FRACTAL FOREST

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East Africa sustainable timber construction
Supply and demand study

Decarbonising the construction boom

By 2050 one billion additional people will live in African cities, all of whom need decent housing, schools and places to work. If the Paris Agreement to limit the world's temperature increase to 1.5°C above pre-industrial levels is to be met, a range of solutions are urgently required to decarbonise the coming construction boom.

Find out more

This is the short version of the East Africa sustainable timber construction supply and demand study. To discuss this report or for a copy of the longer version with further details on the methodology, scenarios, residential typology study, the supply and demand model contact Caroline Ray caroline.ray@arup.com.

As a natural low carbon material, the role that timber can play in place of carbon intensive materials such as steel and concrete is gaining increased attention. A recent study[1] suggested that housing 90% of the world's growing urban population in mid-rise wooden buildings could prevent 106bn tons of carbon emissions by 2100. This is equivalent to the last 20 years of USA carbon emissions.

Material switching on this scale would create unprecedented new demand for timber which in turn leads to concern over whether it can be supplied sustainably from managed plantations without adverse impact on natural forest.

This research presents the findings from a supply and demand study for sustainable timber in construction, and mass engineered timber (MET) in particular. It includes 20-year projections of how this may change under three scenarios: 'business as usual', a realistic 'timber transition', and optimistic 'timber renaissance'.

Given the scale of the challenge we face to balance the needs of the environment and of society our optimistic scenario or 'timber renaissance' is purposefully ambitious, requiring systemic change in the enabling environment, supply chain and the construction industry.

Method

Our research focused on three overarching factors, the enabling environment, supply, and demand. Research into the enabling environment and demand focused on Kenya. While supply, looked at Kenya, Tanzania and Uganda.

Data gathering was based on stakeholder mapping, documentation review and interviews. Subsequently we developed qualitative descriptions of the three scenarios as a way of illustrating change required to realise each.

We also developed a supply and demand model, for greater understanding of and insight into the supply chain. The supply side traces volumes from plantations through to kilns, separating the pre-requisite steps required for engineered timber. The demand side focuses on the residential sector, specifically the use of engineered timber for mid rise residential buildings, and sawn timber for single family dwellings.

In order to inform the indicative model, we carried out a concept design of a mid-rise residential timber building. This enabled us to explore cost, carbon, fire engineering and buildings insurance, specific to the Nairobi. Whilst the typology chosen is relatively typical it does not necessarily equate to an average design and so the numbers generated by scaling up this typology in the demand model should be treated with caution.

[1] 1 Mishra, A., Humpenöder, F., Churkina, G. et al. (2022) Land use change and carbon emissions of a transformation to timber cities. https://doi.org/10.1038/s41467-022-32244-w

Findings

Enabling Environment

The enabling environment for the use of sustainable timber in construction is currently undeveloped with gaps across governance, policy, incentives and regulation.

Whilst the Kenya Forestry Service and Kenya Timber Manufacturers Association represent growers and manufacturers respectively there is no industry body dedicated to use of sustainable timber in construction. Establishing such a body will provide a focal point for driving initiatives across this area. The Tanzania National Timber Sector Development Framework is a key reference and developing a similar framework for Kenya could be a priority action for such a body.

Policy both within Kenya and as relates to imports from Uganda has not been conducive to supply. The logging moratorium in Kenya has served to stifle the domestic manufacturing supply chain. By contrast the EU funded SPGS has been effective in increasing projected pine volumes in Uganda. The import costs from Uganda and Tanzania will have a significant effect on future demand and regional coordination and cooperation will be key.

To date national incentives such as tax relief on the importation of raw timber have been applied inconsistently. Demand policy within Kenya does not explicitly promote timber in construction, although steps are being taken to promote green technology, for example through EDGE certification. Financial institutions are providing loans and bonds to support green construction, often tied to the use of IFC EDGE as a framework/target, presenting an opportunity to influence material choice. Ideally this would be backed up through a national carbon taxation mechanism and integration of emissions targets into Government strategies. At present there is an active voluntary carbon trading market in Kenya, primarily for international buyers but with an increasing local market. The majority of these projects are in the forestry sector indicating such opportunities are already being pursued.

At time of writing, the Kenya National Building Code 2020 remains in draft. If approved it would support timber design via the Eurocode suite, until then however there is no code for engineered timber. The draft does not include targets for carbon emissions. Once approved the next step will be the authoring of a Eurocode National Annexe for Kenya, for the design and construction of timber and MET, including local empirical timber design values.

Buildings insurance and fire risk are often cited as barriers to uptake. For MET to be used as a structural building material (especially at height), there will be a requirement to adopt a fire engineered performance-based approach. Insurers are open to new technology but are likely to require additional design documentation in the form of fire life safety and strategy reports. A key impact on building design is a requirement for sprinklers. According to our typology study this could add as much as 18% to the overall building cost compared to traditional construction which does not require this measure.

Initial consultations suggest building insurance premiums will be in the region of three to four times higher when using MET as a structural material. Building insurance premiums are based on economies of scale and this premium would likely reduce in case the technology became more common.

18%

Annual growth in construction, Nairobi's fastest growing sector, between 2016-2020

2.3bn m^3

Predicted global demand for sawn timber in 2020

Supply

Pine, a softwood, is the most commonly available timber in the region followed by eucalyptus which is a hardwood. Pine is well suited to use in construction as sawn wood or else as engineered timber. Tanzania has the largest area of timber plantation in the region and associated volume of timber supply, this is anticipated to remain the case under all three scenarios.

Uganda has the smallest area of plantations of 105,000ha, but as a consequence of the successful SPGS a large volume of pine sawlogs is expected to come onto the market in the next ten years. This will far exceed the capacity of the Ugandan market to either process or utilise the timber and the export of timber will be required to avoid a drastic reduction of domestic wood prices.

It is important that any further increase in demand is met by sufficient supply to prevent disruption to material flows. This study suggests that under ‘business as usual’ there would be sufficient supply of timber from these plantations to support increased use in construction, but that ‘business as usual’ manufacturing capacity would prevent this. The ‘timber transition’ scenario sees a modest increase in annual sustainable cut, associated primarily with the Kenya logging ban being lifted and KFS plantations (150,000ha) becoming productive. The ‘timber renaissance’ scenario assumes expansion of private plantations (180,000ha) across the region. Further work is required to understand the viability of KFS replanting, private Kenyan small holdings as well as regional land availability and biodiversity impact of such an increase in plantation area.

In regards to FSC certification, although Uganda has the smallest total plantation area, it has the largest resource of well-managed FSC certified plantations. Kenya has no FSC certified plantations. The current total of FSC certified plantations in the region is 47,000ha or 7%.

Engineered timber must first be kiln dried and of suitable size and quality before it can be glued together. FSC certification is highly likely to be another prerequisite, as clients, developers and consumers looking to utilise MET, will require assurances that the timber being used is sustainably sourced. Kiln capacity, FSC certification and forest management practices (and therefore quality and suitability for construction) all require strengthening. Finger jointing capacity is also very low, although considered easy to establish and so should not be a bottleneck in case of investment in MET. In comparison there is greater sawmill and treatment capacity, noting absence of data for sawmills outside of Kenya.

Although Uganda has the smallest total plantation area, it has the largest resource of well-managed FSC certified plantations.

Under the ‘business as usual’ scenario the region is estimated to generate just over 2million m^3 of sawn timber. Once consideration is made for FSC certification, quality and kiln capacity the volume drops to just 63,000m^3. By comparison the UK produces three million m^3.

Investment is needed along the supply chain, not just in the establishment of MET factories of which there is effectively no capacity at present. MET requires stringent quality control during the gluing process and specialist testing to ensure quality. A number of larger companies, namely Green Resources and The New Forests Company have installed kilns to dry timber from their sawmills which would allow this timber to be used to manufacture engineered wood products.

Under the ‘timber renaissance’ scenario, annual production of sawn wood increases to just over four million m^3 with sufficient kiln capacity to dry nearly one million m^3 and MET capacity of ~0.5million m^3. Kiln capacity should exceed MET capacity in order to ensure a supply of structural grade sawn timber for other uses such as trusses. By comparison the USA currently produces ~1million m^3 of MET. This scenario assumes that over 40% of multi storey residential and commercial market demand is met by engineered timber buildings (either hybrid or fully timber).

Demand

Demand for both MET and structural grade sawn timber are currently low, as evidenced by the lack of the kilns and MET factories. Where sawn timber is used in construction it is typically ‘green’ (timber that has not been kiln dried), with demand currently estimated at 0.5million m^3.

The population of Nairobi is growing at a rate of 4.7%, among the highest growth rates in Africa. Construction was the fastest growing sector between 2016-2020 with 18% annual growth.

Kenya needs to build about 200,000 new housing units every year in its cities just to keep pace with population growth and rocketing demand, according to a World Bank study.

An embryonic green building market exists and this is likewise forecast to grow, with Manufacturing Africa assessing that low-cost housing and apartment blocks present the two largest markets for sawn timber.

Global demand for sawn timber was predicted to reach 2.3billion m^3 in 2020[2], with much of that demand driven by construction. Engineered timber supply is a small fraction of this, with USA and Europe combined accounting for ~5million m^3 or 0.2%. Housing and particularly single-family dwellings are a key driver in the global and regional demand for sawn timber where it is used to form trusses and rafters for roofs in particular.

MET can be well suited to the demand for mid-rise residential construction in urban areas due to potential savings associated with prefabrication and being a lightweight material. Glulam is well suited to longer span beams or columns whilst prefabricated CLT panels are typically used for floors and walls, allowing columns to be omitted and saving time on site.
By replacing heavy materials such as stone and reinforced concrete with timber you reduce the weight of the building, which has additional savings in the design of the supporting beams, columns and foundations, further reducing the amount of concrete required.

Awareness of MET in Kenya is low among the public, developers, authorities and the construction industry.

Universities and other educational institutions are not thought to teach timber design. Materials are studied in general but not specifically timber or MET. Known structural timber projects have relied on international expertise for both structural and fire design. In contrast carpentry is one of the primary trades in Kenya with nearly 15,000 registered carpenters, albeit primarily focussed on furniture, doors, windows. This provides a significant base from which to upskill recognising that additional training would be required for structural use of sawn timber and certainly for engineered timber which requires specialist skills and tools for fabrication and assembly.

[2] FIM. (2017) Update on Global Timber Demand. https://greshamhouse.com/wp-content/uploads/2019/10/b559c09a1d19574edffdb71b3cfb249c_df1552964b6c5812ba8314ec47e52a42.pdf

Cost will be key in overcoming distrust of a new technology such as MET and in driving demand for timber in construction generally.

Since the introduction of the logging moratorium the cost of sawn timber in Kenya has doubled, far exceeding costs in Uganda. Importing sawn timber from Uganda brings significant added and sometimes uncertain costs. With very limited MET manufacturing capacity in the region locally sourced engineered timber is currently prohibitively expensive. South Africa manufacturers for glulam and CLT are globally competitive and are typically cheaper than European manufacturers. Importing MET into Kenya from South Africa is likely to add at least 20% to the cost.

Buildings are made of various components with different materials bringing different qualities which are not necessarily directly comparable at component level and so it is important to assess overall building cost. Our mid-rise residential typology suggests that under the ‘business as usual’ scenario both hybrid and fully MET options are significantly more expensive (+38% and +66%) than traditional construction. Notably fire protection in the form of sprinkler systems accounts for 15-18% of the overall building cost. For comparison, CPS, a developer in Tanzania reports CLT as currently being 15% to 25% more expensive than standard construction, but fully tax exempt.

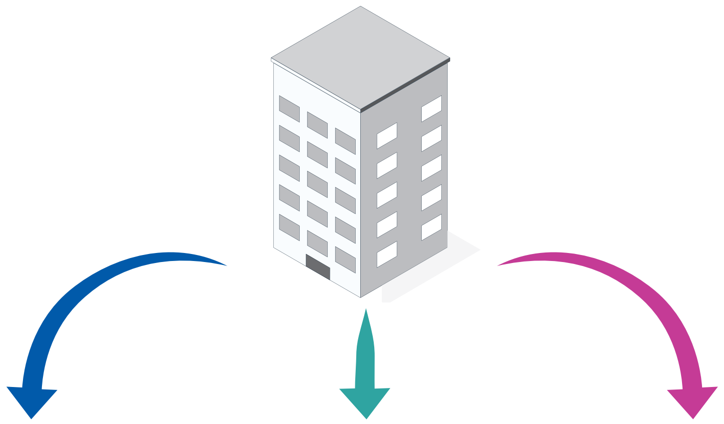
For the ‘timber renaissance’ scenario the overall building costs for hybrid construction becomes comparable (+7%) to traditional construction methods and mass timber construction becomes more cost competitive (+17%). Fire protection in the form of sprinkler systems could account for ~10% of the overall building costs.

Whilst utilising lightweight timber for mid rise buildings enables savings in other parts of the structure it brings additional requirements such as fire protection which serve to counteract that saving. The ‘timber renaissance’ scenario assumes a rate of 600USD/m^3 for engineered timber, which is at the low end of rates from South Africa which in turn are lower than average globally, further illustrating the challenge of competing on cost.

Timber is being increasingly put forward as part of efforts to decarbonise construction. Our mid-rise residential typology study suggests that up to 40% of the embodied carbon could be saved compared to traditional construction materials utilised in Nairobi. Uptake of best practice environmental approaches in the manufacturing supply chain could increase this saving to ~50%.

This would represent a total saving of embodied carbon by 2040 within the multi storey residential sector of 234,000 tCO_2e and 2,970,000 tCO_2e under our ‘timber transition’ and ‘timber renaissance’ scenarios respectively.

Utilisation of the voluntary carbon market presents a possible opportunity to improve cost competitiveness of timber buildings. Our study determined a carbon price of 330-500 USD/tCO_2e to bridge the difference in construction cost, far exceeding the current market average.



		Traditional			Hybrid			Mass timber		
Material volumes (m^3)	Concrete	~1,300			~800			~500		
	Timber	0			~400			~1,000		
		BAU	TT	TR	BAU	TT	TR	BAU	TT	TR
Cost (USD/m^2)		564	564	564	779	692	607	939	796	659
Embodied carbon (tCO_2e)		1,181	1,181	1,181	837	837	800	705	705	616
Carbon price to eliminate cost difference compared to traditional (USD/tCO_2e)		n/a	n/a	n/a	1,875	1,116	338	2,363	1,462	504
Buildings insurance premium (% of the total sum insured)		0.2%	0.2%	0.2%			0.65%			0.775%

Residential Typology Study

A hypothetical mid rise tower was designed to concept stage in timber and compared against a traditional reinforced concrete tower and a third hybrid design.

The table summarises material volumes, cost, embodied carbon, carbon price required to eliminate any cost difference and buildings insurance for each of the three designs.

The study shows the cost of construction for timber and hybrid reducing in each scenario as a result of economies of scale. These reductions are insufficient to match traditional construction and they remain +17% and +7% more expensive respectively in the ‘timber renaissance’ scenario.

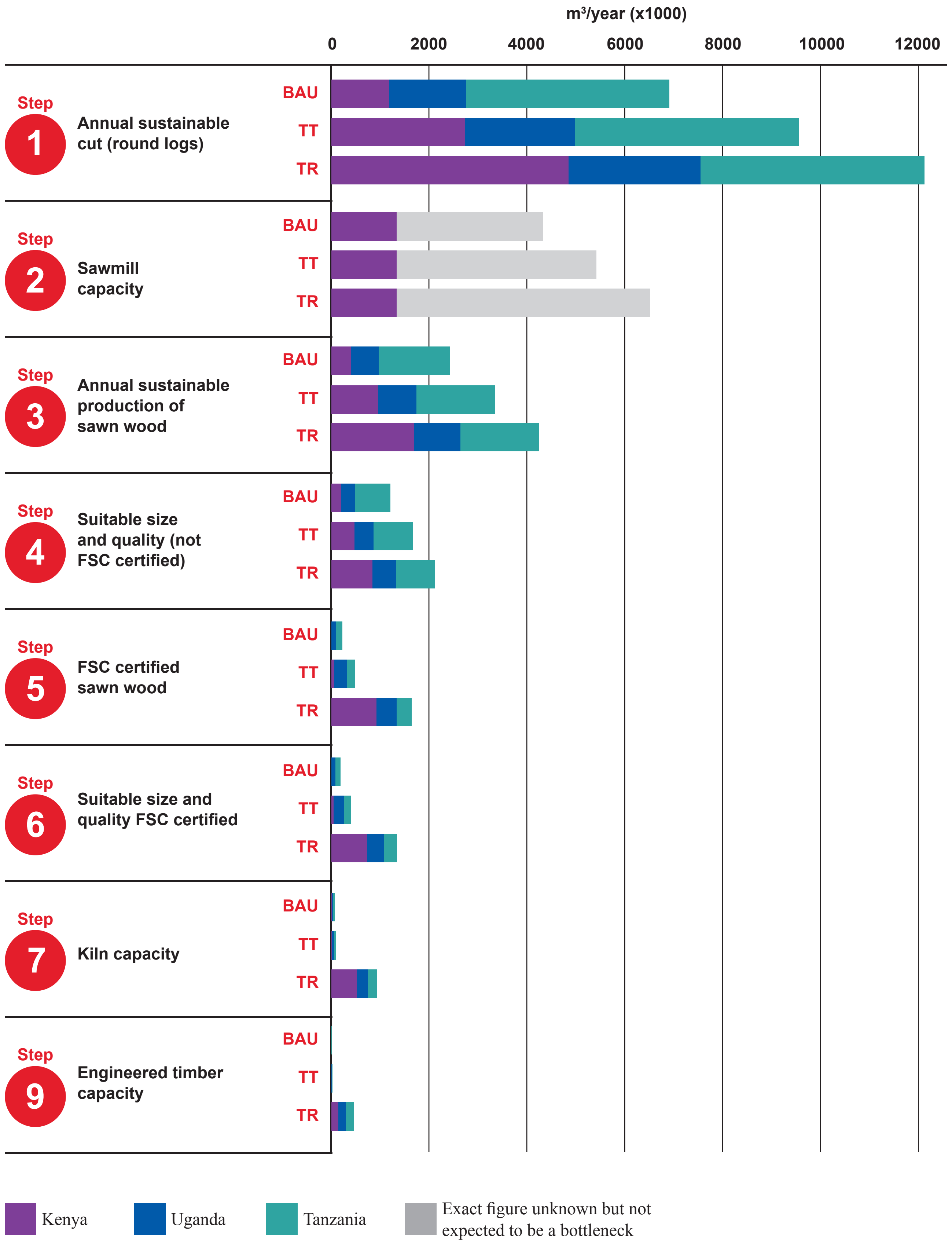
Embodied carbon savings from timber are significant, and could be improved further by emulating European MET manufacturer standards of efficiency and renewable energy, with a reduction of 40% for a fully timber building under the ‘timber renaissance’ scenario.

Regional Supply - Scenario Comparison

Under 'business as usual' there is effectively no MET capacity and there are significant drops in capacity at each step illustrating the need for investment along the supply chain. FSC certification and kiln capacity are key constraints where capacity should be increased if MET factories are to be established. Sawmill capacity may also need to increase, depending upon the total regional capacity (which is currently unknown).

Whilst the annual sustainable cut far exceeds the capacity of subsequent step it is assumed it would also need to increase. This acknowledges the fact that timber flows outside of the construction industry are not accounted for in this study.

	BAU	TT		TR	
Regional plantation area (ha x1000)	519	739	▲ 42%	917	▲ 77%
(m³/year (x1000))	BAU	TT		TR	
1 Annual sustainable cut (round logs)	7,000	9,600	▲ 37%	12,200	▲ 74%
3 Annual sustainable production of sawn wood	2,450	3,375	▲ 37%	4,275	▲ 74%
4 Suitable size and quality (not FSC certified)	1,225	1,675	▲ 37%	2,150	▲ 74%
5 FSC certified sawn wood	225	485	▲ 115%	1,660	▲ 640%
6 Suitable size and quality FSC certified	190	410	▲ 115%	1,350	▲ 640%
7 Kiln capacity	63	88	▲ 40%	950	▲ 1400%
9 MET capacity	0.2	40	N/A	470	N/A



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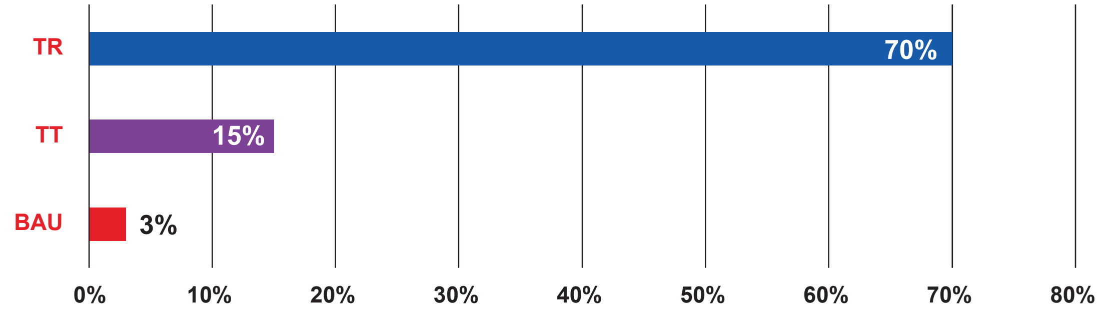
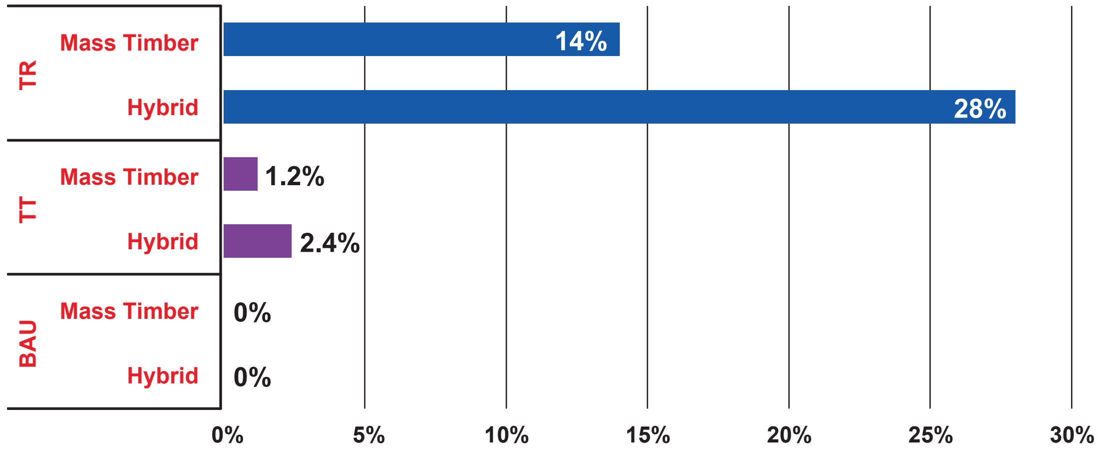
Kenya Demand - Scenario Comparison

Comparing the three scenarios in terms of market share, resulting demand for new buildings and volume of timber required in the year 2040. A cumulative market share of 3.6% under 'timber transition' scenario would require between one and two large MET factories. A 42% market share under the 'timber renaissance' scenario would require between 17 and 25 large factories.

Green Building Market % in 2040



Timber Market % in 2040



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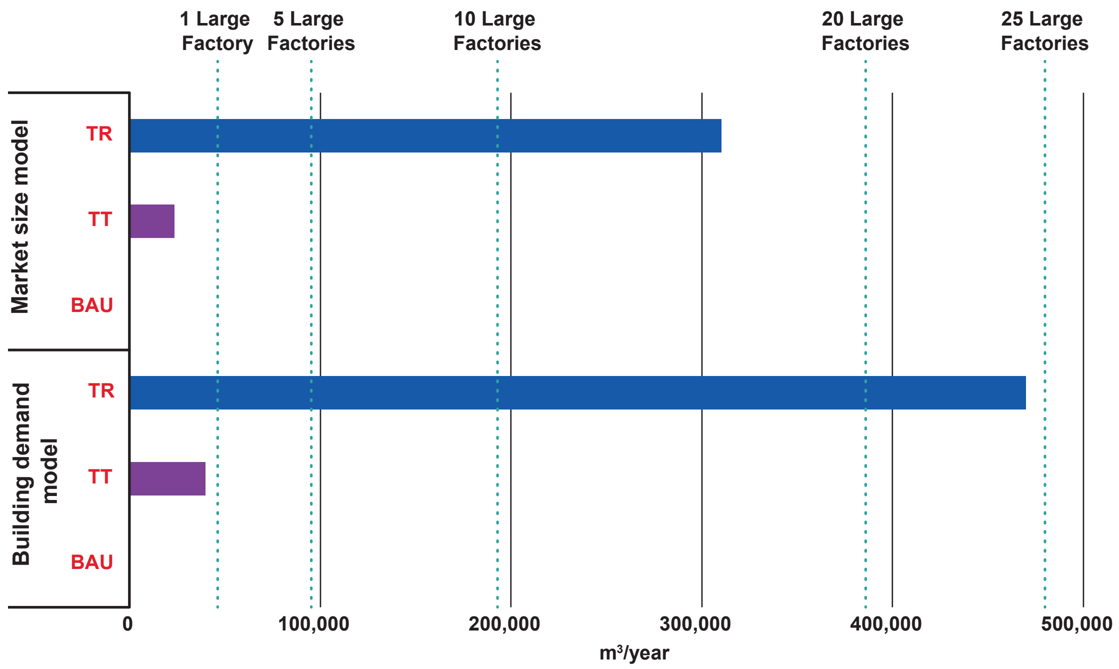
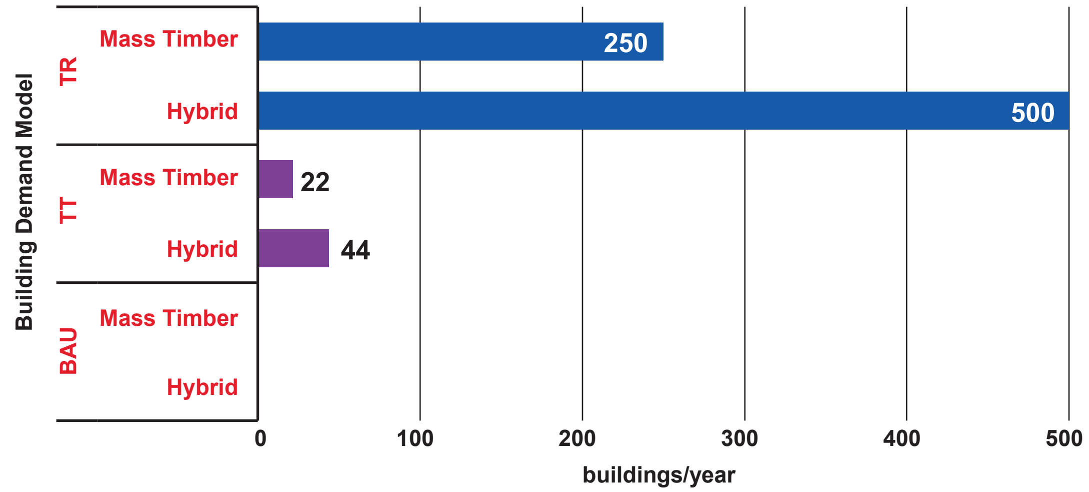
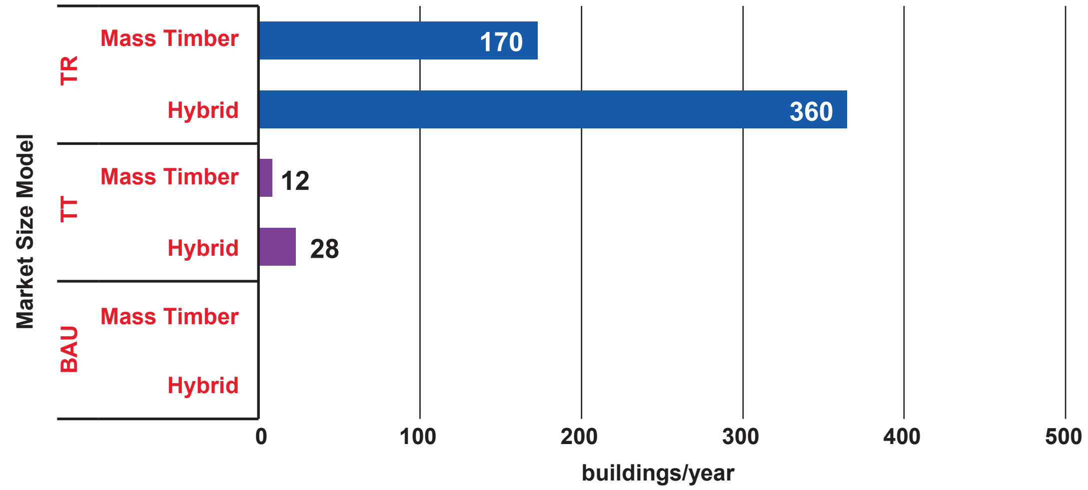
Estimated Volume Demand of Mass Timber in 2040



Estimated No. of Buildings Constructed in 2040 based on the Building Demand Model



Estimated No. of Buildings Constructed in 2040 based on the Market Size Model



Supply vs Demand

The demand for sawn timber across the construction industry accounts for ~30% of the annual sustainable sawn timber supply in all three scenarios. The assumption is that the remaining timber continues to be used in other industries.

The demand for MET takes up 30 to 50% of all of the suitable sawn timber in the ‘timber transition’ and ‘timber renaissance’ scenarios.

This would leave 50 – 70% for other uses of structural grade sawn timber. This is high compared to present day economies that have MET capacity where it remains a small part of the overall timber construction industry.

Supply and demand volumes for ‘green’ sawn timber and MET in 2040

	Regional supply		Kenya demand (residential and commercial sectors)	
	Sawn timber	Sawn timber suitable for MET	Sawn timber	MET timber
	Step 3 Annual sustainable sawn timber before considering FSC, kiln capacity, size and quality	Step 7 Kiln dried, fSC certified sawn timber with required size and grading for MET	Estimated demand for sawn timber used for all informal construction e.g. trusses, formwork etc.	Estimated range of demand for MET based on indicative demand models.
BAU	2,500,000 m³/year	63,000 m³/year	750,000* m³/year	0 m³/year
TT	3,400,000 m³/year	88,000 m³/year	975,000* m³/year	23,500-40,000 m³/year
TR	4,300,000 m³/year	946,000 m³/year	1,300,000* m³/year	310,000-470,000 m³/year

*BAU sawn timber demand estimates are based on extrapolations to 2040 from current demand estimates (with an estimated annual growth of 4.2%).[3] An arbitrary 30% and 75% increase has been applied to represent sawn timber demand increases in the ‘timber transition’ and ‘timber renaissance’ scenarios, representing increased uptake of timber construction generally.

[3] Gatsby. (2019). KCFP value chain assessment – Sawn Timber.

Decarbonising the Built Environment

The overall embodied carbon saving that could be achieved in Nairobi by the year 2040. The model assumes an incremental increase in the use of timber up to 2040.

This calculation combines the embodied carbon calculation from the mid rise residential typology study with the indicative building demand model.

	BAU	TT	TR
Total number of buildings by 2040	N/A	**400** hybrid buildings	**4,500** hybrid buildings
	N/A	**200** mass timber buildings	**2,250** mass timber buildings
Total embodied carbon saving by 2040	N/A	**~234,000** tCO_2e	**~2,970,000** tCO_2e

Action plan

This section describes a prioritised action plan with short, medium and long term actions in line with the research framework. It is recognised that the owners for particular actions will represent a broad range of stakeholders and ability to influence will vary. Further detail on actions to be taken can be found in the scenarios.

	Short term	Medium term	Long term
Enabling environment	Industry body dedicated to advancing the use of sustainable timber in the construction industry is established. Kenya logging moratorium lifted for sustainably managed forests. National Timber Sector Development framework is authored and implemented. National Building Code 2020 to be approved.	EDGE certification is championed by government and applied to increasing proportion of the industry with target levels increased over time. Uganda SPGS is replicated across the region. Eurocode National Annexe for Kenya authored for design and construction of timber and MET. KEBS develops MET testing standards. Kenya develops a carbon taxation mechanism, with a forward pricing corridor tied to the Paris agreement.	Import duties are set to encourage regional trade. Ministries develop decarbonisation plans for commercial, industrial, residential construction sectors.
Supply	Timber manufacturers invest in MET and kilns in particular. Existing plantations are managed sustainably.	Quality increases through improved forest management practices. FSC certification increases, as does practice of grading.	
Demand	Landmark showcase projects are completed. Industry awareness campaign initiated, focussing initially on link to EDGE.	Kenya specific courses developed for design professionals. Local university/educational institution to incorporate a timber design course within its curriculum. Mechanism to be put in place that allows lessons learnt from first timber/MET projects to be shared throughout the industry. An awareness campaign is established to champion benefits of timber construction linked to sustainability, EDGE, fire safety.	Local engineering firms to develop capacity in performance based fire engineering. National Building Code subsequently updated to include carbon emissions targets.

Priority actions

Priority Actions

Near term priority actions, balancing the need to address supply and demand in tandem, supported by a strengthened enabling environment.

Regional coordination and cooperation will be key, particularly around supply.

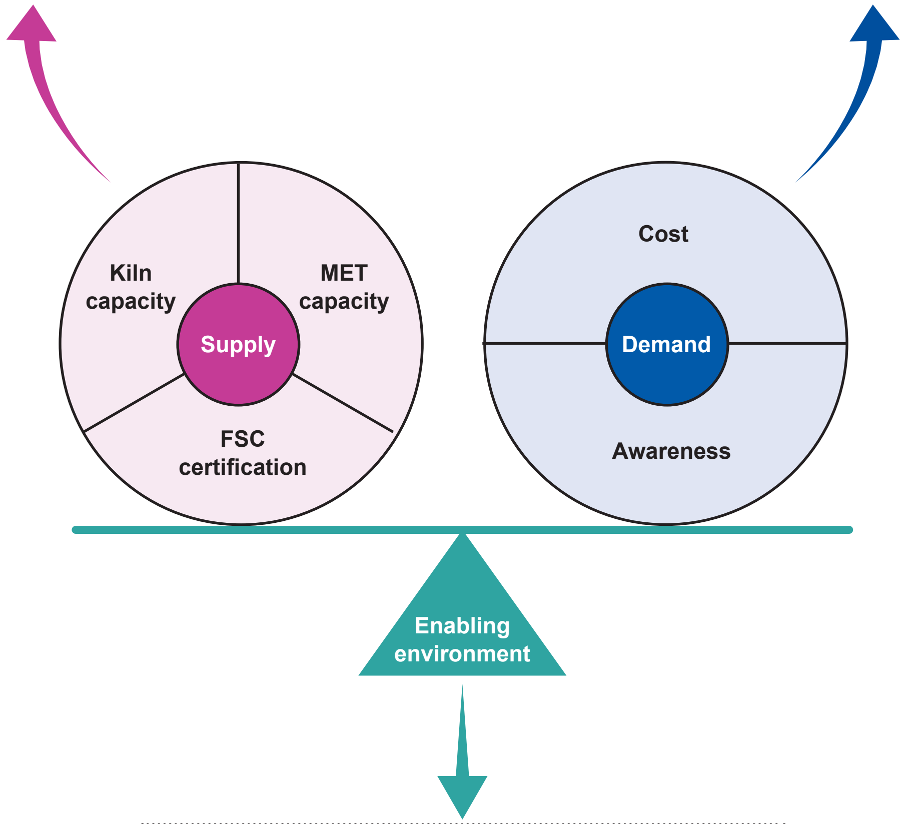
Any investment in MET first requires a reliable supply of kiln dried sustainable timber of suitable size and quality. Supply chain investment should seek to increase structural grade sawn timber as well as engineered timber recognising demand particularly for single family dwellings as well as mid rise residential.

Further investigate fire protection costs.

Commission econometric model to understand impact of carbon markets on the cost of timber over time.

Promote use of timber as a way to achieve EDGE certification and access climate finance.

Raise awareness through landmark demonstration projects and reassure the industry of viability.



Establish a body dedicated to promoting sustainable timber in construction with aim to influence at highest levels. Priorities include developing a National Timber Sector Development Framework.

Disclaimer

This report is not intended for and should not be relied upon by any third party and no responsibility is undertaken to any third party. In preparing this report we have relied on information provided by others and we do not accept responsibility for the content, including the accuracy and completeness, of such information. Forward-looking projections, forecasts, or estimates are based upon interpretations or assessments of available information at the time of writing. We accept no responsibility for the realisation of any projection, forecast, opinion or estimate. Findings are time-sensitive and relevant only to conditions at the time of writing.

We caution that data scarcity, complexity of interdependent factors and resulting assumptions require the supply and demand model be treated with caution. The value of the model, the qualitative scenarios and the typology study (as detailed in the full report) is in identifying bottlenecks and areas for further work.

Acknowledgements

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The project team which carried out the study were Caroline Ray, Tim White, Tom House, Andrew Lawrence, Gavin Maloney, David Barber and Kristian Steele of Arup and Mike Howard of Fractal Forest.

Glossary

CLT — Cross Laminated Timber
CLT panels consist of layered timber boards stacked crosswise at 90-degree angles. Glue is applied between layers and then pressed hydraulically, pneumatically or by vacuum. Finger joints and structural adhesive connect the boards length ways.

EDGE — Excellence in Design for Greater Efficiencies
EDGE is an innovation of International Finance Corporation, a member of the World Bank. EDGE was created to respond to the need for a measurable and credible solution to prove the business case for building green and to unlock financial investment.

FSC — Forestry Stewardship Council
FSC is an international, NGO dedicated to promoting responsible management of the world's forests. FSC's certification system, enables businesses and consumers to choose wood, paper and other forest products made with materials that support responsible forestry.

LULUCF — Land Use, Land-Use Change and Forestry
LULUCF is one of the sectors under the United Nations Framework on Climate Change that measures and accounts for emissions and removals of CO2 from land and forests.

MET — Mass Engineered Timber
MET is a collective term for a group of building materials comprising engineered wood products with improved structural integrity. Usually consisting of structural panels or beams made from multiple solid pieces of timber bonded together.

SPGS — Sawlog Production Grant Scheme
SPGS is an European Union funded scheme in Uganda providing financial grants and technical support to commercial tree planters, rural communities, public and private institutions, to promote investment in commercial tree planting and increasing the income of rural populations.

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