RENOVATION VERSUS RECONSTRUCTION: WHAT IS THE BEST ALTERNATIVE FROM AN ENVIRONMENTAL POINT OF VIEW?

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Keywords

Renovation, reconstruction, ACV, thermal performance, residential building

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Abstract

The I3E renovation project was selected as part of the "Towards eco-friendly buildings for 2020" call for research project launched by ADEME end of 2013. It is led by Cycleco and Enertech. I3E's objective is the development of an assessment methodology for environmental, energy efficiency and economic (I3E) indicators to be used by professionals as a decision support tool when exploring different renovation and demolition/ reconstruction solutions. I3E focuses on the comparison of rehabilitation and reconstruction projects focused on the energy efficiency of collective housing constructed between 1949 and 1974 in continental climate areas. It includes a combined Life Cycle Assessment (LCA) and a Life Cycle Costing (LCC) on two case studies. Each case is based on two real projects, one renovation and one new construction. Several scenarios were studied according to targeted goals in terms of energy efficiency and materials (conventional or biosourced).

The present paper reports the LCA results get for a selection of five scenarios per case study, one reference scenario, two renovations (French Thermal Regulation 2005 et Passivhaus label) and two demolition/reconstruction (French Thermal Regulation 2012 et Passivhaus label). Firstly, it appears that a better thermal performance conducts to a better life cycle performance. In addition, it brings to light the fact that Domestic Hot Water (DHW) heating and production systems play a significant role in the environmental performance. In particular, for a same heating and DHW system in renovation and demolition/reconstruction scenarios, the renovation is preferable to reconstruction. Besides, if a project owner thinks about modifying the heating and DHW system for the reconstruction, this choice will potentially be a determining factor. Eventually, several sensitivity analysis have been conducted on the following aspects: building life span, reference period, dynamic evolution of the building thermal performance according to windows and heat generators degradation in time, end of life scenario and reference flow. It appears the modification of hypothesis on these aspects leads to relatively small variations and to the same conclusions.

Keywords

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1. INTRODUCTION

The study is performed in the framework of the research project "I3E Renovation" conducted by Cycleco and Enertech and funded by the French Environment and Energy Management Agency (ADEME). For this, ADEME followed up the study, brought recommendations and orientation. In addition, a review committee has been consulted all along the study.

The objective of the I3E Renovation project is the realisation of a ready-to-use method and tool-box intended to the building professionals to help them define the most eco-friendly and economical scenario for the renovation a/o reconstruction of residential buildings. The study focuses on energetic renovation of residential buildings built between 1949 and 1974 under continental climate. It includes a combined Life Cycle Assessment (LCA) and a Life Cycle Costing (LCC). Two case studies are investigated. The present paper reports the LCA results get for a selection of five scenarios per case study, one reference scenario, two renovations variants and two demolition/reconstruction variants.

2. GOAL AND SCOPE DEFINITION

2.1 Goal definition

The LCA aims to identify key parameters of the renovation and reconstruction projects' environmental performance. It also provides the data that are insignificants for the comparison between scenarios and thus which can be neglected.

2.2 Scope definition

Several scenarios are assessed in each case study, from the necessary minimum renovation project to the demolition and rebuild of a new building of ambitious energetic performance. The present paper focuses on five scenarios:

- Sc1: No renovation, minimum replacements of components
- Sc 2: Renovation compliant with French Thermal Regulation (TR) 2005
- Sc 3: Renovation compliant with the Passivahaus standard
- Sc 4: Rebuild compliant with French TR 2012
- Sc 5: Rebuild compliant with the Passivahaus standard (TR – 20%)

The reference flow is the square meter of living area. The functional equivalence between the scenarios is not strict but rather framed between bounds. In that sense, the scenarios are equivalent in terms of inhabitants' density, indoor temperature, DHW supply and building ventilation. All other building functions are disregarded.

In consequence, the functional unit (FU) assessed is: "Provide 1 m^2 living area on a land of S m^2 located in L, of a ratio living area/inhabitant comprise between 16 m^2 and 21 m^2, ventilated, of an indoor temperature and with Domestic Hot Water (DHW) supply compliant with current regulations, during RefP years" with S the area of the land available, L the location of the existing building, and RefP the Reference Period of the study.

The RefP is defined according to the existing building construction date with the Equation 1. It is assumed that every buildings considered in the study (the existing ones and the newly built ones) have a total life span of 100 years.

$$RefP = 100 - (\text{Renovation/Rebuilt date} - \text{Construction date}) \qquad (1)$$

The study presents cases of multi-functionalities which can be resumed in two categories: components still functional at the end of RefP and works on site that can occur in or out the RefP. Theses multi-functionalities are managed in compliance with the ISO standards [1] [2]: system expansion and substitution of the avoided processes. In practice, the inventory (I) taken into account is the one expressed in the Equation 2 where LS stand for Life Span.

$I_{RefP} = I_{Total} \times LS \text{ in } RefP / LS_{Total}$ (2)

Specific data have been collected for the quantities of building materials used for renovation / rebuild and for the energetic consumption during use phase. All others life cycle steps are considered using conservative generic data.

The present paper focus on four indicators: climate change, non-renewable energy, particulates matter formation and marine eutrophication.

3. ASSESSMENT RESULTS AND ANALYSIS

3.1 Assessment results

The following charts show the comparison of scenarios on the four environmental impact categories for both case studies.

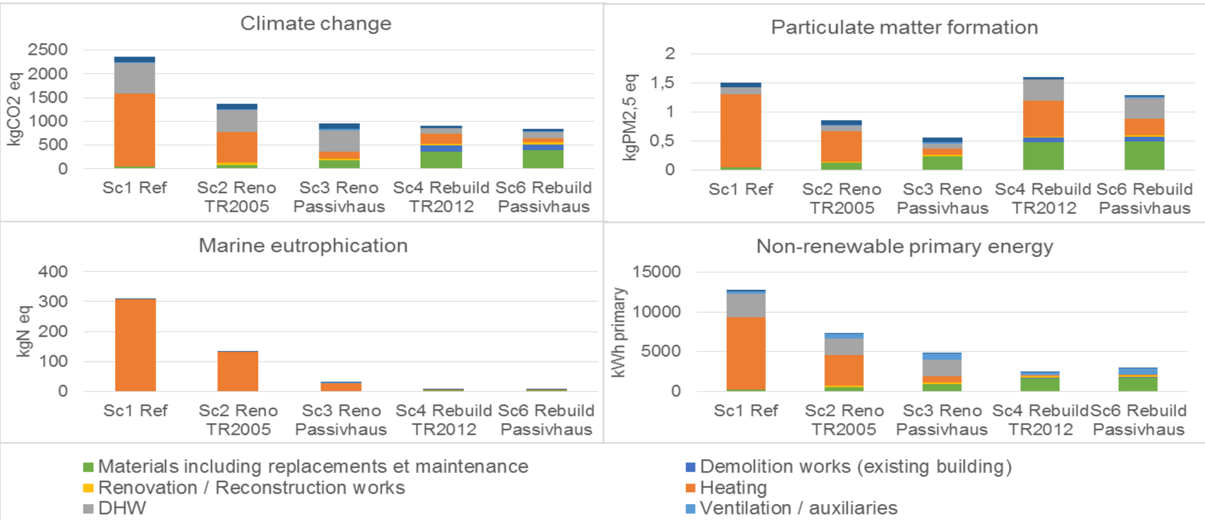

Figure 1: Comparison of scenarios case study n°1

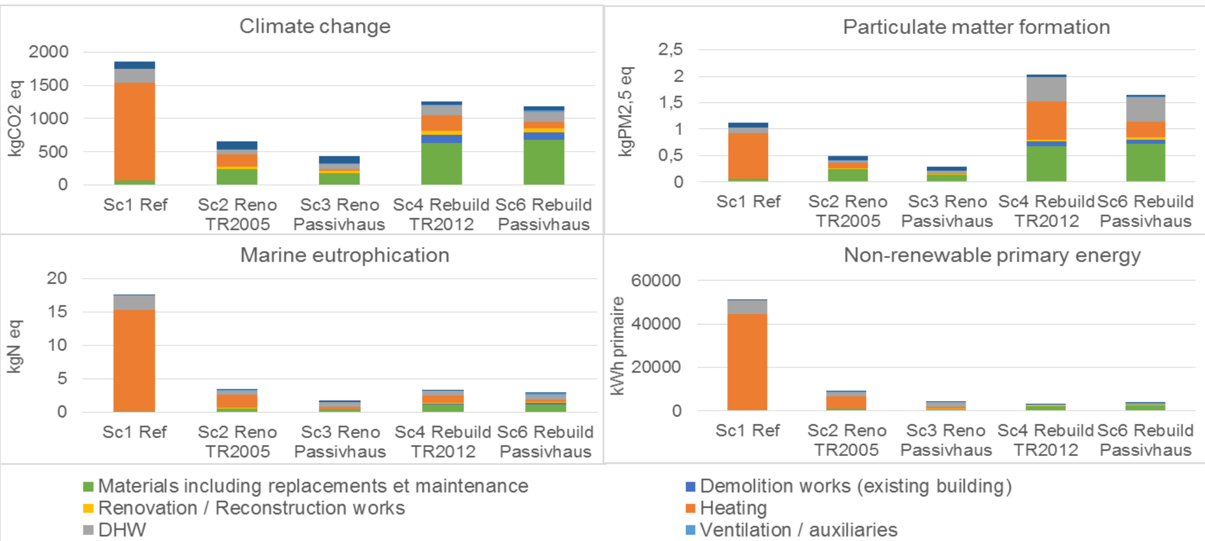

Figure 2: Comparison of scenarios case study n°2

Firstly it appears that the classification of scenarios varies from one impact category to another but also from one case study to another. In particular, it is not possible to conclude on the best scenarios between renovation and reconstruction. We note that the reference scenario is among the most impacting ones. In addition, the Passivhaus scenarios (3 and 5) are better than the French TR scenarios (2 and 4 respectively) except on the non-renewable energy indicator. Eventually, the impacts are dominated by Heating, DHW and Materials contributors.

3.2 Sensitivity analysis

Sensibility analysis have been conducted on the following aspects: RefP and buildings LS, the dynamic evolution of the building thermal performance according to windows and heat generators' degradation in time, the end of life scenario, the reference flow (the housing; the inhabitant) and the Heating and DHW systems.

Except for the last one, the modification of hypothesis on these aspects leads to relatively small variations and the same conclusions.

The following table shows the heating and DHW systems considered in the study.

Table 1: Heating and DHW systems

	Case study n°1		Case study n°2	
	Renovations Sc1, 2, 3	Rebuilding Sc4, Sc 5	Renovations Sc1, 2, 3	Rebuilding Sc4, Sc 5
Heating system	District heating (53% biomass, 26% cogeneration gas)	Wood pellets	Sc1: Electricity Sc3,4: Heat pump air-water	Wood pellets
DHW system	Gas	Wood pellets	Thermodynamic boiler	Wood pellets

The sensitivity analysis conducted on the heating and DHW system takes into account wood pellets for both heating and DHW for renovation scenarios. The final energy consumption is adjusted according to the system efficiency. The rebuilding scenarios are not modified. With a heating and DHW system based on wood pellets in all scenarios, we get the following conclusions:

- For a same building thermal performance, the renovation scenario is always better than the reconstruction scenario;
- The variants Passivhaus have a better environmental performance than the TR variants, both for renovation and reconstruction, except on the non-renewable energy impact category. On this indicator, the Passivhaus variants have a bigger burden when dual flow ventilation is involved.

4. CONCLUSIONS

The LCA brings to light the fact that the thermal performance as well as the heating and DHW system play a role of utmost importance on the life cycle environmental performance of the building. In particular, if the modification of the heating and DHW system is only possible in case of reconstruction, this parameter will potentially be a determining factor. A first comparison of variants taking into account the heating and DHW final energy consumption only, is easy to make at the early stage of a renovation or reconstruction project and already brings support to decision.

REFERENCES

[1] ISO, I. (2006). 14040 Environmental Management–Life Cycle Assessment–Principles and Framework, http://www.iso.org/iso/catalogue_detail?csnumber=37456.

[2] ISO, I. (2006). 14044 Environmental Management–Life Cycle Assessment–Requirements and guidelines, http://www.iso.org/iso/catalogue_detail?csnumber=38498.

Le projet I3E Rénovation a été retenu dans le cadre de l'appel à projets de recherche "Vers des bâtiments responsables à l'horizon 2020", lancé par l''ADEME fin 2013. Il est porté par Cycleco et Enertech. I3E Rénovation vise à l'élaboration d'une méthodologie d'évaluation et d'outils d'évaluation d'Indicateurs Energétiques, Economiques et Environnementaux (I3E) pour l'aide à la décision entre différentes solutions de rénovation ou démolition / reconstruction. Le projet est réalisé en impliquant les acteurs clés de l'évaluation environnementale du bâtiment et les potentiels utilisateurs de la méthode. Le projet se concentre sur la comparaison de projets de rénovation et de reconstruction choisis et motivés par l'amélioration énergétique des bâtiments de logement collectifs construits entre 1949 et 1975 sous climat continental. Il inclut une Analyse du Cycle de Vie (ACV) et une Analyse en coût global de deux cas d'étude. Chaque cas est basé sur deux projets réels, un de rénovation et un de reconstruction. Plusieurs variantes sont étudiées en fonction des objectifs de performance énergétique et des matériaux utilisés (conventionnels ou biosourcés).

L'article rapporte les résultats de l'ACV obtenus pour une sélection de cinq scénarios par cas d'étude : un de référence, deux rénovations (Réglementation Thermique 2005 et label Passif) et deux reconstructions (Réglementation Thermique 2012 et label Passif). Les indicateurs regardés sont le changement climatique, l'eutrophisation marine, la formation de particules fines et l'énergie primaire non renouvelable. Premièrement, il apparait que plus le bâtiment est performant thermiquement, moins il est impactant sur le cycle de vie. Par ailleurs, on note que les systèmes de chauffage et de production d'Eau Chaude Sanitaire (ECS) jouent un rôle déterminant dans l'analyse environnementale et énergétique. La comparaison des scénarios à système de chauffage et de production d'ECS identique, conduit, pour chaque cas d'étude, au même résultat: la rénovation est plus bénéfique que la reconstruction. En outre, si un maître d'ouvrage envisage des systèmes de chauffage distincts dans ses différentes variantes, ce choix sera potentiellement déterminant. Les résultats montrent aussi que, à système de production de chaleur identique, les scénarios avec objectif de performance Passif ont moins d'impacts environnementaux sur le changement climatique, l'eutrophisation marine et la formation de particules fines. Sur l'énergie primaire non renouvelable, les scénarios Passif incluant une ventilation double flux sont plus impactants. Enfin, différentes analyses de sensibilité ont été menées sur les aspects suivants : durée de vie des bâtiments, période de référence, évolution dynamique des performances thermiques du bâtiment en fonction de la dégradation des fenêtres et des générateurs de chaleur, scénario de fin de vie et flux de référence (m2 habitable, logement ou habitant). On observe que la modification des hypothèses sur ces points conduit à des variations relativement faibles et à des conclusions identiques.