Timber construction in Ireland for the mitigation of climate change and the housing crisis in 2022

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ABSTRACT: The current carbon footprint of the construction sector in Ireland together with the need for new homes to satisfy housing demand make it difficult to meet Ireland's commitments for the reduction of emissions. The challenge of increasing the number of homes while reducing emissions can be partially mitigated with an increased use of timber in the construction sector. This study analysed the potential of timber construction in Ireland to mitigate climate change while addressing the housing needs. The analysis drew different scenarios regarding the percentage of dwelling types in the coming years, and the share built with timber (timber frame and cross-laminated-timber) and masonry or concrete. Overall, scenarios with larger use of timber produced greater annual greenhouse gas abatement, although the type and mix of dwellings had a large influence, with larger emissions savings associated with the construction of apartments where masonry and concrete were substituted for mass timber. The best scenarios for the mitigation of climate changes while addressing the housing needs in Ireland combined a strong increment of timber scheme houses and apartments in the short term, with a larger presence of medium and high-rise buildings that produce less emissions than the equivalent in concrete.

KEY WORDS: Timber; CLT; LCA; Embodied carbon; Emissions.

1 INTRODUCTION

The goal of the Paris Agreement to limit global warming to 1.5°C above pre-industrial levels needs the construction sector to reduce its greenhouse gases (GHG) emissions. Building construction and operations accounted for 37% of energy-related carbon dioxide (CO_2) emissions in 2020 [1]. The GHG emissions of materials and/or processes associated with producing, transporting, installing and disposal are called embodied carbon (EC). The EC is quantified using Life Cycle Assessment (LCA) methodology [2, 3].

In 2020, as part of the European Green Deal, the European Commission announced plans to reduce the EU's GHG emissions by at least 55 % by 2030 compared to 1990 levels [4]. Ireland's emissions of GHG in 2019 were 59.8 Mt of CO_2e [5], 9.9% higher than emissions in 1990. These emissions were the second worst per capita in the EU, and 53% higher than the EU28 average of 7.9 tonnes [6]. The latest Irish Government commitment is for a 7% annual GHG emissions reductions for 2021-2030 [7]. In the transition to a climate neutral economy by 2050, the Climate Bill 2021 [8] states that the first two carbon budgets "*shall provide for a reduction of 51 per cent […] on December 31st, 2030, from the annual greenhouse gas emissions reported in 2018*". Ireland's emissions of GHG in 2018 were 60.9 Mt of CO_2eq [9].

Whereas the emissions need to be reduced, according to the Central Statistics Office (CSO), Ireland's population is expected to increase from 4.7 million to between 5.6 and 6.7 million by 2051 [10], depending on the assumptions, creating significant further demand for housing in the coming decades. To meet this demand, 30,000 additional housing units must be provided per annum (p.a.). The Central Bank of Ireland [11], using the high migration demographic projection of the CSO, estimates a demand of a*round 33,000 units per year from 2020-2039, falling to 26,000 per year from 2040-2051*. This is a total of 972,000 units. The Irish Business and Employers Confederation estimates 32,000 homes/year between 2019-2051 [12]. The National Development Plan 2021-2030 [13], states that 600,000 new homes will be required by 2040, planning to deliver almost 400,000 new homes between 2020 and 2031 (roughly 33,000 new homes p.a.), which will have *an embodied carbon cost of somewhere between four and six megatons of CO_2e, based on the current carbon intensity of construction* (Dr Kinnane, [14]).

Other scenarios draw even higher demands for new homes when considering obsolescence and changing household size [15]. In this regard, apartments can play an important role to address the housing crisis. Ireland has the lowest apartment rate in Europe at 12% [16] with the next lowest being Malta (22%) the Netherlands and Belgium (both 28%). Ireland has the highest percentage in Europe of population living in a house at 92% whereas the average in the EU is 53% [17].

The challenge of increasing the number of homes while decarbonising the construction sector can be partially mitigated with a larger use of timber as shown in Figure 1 and Figure 2. Wood and engineered wood products are bio-based materials of lower EC than concrete, masonry or steel [18-20] that can also store carbon (CS) for as long as the material is used. According to the Intergovernmental Panel on Climate Change (IPCC), not only that, *in the long term, a sustainable forest management strategy aimed at maintaining or increasing forest carbon stocks, while producing an annual sustained yield of timber, fibre or energy from the forest, will generate the largest sustained mitigation benefit* [21]. In Sweden, a study [22] analysed the emissions from the construction of a multi-storey building, and showed that the GHG mitigation efficiency of a wood-frame compared to a concrete-frame is higher even if in the concrete-frame alternative the forests that would provide the timber are used for carbon storage. A study in the UK [23] compared the 100-year GHG mitigation achieved by newly planted commercial Sitka spruce (the main timber species in Ireland) and newly planted broadleaf conservation forests modelling the planting rate of 30,000 ha/year from 2020 to 2050 recommended by the UK Committee on Climate Change. The study found that harvesting and using the timber from Sitka spruce forests harvested in year 50 (a conservative rotation length for this species in Ireland) followed by replanting achieved better cumulative GHG balance than new broadleaf or Sitka spruce forests unharvested.

Currently in Ireland, about 24% of new builds are constructed using timber frame, far from the 83% used in Scotland [24]. In addition, building regulations in Ireland limit the use of combustible materials such as timber where the height of the top floor is over 10 m, equivalent to a building of 4 storeys [25]. The current study aims to show the potential of timber construction in Ireland to mitigate climate change. The study draws different scenarios that satisfy the demand for new builds for the period 2022-2050, using different combinations of dwelling types and construction materials. The ultimate aim is to compare the impact of timber construction, including modern engineered wood products, and the most common construction material and typologies in Ireland.

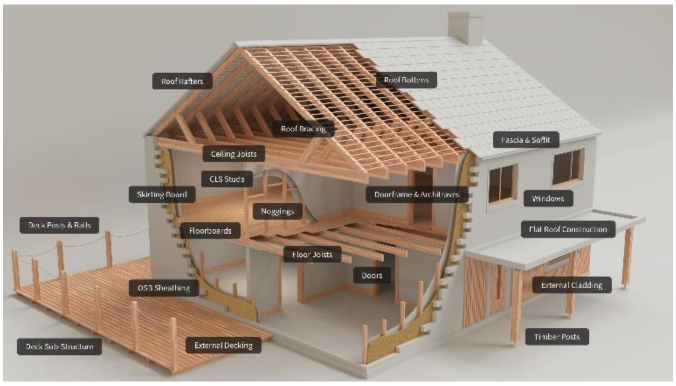

Figure 1. Potential applications of wood in domestic construction. Source [26]

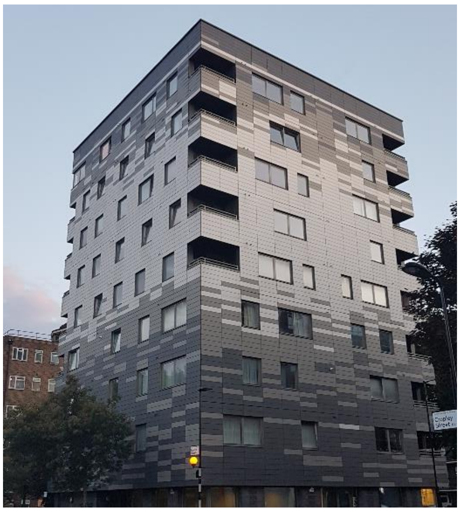

Figure 2. Murray Grove, London. Nine-storey CLT

2 MATERIALS AND METHODS

A study by the BioComposites Centre at Bangor University [27] analysed the EC and CS associated with the typical housing archetypes in the UK, very similar to those in Ireland. This study is used here (Table 1) as the basis to investigate the potential CO_2 emissions associated with satisfying the housing demand that Ireland faces in the coming decades. The calculations covered the product stages of the life cycle of the structural elements (modules A1-A3), according to EN15804 [28] (excluding internal finishes and fittings). For each housing archetype different building solutions were investigated. The functional units were matched within each archetype for identical floor plan, and matching wall, roof and glazed areas. Following the guidelines by RICS [3], the CS and EC are reported separately.

Table 1. EC and CS (kg CO_2e/m^2) of structural elements, A1-A3, for different archetypes and materials (TF: Timber frame; CLT: Cross-Laminated-Timber). Size shows the internal area and number of bedrooms (B). Low and medium-rise are 3 and 6 storey respectively. Values adapted from [27]

Archetype	Size (m^2, B)	EC	CS
Bungalow, masonry	58.5, 2B	264	-71
Bungalow, TF		235	-111
Detached house, masonry	117, 4B	177	-72
Detached house, TF		150	-109
Detached house, TF & clad		102	-126
Apartment, low-rise, masonry	70.1, 2B	176	-57
Apartment, low-rise, TF		132	-97
Semi- Detached, masonry	84.4, 3B	187	-67
Semi- Detached, TF		152	-105
Mid-terraced, masonry		161	-67
Mid-terraced, TF		137	-103
Apartment, low-rise, masonry,	50, 1B	176	-57
Apartment, low-rise, TF		132	-97
Apartment, medium rise, concrete		414	-61
Apartment, medium rise, CLT		158	-309
Apartment, medium rise, concrete	70.1, 2B	414	-62
Apartment, medium rise, CLT		158	-309

The CSO defines the dwelling types in Ireland as single, scheme and apartment. Table 2 shows the EC and CS using the values per living unit in Table 1 and adapted to the CSO housing archetypes. For that, it was assumed that 50% of single houses were bungalows and 50% 4-bedroom detached houses. For the scheme houses, the distribution from the CSO [29] was used: 12% detached, 17% mid-terrace, and 65% semi-detached houses, and adjusted relative to the 94% of the breakdown (the remaining 6% belongs to "others"). For the apartments, it was assumed that these were 2-bedrooms equally split between 3 and 6-storey unless otherwise stated.

Table 2. Average EC & CS per housing unit.

		Single	Scheme	Apartment
Traditional	EC, t CO_2e	18.09	16.03	20.68
	CS, t CO_2e	-6.3	-6.00	-4.185
Timber	EC, t CO_2e	15.64	13.21	10.17
	CS, t CO_2e	-9.59	-9.34	-14.26

The analysis draws different scenarios regarding the number of new homes, and the share built with timber. The new dwelling completions in the year 2019, which showed the largest construction activity of the last five years, was chosen as the most recent pre-Covid reference (Table 3). It must be noted that currently timber dwellings (24% of the total) only cover light frame construction. The scenarios assume that future emissions will remain the same as the baseline scenario.

Table 3. Dwelling types in 2019 in Ireland.
Source: [29] and Timber frame industry data.

	Single	Scheme	Apartment
Traditional	4,817	7,863	3,407
Timber	250	4,650	100
Total	5,067	12,513	3,507

This study assumes a slight increment of units built in 2022 (22,000) compared to 2019 (21,087) and then 1,500 additional units per year to reach 33,000 units p.a. by 2030. This gradual increment is justified as to due to the limitations of the sector (workforce, machinery, etc.) it is unlikely that there will be a large increment in new homes in the short term. The level of new homes is maintained until 2040, falling to 30,000 per year from 2041-2050. The reason for drop to 30,000 per year, instead of the 26,000 projected by The Central Bank of Ireland, is to compensate for the lower growth in the initial years. Based on these assumptions a total of 881,000 units will be built in the period 2022-2050, with an average of 30,400 new homes p.a. For the period 2022-2040, the total is 581,000 units (the National Development Plan states that 600,000 new homes will be required in the period 2021-2040).

Regarding the percentage of dwelling types and share built with timber over the period studied, the analysis draws different scenarios. This is mostly based in the need to increase the proportion of apartments.

All scenarios maintain that in 2022 the mix of dwellings will be the same as in 2019, i.e. 24%, 59% and 17% for single houses, scheme houses and apartments. The models, except for scenario i), assume that the percentage of apartments increases by 1% p.a., from 17% in 2022 to 30% in 2035 and maintaining that percentage thereafter. The increment of apartments reduces the percentage of scheme houses. The percentage of timber units in 2022 remains the same as in 2019 at 24% of the total (1%, 22% and 0.5% single houses, scheme houses and apartments respectively) in i and ii, and in the rest of scenarios amounts to 26% where the 2% increment is proportionally spread among the dwelling. Details for each scenario (summary in Table 4) are:

i) The dwellings distribution (24%, 59% and 17% single houses, scheme houses and apartments respectively) and percentage of timber units within a dwelling (5%, 37% and 3% respectively as shown in Table 3) remains like in 2019 for the whole period studied. That is, nothing changes except the number of new units is larger.

ii) The percentage of timber units within a dwelling type remains the same as in 2019. The total percentage of apartments increases by 1% p.a., from 17% in 2022 to 30% in 2035.

iii) After 2022, there is an increment of 5% p.a. in the percentage of timber buildings within each dwelling type until reaching a maximum of 70%. This is only reached by the scheme houses by 2033.

iv) After 2022, there is an increment of 5% p.a. in the percentage of timber scheme dwelling and 10% p.a. in single and apartment dwelling until reaching a maximum of 70%.

v) After 2022, there is an increment of 5% p.a. in the percentage of timber scheme dwelling and 15% p.a. in single and apartment dwelling until reaching a maximum of 70%. From 2025 all the apartments are 6-storey.

vi) Like v but the apartments were considered the average between 3- and 6-storey for the whole period.

vii) The scenario aims to build 50% of all dwellings in timber in a maximum of 10 years. There is an increment of 5% p.a. in the percentage of timber scheme dwelling, 25% p.a. in single dwellings and 33% p.a. in apartments until reaching 50% within each dwelling type.

viii) Similar to scenario v but from 2025 there is a strong increment of 6-storey CLT apartments that by 2032 make 70% of the dwelling type.

ix) Similar to scenario v but the timber apartments are limited to 5% of the apartments from 2025. Between 2022-2025 apartments are 2-bedrooms equally split between 3 and 6-storey. From 2025 all the apartments are 6-storey, either CLT (5%) or concrete (95%).

Table 4. Summary of scenarios.

	2022 Timber / Total	% Increments in timber and CLT p.a.			Max % Timber within dwelling
		Single	Scheme	Apartment	
i	24%	-	-	-	-
ii	24%	-	-	-	-
iii	26%	5	5	5	70
iv	26%	10	5	10	70
v	26%	15	5	15	70
vi	26%	15	5	15	70
vii	26%	25	5	33	50
viii	26%	15	5	15	70
ix	26%	15	5	15	70 & 5

3 RESULTS

Overall, scenarios with larger use of timber produced greater annual GHG abatement, although the type of dwellings had a large influence. Table 1 and Table 2 showed that larger EC savings are associated with construction of apartments (more than 60% comparing 6-storey CLT and concrete buildings). For the most common semi-detached house the reduction in EC is almost 20%.

Figure 3 shows the variation in the EC emissions associated with the construction activity. Scenario i could be considered business as usual (BAU). It has less apartments (146,520) than the other scenarios (239,189). The drop in 2041 is associated with a reduction in the construction from 33,000 to 30,000 new housing units.

Figure 4 shows the EC emissions per dwelling unit. For scenario i, where the % of dwellings and timber buildings are like in 2019, the average housing unit produces 16.6 kt CO_2e. An almost identical EC emissions are produced by scenario iii, that built 36% of new dwellings in timber, and 7.1% of the apartments in timber or CLT (compared to 2.9% in scenario i). Scenarios iv and vi show a slow reduction in the EC in the first years, accelerated from 2035 when the apartments reach 30% of the dwellings. As the result of a larger increment in the number of timber units in scenario vi, the timber buildings from 2035 are 62% (against 49% in iv), and from 2045 amount to 70% of the total.

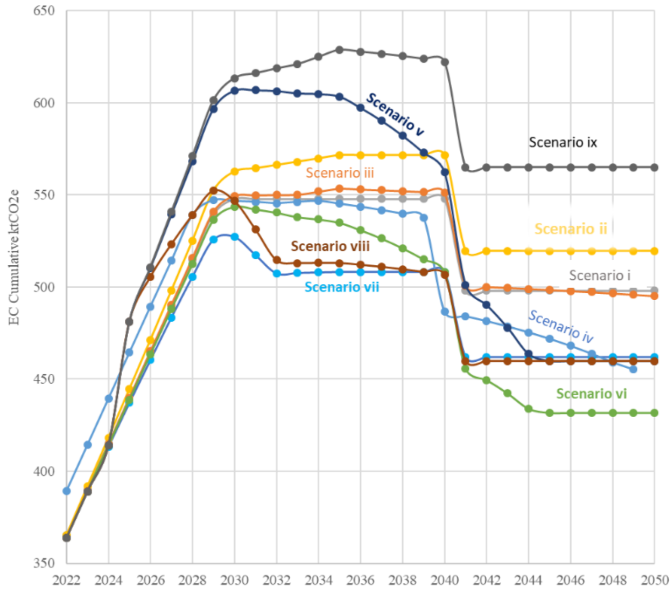

Figure 3. EC emissions for different housing scenarios between 2022 and 2050.

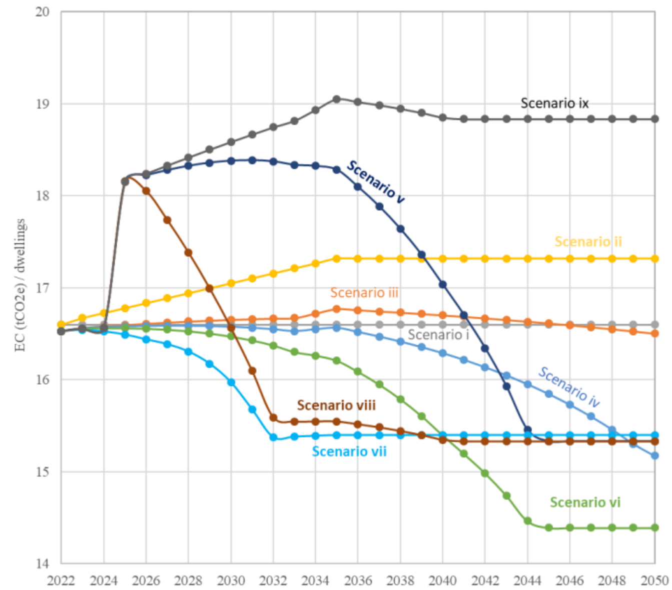

Figure 4. EC emissions per dwelling for different housing scenarios between 2022 and 2050.

Scenarios v and viii only include 6-storey apartments from 2025, which translates in the sharp EC shown in Figure 4. Afterwards, both scenarios increase the % of apartments until reaching 30% in 2035, which is maintained thereafter. In scenario v the % of timber increases until reaching 70% in 2045 whereas in scenario viii the 70% is reached in 2032 and therefore the number of CLT apartments over the period is larger.

The difference between v and vi is the type of apartments, where the EC of 6-storey concrete building are much higher than 3-storey. The largest reduction of EC in the next 10 years is described by scenario vii, in which 50% of all dwellings are built in timber in 2032, with schemes houses reaching this percentage in 2026.

However, the EC does not describe the whole picture of the GHG abatement. Table 5 shows the summary of accumulated EC and CS for the nine scenarios analysed. Scenario i has less apartments than the other scenarios and a low % of timber used that results in higher EC than other scenarios and very low potential for CS. The most beneficial scenario for GHG abatement is viii, which combines low EC and the largest CS giving the lowest cumulative net carbon. Scenario ix, that increases significantly the number of 6-storey concrete buildings, is the worst due largely to the high EC.

Scenarios vi and vii are the second most beneficial for GHG abatement. They describe the lowest EC and a high CS. Scenario vi, increases the use of timber until reaching 70% within each dwelling type. It builds more timber units (50%) than scenario vii (45%), but less apartments with timber. Scenario vii draws a sharp increment in the timber buildings in the first ten years that results in a strong reduction of EC and in a higher % of timber apartments over the full period.

The GHG abatement of scenarios iv and v is slightly better than the average due to a relatively low EC and high CS.

Scenario ii is the second least beneficial situation. It maintains the percentage of timber units in each dwelling type, but it reduces the total number of scheme houses (that bear most of the timber construction) as the result of building a larger percentage of apartments. This reduces to 20% the total percentage of timber units built in 2022-2050. The difference with scenario viii in the cumulative net carbon are 0.142 Mt CO_2e p.a. more in scenario ii.

The greatest CS occurs in the scenarios viii and v, with average of 0.105 Mt CO_2e p.a. and 0.07 Mt CO_2e p.a respectively. This is due to the large number of CLT apartments.

Table 5. Accumulated EC & CS for different housing scenarios between 2022 and 2050.

	Average % Timber	Timber apart (% total apart.)	EC	CS (-)	Net
			Mt CO_2e		
i	24	4,178 (2.9%)	14.6	5.8	8.8
ii	20	6,820 (2.9%)	15.1	5.6	9.6
iii	36	16,930 (7.1%)	14.7	6,1	8.6
iv	42	41,471 (17%)	14.3	6.4	7.8
v	50	82,883 (35%)	15.0	7.6	7.5
vi	50	82,883 (35%)	13.8	6.9	6.9
vii	45	99,971 (42%)	13.8	6.9	6.9
viii	57	141,117 (59%)	14.0	8.6	5.5
ix	42	11,790 (4.9%)	16.4	6.4	10

Figure 5 shows that when considering the cumulative net carbon effect (EC and CS together) scenarios viii, vii and vi are the most beneficial in the GHG abatement.

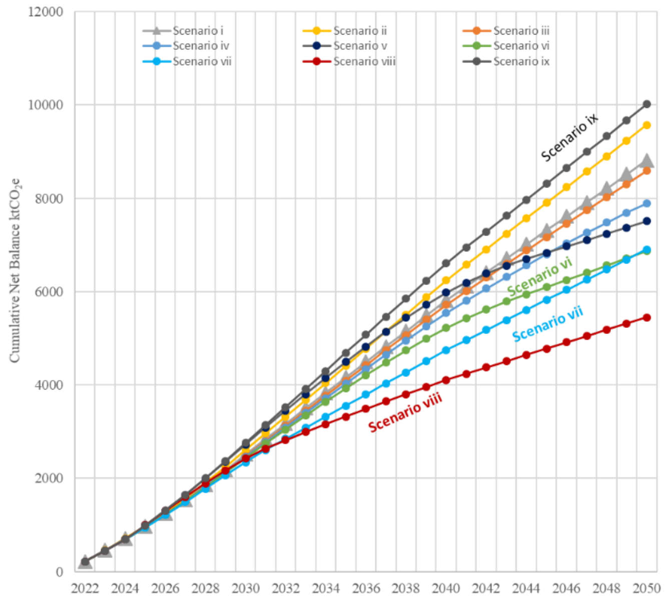

Figure 5. Cumulative net carbon for different housing scenarios between 2022 and 2050.

4 DISCUSSION

The best scenarios for the mitigation of climate changes while addressing the housing needs in Ireland are viii, vii and vi that combine a strong increment in the number of timber scheme houses with a larger presence of medium and high-rise buildings that can accommodate the housing demand while producing less emissions than the equivalent in masonry and concrete. In particular, scenario viii avoids 3.3 million tonnes CO_2e compared to scenario i that represents BAU.

According to the hypothesis formulated, Ireland would reach the highest rate of construction in 2030. At this time, total emissions of GHG should be reduced to at most 31,1 Mt CO_2e in agreement with Climate Bill 2021. For the period 2022-2030, the best scenario is described by scenario vii, where the net carbon emissions (EC minus CS) produced are 411 kt CO2e less than those produced by scenario ix, which increases significantly the number of 6-storey concrete buildings.

In the same period, scenario vii produces 61.4 kt CO_2e less EC than scenario i, BAU. Adding the CS in the period, the difference between scenarios vii and ix in the cumulative net is 164 kt CO_2e. For the year 2030 only, there are EC savings at 20.6 kt CO_2 compared to scenario i. This difference is roughly equivalent to the carbon sequestered by 3,700 ha of average Irish forest in one year [30].

The reductions of emission for the different scenarios may seem modest. However, it must be understood in the context of a sector which activity will likely increase in the next decades and that needs to reduce the GHG emissions with immediate effect. In addition, the case study only covered residential buildings. The differences in EC could be larger when using timber cladding instead of brick that reduces the EC significantly [31], even after several replacements, and can account for a reduction of 2.9% in EC and a 3.1% increase in CS using 25% timber cladding of the external wall area [27]. The current study considers a lower number of apartments than the housing needs according to Lyons [15] who regarding the lack of apartment home states: *it would be prudent for policymakers to cater for a slow transition over coming decades to a society with household sizes similar to Western European averages now*. The results show that the GHG abatement could be larger if more apartments are built. However, this will require a revision of the building regulations in Ireland to allow timber buildings of more than four storeys. The National Building Code in Canada for example allows for up to 12 stories, and the UK counts with many examples of timber frame buildings of six or seven storeys.

The presented analysis assumes that after the service life has been achieved, new dwellings will replace the old ones. Therefore, if the timber elements are not reclaimed and reused the CS released to the atmosphere is compensated by new construction. In this regard, it is important to highlight the relatively short rotation lengths used in Ireland for harvesting forest crops (35-45 years) in comparison to continental Europe. This is due to the growing conditions that allow to reach merchantable volumes earlier, and the poor quality of sites to which forestry is typically relegated (richer soils are used for agriculture) together with wind exposure of Ireland that advises against leaving trees standing for too long at the risk of being windthrows [32].

The savings of CO_2e using timber would be larger if assessing more stages of the life cycle. For a cradle-to-grave boundary (from production to end of life), Walsh and McAulliffe [33] estimated an annual savings of 460 kt CO_2e based on the construction of 25,000 new timber frame homes in Ireland in comparison to traditional masonry construction. The study covered stages A1 to C but found the largest difference in the stages A1-A3. The building materials used in the timber house produced a saving of 124.1 kg CO_2e/m^2, 41% less carbon than the masonry construction materials. This difference is larger than that used in the analysis of the current study. It is also important to notice that the end-of-life C1-C4 in the timber frame building produced 3.1 kg CO_2e/m^2 less, with the additional potential benefit of reclaiming timber for other projects [34]. The total EC (modules A1-A4, B4-B5, C1-C4) was 353 kg CO_2e/m^2 for the masonry house and 218 kg CO_2e/m^2 for the timber frame building. Including the effects at the end-of-life allows to account for the carbon sequestration [3], that amounted to 42 kg CO_2e/m^2 and 78 kg CO_2e/m^2 in the masonry and timber frame units respectively. Thus, the presented study uses conservative values of the GHG emissions associated with traditional and timber materials used as structural elements in construction compared to other studies, but it still shows significant evidence of the benefits that timber construction can bring to the mitigation of climate change. In support of this, the Timber Engineering Research Group at NUI Galway is leading the SAOLWood project, which aims to create a lifecycle inventory with data specific to harvested wood products used in construction in Ireland.

5 CONCLUSIONS

The decarbonisation of the construction sector is necessary in order to mitigate the effect of climate change and achieve the Irish Government commitment of GHG emissions reductions while addressing the increasing demand for housing in the coming decades. This paper has shown that medium to strong increase in the construction of timber buildings, particularly apartments, delivers more GHG saving than scenarios with limited use of timber. Further research is needed to include and quantify the potential benefits of timber for reuse and recycling as part of the circular economy.

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