OmrådeLCA, assessment of area development: Case study of the Zero-Emission Neighbourhood Ydalir

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Abstract. The built environment is a major contributor to global greenhouse gas (GHG) emissions. There is a growing need to quantifying GHG emissions, and LCA tools can be used to help address them and find the key contributors. In order to compare different solutions of development of the built environment in the early stage planning process, the OmrådeLCA tool has been developed. OmrådeLCA has the unique advantage, compared to other similar tools, of using the system expansion approach, which allows for comparing different scenarios based on the same functional unit. We applied OmrådeLCA on Ydalir (Norway), a zero emission neighbourhood in an early stage planning process. The results show how significant the share of emissions from transportation are, contributing to more than 60% to the total GHG emissions. Sensitivity analysis shows that choices made, and data used in modelling transportation significantly impact resulting GHG emissions. Thus, conducting a thorough analysis of factors affecting transportation is important for obtaining representative results when using OmrådeLCA. The results from the assessment of Ydalir with OmrådeLCA have been compared with results from the same case assessed with a tool developed by NTNU. The comparison shows relatively small differences in calculated results. This small degree of variation between the two tools in calculated results, demonstrates that OmrådeLCA can provide good estimates even at an early stage. This gives the tool great utility value because it is in the early stages of a project major actions can be performed and decisions made that will affect the emissions the most.

1. Introduction

The built environment, referring to the building and transportation sector, is a major hotspot of environmental impacts, accounting for 55% of total global greenhouse gas (GHG) emissions [1]. To reduce the impact the built environment has on the climate, several different measures and actions can be implemented [2]. Zero Emission Buildings (ZEB), compensate for total greenhouse gas emissions emitted over the building lifecycle by producing local renewable energy. The construction of ZEBs and Zero Emission Neighbourhoods (ZEN) [3] are measures which can contribute to minimising GHG emissions from new construction. Conducting GHG emission calculations is essential in order to document and assess the impact from the built environment and to compare different solutions and alternatives. LCA is a methodological framework used to analyse the environmental impacts of goods, services, materials, etc. The ISO standards ISO 14044 [4] applies for how to perform an LCA. In Norway, LCA methodology for assessing buildings has been standardised in NS 3720 [5].

A study by Wiik et al. [6] on lessons learnt from embodied GHG emission calculations in zero emission buildings from the Norwegian ZEB research centre found that the main contributors to total GHG emissions for building components are the building envelope (ca. 65%), and for the life cycle
stages, the production and replacement of materials (ca. 55–87%). The study by Wiik et al. considered buildings adhering to a high building standard, resulting in a reduced need for operational energy. Dahlstrøm et al. [7] compared GHG emissions from a single-family dwelling built according to conventional building standards with a higher energy (passive house) standard, also considering the impact of the choice of emission intensity for electricity. The study highlights the increased significant the emissions from operational energy use got when shifting from both a higher building standard to a conventional one, and an electricity production mix with a low emission intensity to one with a higher intensity.

When expanding the scope and system boundaries to be applicable on a neighbourhood scale such as ZEN, transportation must also be accounted for. Lotteau et al. [1] carried out a study on 21 existing case studies on the neighbourhood scale. Although they found significant differences both in the type of projects, the scope of the studies, functional units and system boundaries, some general trends were identified. The buildings (construction and use of materials over the life cycle) were found to be the main contributors to GHG emissions, followed by transportation. However, Norman et al. [8] found transportation to be the largest contributor to total GHG emissions, contributing to 40-60% of the total.

There is growing interest in the field of urban sustainability assessment on the neighbourhood scale, as mention by Lotteau et al. [1]. When developing areas according to the ZEN principle, robust quantitative estimation methods for GHG emissions applicable on the neighbourhood scale and at different stages of the planning process are needed. These methods and tools must meet the best practice for assessing GHG emissions and be in line with current frameworks and standards.

OmrådeLCA is an assessment tool for GHG emissions from areas, developed by Asplan Viak AS. The tool is based on the LCA framework, and considers emissions arising from use of building materials, operational energy use in buildings, and transportation of inhabitants on the neighbourhood scale.

The motivation for conducting the study described in this paper has been to further develop OmrådeLCA from its original version, as a high-quality tool for assessing GHG emissions from areas that in a transparent way can show results and importance of different choices taken and crucial factors for the development of new neighbourhoods. To assess the quality of the updated version of OmrådeLCA, the tool has been applied to the specific case Ydalir (Norway) and results have been compared with results from an assessment of the same case using a similar tool developed by NTNU. The study also considered the underlying methodology of OmrådeLCA in comparison with the NTNU ZEN-tool.

2. Method

2.1. Model

OmrådeLCA (which can be translated into English as AreaLCA or NeighbourhoodLCA) is a calculation tool developed by Asplan Viak in order to assess accumulated GHG emissions of area development. The underlying methodology of OmrådeLCA aims to shed light on the question; What is the best development path regarding GHG emissions for a given project [9, 10]?

The tool is intended mainly for use in an early planning stage, often before a regulation plan is approved, to compare different scenarios for development of an area or neighbourhood. Choices under consideration may be a different mix of building functions (such as apartments, single-unit dwellings, kindergarten and offices), and energy- and transportation solutions. To be comparable, these different scenarios must be assessed using the same functional unit, as stated in the LCA standards ISO 14040 and ISO 14044. This is done by using a methodological approach in LCA known as system expansion. Each scenario is assessed on the basis of the same overall functional mix of built area or number of inhabitants, per building category. The functional unit is set according to the scenario providing the largest built area or number of inhabitants, and for the other scenarios, it is assumed that any area that is not provided within the given scenario must be provided (built) in another (alternative) location. An illustration of this approach is given in Figure 1. The functional mix illustrated in this example is a mix
of apartments, offices and a kindergarten. The difference between scenario 1 and 2 is the built square metres of housing and kindergarten that needs to be compensated for in the “alternative fulfilling of the function”. As most other assessment tools use an attributional LCA approach, where only the environmental impact of each scenario as it is defined is assessed separately, this system expansion approach distinguishes OmrådeLCA from other tools [9, 10].

![Comparison scenario 1](image1)
![Comparison scenario 2](image2)

**Figure 1. Methodological approach in OmrådeLCA.**

The tool calculates emissions based on built area (BRA) and divides the calculations into three primary modules. These are materials, energy use, and transportation. The modules included in the tool compared to the NS3720’s modular structure can be seen in Figure 2. OmrådeLCA uses data from national and local statistics, travel habit surveys, LCA databases and LCA studies. These generic data are combined with case-specific data which can be entered in the tool. Various modelling choices and scenario selections can also be made within the tool in order to tailor the analysis to a specific area development case.

![Modules included in OmrådeLCA according to NS 3720.](image3)

**Figure 2. Modules included in OmrådeLCA according to NS 3720.**

Through the described study, OmrådeLCA has been further developed from the original version made by Asplan Viak. The most important changes are as follows: emissions from use of construction materials have been subdivided according to the different modules of NS 3720; local energy production can be implemented easily; use of specific data for energy mix, development pattern and energy standards has been enabled. Also, result calculations have been made more transparent. Results are expressed in different functional units, and given according to the different modules specified in NS 3720, as well as cording to the different building categories considered. In addition, sensitivity analysis of different assumptions has been implemented.
2.2. Ydalir, a ZEN case study

Ydalir is an area located 1.5 km outside the Norwegian city of Elverum. It is to be developed as a residential area over the next 20 years, consisting of approximately 100,000 m² of residential buildings, a kindergarten and a school [11]. Ydalir is one of nine pilot projects within FME ZEN, the Research Centre on Zero Emission Neighbourhoods. A neighbourhood within FME ZEN must aim to reduce its GHG emissions towards zero over its life cycle [12].

In the case of Ydalir, several measures for reducing GHG emissions have been implemented. Transportation by car has been limited by considerably lowering the share of parking lots per household, where the parking lots in addition are located in a separate shared parking house prepared for charging of electric cars. Ydalir is in close location to the city-centre where transportation by walking and cycling are given priority in infrastructure development, together with preparations for better public transportation opportunities. Other measures include local energy production by solar panels and CHP (combined heat and power) using biofuel as energy carrier, use of materials with low associated GHG emissions in buildings, and implementation of passive house standard or better in buildings [11].

These measures have as far as possible been implemented in OmrådeLCA. Improved energy standards and use of local energy production are both easily implemented. Transportation is however not as easily implemented in the tool. Travel survey (RVU) data for cities in Norway of the approximately same size as Elverum has been used as a basis. The data have further been adjusted according to a study [13] on the impact of transportation changes to account for the expected reduction in car usage at Ydalir. The measure of using materials with low associated GHG emissions in buildings is not used in OmrådeLCA for this case. The function exists in OmrådeLCA but is not used since there are no values for how low the emissions are estimated to be compared to “normal” or ZEB buildings. Therefore, due to the lack of data, a conservative approach has been chosen, where GHG emissions from materials are assumed to correspond to other ZEB projects or passive houses.

The system boundary for the assessment is set to include materials for buildings and local energy production, operational energy use in buildings and the transportation of residents. A 60 year period of analysis has been used.
3. Results and discussion

3.1. Comparison of results and methodology of OmrådelCA and the ZEN-tool

Results from the OmrådelCA assessment of Ydalir can be seen in Figure 3, per main category: materials (including materials for local energy production), operational energy use and transportation. Corresponding results for a reference scenario representing development according to today’s building standard in an average location in Elverum are also included for comparison.

![Figure 3. Total GHG emissions from the assessment of Ydalir with OmrådelCA and the ZEN-tool.](image)

The percentages presented in the figure represent the difference in emissions assessed with the two tools compared to the reference scenario. The difference from the ZEN-tool compared to OmrådelCA is a reduction of 44 %, 14 % and 8 % respectively for the categories materials, energy use and transportation, and 21 % reduction comparing the total emissions. The difference in calculated GHG emissions from materials is mainly due to quite significant differences in emission intensities per m² used in the two tools. OmrådelCA, intended for use in an early planning stage, uses average values for emissions per square meter for the given building category and building standard. The ZEN-tool, on the other hand, uses specific data from LCAs performed on the planned buildings at Ydalir. The resulting emission intensities per m² in the ZEN-tool are lower than corresponding calculations for other ZEB buildings. The ZEN-tool, using actual numbers causes the emissions from materials in the ZEN-tool to likely be more correct for this specific case. The results, 44 % decrease in emissions from materials assessed with the ZEN-tool compared to OmrådelCA, thus show that by using average values in OmrådelCA, results can be quite inaccurate. However, by using an additional reduction/increase in the emission intensity in OmrådelCA in cases where the emission intensity is estimated to be lower or higher than the average, results in OmrådelCA can be much more accurate.

The two tools give quite similar answers regarding emissions from operational energy use. Both tools calculate energy demand according to the Passive house standard. The calculations of emissions from local energy production are quite similar too. They both assign net negative emissions to electricity produced with solar panels (due to replacing grid electricity), and assumes the CHP replacing district heating or grid electricity. The difference in the results lies in some small variation of the data used for emission intensities and production data for solar panels, together with some differences in how estimations and allocations have been performed for the on-site energy production by the CHP. The difference (14 %) in the results regarding emissions from energy use for the two tools has less of a significance in view of the small share of the total emissions coming from energy use (4,9 % in the OmrådelCA assessment of Ydalir).
Although calculations of transportation demand are based on the same transport survey data in both tools, there are still some significant differences (8 %) in calculated transportation emissions. This is caused by differences in the background on emissions from vehicle production and direct emission from vehicle operation.

Figure 3 shows results of an assessment where the same elements are included in both tools. However, there are some system boundary variations between the tools in this respect. The ZEN-tool includes local infrastructure, meaning roads, sidewalks and outside parking lots. This is a strength of the ZEN-tool compared to OmrådeLCA. However, OmrådeLCA is intended at an early stage where information on the size and amount of such infrastructure will rarely be available. In addition, if it was to be included in OmrådeLCA, it must also be accounted for in the alternative location of built area in order to fulfil the functional mix, which will be challenging to estimate with sufficient accuracy. However, as emissions from the infrastructure included in the ZEN-tool account for only 6 % of total emissions in the Ydalir case, this is not considered to be a very significant weakness in OmrådeLCA. OmrådeLCA, include opportunities to account for emissions from additional building components, soil stabilization and change in land area. OmrådeLCA also provides greater flexibility in adapting model parameters than the ZEN-tool. However, as the case-specific data needed to apply these features in the Ydalir case was not available, the potential impact of these additional features was not quantified.

The main difference in methodology for the two tools lies in which project stage they are intended to be used. OmrådeLCA is an early stage tool, meaning that generic data are used more extensively, with the opportunity of replacing these with specific data where available, while the ZEN-tool relies mostly on specific data. Another key difference is the possibility in OmrådeLCA to compare results towards a reference scenario or several other alternatives using the same functional mix of built area. This makes it possible to find not only the alternative with lowest associated GHG emissions for a given area, but also the alternative causing the lowest amount of GHG emissions for a given function, e.g. 10 000 inhabitants.

By comparing with a reference, it is easier to evaluate the environmental performance of the Ydalir development. As can be seen in Figure 3, the assessment of Ydalir with OmrådeLCA causes 12 % less GHG emissions than the reference scenario. The use of solar panels and better building standards reduces emissions from operational energy use by 38 %, but as energy use accounts for only a small part (4,9 %) of total emissions, this does not greatly affect total emissions. The impact of solar panels is also diminished because of the low associated emissions per kWh from the Norwegian electricity grid mix causing more emissions from materials than gained during energy production, compared to just using electricity from the grid. Calculated emissions from use of building materials are almost identical as in the reference case despite the fact that the emissions intensity per m² used for ZEB/passive houses is higher than in the reference case, where TEK 17 standard is used. The reason for this is a high area efficiency in the Ydalir case, causing less m² required to accommodate the given number of inhabitants than required in the reference case.

The reduction in emissions from transportation of 15 % must be regarded as a conservative estimate. As mentioned previously, several ambitious measures to reduce car travel are planned at Ydalir. However, due to the lack of RVU data to model the planned effects, conservative estimates have been used. It is therefore reasonable to assume that the actual reductions in emissions from transportation will be greater than 15 %.
3.2. Importance of transportation

Travel habit data vary significantly between different locations, and it can be challenging to assess which dataset most accurately corresponds to the location of a specific project or alternative location. OmrådeLCA therefore includes the possibility to compare results for different choices regarding travel data selected, as well as using project specific data. Figure 4 illustrates how much calculated emissions related to transportation vary depending on the chosen RVU dataset for the Ydalir case, using datasets for areas in the Oslo and Akershus areas as examples.

![Figure 4. Emissions from transportation when using different RVUs.](image)

Emissions varies from a 15 % decrease by choosing Oslo centre to a 63 % increase by choosing Akershus county when comparing with the Ydalir RVU. This is a large difference, showing how important it is to do thorough analyses of transportation. This is supported by differences shown in Figure 3 for emissions from transportation. When performing a sensitivity analysis for some key parameters, shown in Figure 5, it is also evident that transportation affect the results greatly. Each parameter of the analysis is in turn altered with a 25 % increase, and by doing so for the average travel distance, the total emissions from Ydalir increase by 15.3 %. This underscores the importance of performing thorough analyses of transportation when conducting an LCA on the area/neighbourhood scale.

![Figure 5. Sensitivity analyses of emissions from Ydalir, where each parameter is increased by a factor of 25 %.](image)

The decrease in emissions of Figure 5 when increasing the area per inhabitant is because of a lower total amount of inhabitants of Ydalir, leading to diminished total transportation demand. This can lead to the misinterpretation that fewer people per square meter is better. If the functional unit was not total emissions from the neighbourhood, but emissions per inhabitant, the result would be the opposite.
4. Conclusion

Calculations of GHG emissions and reduction measures are a vital aid in the effort to reduce greenhouse gas emissions from the built environment. OmrådeLCA is a calculation tool that assesses GHG emissions of the built environment on a neighbourhood scale in an early stage planning. It calculates GHG emissions in three main parts, materials, operational energy use and transportation. OmrådeLCA have in this study been further developed from its original form, and been tested on the case of Ydalir, a ZEN consisting of both residential houses, a kindergarten and a school. To verify the results and methodology of OmrådeLCA the results from the same case of a tool made by NTNU have been compared to OmrådeLCA’s. The two tools generally calculate emissions in a similar way, and thus yield quite similar results. The main differences in the calculation results are due to differences in the background data used. OmrådeLCA, intended for an early stage of a project, uses mostly generic data, while the ZEN-tool, intended for use at a later stage when data are available, uses mostly specific data. The small degree of variation between the two tools in calculated results, demonstrates that OmrådeLCA can provide good estimates even at an early stage. This gives the tool great utility value because it is in the early stages of a project major actions can be done and decisions made, that will affect the emissions the most. OmrådeLCA’s system expansion approach is a feature that make OmrådeLCA different from a lot of other tools, and makes it well suited to assess the overall consequences for emissions from area development.

Transportation is the category contributing to the largest share of total GHG emissions in both tools. Sensitivity analyses performed with OmrådeLCA also show that emissions from transportation depend greatly on the choice of travel survey data used and assumptions regarding travel distances. In order to obtain representative and robust results, it is therefore important to conduct thorough analysrs and interpretation of data concerning transportation, and also to show the effect of different measures. This study shows that OmrådeLCA has the functionalities needed to make good and robust analyses, and the tool is therefore well suited to be used as a decision tool in case of area development and minimization of greenhouse gas emissions.

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