BUILT BY NATURE

Impact scan for timber construction in Europe

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Executive summary

BUSINESS-AS-USUAL

On a European level, the built environment is responsible for 40% of our CO_2-eq emissions and roughly 60% of our material consumption, making it one of the most impactful economic sectors. This impact is not divided equally over the different regions of the EU27+UK:

- According to predictions from the Joint Research Commission and Metabolics Urban Mining model the construction of homes in the EU 27+UK will accumulate up to 31 million to 2030.
- Western Europe accounts for 61% of total construction material demand until 2030, with Germany making up 25%, France 19%, and the UK 14%.
- 9,020 Mton of construction materials will be needed until 2030, with 97.4% allocated to new construction and 2.6% for renovation. The same as 185 pyramids of Giza.
- Residential buildings account for 70.3% of the material demand, while utility buildings account for 29.7%.
- Concrete, primarily used in the structure of a building, is the most prominent building material, comprising 70% of the total mass and 49% of the CO_2-emissions.
- If we keep constructing the way we do now, we will surpass the carbon budget allocated to the EU27+UK construction sector in 2026 according to our calculations based on the Paris agreement.

IMPACT OF BIO-BASED CONSTRUCTION:

To reduce this impact, it is essential to apply bio-based materials and increase the amount of sustainable timber in construction.

- A total CO_2-reduction of 18% (37 Mton) can be achieved in 2030 if 50% of new residential construction is bio-based. This would be for the year 2030, the cumulative impact from 2023 till 2030 is less due to a 'growth path' towards this 50%.
- A yearly additional long-term carbon storage of 69 Mton in 2030 can be achieved.
- This requires 566 million m^3 of roundwood until 2030. The production capacity of Engineered Wood Products (EWP) therefore has to increase significantly in the coming years.
- Only 3.6% (18.5 million m^3) of roundwood is used for the production of EWPs, such as cross-laminated timber, glue-laminated timber and laminated veneer lumber. The rest is mostly used for energy production and production of paper products.

LIMITS TO GROWTH

There is a limit to the increase of the sustainable wood supply that can be harvested without compromising vital functions provided by our forests.

- There is a distinction between the theoretical harvest potential (net annual forest growth), which would allow an increase of roughly 50% of the annual wood supply and the realistic harvest potential: 10-20% (attainable within 10–20 years). The projected wood demand under high ambition scenarios for construction can not be met by the potential increase of sustainable harvested wood in the short term.
- The utilization of wood and wood co-products for energy- and pulp production must be limited as much as possible and wood should be redirected to higher value, long-term carbon storage applications such as construction
- Significant land-use change due to timber construction is projected in the long term as forest plantations will have to expand to meet demand. In an ambitious scenario, the total increased wood demand results in an increase of 150,000 km^2, approximately 3,5 times the surface of The Netherlands.
- Climate change will have severe effects on forest ecosystems, which can be addressed by creating climate-resilient forests.
- Innovations and strategies are needed to guarantee biodiversity, healthy forests and wood sufficiency: this can be accomplished by creating and using products made from climate-resilient species, stimulating re-use, and prioritizing efficient wood utilisation.

01 Introduction

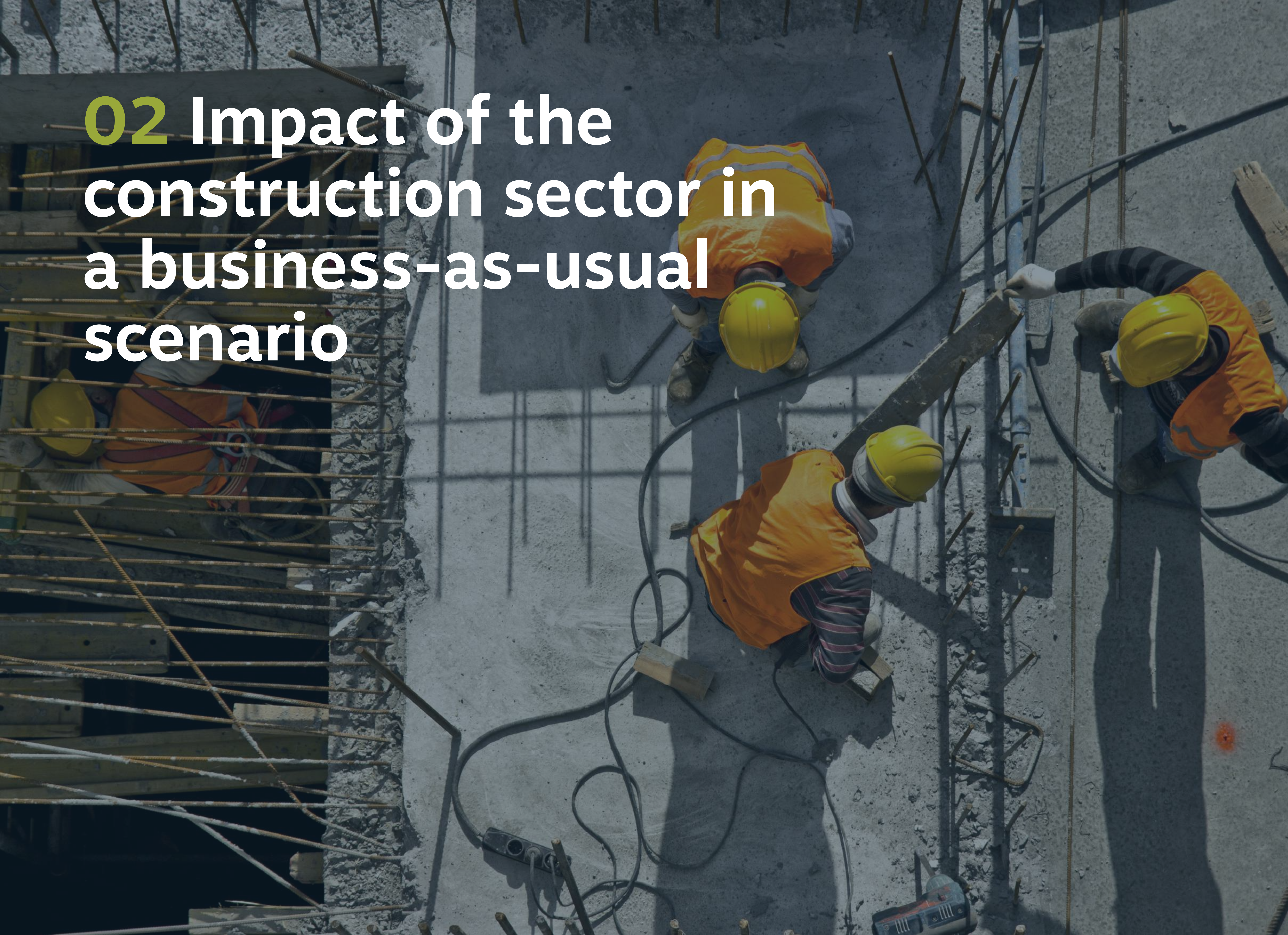
INTRODUCTION

The (European) construction sector is a major economical and environmental impact driver. This sector emits roughly 40% of our annual CO_2-eq emissions and uses up to 60% of our resources. One of the most promising reduction strategies is the application of bio-based construction materials to replace their 'mineral' and CO_2-intensive counterparts. In the current debate regarding bio-based construction, there is confusion regarding the potential impact and geographical implications of a bio-based construction sector. How does the large-scale application of bio-based construction materials impact our forests? Are we not shifting the burden to another planetary boundary if we solely focus on the reduction of carbon emissions? This report is a first step in a longer aim to create clarity on these topics. To do so, the following topics are addressed.

- What is the current environmental impact of the construction sector in the EU27+UK and how does this impact relate to the planetary boundaries such as climate change and our 1.5°C carbon budget?
- How much can we reduce the impact of the construction sector by applying timber alternatives to materials that are the most carbon intensive?
- How does this increased demand for timber relate to the (growing) capacity of the European forests and what systemic barriers should we take into consideration when making these decisions to prevent burden shifting?

In this paper a future modelling exercise has been executed based on the most accurate data currently available. However, the modelling of future scenarios will always demand a certain amount of assumptions to be made which might potentially deviate from a volatile and quickly changing reality.

02 Impact of the construction sector in a business-as-usual scenario



SPATIAL DISTRIBUTION OF MATERIAL DEMAND AND IMPACT

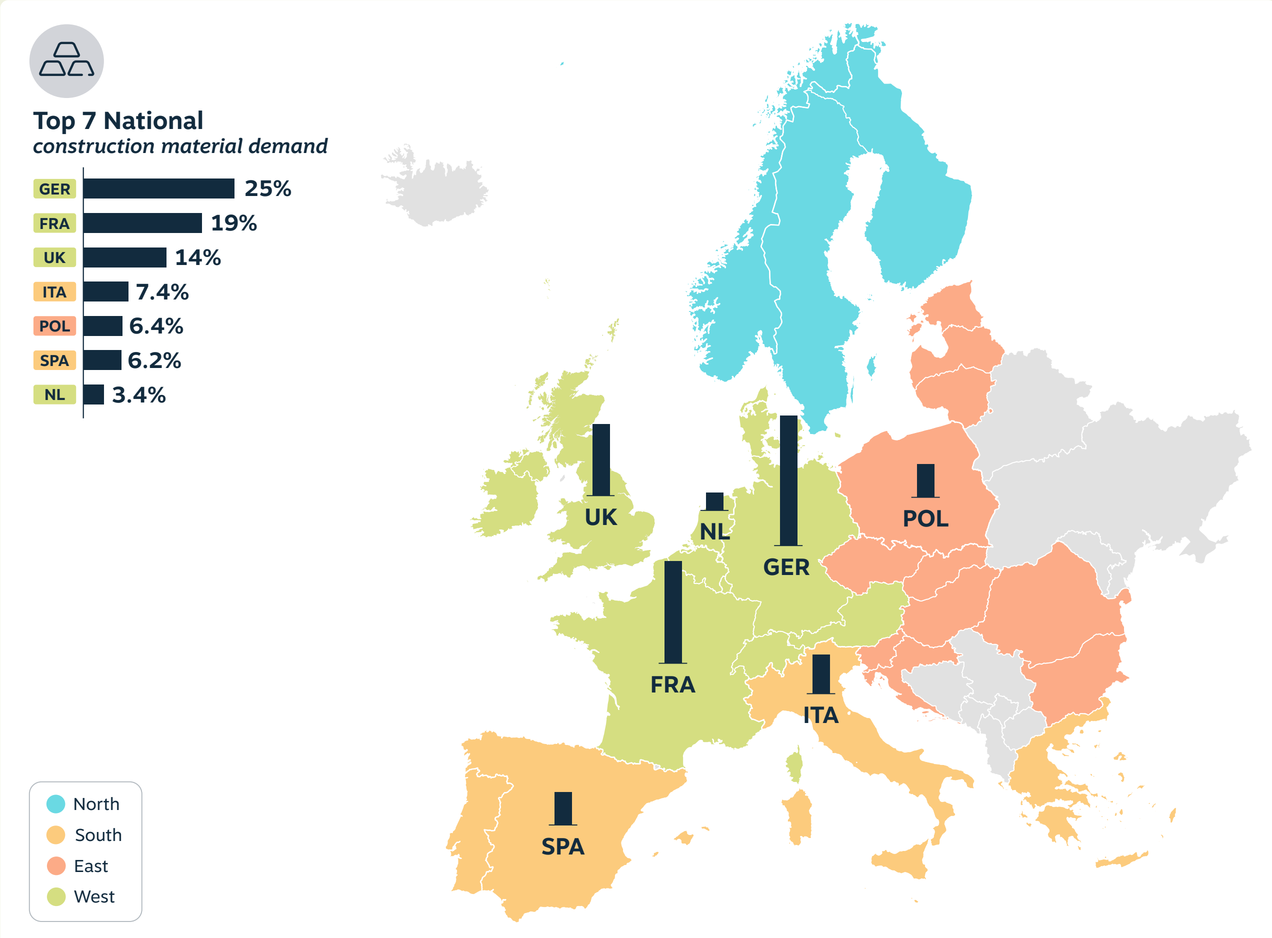


Figure 1 *Top 7 National construction material demand as based on the material flow analysis executed by Metabolic.*[1]

Figure 2 *CO_2-budget of the residential and utility construction sector.*[1]

It is important to understand the current impact and construction practices of different regions in Europe to understand the potential of bio-based construction. Based on numbers from the EU housing observatory[29] and Metabolic's Urban Mining Model analysis reveals that until 2030 9,020 million tons of construction materials will be needed. **Western Europe accounts for 66% of all construction materials.** Together, the seven countries with the highest material demand represent 81% of the total demand until 2030 (see Figure 1). Germany leads with a 25% share, followed by France with 19%, and the UK with 14%.

The large demand for construction materials results in significant carbon emissions. Based on bottom up analysis we estimate that in a 'business-as-usual' scenario, **the EU27+UK's construction sector will exceed its allocated carbon budget for limiting global warming to 1.5°C in 2026.** The budget for 1.7°C and 2.0°C will run out in 2029 and 2031 respectively, as shown in Figure 2. For a comprehensive explanation of the methodology and the application of Metabolic's Urban Mining Model in estimating construction material demand, please consult the Annex 1.

IMPACT PER BUILDING TYPOLOGY

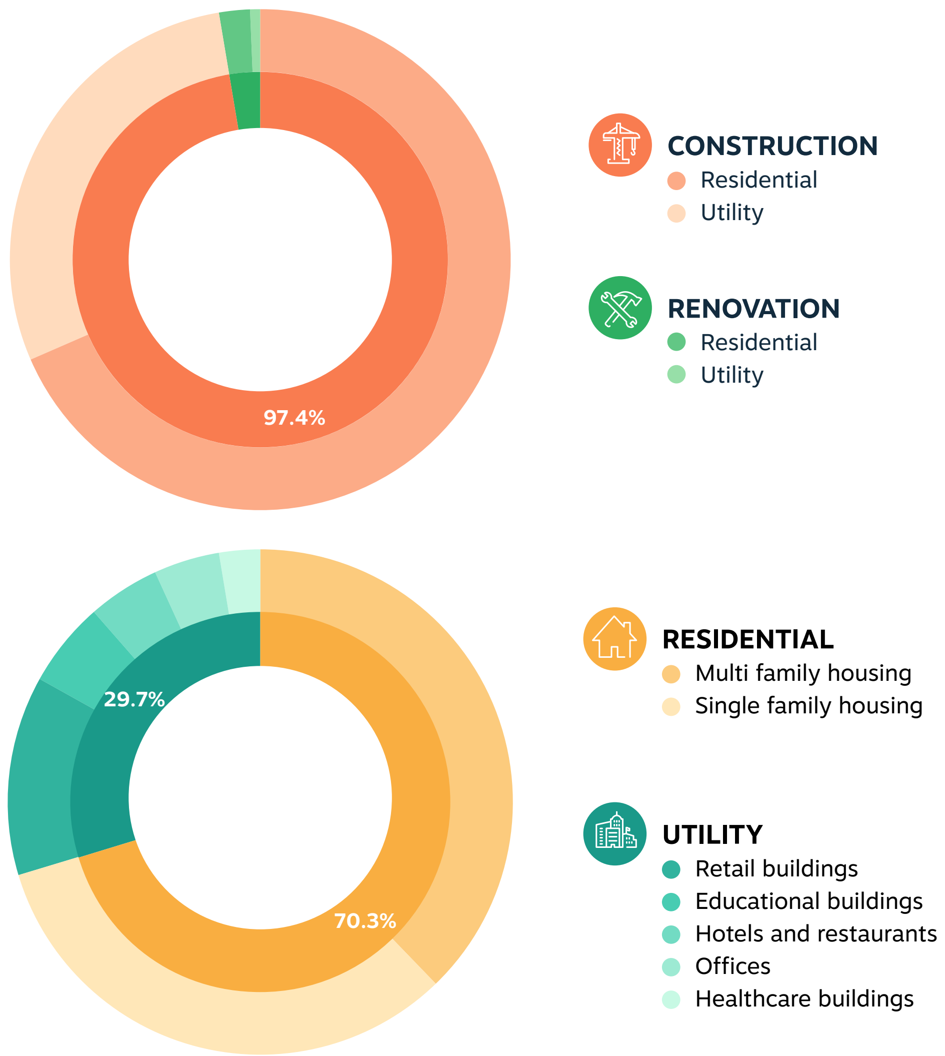


Figure 3 *Share of new construction and renovation and share of residential and utility buildings within new construction.*

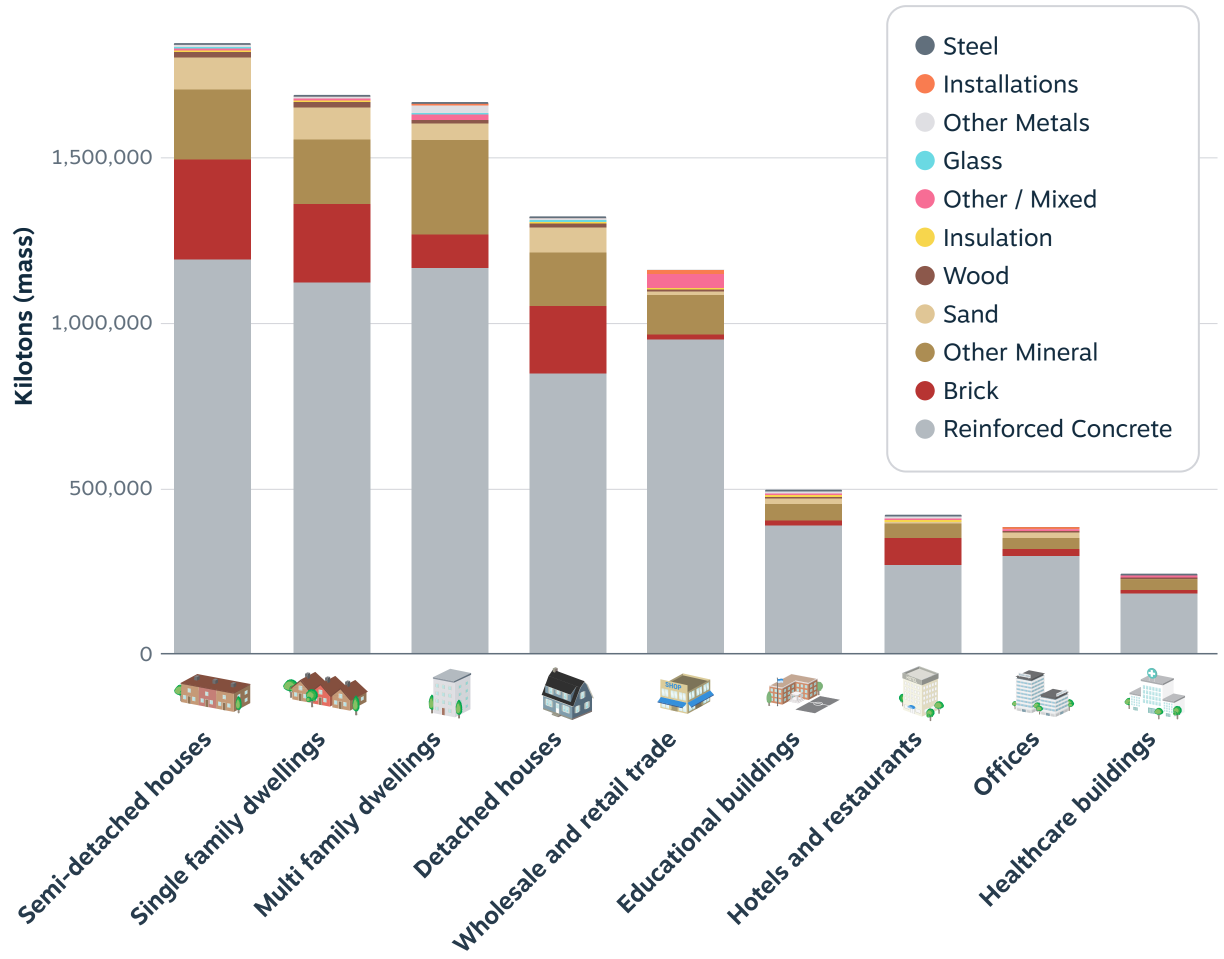


Figure 4 *Material demand (by mass) per building typology and building material based on typologies defined in Metabolics Urban Mining Model.*

The analysis highlights **new construction** as the predominant factor until 2030 (see Figure 3). **97.4%** of all materials (by mass) are allocated towards new construction, **and only 2.6% is attributed to renovation.** In the annex additional insights have been added which also show the volume of material consumption for specific typologies and scenarios.

Breaking down the material demand within the field of new construction, **residential buildings** account for **70.3%** of the material demand, compared to 29.7% for utility buildings. In terms of dominant building typologies, when considering mass, **semi-detached houses** are the most demanding building typology, followed by single-family and multi-family dwellings (see Figure 4).

IMPACT PER MATERIAL AND LAYERS OF A BUILDING

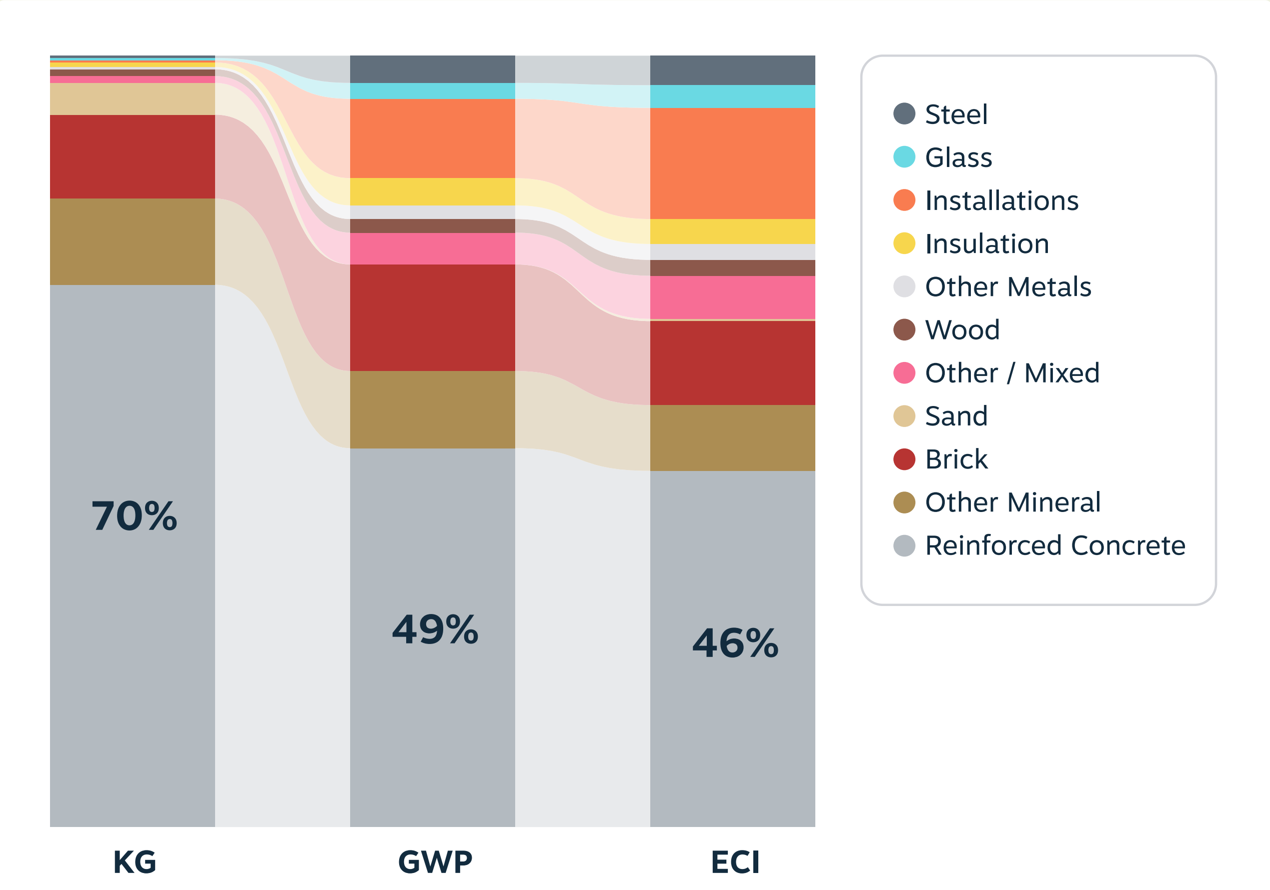


Figure 5 *Material demand by mass, GWP, and ECI, per building material based on Metabolic's Urban Mining Model.*

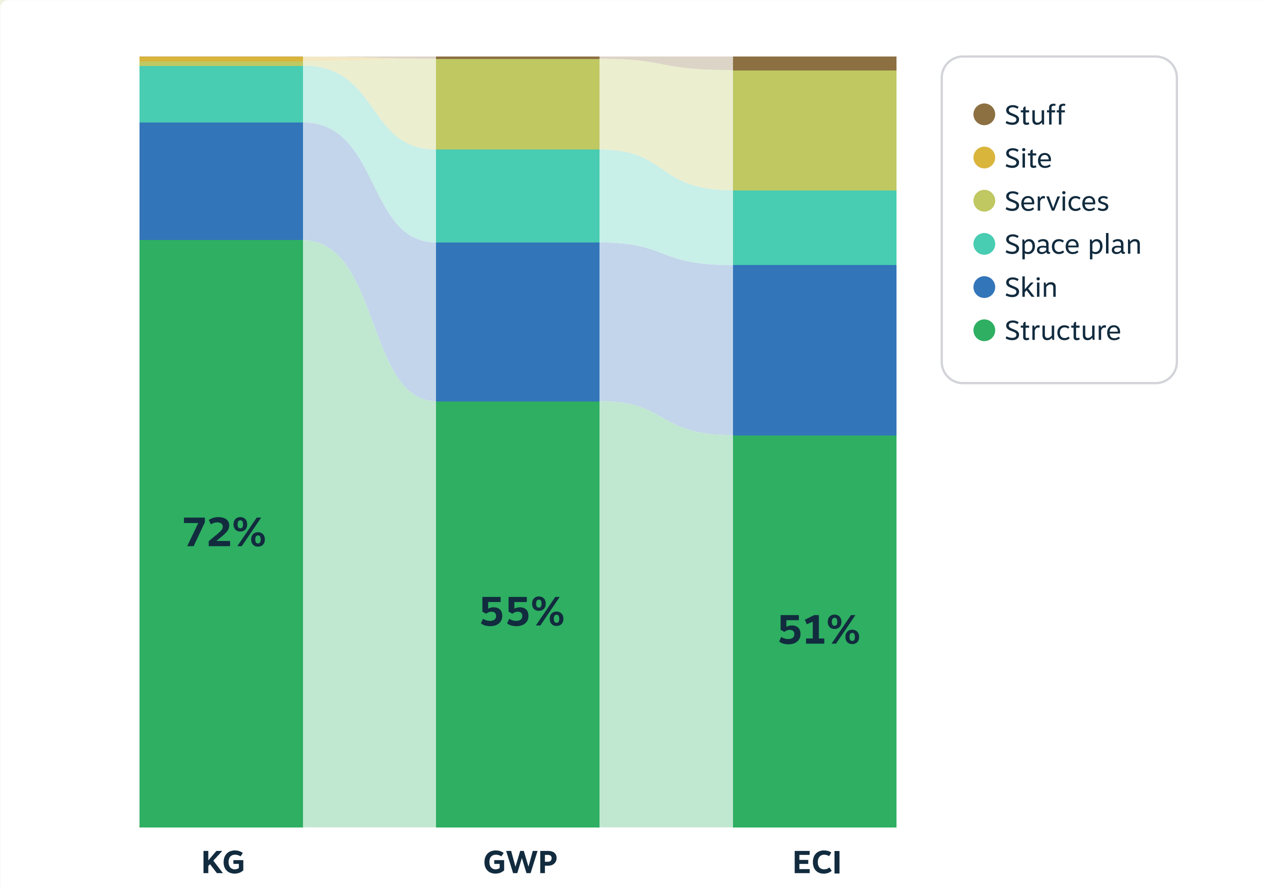


Figure 6 *Material demand by mass, GWP, and ECI, per S-layer based on Metabolic's Urban Mining Model.*

Concrete is the most utilized building material, representing 70% of the total mass. Concrete's substantial mass contribution translates to it being responsible for **49%** and **46%** of the overall **GWP** and **ECI** of all building typologies combined, respectively (as shown in Figure 5). Installations and insulation, glass, and steel, both have a minimal contribution to the total mass, but a high ranking in regard to the environmental impact. In the annex additional insights have been added which also show the volume of material consumption for specific typologies and scenarios.

The structure of a building stands out as the primary contributor to both the mass and overall impact of all buildings combined (Figure 6). The **skin** ranks as the second most significant contributor in terms of environmental impact, for both the GWP and ECI. The structure and skin contribute to **78%** of the impact in ECI. A detailed explanation of the S-layers, GWP, and ECI and of the evaluation can be found in the Annex 2.

CONCLUSION

Western Europe accounts for 66% of all material demand in Europe. Germany, France, and the UK have the highest material demand. Together, the seven countries with the highest material demand represent 81% of the total demand until 2030. In a business-as-usual scenario 9,020 Mton of construction materials will be needed until 2030.

The majority of materials being used for development of **new construction** (97.4%) are used for **residential buildings**, with a share of 70.3%.

Concrete stands out as the most impactful building material, playing a crucial role in the building's structure. The **structure** and the **skin** are identified as the most impactful layers by mass and environmental impact (ECI). In the following analysis we quantify the impact of replacing these materials with biobased alternatives.

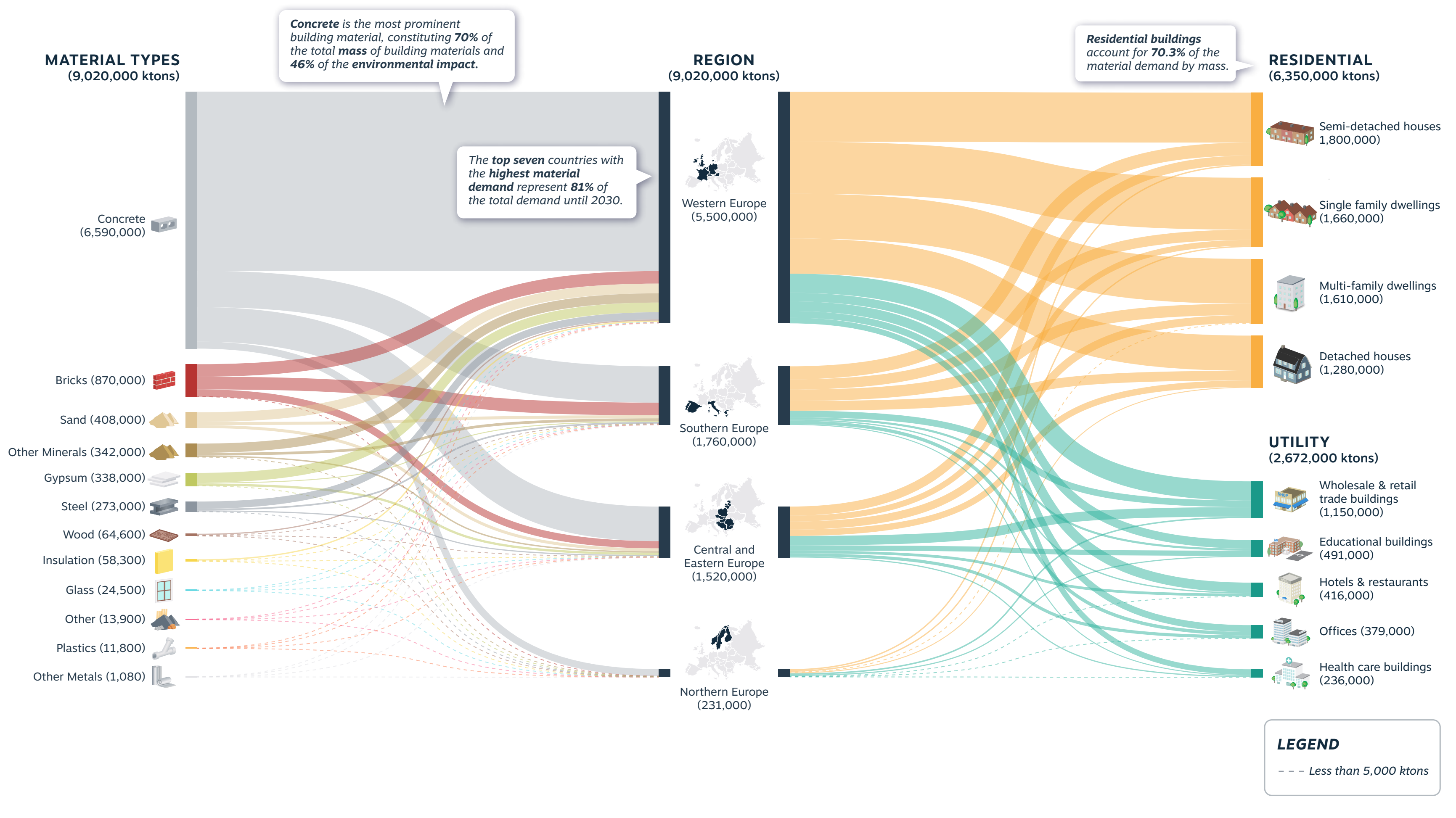


Figure 7 *Material Flow Analysis of cumulative material demand until 2030 in EU27+UK, per building material, region, and building typology.*[1]

03 The potential of implementing bio-based construction

IMPACT REDUCTION AND CARBON SEQUESTRATION

By shifting 50% of the construction of residential typologies towards bio-based alternatives (CLT and timberframe), **the environmental impact of the EU27+UK construction sector can be reduced by 18% in 2030.** This would mean the environmental impact in the year 2030. The cumulative impact between 2023 and 2030 would be less due to the projected adaptation rate. This equates to 37 Mton of reduced carbon emission, which is roughly the same as 120,000 rocket launches. This is a direct reduction in emitted CO_2-eq during the production of the materials needed to construct both the structure and facade of these residential typologies (see page 15 for elaboration). Still considerable emissions remain due to the application of installations, concrete foundations and other materials. In Annex 4 the cumulative material demand until 2030 in different scenarios is shown.

If the carbon sequestration of the applied materials is taken into consideration, replacing 50% of the constructed residential typologies with bio-based typologies would allow us to sequester an additional 69 Mton of carbon, which would cut the emissions of the construction sector roughly in half. Here we need to take into consideration that this carbon has been stored in the past 30+ years and that we can only start counting new carbon sequestration if we make sure there is enough newly planted forests. It is assumed that the wood used for engineered wood products in the analysis is pine, with a carbon sequestration rate of 715 kg CO_2 eq per cubic meter of wood.[2]

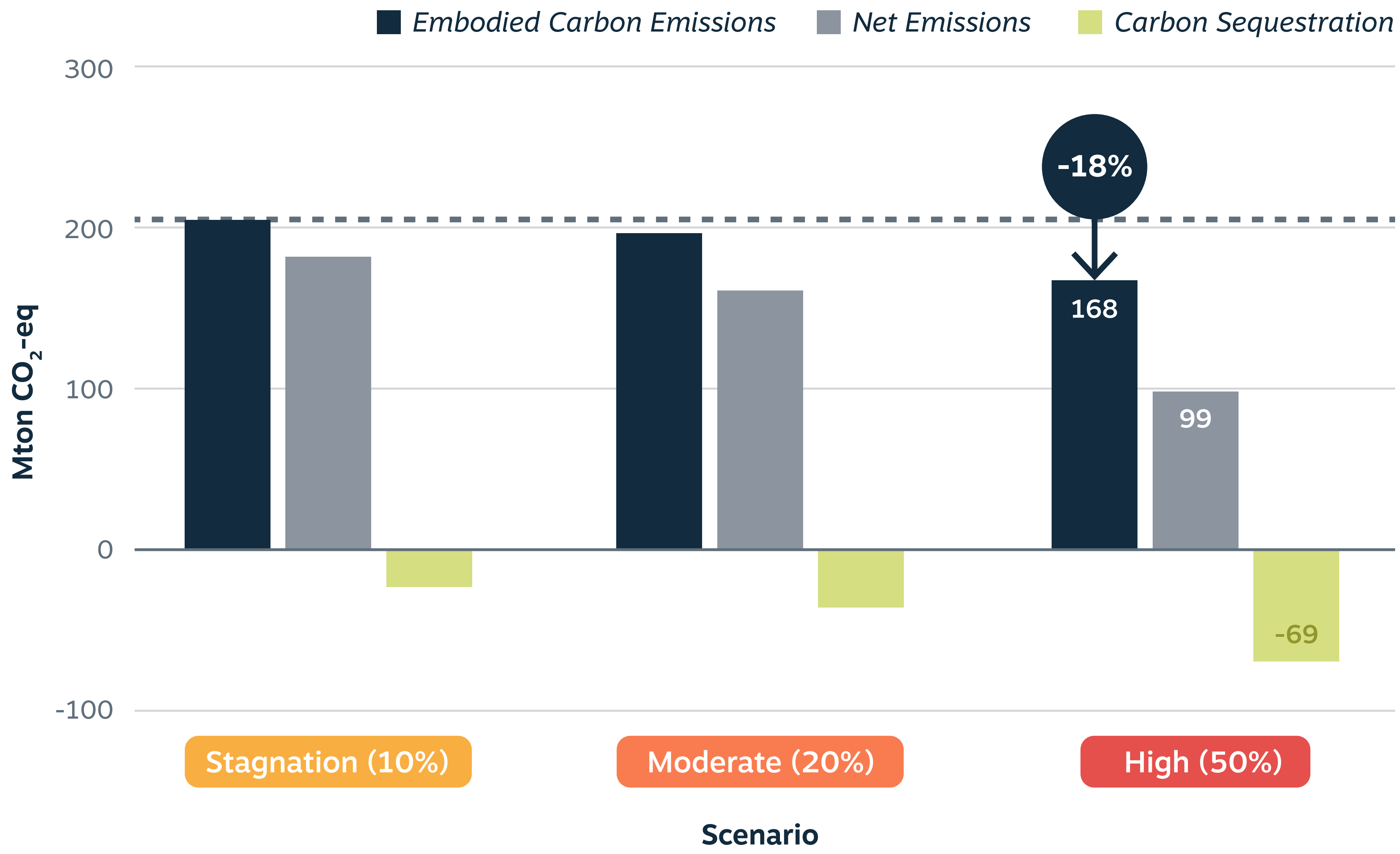


Figure 8 CO_2-emissions and CO_2-sequestration and net emissions in 2030 from construction of new residential buildings.

BIO-BASED CONSTRUCTION SCENARIOS: AMBITION LEVELS

Three scenarios are used to assess the impact of different ambitions levels, expressed in percentage of new residential buildings that will be constructed from bio-based materials in 2030. A bio-based building is defined as a building that uses timber as the main structural material and main material for the skin of the building. The building typologies and materials used in these scenarios are explained on the next page. The timeline for this analysis is 2023-2030. In this period the most urgent policy goals are formulated.

The following scenarios are used in our analysis:

- **Stagnation (10%):** the estimated current share of newly constructed bio-based buildings is projected to remain unchanged from the current estimated market share until 2030.
- **Moderate ambition (20%):** there is a slight anticipated growth in the proportion of bio-based buildings by 2030. Considering the current momentum and policies, the moderate ambition scenario is estimated to be the most probable outcome.
- **High ambition (50%):** new policies and innovations will accelerate the bio-based buildings sector to a high degree. This scenario might be difficult to reach, but was modelled to gain insight into the potential of a biobased focused construction sector.

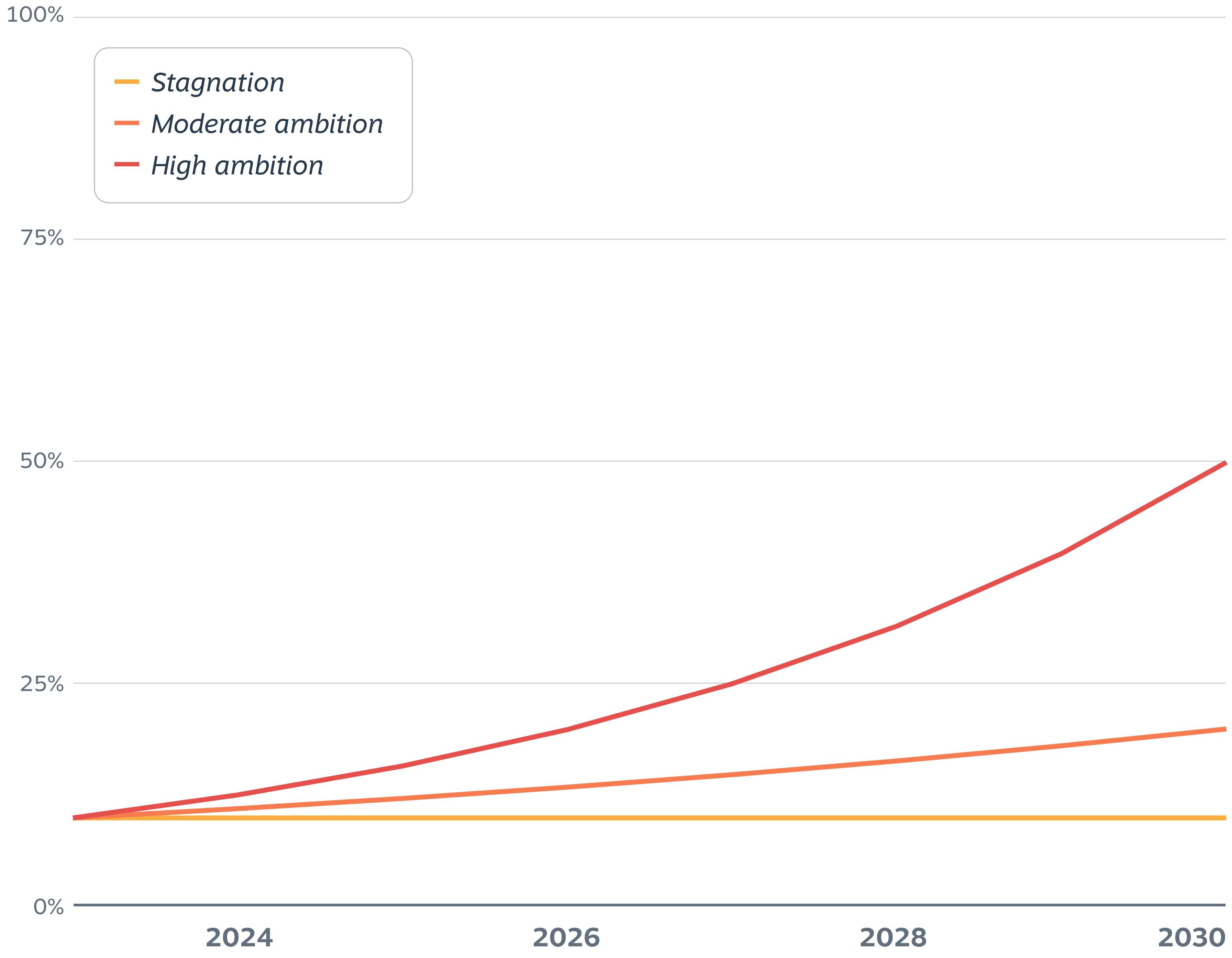


Figure 9 *Bio-based construction market share scenarios until 2030 (EU27+UK).*

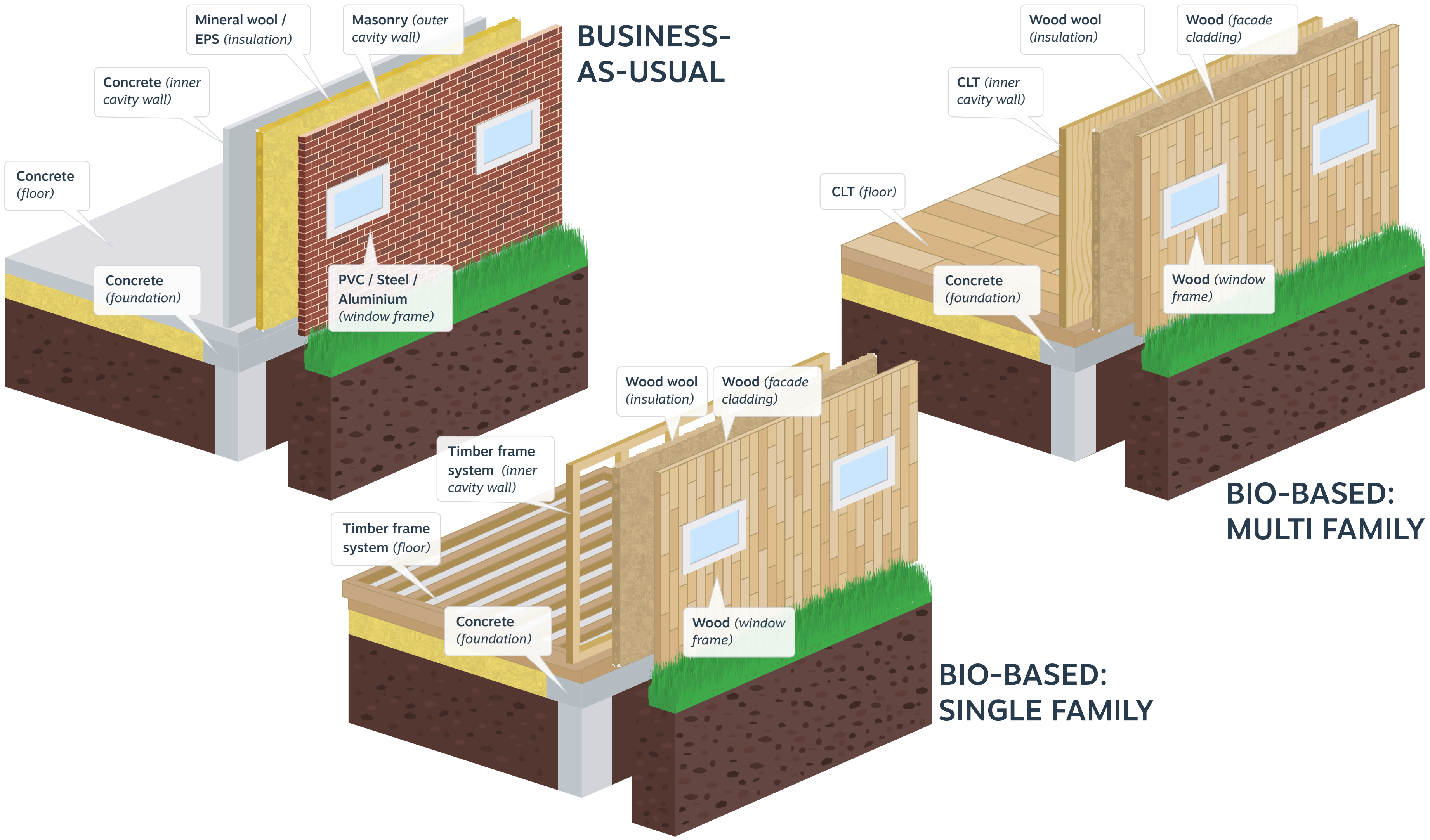
BIO-BASED CONSTRUCTION SCENARIOS: TYPOLOGIES

Based on the insights regarding the most impactful building layers and materials in chapter 2, building typologies are developed to assess the potential impact reduction of bio-based construction.

Impactful materials in the structure and skin are replaced by bio-based alternatives in bio-based typologies and compared to business as usual typologies. In Figure 10, the difference between a business-as-usual typology and a bio-based typology is shown. The conventional building is different for every geographical region (page 8) in Europe. The bio-based replacements are custom-made to suit the specific building profiles in each region. The conventional building in Figure 10 pertains to Western Europe, with the Netherlands serving as the reference country.

Biobased typologies:

- In the multi-family bio-based typologies, the concrete structure is substituted with Cross-Laminated Timber (CLT) elements, which possess excellent strength properties suitable for constructing buildings with more than three floors.
- The structure of single-family and (semi)-detached houses predominantly consists of timber frame construction.
- The outer layers of the building envelope remains consistent across all bio-based building typologies: thermal insulation will incorporate wood wool insulation, while the outer layers will feature wooden cladding and wooden window frames.
- The 'spaceplan', 'system' and 'stuff' layer are the same in the business-as-usual and bio-based typologies.



Layer	Business-as-usual typologies	Bio-based: multi family typologies	Bio-based: single family typologies
Structure	**Foundation:** concrete **Floors:** concrete **Load-bearing Walls:** concrete	**Foundation:** concrete **Floors:** CLT **Load-bearing walls:** CLT	**Foundation:** concrete **Floors:** timber frame floor system **Load-bearing walls:** timber frame wall systems
Skin	**Inner cavity wall:** concrete **Insulation:** mineral wool / EPS **Outer cavity wall / facade:** masonry **Window frame:** PVC / Steel / Aluminium	**Inner cavity wall:** CLT **Insulation:** wood wool **Outer cavity wall / facade:** wood cladding **Window frame:** wood	**Inner cavity wall:** timber frame wall system **Insulation:** wood wool **Outer cavity wall / facade:** wood cladding **Window frame:** wood

Figure 10 *Building typologies and products used in the impact analysis.*

04 Implementing bio-based construction within planetary boundaries

TIMBER AND EWP DEMAND

Based on current modelling the production capacity of engineered wood products (EWP) needs to increase nearly fivefold to meet the projected demand of 33 million m³ in 2030 and to achieve 50% bio-based construction in 2030. Also 22 million m³ of timber frame products will be needed which results in an estimated 566 million m³ of roundwood demand or 140 million m³ annually in 2030. This is 109 million m³ or 4.5 times more than if we keep building according to a stagnation scenario.

The current wood production and additional sustainable harvest potential in Europe can not supply the demand by 2030 for a 50% scenario, unless wood is redirected from other applications to construction applications (see page 19). The projected demand can facilitate the construction of approximately 1,433 million m² or 9 million bio-based buildings (see Table 1). It is important to note that these projections focus solely on the timber products and roundwood utilized for the building's structure.

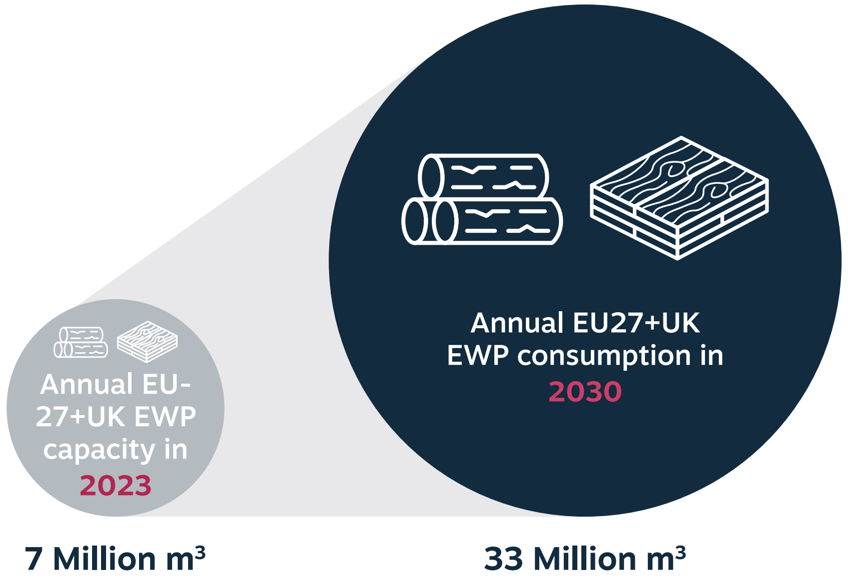


Figure 11 *The increasing demand for engineered wood products.*

Table 1 *The demand for engineered wood products, timber frame products, roundwood, m² of timber buildings constructed and number of timber buildings constructed under different scenarios.*

	EWP products demand until 2030 (million m³)	EWP products demand in 2030 (million m³)	Timber Frame (TF) products demand until 2030 (million m³)	Timber Frame (TF) products demand in 2030 (million m³)	Roundwood demand for EWP + TF Until 2030 (million m³)	Roundwood demand for EWP + TF in 2030 (million m³)	m² timber buildings constructed (million m³)	Number of timber buildings constructed (million m³)
Stagnation (10%)	53	7	45	6	237	31	558	4
Moderate Ambition (20%)	76	13	60	10	332	58	811	5
High ambition (50%)	134	33	97	22	566	140	1,433	9

FORESTS AND WOOD PRODUCTION

Forests cover approximately one-third of Europe's land surface, and over the past 30 years, the total forest area has increased by 9%. European forests play a vital role in sequestering around 10% of the EU's CO_2 emissions, and wood construction products contribute to long-term carbon storage.[8] Forest are relatively even distributed among the EU27+UK.[8]

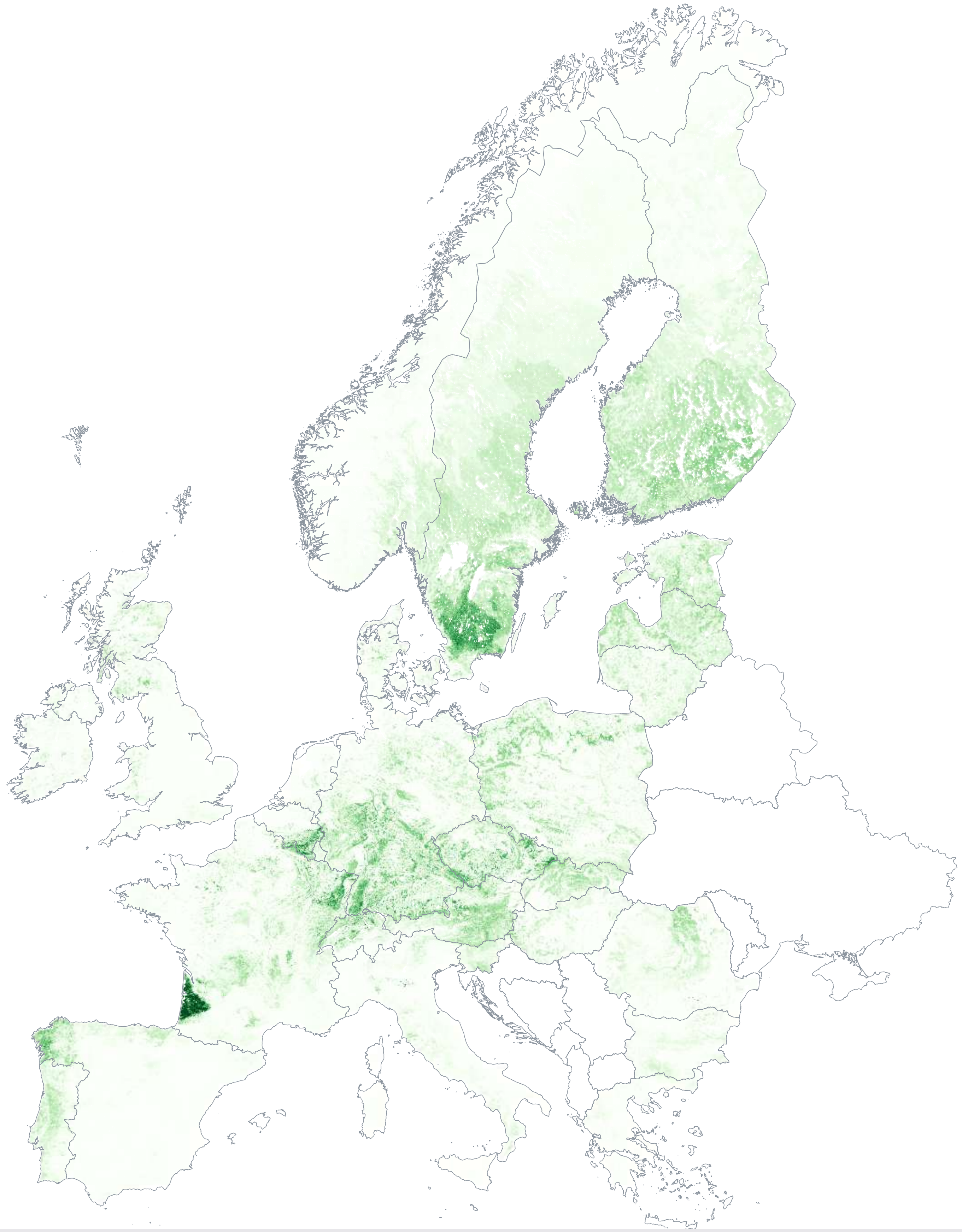
The most productive forest regions in Europe are located in the Nordics (Sweden and Finland) and the DACH-region (Germany, Austria and Switzerland), which together account for at least 50% (235 million m³) of the total annual average roundwood production of 458 million m³ (average 2011-2021) in the EU27+UK[6]. France and Poland are also significant roundwood producers. In 2021[6], the total production of the EU27+UK was 507 million m³.

Softwood species such as spruce, fir, pine, and larch are mainly used for the production of bio-based construction products. These species dominate wood production in Europe and are favored for their properties and abundance. Most of the supply chain, including wood-processing machinery, is adapted to process softwood rather than hardwood. However, using deciduous (hardwood) species for construction presents potential advantages in the face of climate change and the growing need for resilient forests (see page 21).

LEGEND

Wood Production
(m³ / km² / yr (average 2000-2010))

0 — 1,000



ROUNDWOOD PRODUCTION TOTAL:
458 million m³

73	Sweden
64	Germany
60	Finland
51	France
42	Poland
19	Czech Republic
18	Austria
17	Spain
16	Romania
14	Latvia
12	Portugal
72	Other countries

Figure 12 *Wood production in the EU27+UK.*[6, 8]

EWP PRODUCTION

EWP Production

More than 90% of EWP production takes place in the DACH region with Germany and Austria leading the market (see Figure 13). Engineered wood products (EWP), in this analysis, are defined as cross-laminated timber, glue-laminated timber and laminated veneer lumber.

Currently, there are no publicly available datasets on engineered wood product (EWP) production and therefore adoption of these materials is hard to monitor. However, more detailed data might become available from 2024 onwards, as the FAO has announced a revised classification of forest products.[9] Until then, Metabolic has created a dataset based on desk research with production locations of EWPs.[10]

The total annual capacity of production locations of engineered wood products in the European Union (EU), including planned production locations, is estimated to be 7.4 million m^3. Only 3.6% (18.5 million m^3) of roundwood is used for the production of EWPs. The majority is used for energy production and production of paper products. There are 19 production locations with unknown capacity, but when extrapolated this would account for an additional 1 million m^3. In recent years, there has been a growing EWP production capacity in the EU.[11]

Transportation emissions

Our analysis revealed that transportation contributes a relatively small proportion of total emissions in the supply chain of timber construction. The findings of this analysis can be found in Annex 3.

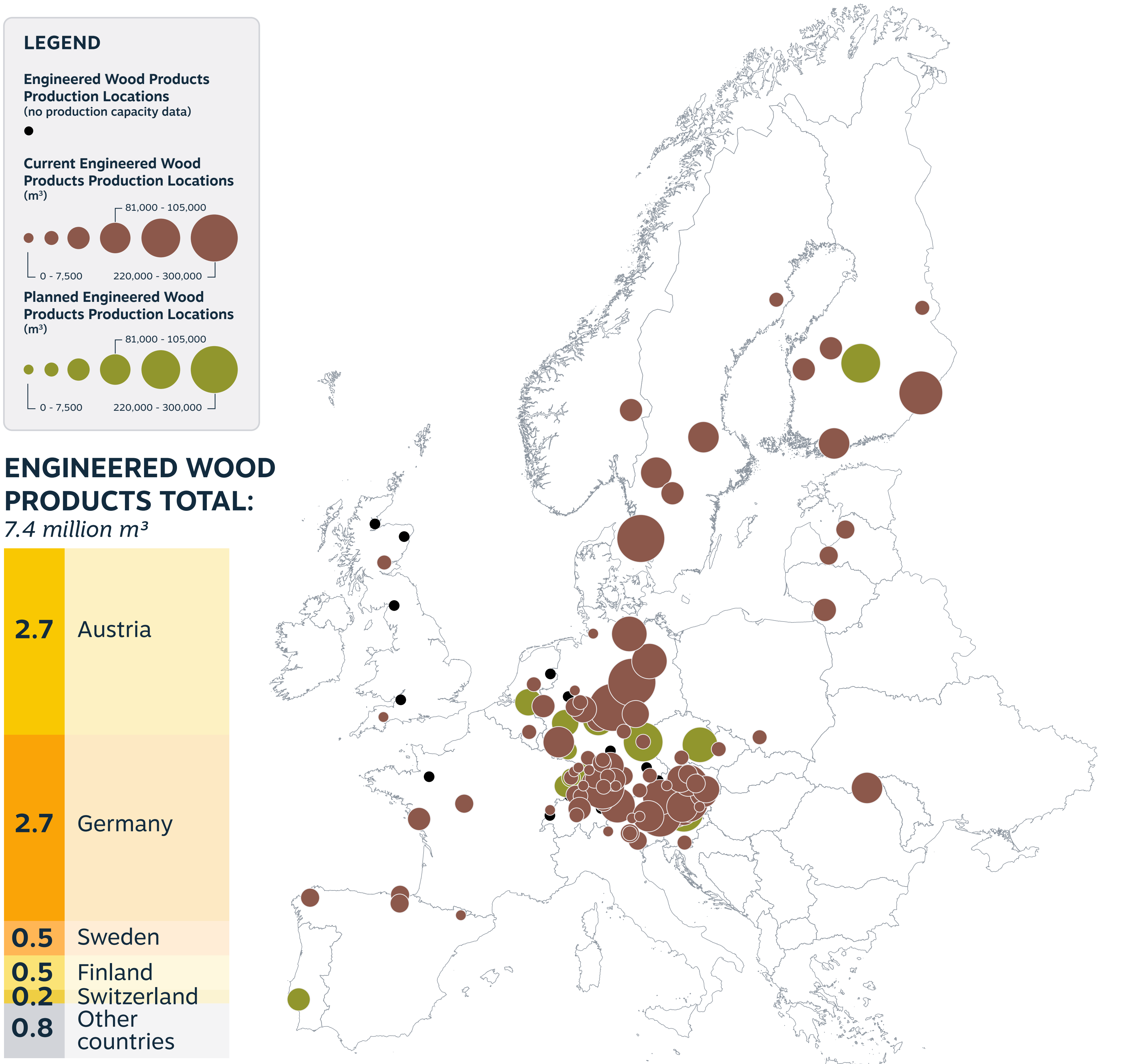


Figure 13 *EWP production locations and capacity.*

AVAILABLE WOOD IN EU27+UK

Based on current projections for a high ambition (50%) bio-based construction scenario an increase of at least 140 million m^3 roundwood in 2030 is projected (page 17) while harvest can only be increased sustainably with 40-90 million m^3, as described in a recent study by Wageningen University.[12] This poses a risk to sustainable wood supply. Across all sectors a significant increase in wood demand in the EU is expected[13] due to increased interest in the bioeconomy. The EU Bioeconomy Strategy aims to increase the utilization of wood for bioenergy and the construction industry.[14] Understanding sustainable timber supply requires distinguishing between: theoretical harvest potential (100% of net annual forest growth) and realistic harvest potential (based on the forests available for wood consumption or FAWS).[15] FAWS refers to forests without significant environmental, social, or economic restrictions on wood supply. Forests fulfill many different functions such as a basis for biodiversity. The EU Biodiversity Strategy[16] aims to protect 30% of land area.

The study[12] shows that the additional potential for wood harvesting is limited, and smaller than previously thought, unless more investments are made in afforestation and forest management. There is 'a considerable gap between the theoretical additional potential (the difference between net annual increment and annualfellings) and the realistic additional harvest potential (218 million m^3 versus 90 million m^3). The maximum additional potential can only be reached if all forest owners intensify wood mobilization and less considerations are made for ecosystem services, biodiversity conservation, erosion risks or recreation. The maximum additional potential is not desirable and unrealistic because forests have to fulfill many different functions. The realistic additional harvest potential found in the literature was an increase of 21% or 90 m^3. This potential should be attainable within 10–20 years. However, when looking into the local context of specific regions, it was found to be even closer to 10% or 40 million m^3 per year.

Also under more conservative projections the limits of wood supply become visible. An older study[17], before the increased interest in the bioeconomy, analyzed national-level projections of wood supply, assuming restrictions, and concluded there would be a shortage of 185 million m^3 of wood supply in 2050.

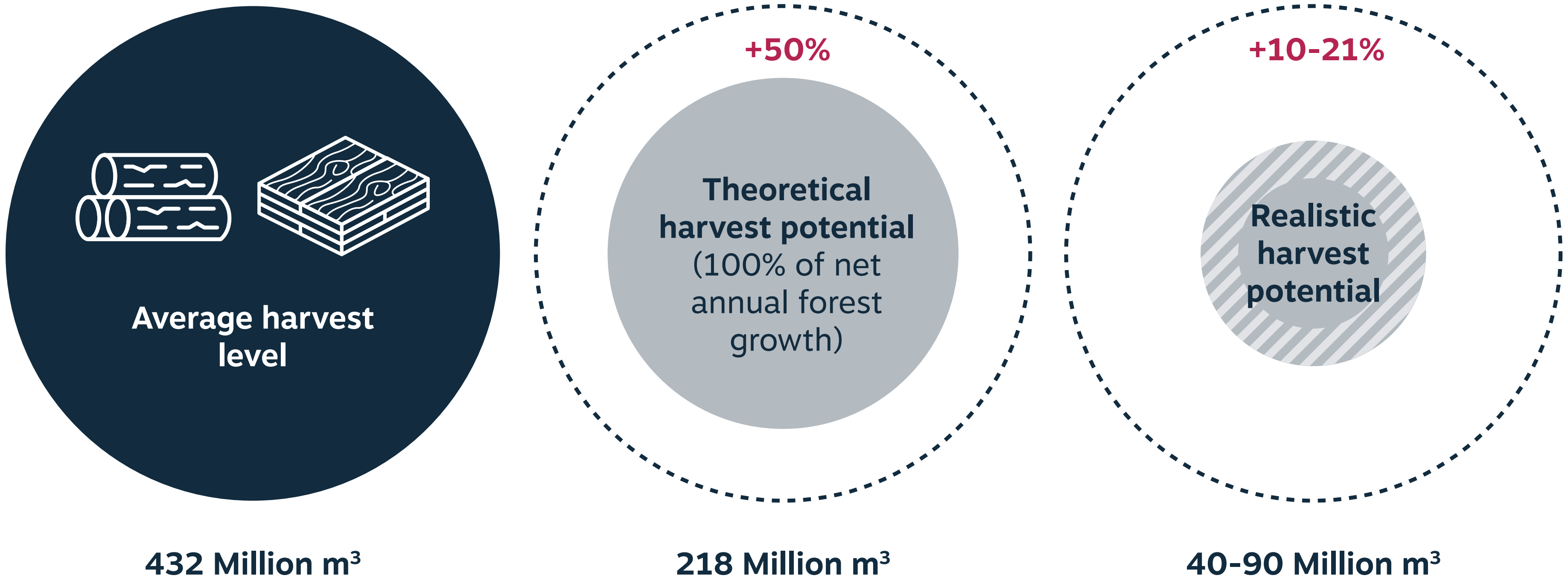


Figure 14 *Annual harvest level (2015), theoretical harvest potential and realistic harvest potential in EU27+UK (adapted from Bas J W Lerink and others[12])*

CLIMATE CHANGE IMPACTS ON FORESTS

Climate change poses significant challenges to forest ecosystems in the EU27+UK. More frequent and severe droughts[18] in many regions can negatively impact forest health, productivity and carbon sequestration. Drought-induced water stress can weaken trees[19], making them more susceptible to pests, diseases, and wildfires. Infestations and diseases can weaken forests and reduce productivity, as seen with the Norway Spruce in Austria[20] in the last years, and increase the risk of forest decline and decreased carbon sequestration. Reduced water availability also affects forest regeneration and can lead to shifts in species composition and distribution. Currently, two-thirds of forests in EU27+UK are potentially vulnerable to natural disturbances. Southern and Northern Europe are particularly susceptible[21] to wildfires, insect outbreaks and windstorms.

Additionally, recent studies in France showed that rising temperatures can have detrimental effects[22,23] on the ability of trees to act as carbon sinks, particularly during warm summers. As temperatures increase, trees may experience physiological stress, leading to reduced photosynthesis rates and increased respiration. This imbalance can cause a decline in carbon uptake, limiting the capacity of forests to grow and sequester CO_2. Climate smart forestry, as described on page 23, can be a potential solution to climate change risks.

Figure 15 *A tree that is affected by bark beetles.*

INCREASING FOREST PLANTATIONS: LAND USE CHANGE

Based on our modelling exercise we see that to meet future timber demand in the long term, new forest plantations are needed. New forest plantations imply land use change, as shown in Figure 16. A recent study[24] by the Potsdam Institute for Climate Research found that in high-ambition scenarios (defined as 90% of new urban housing in timber in 2100): **the forest plantations that are needed for ambitious timber construction scenarios contribute to an increase of roughly 21% on the spaceclaim of forest area in the EU.** The combined (also from other sectors) increase in forest plantation area is the same as 30 Mha (in 2020 the total FAWS was 137 Mha[7]) or the same size as Finland. The expansion of forest plantations will result in a reduction in the area of cropland, pastures and rangeland in the EU. The study shows that in Europe new forest plantations will not expand at the cost of primary forest.

On a global level, forest plantations (and cropland) are estimated to **expand at the cost of unprotected natural forests and non-forest natural vegetation.** This might entail losses in biodiversity (natural systems are replaced) and soil carbon. However, land-use change differs greatly per country and region: the negative effects of **land-use change will mainly be in tropical regions**. Additionally, land-use change implies competition for land, which necessitates **strong governance and careful planning, something that may be lacking in certain regions.**

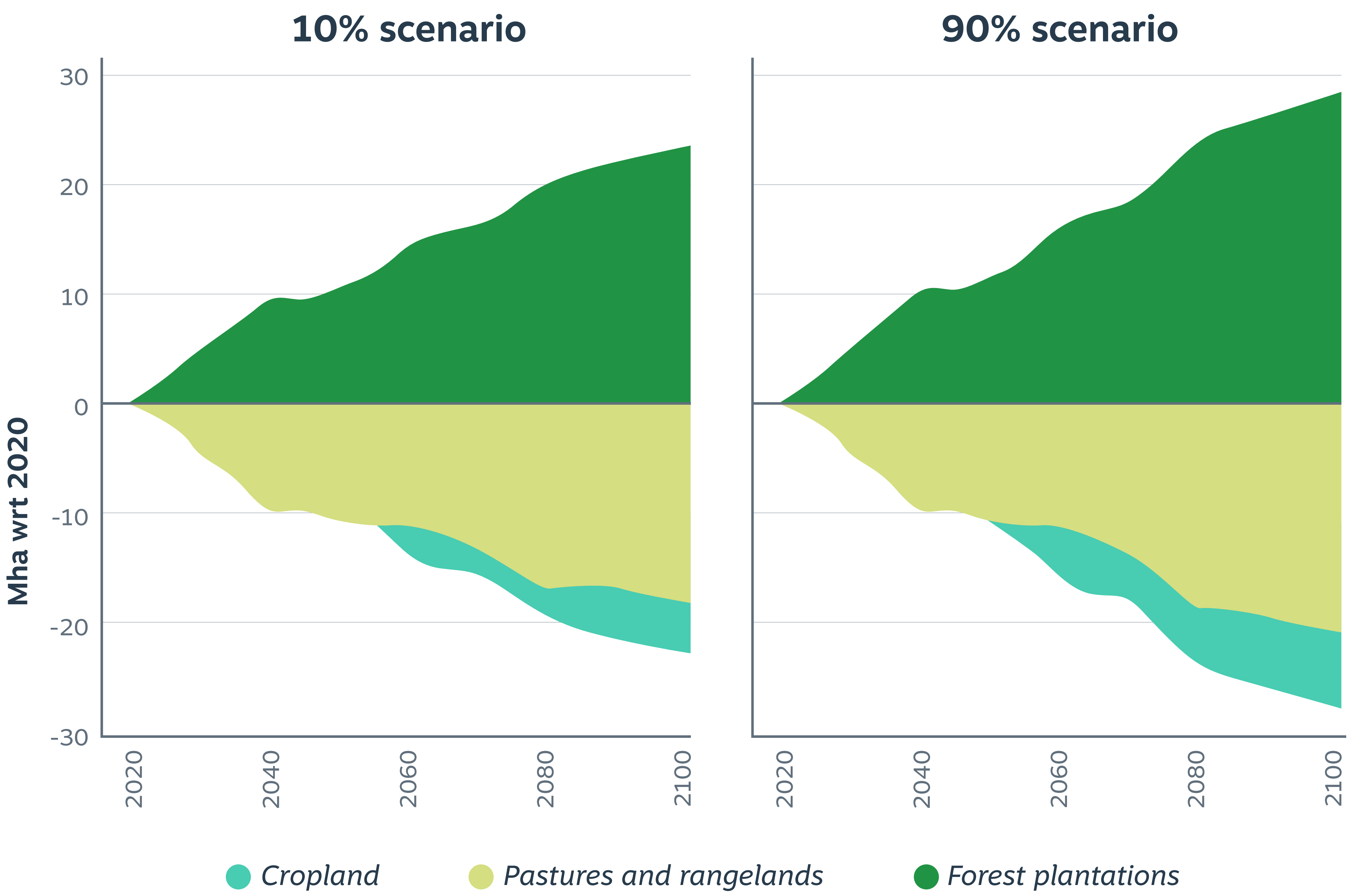


Figure 16

Land use change in EU between 2020-2100 in an SSP2 world. Values above 0 indicate increase in land-use compared to 2020 and values below 0 indicate decrease in land-use compared to 2020 for individual land-use types.[24]

COPING WITH UNCERTAINTIES

Smart, efficient wood (re-)use

To cope with the limits of a sustainable wood supply, a number of strategies[25] can be deployed:

- The utilization of wood and wood co-products for energy production must be limited as much as possible and wood should be redirected to higher value, long-term carbon storage applications such as construction.
- The resource efficiency of wood products can be further incorporated into choosing products for construction projects: LVL has, for example, a lower resource demand than CLT or GLT.
- The material efficiency of existing material concepts must be optimized, for example by combining the resource intensive CLT with less resource intensive OSB.
- Material concepts that can add value to low-quality forest resources and co-products of existing process streams should be developed.
- Markets, infrastructure and supply chains for the high-value re-use of timber products should be developed.

Climate-Smart Forestry and sustainable forestry

Climate-Smart Forestry[26] (CSF) is a methodology to address uncertainties in forest management under climate change by reducing the net emissions of greenhouse gases into the atmosphere, adapting and building forest resilience to climate change and sustainably increasing forest productivity and economic welfare based on forestry (as shown in Figure 17).

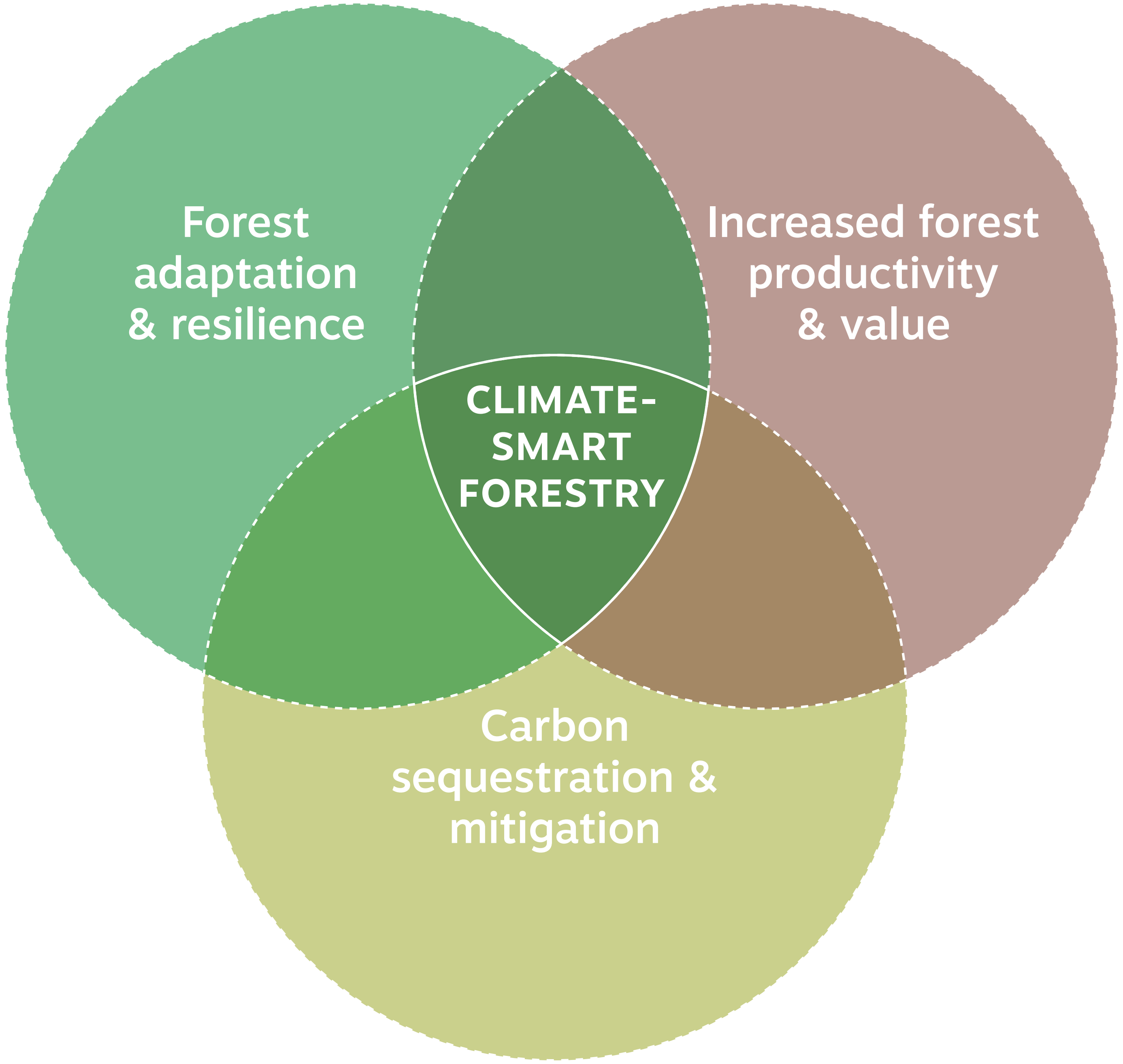


Figure 17 *Climate smart forestry framework (adapted from EFI[27]).*

One aspect of CSF could be the introduction of more deciduous species for resilience of forests in the light of climate change. The application of hardwood for construction products is technically feasible but is not widely applied. Making the sector ready for these 'new' and 'different' types of timber products is essential. This means trialing and certifying products made from these different types of wood to make sure they can be used in construction at scale.

05 Conclusion and next steps

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CHAPTER 05

CONCLUSION & NEXT STEPS

Although the building sector is a major contributor to climate change, by applying bio-based alternatives to conventional 'mineral' construction materials, we can reduce the environmental impact of the EU27+UK sector by 18%. However, the projected increase in wood consumption cannot be resolved within the realistic growth potential of our harvesting activities. This unbalance may have negative effects on the health of our forests and the ecosystem services these supply.

Redirect existing timber flows to be used in 'high- value' applications. The vast majority of currently harvested timber is used for the production of paper products (e.g. cardboard) and energy generation. From a sustainability point of view, using timber (a potential carbon sink) for short cycle products or energy production is not ideal. Redirecting these timber flows to applications in which the stored carbon actually remains stored is essential to reduce our carbon impact on the planet and to not overstretch our forests. Here the cascading of existing wood streams is also essential. Instead of burning a wooden beam after its first cycle, reintroducing it as a window frame could prevent the consumption of 'virgin' wood significantly. If carbon sequestration of the applied materials is taken into consideration, replacing 50% of the constructed residential typologies with bio-based typologies would allow us to sequester an additional 69 Mton of carbon. Here we need to take into consideration that this carbon has been stored in the past 30+ years and that new storage will only take place over time.

Stimulate sustainable forestry practices. To create future-resilient forests that can provide us with ecosystem services and (enough) materials for a construction sector that operates within planetary boundaries, new forestry practices need to be implemented. This is crucial to both increase the resiliency of our forests in a changing climate as well as deal with increased demand from multiple sectors in the future. Based on research from Wageningen University[16], we need up to 20 years to increase the realistic harvest potential by 20%.

Develop bio-based construction with higher resource efficiency, from a broader range of wood species and forest products. We need to use our wood more efficiently to cope with the limits to wood supply by creating and choosing products that demand less wood. Additionally the majority of our current EWPs are made with pinewood. If we want to create more future-resilient forests, we need to start using different types of species. Also secondary wood products should be considered as material sources for new EWPs.

Create thorough measuring systems to better understand actual consumption of wood. There is a lot of confusion about the current production capacity and consumption of timber products. To ensure that we do not overstretch our forests and to monitor the transition to more bio-based construction, a more thorough measuring system is essential, particularly in light of the new classification of wood products coming into effect in 2024.

Understand the inertia in the construction sector. Projects that start today will be realised in 5-10 years. The fact that the construction sector will run out of its carbon budget for 1.5°C in 3 years means that there is no time to waste. Every project we start now needs to incorporate sustainable materials.

Push for bio-based construction, but understand we also need to critically review our demand for new housing. Even if all construction is shifted towards bio-based typologies (in which a significant percentage of 'mineral materials' are replaced with bio-based alternatives) we can 'only' reduce the impact of the sector by 18%. This means that (on top of other sustainability strategies such as circular material use) we also need to drastically reduce the demand for new housing to remain within planetary boundaries. This can be achieved in different ways, for instance by constructing smaller housing units and typologies that are less impactful such as lowrise multifamily housing units instead of detached houses.

More significantly, we need to reduce the amount of housing units we build by making better use of the existing building stock and renovating these buildings to be habitable and shareable by different groups of people.

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This report has been made possible through a generous funding from the Built By Nature Network.

Built by Nature is a network and grant-making fund dedicated to accelerating the timber building transformation in Europe:

- *radically reducing embodied carbon; safely storing carbon in our buildings for generations;*
- *and sequestering carbon by championing forest stewardship and regeneration.*

For more information please visit: https://builtbn.org/

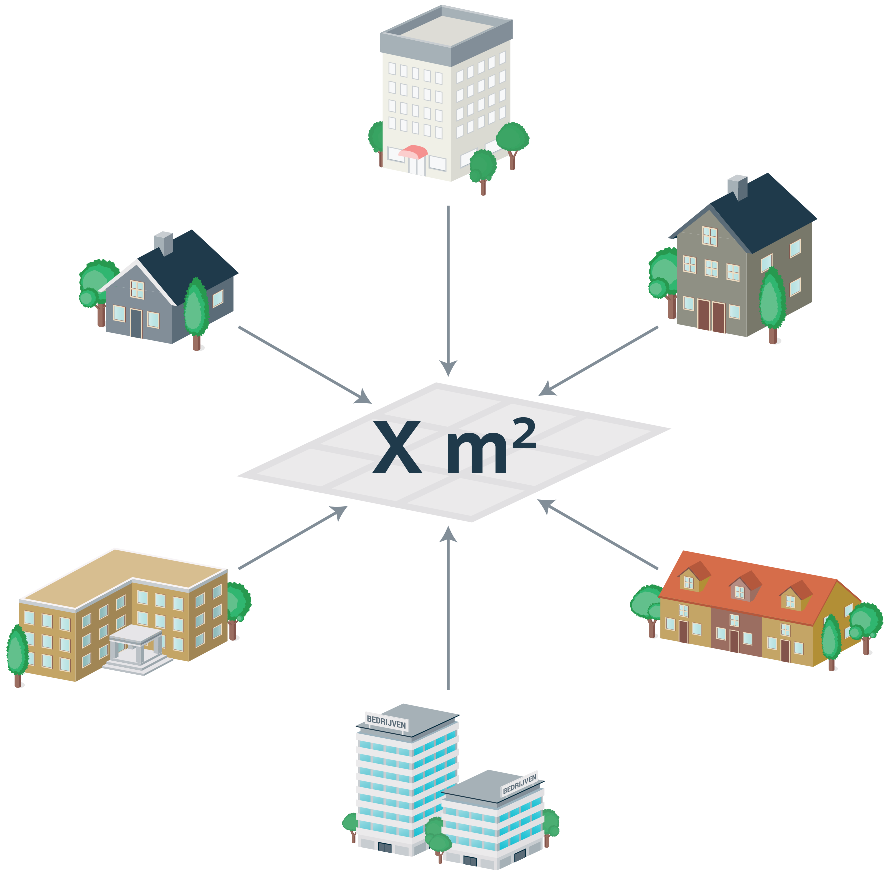
Annex

ANNEX 1: METABOLIC'S URBAN MINING MODEL

To estimate the material demand for new construction, Metabolic's Urban Mining Model was used. This model consists of archetypical building profiles for each of the four regions in Europe (North, South, East and West) and nine different building types as defined by the European Commission. These building profiles contain the total collection of all building products used in the building, from window frames to foundation piles. These building products are then linked to materialization information to estimate the mass and volume of 20 unique material types, such as concrete, insulation, glass etc. The building products are also linked to environmental impact factors from the Nationale Milieudatabase[28], the Dutch national database for environmental data on building products.

These building profiles are then reduced to a number of products per m² footprint of a building (see Figure 18). The numbers per m² are linked to data on the additions to the building stock for each of the building types for each of the countries in the EU27+UK, based on various data sources, amongst others the EU Building Stock Observatory.[29, 30, 31]

Multiplying the total constructed m² per building type and country by the building products required per m² gives us an estimation of the total material demand and linked environmental impact for the construction sector in Europe.



INFOBOX

Building stock additions

The total constructed floor space in m² per building type and country is derived from the combination of two data sources. The first is the total size of the building stock per building type and country, expressed as m². This data is then combined with the construction rates, expressed as a percentage of the total stock that is added on a yearly basis.

INFOBOX

Building variants

For the comparison of conventional construction and bio-based construction in the next chapters, two different building variants are used: the conventional building types, which consist of varying types of mineral materials (mostly concrete) and vary per region. For the bio-based construction profiles, timber-based building profiles are used which use CLT and EWP to replace 'mineral' options where possible.

Figure 18 *Visual representation of material flow model.*

ANNEX 2: S-LAYERS IN BUILDING

Analyzing the material demand provides insights into individual materials' impact, while a holistic evaluation requires assessing materials and their correlated impact at the building layer level as well. This comprehensive approach includes the consideration of Global Warming Potential (GWP) and Environmental Cost Indicator (ECI).

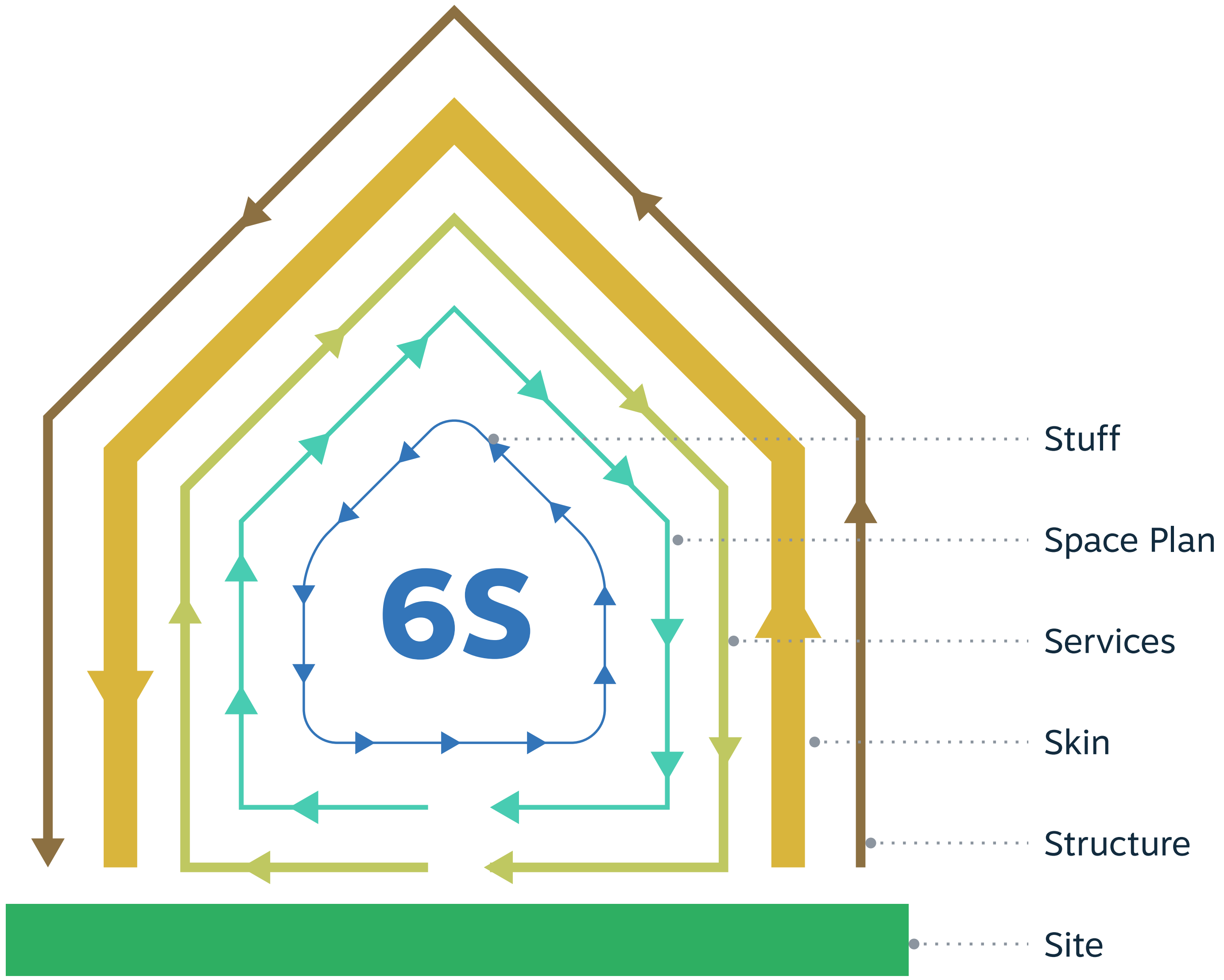


Figure 19 *Shearing layers of Brandt.*

INFOBOX

Shearing layers of Brand

Shearing layers (S-layers) view buildings as composed of different layers, each representing components and different aspects of the building. This framework (see Figure 19) helps analyze their influence on sustainability and performance.

Global Warming Potential

The GWP evaluates the CO_2 emissions associated with the entire lifecycle of a building material or product. It provides insight into the carbon impact of these materials.

Environmental Cost Indicator

The ECI takes into account eleven different environmental indicators, such as acidification, ozone depletion, and freshwater ecotoxicity, among others. These indicators are combined to estimate the overall environmental impact. By incorporating multiple indicators, the ECI ensures a thorough and comprehensive evaluation of the ecological consequences directly related to building materials and their correlated activities.

ANNEX 3: TRANSPORTATION EMISSIONS OF EWP

The main urban centers, the places where the demand for timber construction materials will be, can be serviced with an environmental impact of less than 2.5% of sequestered carbon (<19kg CO_2 per m^3) from current productions locations of engineered wood products.[32]

However, in Southern Europe and Eastern Europe there are many areas where more than 2.5% of sequestered carbon is emitted when CLT is transported there by truck from current production locations to a building site (see Figure 20).

Overall, especially when transportation will decarbonize and supply chains will be optimized, **Europe can be serviced with minimal transportation emissions.** In this analysis it is not taken into account whether production locations can supply the entire demand of a specific region.

While emissions are minimal and might not provide an incentive for establishing more production locations spread throughout Europe, there is also a value in having localized supply chains. There are advantages in having a so-called biomass cluster[33]: in this concept companies are co-located to share information, reduce transportation costs and enhance the utilization of waste wood and therefore save resources to contribute to forest preservation and carbon emission reduction.

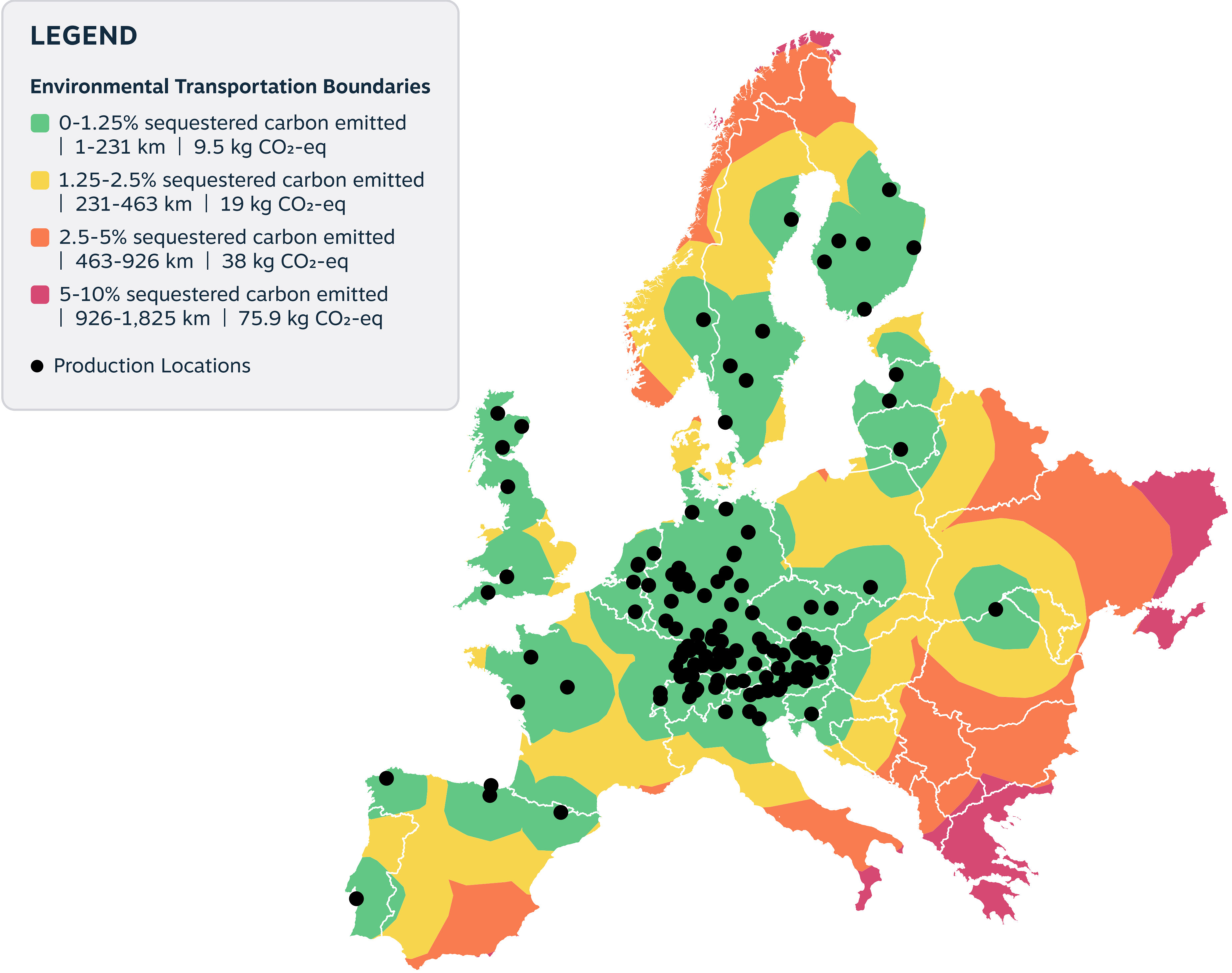


Figure 20 *Transportation emissions for CLT from current and planned EWP production locations in EU27+UK.*

ANNEX 4. CUMULATIVE MATERIAL DEMAND SCENARIO ANALYSIS

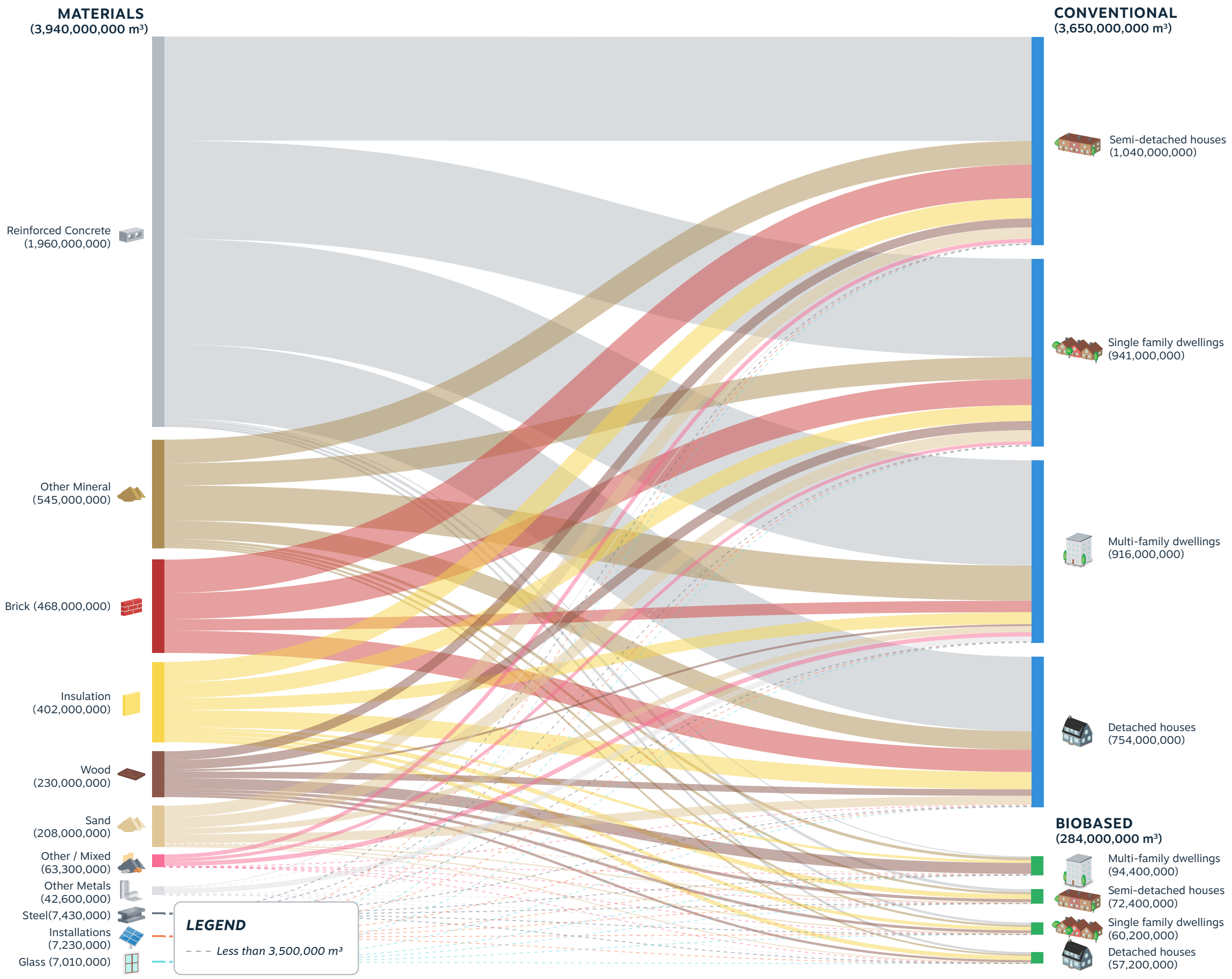


Figure 21 *Cumulative Material Flow Analysis of Stagnation scenario, by volume (m³) until 2030.*

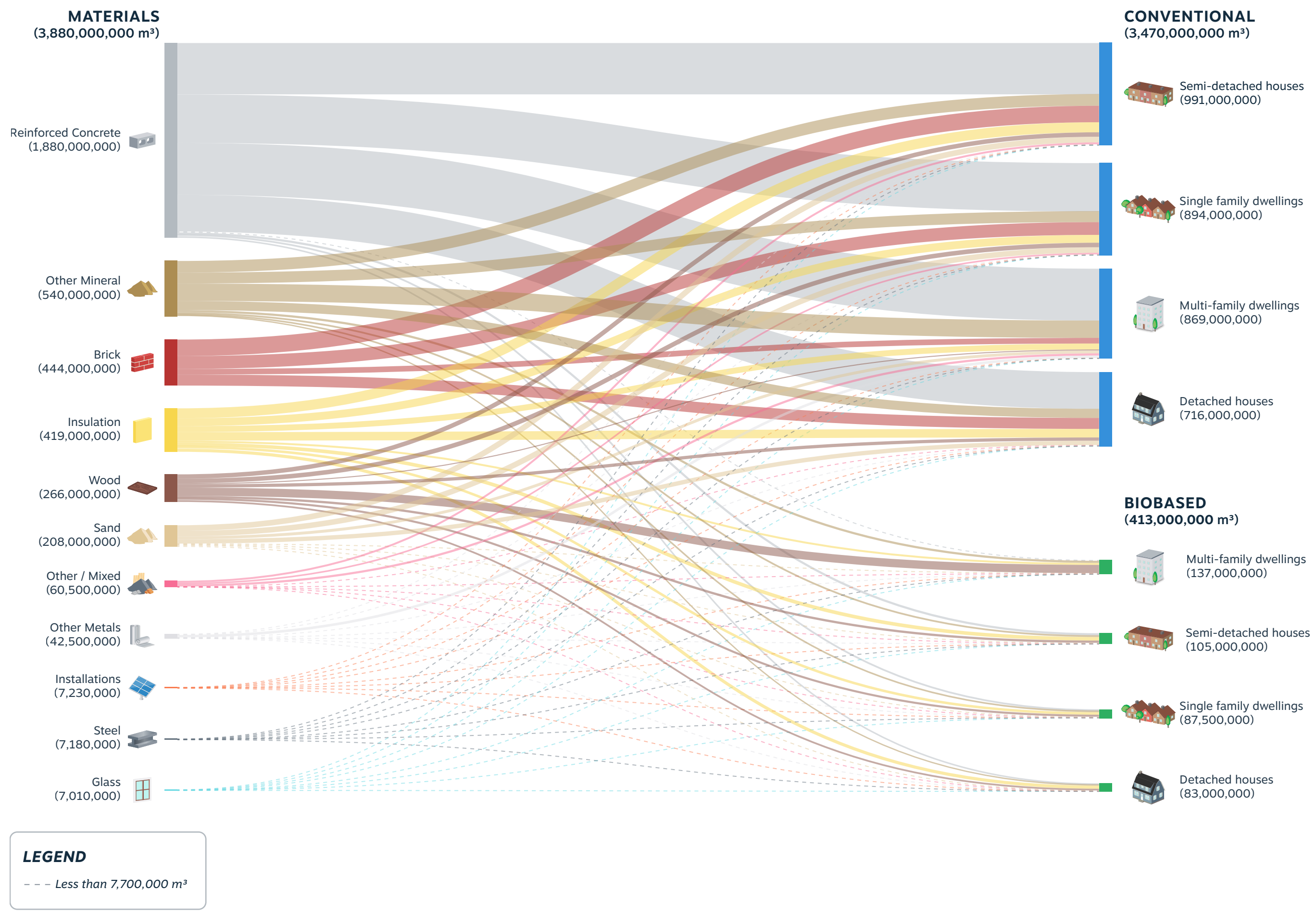


Figure 22 *Cumulative Material Flow Analysis of Moderate Ambition scenario, by volume (m³) until 2030.*

The Material Flow Analysis illustrates the inflow of building materials, by volume, and allocation of the materials towards conventional construction and bio-based construction. In the Stagnation scenario, the existing proportion of bio-based buildings remain unchanged until 2030. As outlined in chapter 2, it is evident that concrete accounts for the majority of the material demand across all residential building typologies. Among the materials used, wood is ranked fifth in terms of volume, with a volume of 230,000,000 m³. Bio-based construction has a share of 7% of the total material inflow, with a volume of 284,200,000 m³. Semi-detached and multi-family buildings have the highest share of material volume in bio-based construction.

The Moderate Ambition scenario presents a reduction in total material inflow of 2%. This reduction is a result of an increase in bio-based material usage in bio-based construction. The total volume of wood is increased to 266,000,000 m³, still ranking fifth of all materials used for new construction. Bio-based construction has a share of 12% of the total volume of material inflow, with a volume of 413,000,000 m³, an increase of 47% compared to the Stagnation scenario.

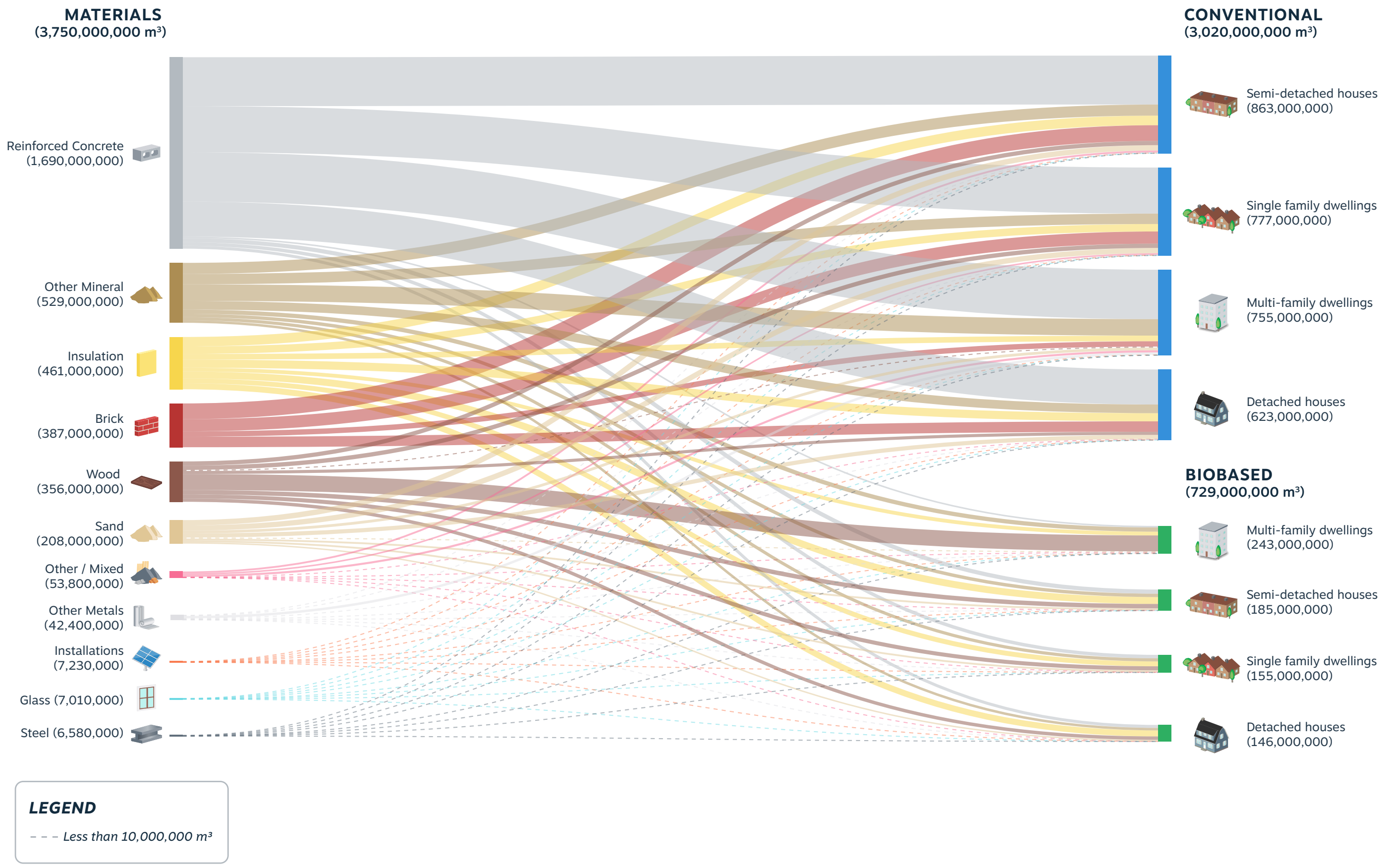


Figure 23 *Cumulative Material Flow Analysis of High Ambition scenario, by volume (m^3) until 2030.*

In the High Ambition scenario, there is a 5% decrease in the overall volume of material inflow compared to the Stagnation scenario. This reduction is attributed to the use of bio-based materials in 50% of new construction. The total volume of wood is increased to 356,000,000 m^3, still ranking fifth among all materials used for new construction. The share of bio-based construction increases up to 19%, with an increase of 170% in comparison to the Stagnation scenario. The volume of materials used for bio-based construction within the High Ambition scenario is now 729,000,000 m^3.

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