Popular Abstract

Climate change poses one of the most substantial threats to humanity today. If global greenhouse gas emissions are not reduced drastically in the near future, it can lead to detrimental consequences worldwide. Policies have been developed on a national and international level to promote climate-neutral industries and societies in order to address this issue. In Sweden, the construction industry is responsible for 18% of the country's total greenhouse gas emissions. Therefore, it is crucial not only to understand the impact generated by the construction industry but also to take the initiative to limit and reduce it. Several definitions of climate neutrality for the construction industry have been developed in the past few decades to address this issue, but despite this, there appears to be disagreement regarding what should be included in such a definition.

This study aimed to evaluate three existing climate-neutral definitions and compare how they impact building design. Life cycle costing (LCC) and life cycle profit (LCP) calculations were performed to compare the extent of required compensatory measures for all definitions. Selected definitions were White Architect's definitions, NollCO_2 definition from Swedish Green Building Council, and ZEB definition from the Norwegian Research Institute. For this study, the only life cycle analysis (LCA) indicator that was assessed was Global Warming Potential due to the vast amount of literature linking it to climate change, and aspects like daylight or indoor air quality were not assessed. White Architects provided the case study building, and a methodology was developed following a literature review analysis to assess the certifications under consideration. First, the base-case building was assessed using each definition. After that, changes were made in accordance with the pre-requisites of each definition. Next, total carbon emissions were calculated based on the system boundaries of energy and LCA. Finally, various climate offset measures were explored to ascertain climate neutrality, including production and export of renewable energy, carbon credit purchase, and biogenic carbon storage. These climate offset measures compensate for the climate impact obtained from each definition and establish a net zero emission balance for the building. In addition, a comparison study was done for the accumulated emissions from each life cycle module and their respective need for climate offset measures.

One of the central parts of this study was to assess if a case-study building could be certified as climate neutral according to assessed definitions. Results indicate that the building managed to reach climate neutrality according to White Architect's definition as well as NollCO_2 and the lowest ambition level from ZEB requirements. Despite the same geometry in all the definitions, the same building design couldn't be certified as climate-neutral without incorporating some degree of energy measures. The study also indicated that there are established standard practices that are recognized by all three definitions. This mainly encompasses methods of how emissions from LCA modules are calculated. However, the definitions showed contrasting final results for the same building due to the choice of different system boundaries and alternative methods on how to account for climate offset measures. The total emissions from the same building varied significantly depending on the scope of each certification, for example, for White Architect's definition, total emissions were 1459 tCO_2e, for NollCO_2 1813 tCO_2e, and for ZEB-COMPLETE 4363 tCO_2e. It can also be noted that the building design's impact was different for each of the definitions. The White Architects' definition favors the use of biogenic carbon, and its design is carbon negative throughout the lifespan of the building without requiring any renewable energy production. Because of strict energy requirements, NollCO_2 and ZEB definitions required heat pump incorporation only to be qualified to be assessed for climate neutrality. ZEB definition is very demanding on energy

efficiency and requires on-site renewable energy production to achieve carbon neutrality, while the NollCO_2 definition requires a considerably oversized PV system.

Exporting surplus electricity back to the grid is a common principle that serves as a climate compensation measure for all three definitions. There are two common ways to account for what emissions are displaced. One is the average emission factor, and the other is the marginal emission factor. NollCO_2 and White Architects' definitions use marginal emissions factor while ZEB definition uses average emission factor accounting, and as both processes account for two different total emissions for compensation measures, very different PV systems were required to achieve climate neutrality.

Climate neutrality for NollCO_2 definition could also be achieved with carbon credit purchase and without any compulsory building design changes. The purchase of carbon credits is a relatively inexpensive and simple alternative for achieving climate-neutral building status and seems to divert responsibility from the building owner and constructor, as carbon credit purchases without any limit or threshold could potentially ignore the importance of climate measure considerations for a building.

Finally, a few reflections from the study are, for example, all certifications should address the unclarity and disagreement of energy type (primary energy or delivered energy), energy carriers, and energy quality (emissions) considered in the calculations. Among all three certifications, the ZEB definition provided the most clarity regarding these points. Perhaps, it would make more sense if all the definition accounts for delivered energy and emissions involving any energy loss during transportation, regulation, transfer etc., could be compensated by the source of energy itself. One more substantial question from this study would be how the same building can account for different amounts of carbon emission at different points of the building's lifetime. It can be seen that the same case study building, at the same time, can be carbon negative and carbon positive according to the different definitions. So why is the same building accounting for different amounts of carbon emission at the same point in its lifespan? Perhaps this is a relatively insignificant question concerning the scale of climate neutrality for the building, but it indicates contradictions between the definitions themselves. Nevertheless, it can be pointed out that the definition of climate neutrality is quite a recent topic, and more research and collaboration is required to achieve consensus and establish a unified framework that all parties can adopt, which is crucial in the subsequent development phases.