Sustainability assessment of modern methods for constructing residential buildings in Ireland

BENCH VALUE

Bioeconomy and wood construction in Ireland

To transition Ireland to a low carbon, climate resilient and environmentally sustainable economy by 2050, the Irish Government considers mitigating the environmental impact of the Irish built environment and agriculture sectors [1], in addition to becoming a global leader in the bio-economy [2], as important objectives in this transition. During this transition to 2050, Ireland is forecast to increase its production of wood materials from 3.2 million cubic meters each year to 8 million by 2035 [2]. Additionally, the population of Ireland is expected to increase by around one million people to almost 5.7 million people by 2040 requiring at least an additional half a million new homes [3].

Bricks, blocks and concrete have been the main material choices for the superstructure of residential buildings in Ireland since the pre-1900's [4]. Timber frame houses have become more common in Ireland since the 1990's [4]. Insulating concrete formwork frame houses are also a superstructure option for Irish housing [5]. With residential buildings moving towards nZEB standards [6], one of the aims of this research was to establish which of three modern methods for constructing Irish residential buildings is the more sustainable from an economic, environmental and social perspective.

The case study

Ireland's residential building stock largely compromises detached, semi-detached and terraced single-family dwellings [7]. Semi-detached houses are Ireland's second most common dwelling type accounting for 471 928 of the occupied dwellings and the second most common house type constructed in the 2000's [7]. Case study buildings for LCA are typically chosen due to the prevalence of a building type in the reference country [8]life cycle energy analysis (LCEA. With the Irish population expected to move to more urbanized areas, semi-detached residential buildings are expected to remain common within Ireland as we move towards 2040. Therefore, a theoretical semi-detached residential two-storey building (117 m^2 heated floor area) was chosen as a case study (Figure 1). Three theoretical semi-detached houses are designed using a traditional, timber and ICF based superstructure. The external systems are illustrated in Figure 2.

The external walls of the three different superstructure designs are designed to have a thermal fabric performance of 0.18 W/m^2K. The timber frame wall is based on the Kingspan Ultima wall system [9]. The ICF wall system is based on the Thermohouse wall system [5]. The internal walls (timber stud walls), external windows and doors (U-value: 1.4 W/m^2K), pitched roof insulated at ceiling (U-value: 0.13 W/m^2K) and first floor (timber joists with OSB sheathing floor panels and plasterboard ceiling panels) building elements are assumed to be the same for each of the different superstructure designs.

As each of the building elements are designed to meet the same thermal fabric performance and meet the new Irish the thermal fabric standards [6], it is assumed the each of the superstructures achieve the same level of air-tightness and energy performance standard.

Figure 1. Theoretical semi-detached case study building.

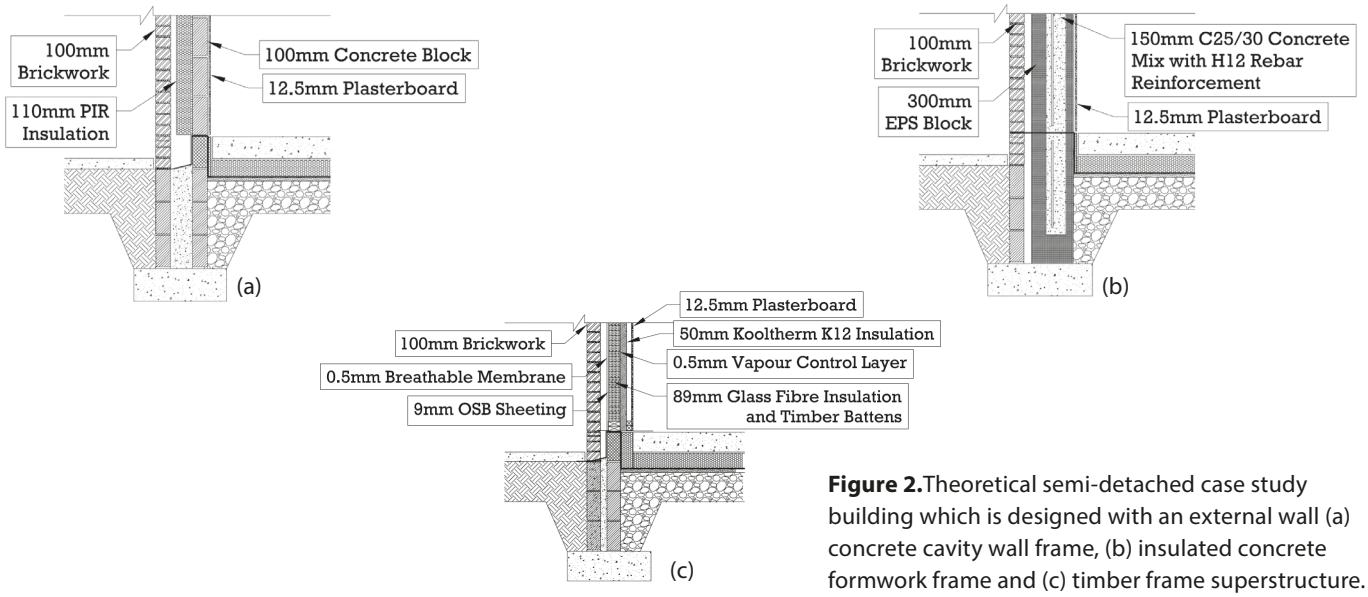

Figure 2. Theoretical semi-detached case study building which is designed with an external wall (a) concrete cavity wall frame, (b) insulated concrete formwork frame and (c) timber frame superstructure.

Results

The three methods for constructing an Irish residential semi-detached house were evaluated from a life cycle cost, life cycle non-renewable energy and life cycle greenhouse gas (GHG) balance perspective (Figure 3). A traditional based superstructure has the lowest life cycle cost (€782/m^2) with the timber (€933/m^2) and ICF (€940/m^2) based designs having similar life cycle costs. The main difference in the life cycle costs is from the external walls. Apart from the external walls and party walls, other materials and products used for designing the building were, for the most part, the same apart from minor differences in material volumes due to the different external wall superstructures.

Unlike the life cycle cost hierarchy, the timber-based superstructure has the lowest life cycle non-renewable energy impact (1769 MJ/m^2). The ICF based superstructure has the largest life cycle non-renewable energy impact (2338 MJ/m^2). The volume of load bearing material in the timber based external walls (2.75m^3 of C16 Sitka Spruce construction sawn timber) is far less than the load bearing material in the concrete block based external walls (9.75m^3 of concrete blocks). Despite the difference in volume of load bearing material and construction sawn timber having less of a non-renewable energy intensity compared to concrete blocks, the environmental intensity of the glass mineral wool insulation

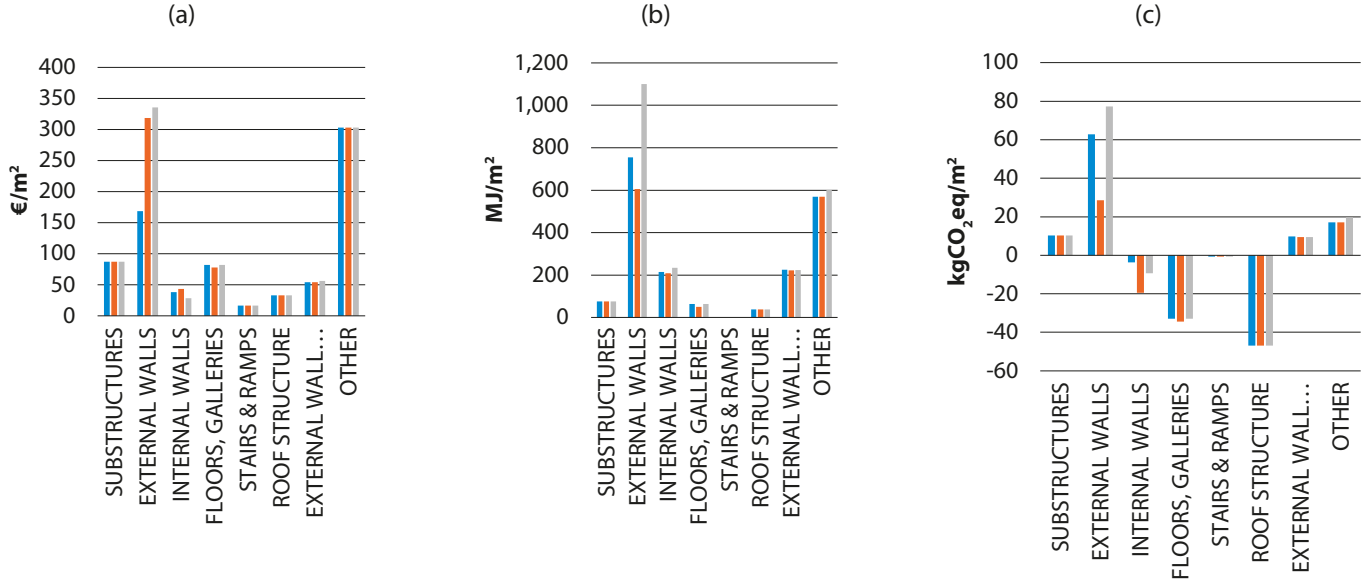

Figure 3. Life cycle (a) cost, (b) non-renewable energy and (c) GHG balance of the building elements in the superstructure designs. Blue = traditional; Orange = timber; Grey = ICF

in between the timber studs results in the timber based external wall having an environmental impact of only 150MJ/m^2 less than the traditional based external wall.

Similar to the life cycle non-renewable energy impact hierarchy, the timber-based design has the lowest life cycle GHG balance impact (-36 $kgCO_2eq/m^2$) with ICF having the highest (108 $kgCO_2eq/m^2$). Due to the building designs having an internal wall system, first floor and roof structure constructed from timber, the internal wall, floors and roof structure categories have a negative GHG balance. Due to the carbon sequestered by the timber, the traditional based design is close to being regarded as carbon neutral (16 $kgCO_2eq/m^2$).

Stakeholder interaction and results of discussions

The University of Limerick hosted a full meeting of the BenchValue project on 24–26th January 2018. In addition to the internal meetings between project partners, this event included a half day meeting with Irish stakeholders. A key part of the event was a discussion to gain stakeholder input to the scope and content of the Irish case study (WP4). There was also a joint discussion on indicators important to include in method development. More details of the event are available here.

Subsequent BenchValue project team meetings and stakeholder events were held in Kaunas, Lithuania (August, 2018), Limoges, France (May, 2019), and Vienna, Austria (October, 2019). Details of these events are provided under their countries related case studies in this report.

The Irish stakeholders event, titled "Enhancing the Forest Bioeconomy: Material Substitution in the Construction Sector", took place at the University of Limerick (UL), Ireland on 25th January 2018. The event was attended by more than 30 people from a variety of national and international stakeholders representing several critical sectors, e.g. the Irish government funding body (DAFM), sawmills, wood product manufacturers, and those involved in academic research.

The attendees at the UL stakeholder event were divided into groups of five people and asked to discuss their expectations for sustainable buildings constructed using the timber-framed method. The feedback notes gathered from the discussion groups were collated and reviewed on the day of the event. the most prominent themes and principle issues/benefits identified by the stakeholders, within the context of Irish timber-framed construction, focused on the following:

i) Longevity - What is the typical lifespan of a timber-framed house compared to the most common Irish alternatives (i.e. traditional concrete block or ICF built houses)?
ii) Affordability – Overall, is a timber-framed house more or less expensive to build and maintain than the alternative methods of construction?
iii) Durability - Will a timber-framed house stand up to the wear-and-tear associated with Irish climatic conditions?
iv) Comfort – Will timber-framed houses perform better or worse for heating, cooling, and air circulation than the alternative methods?
v) Costs – A topic related to affordability, but also considering where cost savings could be made based on choice, local availability, and quantity of building materials.

National recommendations

The Irish Governments recent "Climate Action Plan" [1] calls for public sector champions to engage, motivate, and empower businesses, industry, communities and individuals in the national efforts to mitigate climate change. This report has provided evidence that timber-framed houses have a lower total GHG balance than other common methods of construction. Therefore, increasing the number of houses, particularly in the public sector, built using the timber-framed construction method has the potential to assist in reaching Ireland's goals in reducing its contribution to global warming and the negative effects of climate change.

The Irish Government currently has ambitious goals and an urgent need for affordable housing development in the coming decade [11–12]. Also, in the forestry and wood processing sectors there is significant expected growth in Irish grown timber supply in the years up to 2035 [12]. In order to capitalize on these parallel opportunities, there needs to be a combined effort by both the public and private sectors to drive sustainable climate mitigation measures. Through bodies such as the Department of Housing, Planning and Local Government and the SEAI, and industry representatives such as the Wood Marketing Federation there needs

to be further development of the Irish wood processing sector in support of timber-framed construction. Further investment by these bodies in developing and producing greater value-added timber-based products for construction, e.g. engineered wood products such as Cross Laminated Timber (CLT) and Glulam are also needed.

Further research should investigate the potential impact of Ireland implementing policy instruments and related incentives aimed at lowering the costs associated with timber-framed house construction. The introduction of such instruments and incentives could potentially enable timber-framed houses to better complete economically with the traditional concrete block or ICF house construction methods.

The difficulty in obtaining the necessary Irish data to compile a more complete life cycle assessment, of economic indicators in particular, indicates the need to widen the scope of future national surveys of construction material suppliers, manufactures, and building developers to gain a better understanding of the competing forces in these sectors.

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