Integrating municipal climate targets with planning strategies at building level in a life cycle perspective

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Summary

The paper discusses how life cycle approaches at building level can be integrated into the climate work of local governments, illustrated by a case study in Sollentuna municipality outside Stockholm. Two basic excel tools were used to calculate greenhouse gas emission reductions for an existing housing area and for an early design of two new buildings. Scaling up the case study results to the entire multifamily housing stand of the municipality indicates that there is a potential for new construction by improving the existing building stand without increasing the total emissions of greenhouse gases. Such simple calculations can enable finding adequate levels for energy and climate targets at building level which relate to local or regional climate targets. Both the case study and the scaling up exercise show that the material choice in new construction projects plays a significant role and cannot be ignored when working with climate strategies for the built environment.

Keywords: life cycle assessment, building, climate target, climate strategy, municipality

1. Introduction

Both the application of environmental rating tools (e.g. LEED, BREEAM, etc) and LCA for the built environment has so far mainly targeted stakeholders of the building industries, like architects, housing owners, developers, consultants, etc. Assessment schemes are often said to have a wide possible application. However, in practice its main use has been among building practitioners. Local, regional or national authorities have so far not been supporting or demanding environmental assessment of buildings much apart from a few examples in e.g. Japan where around 20 local governments require a pre-rating by the CASBEE tool to deliver a building permit and the Code for Sustainable Homes in the UK. However, a rising interest is currently seen for the community level sub tools of BREEAM and LEED.

The local level plays a significant role in being the implementation arena for for example CO_2 and energy reduction targets at the national and international levels. Sweden and Europe have adopted challenging environmental goals to be fulfilled by the years 2020 and 2050. For example a 40% CO_2 reduction to 2020 compared to 1990 (outside the emission trade) and a 50% energy use reduction to 2050 compared to 1995. To meet these goals serious actions are demanded not at least from local authorities which are responsible for local planning and building permissions. However, reduction goals tend to be ignored when there are at the same time goals regarding economic and population growth at least in growth regions, that is, a form of rebound effect easily arise.

To be able to pose demands and follow up projects at the local level, calculation methods are necessary. Regarding calculations of greenhouse gas emissions related to buildings, emissions related to operational energy use has been highly focused. Lately, however, the embodied energy and greenhouse gas emissions of construction materials have increasingly been a topic of discussion. A recent investigation of the environmental impacts of the Swedish building and property sectors conclude that production of construction materials and mobile sources related to construction stand for a significant portion of the total greenhouse gas emissions of the sectors [1].

At national, regional or local levels greenhouse gas accounting is often based on a production perspective. That is, only emissions which directly take place within the investigated geographical unit are considered. Since the aim of accounting often is to gather data for national and international registers, this is often feasible. However, to better understand the entire direct and indirect emissions for a certain geographical unit, a consumption (and thereby a life cycle) perspective is necessary. One current initiative drawing towards this perspective is ICLEI [2]. However, so far such accounting is mainly used in specific sustainable city efforts.

An interesting issue is therefore to find better strategies for local authorities to implement mentioned targets into municipal climate strategies and further down in practice in development projects/programs at the local level.

1.1 Aim

The aim of the paper is to discuss how quantitative life cycle approaches at building level can be integrated into the climate work and practice of local governments in order to support implementation of national or international climate and energy targets. This is illustrated by a case study in Sollentuna municipality close to Stockholm city and lessons learnt from this will be concluded and used for suggesting further developments in this area. Sollentuna is a municipality of 64 630 inhabitants close to Stockholm city. The municipality is expanding and the planning office is interested to understand more about the meaning of national and international climate targets on a local scale.

2. Case study

In a former European project, ENSLIC (www.enslic.eu), simplified ways to integrate quantitative life cycle approaches in early design of buildings, were developed. Part of the project included performing case studies and the present case study in Sollentuna is one of these. A main aim of the case study was to test whether it would be possible to fulfil CO_2 reduction goals and still expand the number of dwellings in the municipality. Close to the centre of the municipality a new housing project of 130 apartments (Terrinen) had been initiated and an early design had been sketched. In the same area a housing unit of existing buildings (1140 apartments) with need for upgrading (Traktören), is situated. This area (Terrinen+Traktören) were chosen as study objects for the case study which aimed at studying the following questions:

- How much can the greenhouse gas emissions related to existing buildings in an area be reduced?
- How much new development is possible within the savings of the existing buildings, that is without increasing the total amount of greenhouse gas emissions?

To visualise this, a “cap” was put on the Terrinen and Traktören area within which future improvements and expansion should be hosted. A first sketch of Terrinen with two buildings ranging from 4 to 6 floors is shown in Fig 1. Photos of Traktören which consists of a number of blocks of flats ranging from 3-9 storeys, is shown in Fig 2.

Fig. 1 Preliminary sketches of the new dwellings “Terrinen”. Illustration: Joliark AB.

Fig. 2 Part of the existing building area, Traktören

2.1 Methodology

First different improvement potentials in the existing buildings (Traktören) were calculated. Then demands to be put on the new building within these savings were investigated, i.e different basic constructions and improvements and their associated energy demand and CO_2 emissions. Two basic Excel-tools have been developed to estimate energy use and CO_2 emissions in buildings, one for refurbishment of existing buildings [3] and one for new buildings [4].

2.1.1 Tool for existing buildings

Only energy use during the operation stage is considered. 16 different measures to reduce energy use and CO_2 emissions are available in the tool. For estimation of energy use a simple degree-day model is used. Only heating is regarded since cooling in Swedish dwellings is hardly needed. Internal heat loads and solar gains are dealt with on a general basis by setting the indoor temperature to 13^oC which means that no individual features of the buildings are regarded. U-values typical for different time periods are used. Default values for use of electricity are used (kWh/m^2,yr). CO_2-equivalents per kWh have been calculated from average emissions for different energy sources in Sweden and are stored in the tool.

2.1.2 Tool for new buildings

Energy use during operation and emissions from production of building materials are taken into account. The tool includes the possibility to select the same improvement measures as in the tool for existing buildings. Energy use is also here estimated through a degree-day model. The dimensions of the building and the layers of the building envelop are inserted. Areas, U-values and amounts of materials are then calculated automatically. Default values for use of electricity are used (kWh/m^2,yr). All estimated values are easily replaced by better input data from simulations. Further the CO_2-equivalents associated with the different building parts are calculated. Emissions from material production are taken from different sources and calculation of CO_2-equivalents are made according to IPPC (AR4).

2.2 Input data

2.2.1 Existing buildings, Traktören

For estimation of energy use, gross area (146 340 m^2), average outdoor temperature and year of construction (1972) were inserted in the tool. A number of potential upgrading measures were then tested. For calculation of CO_2e, 33 g CO_2e/kWh for Swedish electricity mix and 50 g CO_2e/kWh for Sollentuna district heating was used both for the existing and new buildings.

2.2.2 New buildings, Terrinen

Sketches were already at hand as indicated above. The basic tool so far only works with rectangular buildings. Because of this the study was made on a fictive rectangular building with the same floor area (9750 m^2) and height (5 storeys) as the above shown building. Presupposed data for the calculations include an indoor temperature of 22 ^oC, 0,5 air changes/hour and an anticipated life time of 50 years. Two construction alternatives were considered, one wooden and one concrete. Embodied CO_2 emissions of the main building elements from manufacturers and the database Ecoinvent are included in the tool.

2.3 Result

2.3.1 Existing buildings, Traktören

The tested improvement measures and calculated energy use and CO_2 emissions are shown in Fig 3.

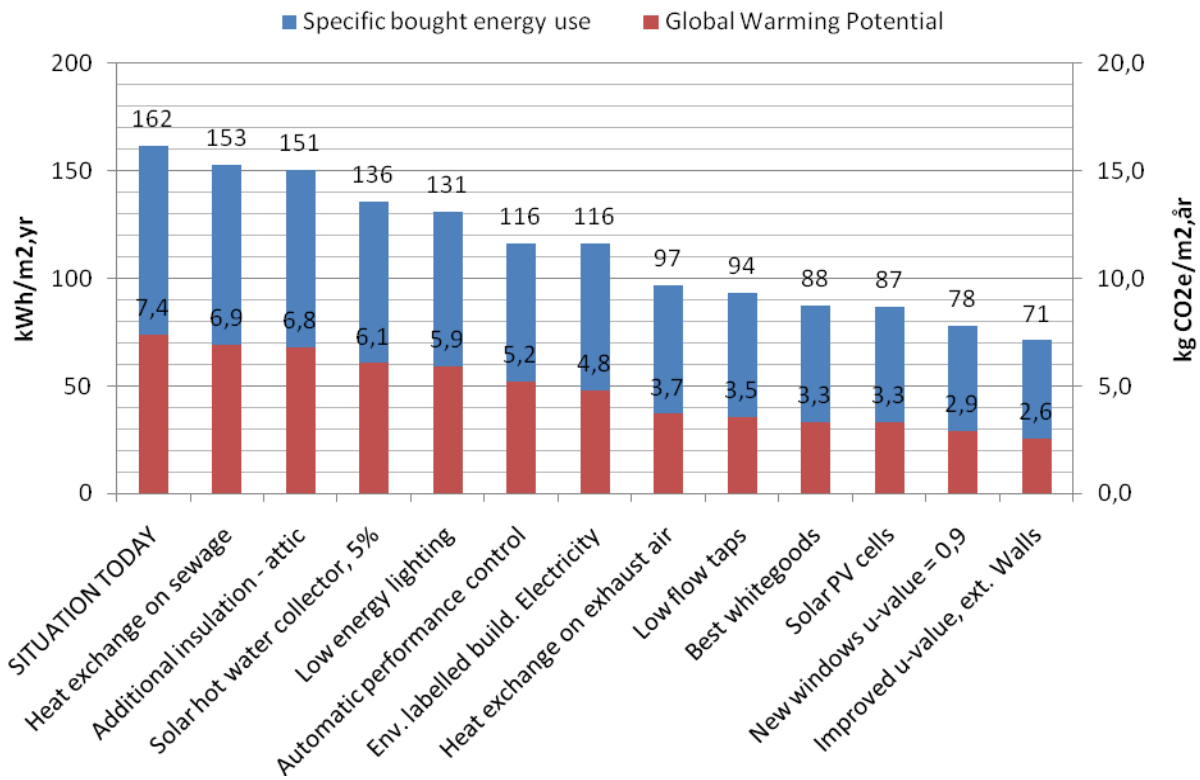

Fig 3. Tested improvement measures in the existing housing unit Traktören. Upper figures are kWh/m2,y and lower figures are kg CO2e/m2,y. The calculation of savings from solar hot water collectors refers to collectors on 5% of the building area.

It seems as it would be possible to reduce the energy to about half and the CO_2 emissions to almost one third. The four last measures (best whitegoods, …, improved u-value external walls) are however expensive in relation to the savings. They may be done if upgrading is needed also for other reasons. Nevertheless, even without these measures, the results suggest an energy reduction with 40% and CO_2 reduction with 50%, i.e. in line with the Swedish and European goals which states a 50% reduction to 2050. However, to fulfil these targets it is necessary to carry out all measures above to also create a space of about 100 tonnes CO2e per year for developing new buildings.

2.3.2 New buildings, Terrinen

A number of possible measures to improve the original design of Terrinen were explored ending up in the suggestion shown in Fig. 4.

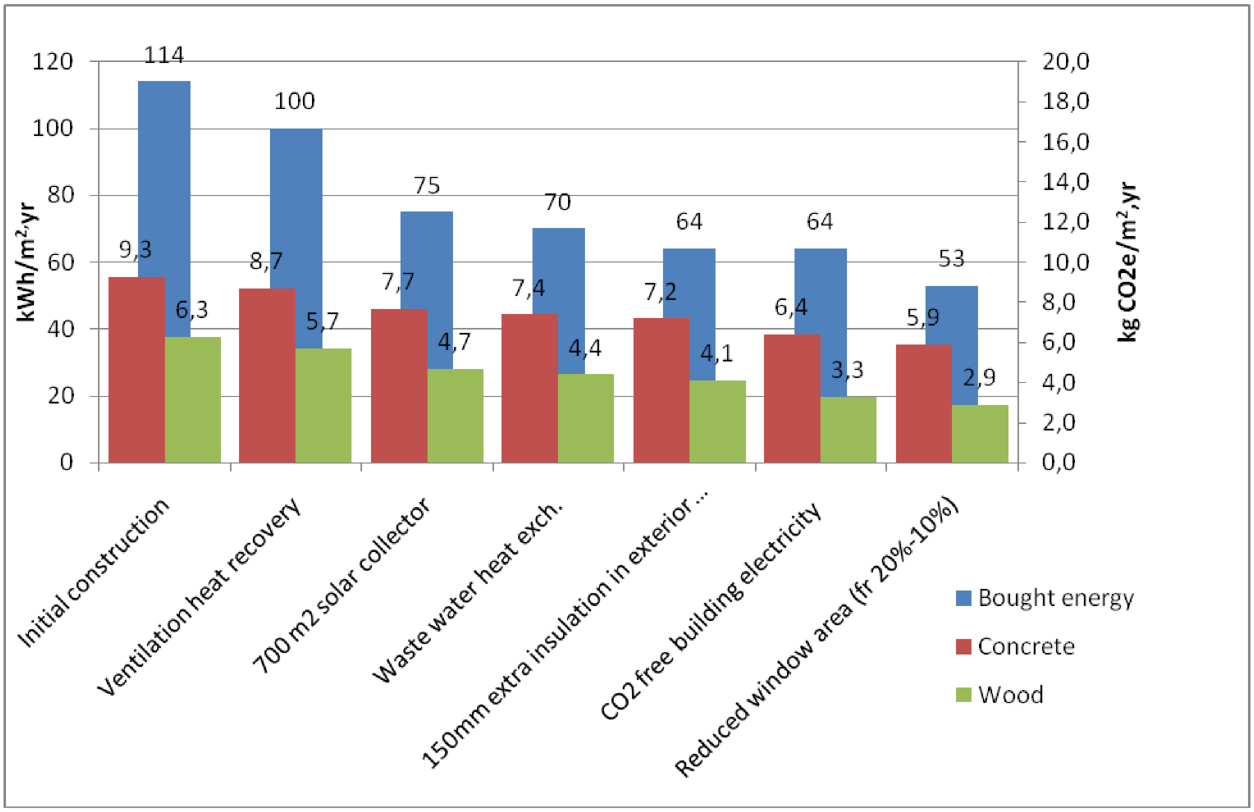

Fig 4. Tested improvement measures in the new building Terrinen.

The calculations indicate that the original early design of the new building with concrete construction contributes with significantly higher greenhouse gas emissions compared to the wooden one. The results show that the possibility to reduce the emissions from the initial construction is great, up to about 50% with relatively simple measures. Of the climate impact of the initial construction, the embodied impact of the material stands for 40% for the concrete and 20% for the wooden construction. With all improvement measures taken the relative importance of the embodied impact increases to nearly 70% for the concrete and nearly 50% for the wooden construction.

2.4 Conclusions from the case study

Since important but not dominating sources of CO_2 emissions, like transports, carpentry and installations, are not included in the calculations of the new buildings, the calculation of greenhouse gas emissions is an underestimation, i.e. the space for new constructions within the reduction goal of 50% to 2050 is somewhat less than concluded above. However, if generalising from this case study, between 0,1-0,3 m^2 new construction would be possible within the frame of the savings of all improvement measures in the existing buildings. The higher figure stands for a new construction in wood with all measures in fig. 4 taken. Under these conditions, CO_2 reductions in the existing buildings in the range of the Swedish and European targets are also fulfilled. From a planning perspective, this case study raises the question of how much new construction would be possible at the municipality level while still reaching long-term national and European energy and CO_2 targets?

3. Scaling up to municipality level

For the local authority it is of interest to roughly scale up the case study, to be able to formulate realistic and relevant targets at the municipality level. In the following, such a calculation exercise is performed. Since the case study concerns multifamily buildings, this exercise is also delimited to multifamily buildings in the municipality.

3.1 Basic data and calculations

Around 50% of the dwellings of Sollentuna municipality are found in multifamily buildings and 50% in detached houses. With the current population growth, the forecast until 2020 is approximately 350 dwellings in multifamily buildings and 50 in detached houses per year. Of the 13 733 dwellings in the municipality in 2009, 6 900 were built during 1961-1980. The calculation exercise builds on that these buildings are improved generating savings in the same range as for Traktören (Fig 3), that is yearly greenhouse gas emissions of 0,45 tons CO_2e/dwelling and year.

For the new construction, the CO_2e savings related to the wooden construction alternative of Terrinen without improvement measures is used. This equals 0,37 tons CO_2e/dwelling and year for the operation of the buildings and 5 tons CO_2e embodied in the materials/ each new dwelling the year it is built. The high figure for materials relate to that it seems reasonable to account for all the impact of the materials the year the new buildings are constructed, when making the total municipality account for a certain year. The calculation exercise is performed based on the numbers of dwellings. It is assumed that Traktören and Terrinen are representative regarding building technology and regarding sizes of dwellings.

3.2 Results

Table 1 shows the results of the scaling up exercise.

Table 1. Results of the scaling up exercise.

Buildings	Number of dwellings	Greenhouse gas emissions 2008 (tons CO_2e/y)		Greenhouse gas emissions 2020 (tons CO_2e/y)	
		Operation	Material	Operation	Material
Existing multifamily buildings built in 1961-1980	6900	6554	0	3100	0
Planned new housing 2011-2020	3500	0	0	1304	1750
Sum		6554		6154	

3.3 Conclusions from the exercise

The exercise shows that a reduction of greenhouse gas emissions in the entire building stand built in 1961-1980 of 50% would enable a space for new construction of a little bit more than the planned 350 new dwellings in multifamily buildings per year. If the 6833 dwellings in multifamily buildings which are not included in the exercise, would equally be possible to reduce with 50%, approximately a 30% reduction of greenhouse gas emissions is realistic if also producing 350 new dwellings each year. The regional development plan for the Stockholm region (of which

Sollentuna is a part) covers regional reduction targets for greenhouse gases, corresponding to a reduction of 26% between 2006 and 2020 and a further reduction of 51% between 2006 and 2030 related to the built environment. The scaling-up exercise indicates thus that there are hypothetically technical possibilities for Sollentuna municipality to reach the regional target of 26%. Nevertheless, once all buildings have been improved, new construction can only take place if the greenhouse gas emissions related to the operational energy are further reduced. This process is currently taking place. Nearly all multifamily buildings in Sollentuna municipality are connected to district heating and this production is more and more covered entirely by renewable fuels. For example, the emission factor used in the case study is significantly lower today than when the study started. This implies that the space for new construction will be lower in the future since the embodied impact of the materials of new buildings will more and more dominate the emissions of the building stand. It should however be stressed that the current regional target is based on a production perspective and thus does not include embodied impact of used materials in new construction.

4. Discussion

4.1 Possibilities to pose demands

Depending on real-estate ownership and current legislation in individual countries, a number of options exist for urban planners to pose or negotiate environmental targets for new urban developments, whether it be smaller developments or entire new city districts. The easiest way is to pose demands on new construction and improvements of the existing building stand owned by the municipality itself. If the municipality owns the land to be developed, to pose targets when giving the land permits is another option. This may also be developed into an architectural competition. This is preferably done by formulating maximum emission frames for the greenhouse gas emissions related to material use and operation of buildings.

In addition, the municipality usually has an opportunity to negotiate targets with developers also under other circumstances. Such a more governing role for local authorities is currently, increasingly discussed due to the intensified focus on energy-saving and climate goals in general. For example, Sollentuna municipality recently decided on a climate strategy document which is currently implemented in concrete action plans. More and more developing companies work with internal environmental management systems and policies which means that they have internal policies and targets they aim to follow. Local authorities could thus appeal to developing companies to take extra measures by claiming their own internal environmental management systems.

In all these opportunities for local authorities to implement overarching environmental targets in practice, it is a necessity to be able to formulate quantitative local targets or emission frames for individual projects, etc.. These need to be both well-founded and possible to follow up. The case study and the scaling-up exercise give a basis to be able to find such target levels.

4.2 Accuracy/reliability of calculations

Simplified calculations like the ones used in this paper can naturally be discussed a lot with regard to their accuracy and reliability. However, the level of detailed accuracy is probably enough to be used as tools for posing demands and evaluating early design offers at the municipality level. The energy estimations of the tools are rough and so are the potential savings. The lacking accuracy is most probably in the same range for all calculations. This means that the overall conclusions drawn from the calculations should be fairly correct but savings for individual measures should not be compared in detail.

The estimated amount of materials is likely quite right but it only covers the main building parts. Installations, carpentry and furnishing are not covered and neither are transports in relation to the construction work. However, the tool for existing buildings is in the current version not covering impact related to the use of materials for refurbishments. It is reasonable that the extent of this impact should be studied in relation to the impact of new production, to analyse whether it ought to be included or not.

A question of relevance is how the embodied emissions of construction materials should be accounted for. When comparing different design alternatives, for example in an architectural competition, it is reasonable to distribute the impact over the building´s life time to be able to account for, for example more long-lasting materials. However, when setting the frames for the entire municipality a link is needed to for example national and regional targets, which in turn implies a reduction in a certain pace. In this perspective, it is more motivated to account for the emissions of the construction materials the year the buildings are erected.

5. Conclusions

Both the case study and the scaling up exercise show that the material choice in new construction projects plays a significant role and cannot be ignored when working with a climate strategy for a municipality which is growing and in which operational energy is based to a limited extent on fossil fuels. To include such data when calculating CO_2 emissions at municipality level is still rare and the study indicates that calculation procedures ought to be improved. Since the suggested applications concern early design phases, simplifications must be made if using life cycle based calculations. That is, the recommendation here is to:

- Only include two life cycle stages: production of construction materials and operation.
- Only include buildings and not the transports the buildings generate.
- Only include construction materials for main building elements, such as roof, slabs, etc.
- Only include the operation of the buildings in terms of energy use during their life-time.

It seems possible to conclude after the calculation exercises of this paper, that there are conditions for maintaining a growing municipality, without a total increase of greenhouse gas emissions, and also considering the embodied greenhouse gas emissions of construction materials. However, the space for new construction is highly dependent on the current energy supply. For Sollentuna municipality the space with current energy mix is somewhere between 0,1-0,3 m^2 per improved m^2 in the existing building stand.

Calculations as the ones in the paper enable a discussion of an integrated approach in order to contribute to the fulfilment of national climate targets. More specifically it might concern finding the right level for setting CO_2 targets when giving land permits, in local architectural competitions or in target negotiations with developers. Reliable calculation and evaluation tools are then necessary and the excel tools used in the case study of this paper are basic but could possibly serve for the mentioned needs. However, fair developments would be to find agreement among a number of experts about the saving potentials of the measures included in the tools, as well as to evaluate whether embodied emissions for materials used in refurbishment, should also be accounted for. The scaling-up exercise is a rough attempt and would also need to be studied further to find a reasonable procedure for trying to account also for consumer goods within the municipal boundary.

6. References

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