advisor is a researcher from NTNU and/or SINTEF involved in the Norwegian Research Centre for Zero Emission Neighbourhoods (ZEN) in Smart Cities. The ZEN advisor can act as an observer in the workshops and development process. However, they can also guide and advise stakeholders on strategies for achieving the KPIs. The ZEN advisor will be the main

contact person for the ZEN stakeholders involved in that ZEN pilot area. This relationship is further described in the intention agreement between the ZEN Research Centre and ZEN partners.

- **Guidance and team work**: The experience from the follow-up of the ZEN pilot projects so far show that it may be difficult for end users and other stakeholders to understand and familiarise themselves with the concept of ZEN and its goals. This could result in resistance against the projects, and it could jeopardise the successful realisation of a ZEN. Further guidance and knowledge transfer are recommended through practical workshops and follow up to ensure that everyone has the same understanding of the ZEN concept and its goals.

Furthermore, the ZEN guideline working group recommends ZEN pilot area partners to have a strong focus on:

- Identifying responsibilities for data collection and documentation for the reference case, the planning phases, the early design phase, the detailed design phase, the construction phase and the operation phase.
- Establish reference values and reference projects for the ZEN pilot areas.
- Identify what the ZEN pilot projects consist of in terms of what elements to include: buildings, infrastructure, and open space (system boundaries).
- Be involved in the definition of an ambition level and in realising this in the pilot projects.
- Be involved in the testing and implementation of the KPIs.

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Appendix A: **Timeline showing the development of the ZEN research centre's ZEN definition**

DATE	PURPOSE	OUTCOMES
27th March 2017	Partner workshop	Use life cycle modules from EN 15978 as a starting point. Start ambitiously to identify design drivers for emission reductions. Use the ZEN pilot areas to discover good solutions. Need clear system boundaries for reuse and recycling. Need clear understanding of reference service lifetimes of materials, components, buildings and infrastructure in relation to the functional unit. Need a clear system boundary for energy systems. Should include indirect emissions from transport and materials. Should assess existing methodologies and frameworks.
27th April 2017	Thematic partner workshop - Planning	
27th April 2017	Thematic partner workshop - Energy	
3rd May 2017	Thematic partner workshop - Buildings and materials	Use NS 3451 Table of building elements to structure GHG emission calculations. Should consider whole life cycle according to EN 15978. Should also include person transport and harmonise ZEN methodology with forthcoming standard NS 3720. Encourage use of EPDs as GHG emission data source.
7th June 2017	Partner workshop	First draft of the ZEN definition is discussed in plenum.
26th June 2017	WP1 sent out a draft of the ZEN definition to specialists within each area.	
17th August 2017	Internal meeting on connection of ZEN definition to the ZEN pilot areas.	Working group formed to draft report on a ZEN definition for the ZEN pilot areas.
21st – 22nd November 2017	ZEN partner workshop	Status update. Workplan for 2018/19.
15th December 2017 – 8th January 2018	Internal hearing	Expert groups were consulted and gave input to the ZEN definition report.
8th January 2018 – 4th February 2018		Reworking of ZEN definition in response to feedback.
February 2018	ZEN partner hearing	ZEN partners were consulted, and gave input to the ZEN definition report.
September 2018	First version of the ZEN definition is published.	In English and Norwegian
October 2018	ZEN Partner Seminar	Presentation of preliminary guideline and workshop on ZEN definition and guideline

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«Sustainable neighbourhoods with zero greenhouse gas emissions»

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