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Net-zero emissions and positive energy districts: An evaluation using attributional and consequential life cycle assessment approaches

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Abstract. Net-zero emissions and positive energy districts are gaining wide attention as solutions for achieving climate neutrality in the built environment, aligning with the European Union's 2050 target. Process-based life cycle assessment is the recognized metric tool selected for evaluating the emission profile of buildings and districts indicated by the recast Energy Performance Buildings Directive of the European Union (2024). The directive, as well as the articles published on the subject, approach the problem using the attributional life cycle assessment. On the other hand, the consequential life cycle assessment approaches can be used in the analysis to describe the consequences of a decision (i.e., effect-oriented or change-oriented) by introducing market mechanisms. To this end, the authors show and describe a case study related to a new district that will be built in Bologna – Northern Italy (41 400 m² of heated/cooled floor surface area). The outcomes were analyzed using the attributional (176 kgCO₂-eq / m²) and consequential life cycle assessment (763 kgCO₂-eq / m²).

1. Introduction

The construction sector accounts for 50-60% of natural resource consumption across Europe, contributing approximately 40% of total energy use and CO₂-eq emissions. Demographic projections indicate that by 2050, 70% of the global population will reside in urban areas [1,2]. In the transition toward decarbonizing cities and the construction sector, districts play a central role by serving as interconnected communities where various elements and energy systems interact. This interconnectedness presents opportunities to achieve climate neutrality that may not be feasible at the level of individual buildings.

European policies aimed at reducing the environmental impact of construction have shifted their focus from individual buildings to districts. The emphasis has evolved from the "nearly zero-energy" approach to more ambitious goals such as "positive energy" and "zero climate emissions" concepts [3]. In this context, the authors present a case study of a district project in Bologna (Italy), encompassing 41 400 m² of heated and cooled floor area. The proposed district aims to be a zero-emissions and positive energy model, serving as a key player and a replicable benchmark for Europe's decarbonization efforts. Climate neutrality is achieved through: (i) construction technologies with a low climate impact, (ii) an advanced 5th-generation district heating and cooling system, (iii) an on-site photovoltaic installation with a peak power of 1.9 MW_p, and (iv) offsetting the residual emissions by purchasing carbon credits. The photovoltaic system generates more electricity than the total energy demand of the district's buildings, covering both regulated



and unregulated energy uses as defined by the current Energy Performance of Building Directive (EPBD), version 3 [4].

The climate profile of districts for these application cases is commonly evaluated using the process-based Life Cycle Assessment (LCA) method (attributional modeling) following the standard EN 15978 [5], in line with the requirements of the new EPBD – version 4 [6], as described in the various urban regeneration projects, for example, promoted by C40 (global network of mayors of the world's leading cities that are united in action to confront the climate crisis) with the tenders called "Reinventing cities" [7]. The Attributional Life Cycle Assessment (ALCA) is commonly used to conduct a hotspot analysis, which focuses on answering the question, "What environmental impact is the product responsible for?" [8]. Alternatively, there is also the Consequential Life Cycle Assessment (CLCA) (not included in EN 15978) in the literature, the function of which is to answer the question "What are the environmental consequences of consuming the product?" The CLCA introducing market mechanisms examines how the relevant physical flows will change in response to a change in demand for the analyzed product; therefore, consequential models only include unconstrained, marginal suppliers, i.e., suppliers who can change their production volume due to increased demand, evaluating long-term effects of a given purchase choice by the end consumer [9].

The authors of this article show and describe the analysis of the case study (the net zero emissions district in Bologna – Italy), presenting the outcomes in terms of emissions of CO₂-eq evaluated using the two modeling approaches (i.e., ALCA and CLCA). The novelty of this work lies in presenting whether the decarbonization choices made and evaluated using ALCA are also valid using the CLCA (i.e., whether the choices made also have long-term spillovers), e.g., overproduction of renewable energy, use of recycled steel and eco-cement with blast furnace slag. It is important to note that in the analysis, the evaluation of the marginal suppliers in the CLCA analysis (i.e., the suppliers expected to respond to a change in demand) is delegated to the ecoinvent 3.10 library "substitution, consequential, long-term" [10]. The analysis of indirect Land Use Change (iLUC) in using wood construction materials was neglected (due to insufficient information on the origin of the wood), even if there is evidence that deforestation occurs globally, and previous CLCA studies come to the result that their climate impact increases significantly considering iLUC [11].

2. Materials and methods

This section explains the methodology used to assess the district's climate profile (greenhouse gas emissions) and the benefits used to achieve the target of net zero climate emissions within the time boundaries of the present study. The product system, system boundaries, functional unit, characterization method, and the options for reaching the net-zero climate emissions proposed by Lützkendorf and Frischknecht are explained [12]. The LCA results were calculated using specific codes developed using a Fortran App, as described in Famiglietti et al. [13].

2.1 Life cycle assessment methodology

The model developed covers the following stages of EN 15978: Modules A1–3 (product stage), Modules A4–5 (construction stage), Module B2 (use stage - maintenance), Module B4 (use stage - replacements), Module B6.1 (use stage – operational energy related to the regulated loads), C1–4 (end of life stage), and D (reuse-recycling-recovery potential). The functional Unit (fU) is equal to 1 m² of heated/cooled floor area with a Reference Study Period (RSP) of 50 years and a Required Service Life (ReqSL) of 60 years. The ReqSL differs from RSP because the former is related to the

service life required by buildings. In contrast, the latter is the period over which the time-dependent characteristics of the object of assessment are analyzed. The other assumptions considered are aligned with Famiglietti et al. [3].

As anticipated, the Life Cycle Inventory (LCI) was implemented using two different system models of the ecoinvent 3.10 library, i.e., (i) “Allocation, cut-off, EN15804” for ALCA and (ii) “Substitution, consequential, long-term” for CLCA. Figure 1 shows the two modeling approaches to evaluate the climate profile of two decarbonization solutions anticipated in the introduction section and better described in section 3, “Case study description.”

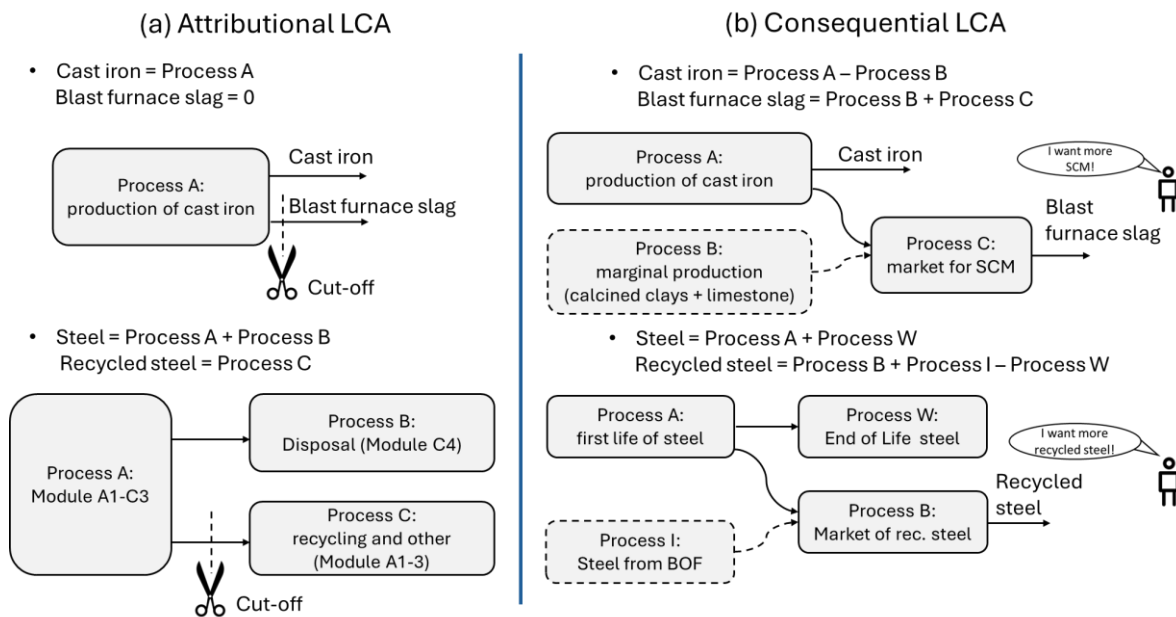


Figure 1. The figure presents modeling for blast furnace slag and recycled steel for (a) ALCA and (b) CLCA. In CLCA, cast iron and primary steel represent the unconstrained determining products (reference products) and, thus, are part of a consumption mix. Blast furnace slag and secondary recycled steel are constrained-dependent products (by-products). The marginal production of blast furnace slag is represented in ecoinvent as calcined clays plus limestone (SCM – supplementary cementitious materials). Recycled steel was schematized according to the “dependent co-product fully utilized,” provided by Weidema et al. [14], where the marginal production is Basic Oxygen Furnace (BOF).

In the CLCA modeling, the identification of the markets and affected suppliers is delegated to the ecoinvent library. In this regard, it is important to highlight that the library concerning the electricity from marginal suppliers (in low voltage) used or avoided (during the overproduction of electricity from photovoltaic modules) indicates for Italy the following sources: hydro, photovoltaic (PV), wind, biomass, and natural gas. The assumption was implemented as described by LCA 2.0 consultants [15], i.e., considering just the suppliers whose production trend exceeds the technology replacement rate. The same was implemented for importing countries, i.e., France, Switzerland, Austria, Slovenia, Montenegro, Greece, and Malta. The climate profile result is equal to 173 (for CLCA) vs. 628 gCO₂-eq / kWh_e (for ALCA, considering the residual mix, i.e., excluding the renewable energy certificates)

The biogenic carbon modeling was evaluated, as described by Hoxha et al. [16]:

- Using the -1/+1 method, which considers carbon sequestration in the production stages, adopting the characterization factors of the Environmental Footprint method 3.1 EN 15804 (for ALCA).
- Using the 0/0 method, adopting the characterization factors of the Environmental Footprint method 3.1 (for CLCA).

The analysis of indirect Land Use Change (iLUC) in using wood construction materials was neglected (due to insufficient information on the origin of the wood), even if there is evidence that deforestation occurs globally, and previous CLCA studies have come to the conclusion that their climate impact increases significantly considering iLUC. Also, the timing was not considered; dynamic discounting means that 1 kg CO₂ in year 0 will impact 1 kg CO₂-eq, whereas the same emission in year 10 is weighted to have an impact of only 0.921 kg CO₂-eq.

2.2 Case study description

The district comprises 14 buildings with an average number of stories equal to 5.5 with a total net floor heated or cooled area of 41 400 m². The district is located in Bologna (Po Valley - Northern Italy). The asset class of the buildings can be summarized in: (i) residential 33 930 m² (82.0%), (ii) commercial 1 170 m² (2.8%), (iii) retail 1 800 m² (4.3%), and hotel 4 500 m² (10.9%). The ratio of the total gross area and the net heated and cooled area is equal to 1.55.

The construction technologies and their thermal transmittance used for the buildings of the district are described as follows:

- Foundation system: includes foundations and underground structures made of cast-in-place reinforced concrete with a characteristic strength of C32/40, using type III cement (eco-cement) and 100% recycled steel bars.
- Structural system: includes an engineered wood (Glued Laminated Timber certified in accordance with Chain of Custody (FSC® and/or PEFC™) - steel hybrid frame system and a precast concrete stairwell. As with the foundation system, reinforced concrete involves type III cement (eco-cement) and 100% recycled steel bars.
- Basement slab: consists of a cast-in-place reinforced concrete slab (type III concrete and 100% recycled steel bars), plaster, expanded polystyrene (EPS) layer on the lower surface, and sand-cement screed on the upper surface ($U = 0.18 \text{ W/m}^2\text{K}$).
- Inter-floor slab: consists of a wood-concrete slab, also involving type III cement and 100% recycled steel bars, completed with a metal false ceiling, a layer of gypsum board on the lower surface, and a sand-cement screed and acoustic underlay on the upper surface.
- Roof slab: consists of a wood-concrete slab, also involving type III cement and 100% recycled steel bars, completed with a metal false ceiling and gypsum board on the lower surface, a bituminous membrane, polyurethane foam insulation, vapor barrier, and sloped screed on the upper surface ($U = 0.18 \text{ W/m}^2\text{K}$). For 45% of the roof area, a green roof is foreseen, to which the construction system adds: (i) a 30 cm layer of soil, (ii) a filtering membrane, (iii) accumulation and drainage layers totaling 4 cm, and (iv) retention felt.
- Opaque envelope system: framed wooden system with rock wool insulation and double Oriented Strand Board (OSB) panel, internal counter-wall with steel substructure, rock wool insulation, and a double layer of gypsum board, external cladding in fiber-cement ($U = 0.18 \text{ W/m}^2\text{K}$).
- Glazed parts of the envelope: consist of polyvinyl chloride (PVC) frames and double glazing ($U = 1.3 \text{ W/m}^2\text{K}$).
- Internal partitions: drywall system consisting of a double layer of cladding and intermediate gypsum board, steel metal framing with C-shaped studs and U-shaped guides, and a double layer of glass mineral wool insulation.

The scenario foresees the refurbishment of existing buildings for 290 m² of net heated/cooled floor area. Therefore, the proposed construction solution is applied to 41 110 m² of the area. For the remaining 290 m², only the following aspects were considered: (i) opaque

envelope, (ii) glazed parts of the envelope, (iii) internal partitions, and (iv) systems, with the rest of the systems assumed to be recovered.

2.3 Energy needs and energy systems

The theoretical energy needs of the buildings are assessed based on the approach proposed by standard ISO 52016, as described in Famiglietti et al. [13,17]. The theoretical energy needs are provided in Table 1. The values were calculated using the dataset provided by the Meteororm 8 software [18] for a weather station located near Bologna airport. The contemporary typical year is constructed from data collected between 1964 and 2019. Future scenarios were not evaluated in this article because they were considered outside the scope of this research (analyzed in Famiglietti et al. 2024). As introduced, the buildings are powered by a 5th-generation district heating and cooling network (DHC). The network is composed of:

- An energy center comprises a borehole heat exchanger, a water source heat pump, and an energy storage (balancing unit). For cooling, heat exchange with groundwater is sufficient (extracting at 285.15 K and rejecting at 295.15 K). For heating, the central heat pump is used to extract heat from the groundwater (at 285.15 K) to increase the temperature of the balancing unit.
- Two hydraulic loops with a difference in temperature of 5 K and an average temperature of 298.15K.
- Substations (one for each building) are composed of heat exchangers, one heat pump for space heating, one heat pump/chiller for Domestic Hot Water (DHW) and space cooling, and a storage tank for DHW. The substations supply water to buildings for heating, DHW, and cooling at the following temperatures: 323.15 K, 333.15 K, and 287.15 K, respectively. The energy is distributed by radiant floor heating systems (for residences) and radiant fan coils (for tertiary).

Table 1 reports the electricity consumption for: (i) auxiliary, i.e., the electricity consumption for pumping and mechanical ventilation, (ii) the regulated electrical consumption for non-residential buildings according to the EPBD directive, i.e., artificial lighting and transport (elevators, etc.), and (iii) loads for home appliances and artificial lighting and transport for residential buildings, i.e., unregulated loads for the EPBD.

Table 1. Energy needs of the district

Service ^a	kWh _{th or el} /m ² .y	MWh _{th or el} /y
Space Heating (SH)	32.7	1 354
Space Cooling (SC)	40.9	1 695
Domestic Hot Water (DHW)	19.7	817
Auxiliary	5.4	222
Artificial lighting and transportation ^b	6.5	270
Home appliances and artificial lighting and trans. ^d	18.6	772

^a SH, SC, and DHW: thermal energy; the others: electricity.

^b It is related only to non-residential buildings.

^c The value equals the total demand over the entire floor area of the district.

^d Artificial lighting and transport for residential buildings.

The electricity consumption for producing thermal and cooling energy required to cover the demand for space heating and cooling and domestic hot water is as follows: 24.7 kWh_e / m².y and 1 023 MWh_e / y. The Total Energy Ratio (TER), calculated as the ratio of the energy needs provided in Table 1 to the demand for electricity for SH, DHW, SC, and Auxiliary, is equal to 3.11.

2.4 Photovoltaic modules installed on-site

The photovoltaic (PV) modules are installed: (i) on building roofs for 3 394 m² (886 kWp and 1 116 MWh_e / y), (ii) and canopies near the buildings for 2 145 m² (560 kWp and 706 MWh_e / y), and (iii) positioned on the vertical barrier dividing the railway and the district for 4 364 m² (492 kWp and 619 MWh_e / y). The electricity production from PV can be considered shared as follows (considering an annual balance between energy produced and energy demand).

- A share of 48% is ideally installed to offset, on an annual basis, the demand for thermal energy required to cover the energy needs for both space heating and cooling and domestic hot water production.
- A share of 10% is ideally installed to offset, on an annual basis, the demand for electricity to cover the ventilation needs.
- The remaining 42% is auto-consumed by the unregulated electrical loads or exported to the national grid, the benefits of which are shown in Module D. The district is in the process of establishing a renewable energy community, in accordance with the normative, technological, and operational constraints of European Directive 2018/2001 and Italian Law 199/2022.

The district effectively qualifies as a Positive Energy District (PED) since the demand for electrical energy for both regulated and unregulated uses, according to EPBD (2 287 MWh_e / y), is lower than the photovoltaic energy produced (2 441 MWh_e / y), as indicated mathematically in the equation below:

$$\int_1^{8760} W_{Demand}(t)dt < \int_1^{8760} W_{PV}(t)dt \quad (1)$$

The ratio of installed PV power peak (1 938 kWp) to the district's gross built area (41 400 m² × 1.55 = 64 170 m²) amounts to 30.2 Wp / m².

3. Results and discussion

Table 2 compares the climate footprint of the two modeling approaches, i.e., Attributional and Consequential LCA. The outcomes are provided by aggregating (i) Modules A1-5, B2, B4, and B6 in A1-B6 column, and Modules C1-4 plus D contributions in C1-D column. The Table provides information (by rows) according to: (i) the climate profile of construction materials, (ii) embodied impacts related to the District Heating and Cooling (DHC) networks, and (iii) embodied impacts and benefits (overproduction of electricity exported) related to the installation of PV modules. It is important to highlight that the benefit of exported electricity was assessed by multiplying the amount of electricity exported (919 MWh_e / y) by the difference between the emission factor of 1 kWh_e produced by PV (73 gCO₂-eq / kWh_e) and the emission factor of the grid (628 and 173 gCO₂-eq / kWh_e).

As indicated in section 2 of the article, the authors considered only the Modules of EN 15978 mandatory and in compliance with the EPBD as Global Warming Potential (GWP) contributors. Thus, (i) the energy loads for energy consumed for the operation of the further building-integrated technical systems beyond what is covered in B6.1 (Module B6.2) and (ii) energy consumed by the occupants' operation of technical systems that enable/support the intended building use, i.e., plug-in appliances, etc. (Module B6.3) are not included in the footprint. These loads were considered in the definition of the PED (since the energy produced exceeds to cover regulated uses, a sufficient condition for EPBD, and unregulated) but not included in the system boundary of the net Zero Climate Emissions District (nZCED).

The results show comparable total values for ALCA and CLCA. In particular, except for PV contribution, the ALCA presents lower burdens in the upstream and higher burdens in the

downstream Modules than the CLCA. In this regard, the electricity exported from PV, evaluated with CLCA approaches, presents fewer benefits because, in the long-term, the national electricity will be decarbonized: natural gas combined cycle, hydro, PV, wind, and biomass plants represent the marginal producers.

Table 2. Results obtained according to ALCA and CLCA.

Elements	Approach	Modules A1-B6 kgCO ₂ -eq/fU	Modules C1-D kgCO ₂ -eq/fU
Construction materials	ALCA	403	233
DHC networks + MEPs within buildings		105	6
PV (embodied + export)		127	-696
Total		634	-458
Construction materials	CLCA	600	115
DHC networks + MEPs within buildings		109	3
PV (embodied + export)		127	-192
Total		836	-73

Figure 2 presents graphically the outcomes shown in Table 2 (a) and the demand and production of electricity over a year (b).

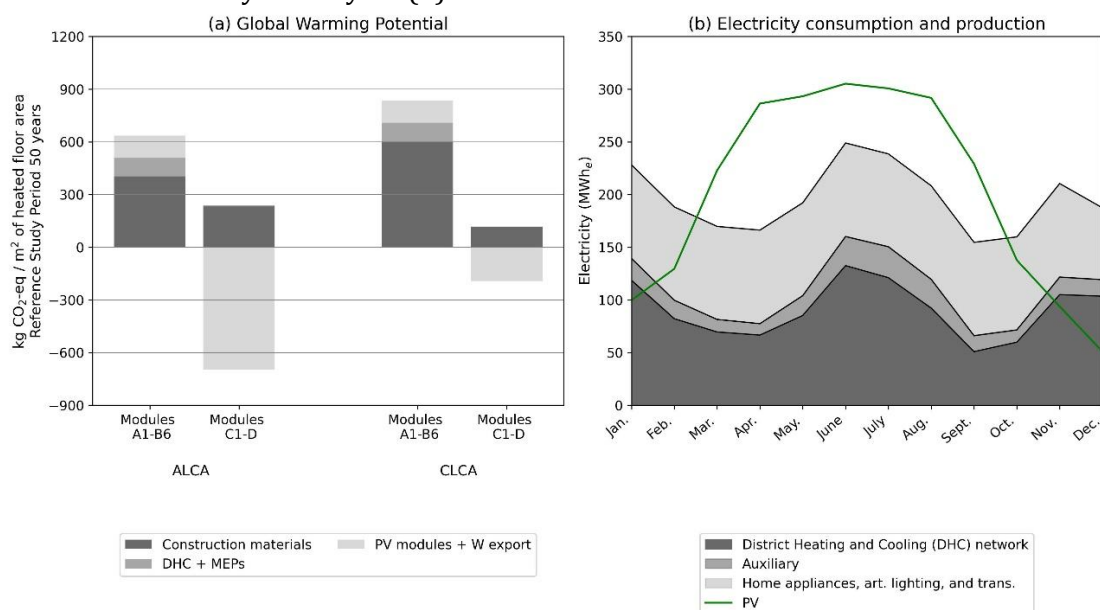


Figure 2. (a) Global Warming Potential per Modules and contributors per ALCA and CLCA, and (b) demand and production of electricity over a year.

4. Conclusions

The authors present the outcomes in this article by evaluating the climate profile of a positive energy district in Bologna (Po Valley – Northern Italy) using the attributional and consequential life cycle assessment approach. The attributional approach is evaluated using standard EN 15978, which aligns with the requirements of the new Energy Performance Building Directive – version 4. The consequential evaluation of the marginal suppliers in the CLCA analysis (i.e., the suppliers expected to respond to a change in demand) is delegated to the ecoinvent 3.10 library “substitution, consequential, long-term.” The district has a heated floor area of 41 400 m² with residential, commercial, and retail asset classes supplied by a 5th-generation district heating and cooling network. The photovoltaic plant, with a total peak power (on-site) of 1.9 MWp, produces

electricity to a greater extent than the electricity demand of the buildings' district for regulated and unregulated uses, as indicated by the Energy Performance Building Directive.

Climate neutrality is achieved through (i) construction technologies with a reduced climate footprint, (ii) a state-of-the-art heat/cold generation system (i.e., 5th generation district heating and cooling), (iii) the photovoltaic plant installed on-site, and (iv) the purchase of carbon credits. The outcomes show a footprint (Modules A1-C4 plus D) of 176 (attributional) and 763 kgCO₂-eq / m² (consequential). In this regard, the electricity exported from PV, evaluated with CLCA approaches, presents fewer benefits because, in the long-term, the national electricity will be decarbonized: natural gas combined cycle, hydro, PV, wind, and biomass plants represent the marginal producers, meaning that (to achieve climate neutrality) buildings must be close to absolute zero being the contribution of PV electricity exports minimal. Policies could use this finding to review the long-term actions related to the built environment.

References

- [1] Ristimäki M, Säynäjoki A, Heinonen J, Junnila S. Combining life cycle costing and life cycle assessment for an analysis of a new residential district energy system design. *Energy* 2013;63:168–79. <https://doi.org/10.1016/j.energy.2013.10.030>.
- [2] Anastaselos D, Oxizidis S, Manoudis A, Papadopoulos AM. Environmental performance of energy systems of residential buildings: Toward sustainable communities. *Sustain Cities Soc* 2016;20:96–108. <https://doi.org/10.1016/j.scs.2015.10.006>.
- [3] Famiglietti J, Aprile M, Spirito G, Motta M. Net-Zero Climate Emissions Districts: Potentials and Constraints for Social Housing in Milan. *Energies* 2023;16. <https://doi.org/10.3390/en16031504>.
- [4] European Parliament and the Council of the European Union. Consolidated text: Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (recast). *Off J Eur Union* 2018:1–35.
- [5] CEN. EN 15978: Sustainability of construction works. Assessment of environmental performance of buildings. Calculation method. *Eur Stand* 2021.
- [6] European Parliament and Council. Directive (EU) 2024/1275 of the European Parliament and of the Council of 24 April 2024 on the energy performance of buildings (recast). *European Union*: 2024. <https://doi.org/10.1080/00344897208656356>.
- [7] C40. Reinventing Cities 2025. <https://www.c40reinventingcities.org/en/professionals/>.
- [8] Hauschild MZ, Rosenbaum RK, Olsen SI. *Life Cycle Assessment. Theory and Practice*. Cham, Switzerland: Springer International Publishing AG; 2018. <https://doi.org/10.1007/978-3-319-56475-3>.
- [9] Ekvall T, Weidema BP. System boundaries and input data in consequential life cycle inventory analysis. *Int J Life Cycle Assess* 2004;9:161–71. <https://doi.org/10.1007/BF02994190>.
- [10] Wernet G, Bauer C, Steubing B, Reinhard J, Moreno-Ruiz E, Weidema B. The Ecoinvent database version 3 (part I): overview and methodology. *Int J Life Cycle Assess* 2016;21:1218–1230. <https://doi.org/10.1007/s11367-016-1087-8>.
- [11] Hansen RN, Eliassen JL, Schmidt J, Andersen CE, Weidema BP, Birgisdóttir H, et al. Environmental consequences of shifting to timber construction: The case of Denmark. *Sustain Prod Consum* 2024;46:54–67. <https://doi.org/10.1016/j.spc.2024.02.014>.
- [12] Lützkendorf T, Frischknecht R. (Net-) zero-emission buildings: a typology of terms and definitions. *Build Cities* 2020;1:662–75. <https://doi.org/10.5334/bc.66>.
- [13] Famiglietti J, Villa G, Romagnosi M, Dénarié A, Scoccia R, Motta M. Net Zero Emissions and Positive Energy Districts: A Potential Solution to Achieve the European Climate Targets. 2024 IEEE Int. Conf. Environ. Electr. Eng. 2024 IEEE Ind. Commer. Power Syst. Eur. (EEEIC / I&CPS Eur., IEEE; 2024, p. 1–6. <https://doi.org/10.1109/EEEIC/ICPEurope61470.2024.10751307>.
- [14] Weidema BP, Ekvall T, Heijungs R. Guidelines for application of deepened and broadened LCA. *Guidel Appl Deep Broadened LCA Deliv D18 Work Packag 5 CALCAS Proj* 2009:49.
- [15] LCA 2.0 consultants. Marginal suppliers. *Consequential LCA* 2024. <https://consequential-lca.org/clca/marginal-suppliers/> (accessed September 19, 2024).
- [16] Hoxha E, Passer A, Saade MRM, Trigaux D, Shuttleworth A, Pittau F, et al. Biogenic carbon in buildings: a critical overview of LCA methods. *Build Cities* 2020;1:504–24. <https://doi.org/10.5334/bc.46>.
- [17] CEN. EN ISO 52016-1:2017 Energy performance of buildings — Energy needs for heating and cooling, internal temperatures and sensible and latent heat loads — Part 1: Calculation procedures. 2017.
- [18] Meteotest AG. *Meteonorm. Meteotest AG* 2024.