Combination of Dynamic MFA and LCA for Zero Emission Neighbourhoods

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Preface

abstract

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Introduction

1.1 Background

In the quest to an environmentally sustainable future, climate change is one of the challenges that greatly stands out. The increase of stressors released and concentrated in the atmosphere such as man-made greenhouse gas (GHG) emissions contribute to global warming and climate change. This in turn impacts not only human society but is transforming the patterns of the biosphere compromising the stability and life in Earth [?].

Among the economic activities that contributes to climate change, the IPCC in its fifth assessment [?] reported that buildings are responsible for 18.4% of total GHG emissions. Of those 12% are indirect emissions mainly from the use of electricity, a share that can vary substantially due to the emission factors of the different types of energy production. When seen in terms of energy consumption, 32% of global final energy is used by buildings.

Mitigation possibilities in terms of energy savings have been identified in the buildings sector, where solutions and technology are ready available. Passive house designs lower considerably the energy consumption of a building and if the house is set to generate energy, nearly or net zero emissions buildings (nZEB, ZEB) and positive energy buildings appear, in these cases the house is a source of green energy.

**Try to unite this too paragraphs, they have similar ideas*

The potential of this sector stands out when compared to other sectors where mitigation strategies are more difficult to achieve. As a result, policies and efforts have been set to lower energy consumption and emissions from this sector. The European Union has set into place the Energy Performance of Buildings Directive and the Energy Efficiency Directive and has established that by 2020 all new buildings should be constructed to be ZEB [?].

The building sector as part of a broader context when combined with mobility, open spaces and networks such as water, sewage, telecommunications, heating distribution and electricity distribution form the built environment [?] [?]. This built environment can be looked at multiple scales, from neighbourhood to urban or city scale. Analyzing it is interesting because sustainability is addressed at a higher and more complex level where different systems and variables overlap. Exciting questions such as how to better design a neighbourhood so that its emissions are reduced towards zero? [?] [?], what parts of the built environment contribute the most to the overall impact?, how to integrate capabilities so that impacts are reduced?, arise.

Multiple LCA assessments at a building level [?][?][?] and at neighbourhood [?][?] and urban level [?][?] have informed and improved the knowledge about the different hotspots in the systems. From a building perspective is the operation of the building that has the major energy consumption and emissions. However, embodied energy and emissions from the extraction and processing of materials in the construction and refurbishment phases lead on when buildings fulfill passive house standards. At a neighbourhood level, it has been identified that when passive house standards are the rule, it is mobility what seems to have a higher impact followed by embodied energy and emissions[?] [?]. However, conclusions are less straighforward due to the complexity and differences between purposes and definitions of built environment analysis[?] [?].

Answering all the arising questions and start developing solutions that resemble the sustainability goal in the built environment is a huge task and requires studying the different pieces separately and as a set so that a greater understanding emerge.

The Research Centre of Zero Emission Neighbourhoods in Smart Cities, ZEN, is a Norwegian initiative that started in 2017, following The Research Centre on Zero Emission Buildings, ZEB, that aims to *"develop solutions for future buildings and neighbourhoods with no greenhouse gas emissions and thereby contribute to a low carbon society"* [?]. Its goals touch on design and planning instruments, new busines models, creation of cost effective and resource and energy efficient buildings, technologies and solutions to operate energy flexible neighbourhoods, decision-support tool to optimize local energy systems and interactions, and creation and management of ZEN pilot projects in Norway [?].*Rephrase it better?*

Among the studies done by the research centre and as part of the analytical framework for design and planning of ZEN, WP1, ZEN report No. 2 [?] released early in 2018 develops a dynamic model that was created and tested using Excel and Matlab. The model calculates the building stock model, the energy demand and GHG-emissions of a neighbourhood in time. This dynamic model uses a detailed initial stock characterized by archetypes (cohort, type of floor area and renovation state), renovation, demolition and future construction patterns; as well as energy carriers, delivered hourly energy intensity profiles per archetype and carbon intensities in time, as input. The output includes a detailed development of the stock over the years, its energy demand and GHG emissions.

One of the strengths of the model is that it calculates future energy demand in an hourly basis by means of a coincidental analysis, this method avoids overestimating the energy demand making the model more precise in terms of energy calculations. This precision is desired when design concepts that intend to couple energy generation from the neighbourhood with enery storage capacity from the mobility system are on the table. *This achieves more efficient use of energy, decarbonization and independent energy systems.* The model is also highly detailed in the way that treats buildings as individual objects, this means that the life of each building can be traced over the years. It is also flexible when defining the initial characteristics of the neighbourhood and parameters for the estimations in time. The GHG emission model used the energy model results and takes into account that carbon intensities can change in time. Finally, the model allows the evaluation of different scenarios.

AQUÍ VOY Taking into account the strengths and detail of the model it has been thought to expand the model and incorporate an evaluation of the material use.

The newest advances in the field indicate that is possible to construct buildings with low carbon emissions. Design and material choices can reduce the energy consumption of a building to its minimun, moreover by incorporating heat pump, solar panels, energy from waste incineration and other energy technologies *refine expression* a building or set of buildings can generate enough energy to level out the energy consumption of its entire operation lifetime. This is indeed a impressive achievement in energy savings. A new challenge then arises which entails reducing and leveling out the energy and emissions from the construction, maintenance and end of life stages of the buildings. Resolving this challenge not only reduces the environmental footprint of buildings to its real minimum, but can further reduce other economic sectors environmental footprint.

The IPCC in its fifth assessment reported that industry contributes with 32% to the global GHG emissions, where 11% are indirect emissions. The majority of this emissions are attributed to the processing of materials into products and services8[**?**]

On the other hand, looking the it is also reported that transport contributes with 14% to total GHG emissions, and industry 32%, where 11% are indirect emissions. Industry emissions are particularly interesting because they mostly entail the processing of materials into products and services. Mitigation options presented in the IPCC report include: energy efficiency, emissions efficieny, material efficiency in manufacturing and product design, product-service efficiency and service demand reduction.

.... include material layer, benefits, purpose, how can it be connected to the model?

....There is a growing interest for the neighborhood scale in the field of urban sustainability assessment. It is a typical operational scale for urban development projects and integrates key levers for urban eco-design. Indeed, this change of scale is driven by the need to address district scale levers to design buildings and neighbor- hoods of higher environmental performance and to address key issues such as bioclimatic design, shared equipment (e.g. district heating), urban density or mobility issues.... Lotteau 2015

.... question that I want to address with this study. - either, embodied emissions of other systems as well? vs. energy benefits? - layer of material to a model that has been developed? - inform amount and types of materials?

- Ultimately is the use of the model and the cases and scenarios to be evaluated that that will bring the biggest benefits. - Importance of LCA and MFA, combined.

1.2 Problem Definition

1.3 LiteratureReview

In this section important concepts and results found in the literature are reviewed as a framework in the development of this project report.

1.3.1 Zero Emission Neighbourhoods, ZEN, Definition, Goals and Ambitions

The Research Centre of Zero Emission Neighbourhoods in Smart Cities define Zero Emission Neighborhoods as

How should the sustainable neighbourhoods of the future be designed, built, transformed, and managed to reduce their greenhouse gas (GHG) emissions towards zero?

1.3.2 Zero Emission Buildings and Zero Emission Neighbourhoods and Embodied Emissions

- Findings of Zero emissions buildings ZEN LCA and MFA? studies/ or ZEB:

One common finding, however, is that buildings with low energy consumption present higher embodied emissions. Embodied emissions refer to the emissions upstream in the value chain due to the construction of the buildings, mostly due to the processing of materials used. Moreover, in the best case scenarios, the energy generated by the ZEB is not enough to balance out these embodied emissions.

- Findings of Zero emission neighbourhood studies: or ZEN:

- Zero emissions concept, zero emission neighbourhood definition, what is desired from a ZEN.

Mobility, buildings, consumption, open spaces, facilities. Ambitions. (LCA)

Before introducing the findings.. it is important to introduce the definition and ambitions of a ZEN.

Even though ZEN studies are difficult to compare due to the particular functional units and boundaries set in each case, one interesting finding is that the use of transport in the neighbourhood has the higher emissions, followed by the production stage of the buildings or embodied emissions, (when considering passive houses).

Meaning that the effect of transport in a neighbourhood is more harmful than the embodied emissions.

What are the measures to be prioritize? transport? buildings? infrastructure?

Energy measures in a neighbpurhood scale are important because they define the capacity of a neighbourhood to produce its own energy. It has been state that yearly energy consumption data of a neighbourhood/building does not allow to estimate reliable results because of the peak concept. In order to prove this a model has been developed by the ZEN research center that estimates the actual energy requirement, showing that in fact the not taking into account the coincidence factor leads to overestimation of the energy requirement.

*Lotteau, 2015. Critical review of life cycle assessment (LCA) for the built environment at the neighborhood scale + 21 existing cases of LCA at the N scale. + build knowledge to feed urban policy making or eco-design purpose. + built environment - refers to buidlings and transportation. summation of all human-made structures, infrastructure and trasportation systems. paper. buildings, open spaces (roads,green spaces), networks and mobility + studies at the building scale - dominance of use phae, and increase of share of embodied energy for low-energy buildings. mostly process- base and LCEA, focus on energy issues. + city scale: + results. + sensitivity of the results, operationals, mobility and embodied, range and sensitivity + complexity of a neighbourhood, need for contextualization, + dynamic LCA, attributional vs. consequential. *Anderson 2015. + Structural materials, vs architectural materials. cement. industry + Structural systems and structural materials. + induced impacts- interaction between individual buildings and urban context.

- ZEN Report 2, findings and important details.

1.3.3 Materials in buildings

1.3.4 Circular Economy

- Materials in buildings, passive buildings, difference in emissions from different type of buildings?. Refurbishment.

- From zero emission buildings to zero emission neighbourhoods. Hotspots. Embodied emissions, transport. Difficulties and differences when modeling LCA results. What has been learned from LCA in ZEB and ZEN. - Energy model hourly resolution of energy demand. Advantages.

To target this a dynamic model has been developed by the ZEN research center. This model

- Circular economy? reduce embodied emissions? close the loop. h

System thinking, prevent, reduce, reuse, recycle.

- Zero emissions concept, zero emission neighbourhood definition, what is desired from a ZEN. Mobility, buildings, consumption, open spaces, facilities. Ambitions. (LCA)

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- Circular economy? reduce embodied emissions?

1.4 LCA in Buildings

Vilde Borgnes:

-Balance boundaries, life stages -Physical boundaries

More recent studies emphasise the importance of including the energy and associated GHG emissions embodied in the materials. Several authors concluded that especially when low-energy buildings are evaluated, the share of the emissions from the use phase decrease compared to other stages of the life cycle (Brown, Olsson et al. 2014) (Chastas, Theodosiou et al. 2016) (Kristjansdottir, Heeren et al. 2017).

The effect of the inclusion of infrastructure is also examined by other authors. In a study performed by Anderson, Wulfhorst et al. (2015), where a neighbourhood built following existing standards in Melbourne was examined, the results show that the contribution from the infrastructure constitutes about 17% of the total embodied energy in the neighbourhood. As an example, they found that “power lines, supported by timber poles every 20 m are more energy intensive over 100 years than the combined concrete and steel in all footings of the buildings”.

An assumption of a fixed service life for all the components will lead to incorrect results because of the variations in the actual lifetimes. In some of the studies reviewed by Mastrucci, Marvuglia et al. (2017), the authors have chosen to let the service life differ among materials and building parts, as well as for refurbishment measures, to avoid this issue

When both operation and materials are considered, for all the three elements, the mobility is the major contribution to global warming in both scenarios, with a share of 54% for scenario 1 and 50% for scenario 2. The buildings contribute to 43% and 47% for scenario 1 and 2 respectively, and only 3% of the global warming potential are caused by the open spaces (for both scenarios). Moreover, when focusing on the life cycle stages, the materials (product stage + replacement) constitute the largest contribution to emissions with a share of 76% for scenario 1 and 57% for scenario 2.

Material efficiencies will increase, and emissions from production of materials will decrease together with the emission intensities in the future.

When deciding what elements and life cycle phases to include in a ZEN definition, it is crucial to have a clear and substantiated understanding of what we want to achieve, and where in the life cycle perspective the major emissions sources is found. If the goal is to decrease the carbon footprint of the neighbourhood (or of the inhabitants in the neighbourhood) to a minimum level, the elements that lead to considerable amounts of emissions need to be addressed.

Regarding the materials, it may be more accurate to use EPD data when calculating the emissions from the buildings, especially when considering a specific neighbourhood. The difference in the results when relying of this type of data, instead on using the Ecoinvent database should be assessed. A standardized way in getting the information of these emissions should be decided, to facilitate comparability between material- and provider choices. It is also crucial to decide the best practice when it comes to the replacements, both when considering the materials in the buildings and infrastructure, energy supply systems in the buildings (photovoltaic panels, heat pump etc.), and especially the replacements of the cars.

...uncertainty yet flexibility at the beginning of a project. ..Think about the differences between LCA and dynamic modeling.

.... ZEN GOALS + 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. + Create cost effective and resource and energy efficient buildings by developing low carbon technologies and construction systems based on lifecycle design strategies. + Develop technologies and solutions for the design and operation of energy flexible neighbourhoods. + Develop a decision-support tool for optimizing local energy systems and their interaction with the larger system. + Create and manage a series of neighbourhood-scale living labs, which will act as innovation hubs and a testing ground for the solutions developed in the ZEN Research Centre.

WP1- Analytical framework for design and planning of ZEN WP2- Policy measures, innovation and business models. WP3- Responsive and energy efficient buildings. WP4- Energy flexible neighbourhoods. WP5- Local energy system optimization in a larger system WP6- Pilot projects and living labs. ...

The ZEN

ZEB and PEB solutions

-Neighbourhood dimension? -

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/ZEB definition: ZEB - "a building that has a very high energy performance, hereby the nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources including energy from renewable sources produced on-site or nearby" (European Parliament and the Council 2010) /// This is from a report shared.. so dont copy./

Transport?

Consumption?

Circular economy?

Methodology

Results and Discussion

Notes

- Zero emissions concept, zero emission neighbourhood definition, what is desired from a ZEN. Mobility, buildings, consumption, open spaces, facilities. Ambitions. (LCA)

- From zero emission buildings to zero emission neighbourhoods. Hotspots. Embodied emissions, transport. Difficulties and differences when modeling LCA results. What has been learned from LCA in ZEB and ZEN. - Energy model hourly resolution of energy demand. Advantages.

- Materials in buildings, passive buildings, difference in emissions from different type of buildings?. Refurbishment.

- Circular economy? reduce embodied emissions?

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