Implementation of socioeconomic criteria for the life cycle sustainability assessment of housing retrofit

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1. Context and scope

In the European context, most of the housing stock must be renovated. Reaching the environmental targets and reducing energy dependence has been focused by policies and regulations [1]. Sustainable renovation entails numerous positive effects on society, dealing with poor conditions of dwellings and keeping the cultural heritage. However, retrofitting might also entail unexpected negative repercussions on health (such as worsen air quality due to the increased air-tightness) or increasing social inequalities [2]. Incentive instruments are necessary to foster retrofitting, and decision-makers need holistic assessment methods to identify renovation practices to encourage: solutions being optimal from the environmental and socioeconomic point of view throughout the whole life cycle.

Life cycle sustainability assessment (LCSA) is an assessment technique that aims at integrating environmental life cycle assessment (LCA hereafter), social LCA and life cycle costing (LCC) [3]. This technique is still very recent, and not developed enough to be applied to assess housing renovation works. The environmental LCA has been widely developed and applied. Also LCC, but applications often disregard externalities and some of the life stages. Social LCA is the most recent methodology and application is still challenging.

Main developments in social LCA are the standard EN 15643-3:2012 for the assessment of buildings [4] and UNEP/SETAC guidelines and methodological sheets for products [5]. On the other hand, building assessment tools are increasingly including socioeconomic aspects. All these references propose socioeconomic criteria to be assessed. Classification varies depending on the source (by topic, stakeholders, categories, etc.). Life cycle stages are not equally covered: the current version of standard EN 15643-3:2012 only applies to the use phase of buildings and the UNEP/SETAC guidelines and methodological sheets only to the production phase. Specific indicators are not standardized, but only suggested in the draft for the future standard prEN 16309, as well as in the UNEP/SETAC methodological sheets. None of the previously mentioned references specifies how to calculate impacts. As presented by Parent et al. [6], most applications (to date) assess relative performances in a scoring scale by comparing to reference points (usually a range between the minimum acceptable value and the ideal situation). Although some approaches exist [7], models for the calculation of impacts are still lacking in social LCA.

2. Goal and approach

This work aims the development of the life cycle sustainability assessment methodology. The goal is to assist decision making in the specific context of Brussels-Capital region towards more sustainable housing retrofitting practices. Since the environmental part has been largely developed by the environmental LCA, the challenge is to add relevant socioeconomic aspects into the methodology.

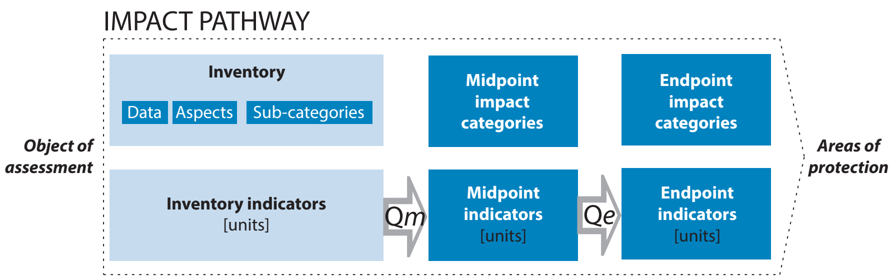

Figure 1: Impact pathway terminology and structure (own elaboration)

In order to ensure the coherence of the methodology, this proposal has been developed similarly to environmental LCA. That is following the so called impact pathway. In LCA, pathway is divided in inventory, midpoint and endpoint impact categories (Figure 1). For socioeconomic issues, this proposal also classifies inventory in sub-categories, aspects and data. Indicators (and related units) have been defined to quantify inventory and impact categories. Characterization factors (Q_m and Q_e in Figure 1) have also been defined to calculate indicators, from the inventory into midpoints (Q_m), and from midpoints into endpoints (Q_e). Some of the midpoint categories and subcategories are characterized with more than one indicator.

Indicators proposed for the life cycle inventory assessment (LCI) are presented in 2.1., characterization models for the life cycle impact assessment or LCIA in 2.2, and discussion and conclusions in 2.3.

2.1 Life cycle inventory assessment (LCI)

In order to perform the life cycle inventory analysis (LCI), our proposal defines socioeconomic inventory indicators and units of measurement. As it has been mentioned before, socioeconomic inventory is classified in levels, here called subcategories, aspects and inventory data. This classification is useful to organize and structure the methodology.

After being adapted to the case of housing and retrofitting (and therefore dismissing the non-applying criteria), most of the social performance categories and subcategories defined in the main reference documents (EN 15643-3, prEN 16309, UNEP/SETAC guidelines) have been included in our proposal (top-down approach). The analysis of the specific context of housing renovation in Brussels-Capital region identified relevant socio-economic issues (bottom-up approach) such as the high unemployment rates and consequent deteriorated working conditions, poor housing stock conditions, unaffordable retrofitting, rates of households in fuel poverty[1], or population increase. These issues were identified not to be addressed by reviewed references, and new indicators have been developed to include them.

By following these top-down and bottom-up approaches, the LCI proposal consists of 21 impact subcategories, 48 aspects, and more than 100 inventory data and sub-data). These criteria are classified by categories "Accessibility", "Adaptability", "Health and comfort", and "Safety and security", "Decent living conditions", "Cultural value", "Development", "Endogen development", and "Sourcing of materials and services".

Indicators, with related units, characterize the inventory. Figure 2 and 3 show inventory indicators and sub-indicators related with health and prosperity. Sub-indicators are necessary to calculate inventory indicators when more than one parameter is involved. From these inventory indicators, midpoint and endpoint impacts are calculated by using characterization factors.

2.2 Life cycle impact assessment (LCIA)

Impacts on sustainability are considered damages to the so called areas of protection. These are natural resources[2], biodiversity[2], human health[2], social well-being[3], human dignity[3], and cultural heritage[4]. For the first three, endpoint indicators (and units) are accepted by the LCA scientific community, that is: damage to natural resources (in surplus cost), damage to biodiversity (in species year), and damage to human health (in disability-adjusted life years or DALY)2. For "Social well-being", "Human dignity" and "Cultural heritage", the level of agreement is not enough yet. However, the relation between economic prosperity and these three last areas of protection is well

1 "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. www.fuel-poverty.org

2 Largely accepted in LCA. For example in ReCiPe method www.lcia-recipe.net/

3 Proposed by Weidema [7]

4 Proposed by the UNEP/SETAC life cycle initiative www.lifecycleinitiative.org

recognized. “Prosperity” seems thus to be a suitable endpoint indicator to assess well-being, human dignity and cultural heritage.

For the impact assessment phase, our proposal defines characterization factors to model pathways relating retrofitting works and impacts on health and on economic prosperity, from inventory indicators to midpoint impacts, and from midpoint to endpoint impacts. As Figure 2 shows, impacts on health related with retrofitting are caused by the so-called “environmental health”, “occupational health”, and “user health”. Prosperity (Figure 3) is considered at the level of society at large in terms of fairness, at the level of the Region in terms of economic growth, and at the household level, in terms of affordability of decent living conditions.

Environmental health (defined in environmental LCA) is affected by emissions to the environment due to material production, disposed materials, operating energy, etc.; **Occupational health** is mainly affected by safe & healthy working conditions. These depend on the sector and country of origin, and on the type of works on site; **User health** is mainly affected by indoor air quality and adequate indoor temperatures. Several and diverse parameters are involved in these inventory indicators. Some of them are related to the type of materials employed (such as emission rate of indoor finishing materials, hygrothermal fabric performance), with technical systems (type of combustion sources, ventilation rate), but also with the household situation (low household income), or a combination of them. For example, the condition of a household to be in fuel poverty is caused by a combination of high energy costs, energy inefficient housing, and low household income. Effects of fuel poor households on health are due to inadequate indoor temperatures and presence of mould and dampness.

Characterization factors are established between inventory and midpoint indicators, and between midpoint and endpoint indicators. Some pathways are very straight forward. This is the case for safe and healthy working conditions [7]: characterization factors multiply incidence (based on statistics and international reports), severity of the disease (0-full health, 1-death), and duration (in working hours). Indicators to characterize the midpoint impact category of occupational health are years of life lost (YLL), and years of life disabled (YLD). Characterization factor to calculate the endpoint impact sums up both units, obtaining result in DALY.

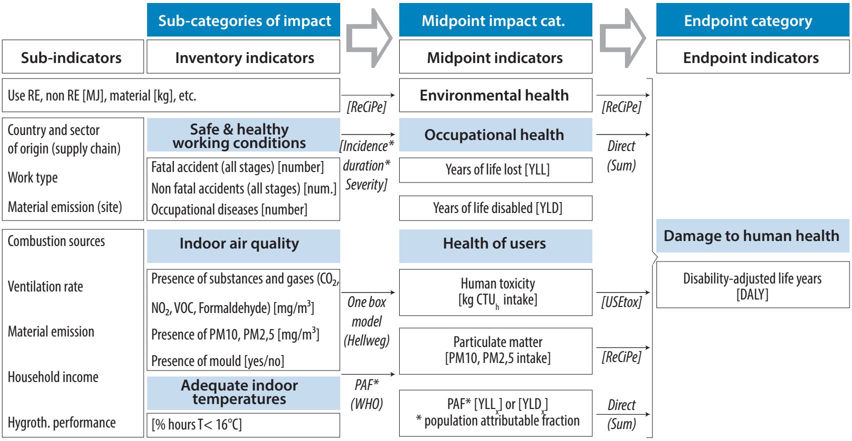

Figure 2: Impact pathways related to health (own elaboration)

Two ways are proposed to model effects on user health. One is based on recent research for the integration of indoor and outdoor toxicity. It is headed by the UNEP/SETAC life cycle initiative, and based on Hellweg's "one box model" [8]. It calculates intake fraction (in comparative units of toxicity CTU_h), by considering the emission rate of finishing materials, ventilation and metabolic activity. Damage on health is calculated with USEtox method[5], based on the intake and effect factor. This would be used for VOC and formaldehyde concentration. The other characterization model is based on the WHO mechanism to calculate the environmental burden of disease [9], used to calculate effects on health caused by the presence of mould and other substances, and by inadequate indoor temperatures. It is based on the population attributable fraction (PAF), based on the relative risk and proportion of people exposed. Midpoint indicators are expressed in years of life lost and years of life disabled due to every different disease (e.g. YLD_{asthma}). Damage to human health (in DALY) is the sum of the different results.

Prosperity of society depends on the job creation and fair salary ensured. It is mainly related with the sector and country of origin of materials and products involved across the supply chain, and data are provided by international reports and statistics. Burden is attributed by working hours employed in the production stages; **Region's prosperity** related with retrofitting works depends on the monetary entries and exits, such as (avoided) aids to unemployment, contribution to social security of workers, subsidies to retrofitting, VAT of products and services, VAT missing due to energy savings, and rehousing costs (for social housing); **Prosperity of households** depends

5 The USEtox model has been developed by the USEtox Team, a team of international researchers from the Task Force on Toxic Impacts under the auspices of UNEP/SETAC Life Cycle Initiative. www.usetox.org

on the affordability to ensure decent living conditions, such as economic accessibility to invest on retrofitting (including rehousing) in the case of private ownership, but also affordability of operation and maintenance cost.

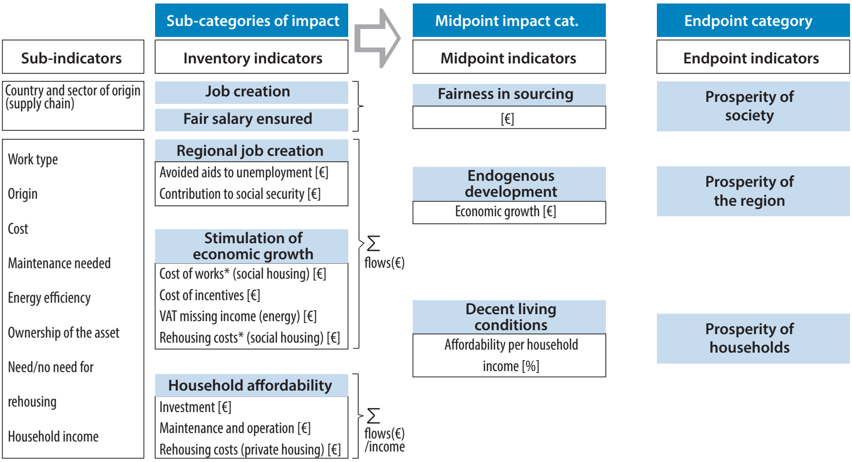

Figure 3: Impact pathways related to prosperity (own elaboration)

3. Discussion and conclusions

Since human health is the area of protection where environmental and socioeconomic life cycle assessment overlap, modeling the complete pathway enables the integration of both issues in a comprehensive analysis. Potential double counting or burden shifting is thus avoided. By driving the assessment until the endpoint indicator "damage to human health" in DALY units, results of different pathways can be aggregated with no weighting.

The association between retrofitting projects and impacts on social well-being and human dignity can be established, but specific characterization factors to quantify them seem still far to be defined. Indicators for cultural value are lacking (in Brussels, heritage seems to be ad-hoc analysis rather than indicator-based methodology).

Although prosperity indicators do not quantify well-being, dignity or cultural value, promoting retrofitting practices with the best impacts on prosperity at the three levels without aggregation (society at large, Region and household's) ensures positive effects on these three areas of protection. Since the goal of this development is to assist decision-making in retrofitting (strongly related to incentive instruments), economic prosperity in terms of fairness, growth and affordability is essential to be considered.

This research establishes the baseline for further full applications of life cycle sustainability assessments. Although still challenging, modeling socioeconomic impact pathways is necessary to perform complete LCSA. Application enables the identification of priorities in retrofitting, or the optimization of incentive instruments.

4. Acknowledgement

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