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Methodology proposal for the life cycle sustainability assessment applied to retrofitting in a local context

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Abstract: *In the European context of upgrading the housing stock energy performance, multiple barriers hinder the wide uptake of sustainable retrofitting practices. Moreover, some of these may imply negative effects often disregarded. Policy makers need to identify how to increase and improve retrofitting practices from the comprehensive point of view of sustainability. None of the existing assessment tools addresses all the issues relevant for sustainable development in a local situation from a life cycle perspective.*

Life cycle sustainability assessment methodology, or LCSA, analyzes environmental and socioeconomic impacts. The environmental part is quite developed, but the socioeconomic aspect is still challenging. This work proposes socioeconomic criteria to be included in a LCSA to assess retrofitting works in the specific context of Brussels-Capital Region. LCSA feasibility and challenging methodology aspects are discussed.

Keywords: housing, retrofitting, life cycle sustainability assessment, LCSA, health

Introduction

The large amount of energy-upgrading retrofitting processes currently taking place in Europe may entail negative effects barely considered in decision making (unexpected impacts on health, fabric performance, economic accessibility to works, cultural value, etc. [1]). Some of the barriers for the uptake of "more sustainable" retrofitting practices (with the best environmental and socioeconomic performance) are: the fact that regulations and policies in the building sector mainly focus the reduction of energy consumption and emissions[1], high investment costs that often determine decisions, complexity of considering all the economic, environmental and social factors involved in decision making, as well as the lack of reliable available information about social performance.

Available tools for the assessment of sustainability in buildings such as labels or rating systems were originally created to assess environmental impacts mainly focusing the use phase. The life cycle perspective is increasingly being included: environmental life cycle assessments are encouraged, or even required (e.g. LEED, CASBEE); socioeconomic factors are also being added, although not covering yet all the life stages, and context specific issues are not addressed. Rating systems are based on scoring scales and weighting, but impacts on all the dimensions of sustainability are not calculated, and weighting is based on expert agreement rather than on effects on sustainability.

The environmental life cycle assessment methodology (e-LCA, or LCA) has been largely developed and applied; life cycle costing (LCC) too, but often neglecting some of the life

[1] EPBD 2010 Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (recast).

cycle stages and externalities; and the social assessment (s-LCA) is still very recent. These methodologies overlap in some of the impacts considered (health is addressed by e-LCA and s-LCA, social well-being and dignity by LCC and s-LCA. Indeed, LCC as one of the branches of sustainability has been questioned by Jørgensen et al [2]. Life cycle sustainability assessment (LCSA) integrates these three methodologies [3]. Although still challenging due to the different state of development of the three methodologies, it seems suitable to work towards this integrated approach [4], since focusing the three techniques separately might imply impact shifting between sustainability dimensions, and the consequent misuse of the term sustainability.

Approach

The final goal of this research is to develop LCSA methodology to be applied to housing retrofitting in Brussels-Capital region. Since the methodology is highly developed for the environmental issues, the focus is on the implementation of socioeconomic criteria. Our methodology approach is presented below, following the structure of life cycle analyses: goal and scope, life cycle inventory (LCI), life cycle impact assessment (LCIA) and interpretation of results

Goal and scope: since socioeconomic assessment is highly context related [5], criteria to be considered must be specifically defined depending on the application. This development focuses decision makers in Brussels-Capital Region: to prioritize retrofitting solutions to be encouraged (by means of economic incentives, dissemination, etc.), to optimize enhancement instruments (how much would be suitable to be invested), to identify opportunities for more sustainable practices, etc.

The life cycle inventory (LCI) consists in collecting all the inputs and outputs throughout the whole life cycle having an influence on the assessed impacts. In a LCSA, the type of data to collect is diverse, related with energy flows, use of materials, economic flows, social performance, etc. For socioeconomic issues, appropriate inventory indicators must be specifically selected and defined. Our approach consists in: (1) transferring the applicable criteria proposed by the main reference documents (Guidelines[2] [5], EN 15643-3[3], rating systems[4] and research projects[5]) into inventory indicators; (2) adapting those indicators to housing retrofit; (3) developing new indicators to address missing context-specific socioeconomic issues. The resulting proposal is presented in next section.

The impact assessment stage (LCIA) analyzes impacts produced by inventory indicators. EN 15978:2012 standardizes environmental impact categories and methods. But socioeconomic impact categories are not standardized, nor the methods of assessment. Nor does the life cycle

[2] Guidelines for social life cycle assessment of products and The Methodological Sheets for Subcategories in Social Life Cycle Assessment

[3] EN 15643-3:2012 Assessment of buildings - Part 3: Framework for the assessment of social performance

[4] LEED, BREEAM, Valideo

[5] Superbuildings http://cic.vtt.fi/superbuildings/, OpenHouse http://www.openhouse-fp7.eu/

initiative[6] propose methods for social impact assessment. Indeed, this initiative recognizes the feasibility of the classification step (to assign impact categories to the inventory data), but recommends not to aggregate or weight results of the three methodologies (environmental, social, economic), due to the early stage of LCSA [3].

Possible approaches are presented by Parent et al [6]: the **socioeconomic relative performance approach** (also called Taskforce's or Type 1) consists of inventory indicators scoring according to reference points (best and worst performance), aggregation, and weighting. Scoring can be done related to a reference scale, and weighting can be based on multiple criteria, such as expert panel advise, monetization, etc.; the **characterization approach** models–for those indicators for which a cause-effect relation exists–the impact pathway, by defining impact indicators, units to quantify them and characterization factors to relate inventory indicators with midpoint and potentially endpoint impacts (Figure 1).

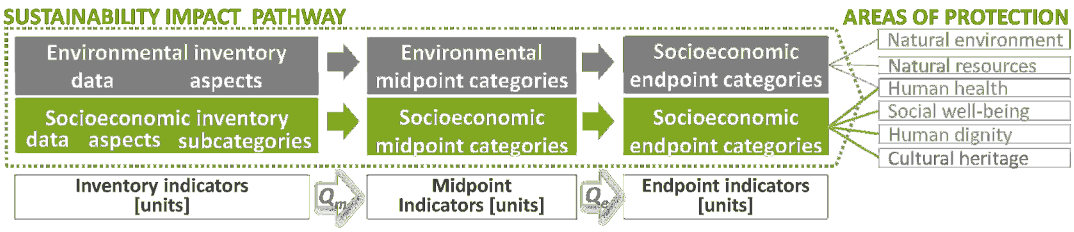

Figure 1. Impact pathway structure and terminology in LCSA. (Q: characterization factors)

The first approach is followed by most building assessment tools. Despite some challenging points (such as the min.-max. reference point definition, or the integration with environmental LCA in a comprehensive assessment), the application is feasible to date. It allows benchmarking socioeconomic performances, to identify opportunities to improve sustainability of a product, service, etc. The characterization model is the similar approach to environmental LCA. This is still challenging due to the lack of evidences between some of the criteria and associated impacts [7]. Although very recent and scarcely applied, interesting approaches exist focusing some of the impact categories, such as Weidema's and Hunkeler's approach, as presented by Parent [6]. In next section, we analyze the feasibility for analyzing impacts on health related to housing retrofitting.

The interpretation of results for the first approach as a "combined" way of reading–as proposed by the life cycle initiative [4]–seems not obvious. Results might be opposite for environmental and social performance, and interpretation rely on identifying opportunities for improvements. By following the characterization model approach, results must be interpreted very carefully, considering data reliability and strength of cause-effect relationship.

Methodology proposal

Goal and scope: in this case, comparisons and conclusions can only be made between similar housing models: similar typology (distribution and construction type), management (social or

[6] UNEP/SETAC life cycle initiative http://www.lifecycleinitiative.org/es/

private housing), tenancy (ownership, co-ownership, or renting), heritage value, conditions before works, etc.

The socioeconomic inventory assessment (LCI) follows the approach presented in the previous section. Figure 2 shows the inventory indicators proposed, with some examples of the data involved, classified by items, aspects and subcategories, as well as the assigned impact categories.

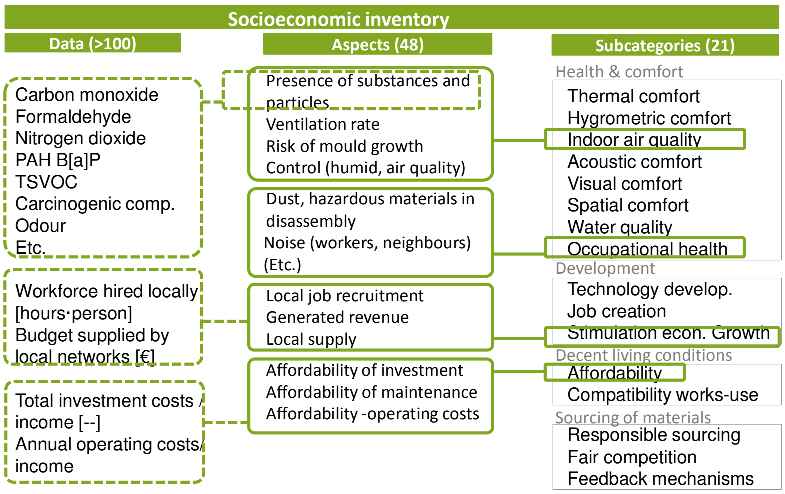

Figure 2. Some examples of socioeconomic inventory, classified by data, aspects and subcategories

Indicators related with accessibility, adaptability, and safety and security, have been transferred from EN 15643-3, and prEN 16309[7]; most criteria related with the responsible sourcing of materials and services have been transferred from the Guidelines; in order to address health and comfort, EN 15643-3 proposal has been completed with other assessment tools and research projects.

In order to address the poor housing conditions, unaffordable investment costs of retrofitting, fuel poverty rates and damaged construction sector, indicators have been proposed to assess affordability of investment, maintenance and operating costs, job creation and local supply, as well as deteriorated working conditions, social dumping, or qualified labour shortage.

Indicators are lacking to characterize cultural value (heritage and architectural quality of new interventions). In Brussels, pre-war housing has been largely studied, although evaluations seem to be case-by-case analyses rather than a standard indicator-based methodology. Post-war housing stock is still challenging.

For the impact assessment stage (LCIA), the objective is to cover all the sustainability issues, the so called "areas of protection". The six considered in this work are: natural resources[8], natural environment8, human health8, social well-being[9], human dignity9 and cultural

[7] Draft prEN 16309 Sustainability of construction works – Assessment of social performance of buildings – Methods (or methodology)
[8] Largely accepted in e-LCA
[9] Proposed by Weidema [8]

heritage[10]. Impact pathways between the object of assessment and the areas of protection are classified in inventory indicators, midpoint, and endpoint impact categories (Figure 1).

Bearing in mind the aim towards a comprehensive sustainability analysis, it seems reasonable to develop socioeconomic assessment by following the same approach than e-LCA (characterization model approach). We analyze in this work the feasibility of modeling the impact pathway for human health related to housing retrofitting. Figure 3 shows the contributors to human health: environmental health, occupational health, and health of building users.

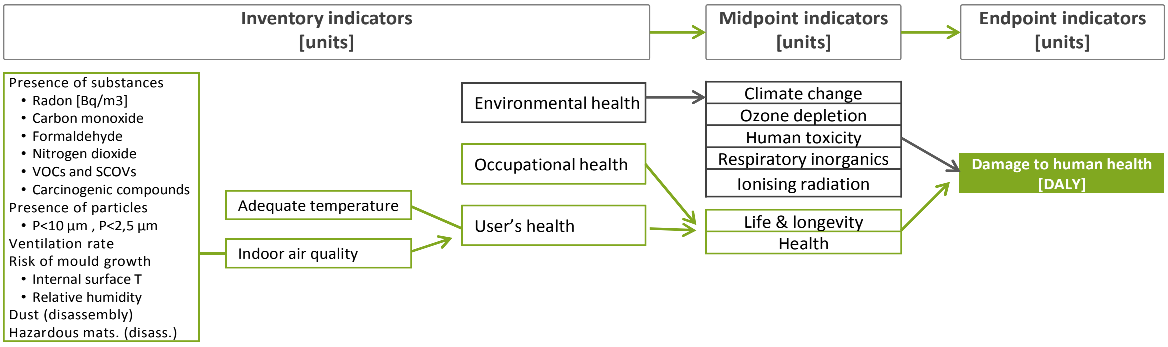

Figure 3. Contributors to health related to retrofitting

The analysis of impacts on **environmental health** is covered by e-LCA. Life cycle stages involved are the supply chain of building products employed in renovation (production and transport), disposal of replaced elements, energy consumed along the remaining life of the building, and final end of life. The inventory analysis is challenging due to the lack of building-specific information in environmental databases (such as Ecoinvent), and the complexity due to the large amount of items involved. Calculation methods define characterization factors.

Occupational health is related with workers involved along the supply chain, workers at site and disposal. For the background processes, available data about working conditions (accident and disease rates, living conditions, etc.) are available by type of works, sector and country[11]. The level of aggregation is too high to differentiate two options for retrofitting included in the same activity in the same country, but makes possible to assign potential impacts depending on the country of origin. In this topic, Weidema has provided estimates of health consequences per unit process [8].

Negative effects on **user's health** are mainly related to inadequate temperatures, and to indoor air quality (including mould, concentration of substances and particles, etc.) [1]. Although the concept might vary depending on the country, the term "fuel poverty" defines the household inability to keep the home adequately warm at an affordable cost, as a result of low household income, poor heating and insulation standards, and high energy prices.

[10] Life cycle initiative

[11] In sources such as reports of international organizations (ILO, WHO), and in the recent SHDB Social hotspot database http://socialhotspot.org/

Indicators of fuel poverty include being in arrears with energy bills, being unable to pay to maintain one's home at an adequate temperature, and having dampness and/or mould in one's home (EPEE[12]). The high costs of retrofitting, added to increasing fuel prices may increase the current fuel poverty rates, and consequent effects on health. Although the link between inadequate temperatures indoors and mortality increase is admitted by the WHO, there is still a lack of evidence about direct effects for pathway modeling, and more research is needed.

Air-tightness improvement and the installation of ventilation mechanisms with heat recovery, might imply indoor pollutant concentrations higher than usual exposures in dwellings before retrofitting. Studies performed in the UK show relations between health and strategies of fabric insulation, ventilation, fuel switching and behavioral changes, by defining pathways for modeling the effects of concentration of pollutants (Radon, smoke, and dampness and mould[13]). These studies highlighted the potential very high levels of PM2,5 exposure [9]. VOC concentrations were excluded due to the lack of reliable evidences.

Research has been done last years to model indoor toxicity. Models are based on Hellweg's [10], considering of material emission rate, ventilation rate and intake fraction. Recent results show that impacts on health due to finishing materials toxicity are in cases one order of magnitude higher than impacts due to air quality outdoors [11]; therefore, these cannot be disregarded anymore. The availability of information about the emission rate of materials is a main gap to solve.

Conclusions

This methodology presents an approach towards LCSA of housing retrofitting in a local context. The inventory assessment in this document proposes the relevant socioeconomic issues to be included beside the environmental ones.

Work must still be done to enable the modeling of human health pathways: to provide less aggregated data about occupational health in the region, to improve knowledge for modeling toxicity in workplaces and housing, as well as providing information about material emission. The areas of protection "human dignity" and "cultural heritage" are still in an earlier state. For these, it seems feasible, to date, to follow the "relative performance approach", and to benchmark options by assessing impacts on a scoring scale basis.

Next steps will tackle the feasibility to assess impacts of different retrofitting works on prosperity, as well as applying the methodology to case studies: energy upgrading works including system update and fabric performance improvement. The goal of the application is to test the feasibility of the methodology, as well as to compare possible options (repercussions of using "conventional" or "natural" materials, different energy-upgrading levels, etc.)

[12] IEE research project. European fuel poverty and energy efficiency http://www.fuel-poverty.org

[13] based on empirical and building physic models, calculated with adaptation of Comparative Risk Assessment method by means of an adaptation of "Comparative Risk Assessment" used by the WHO for the global burden of disease

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