Circular Timber Construction Report

—Mass timber strategy and quantitative analysis for “more” and “longer” use of wood—

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Chapter 0

Value Created by Circular Timber Construction and Its Issues

0.1 Circular Timber Construction

In order to have a sustainable society, it is both necessary to use resources that can be produced in a sustainable manner, and to utilize and reuse the produced resources without waste.

When forest resources, one of the most abundant resources in Japan, are used as building materials in the construction field, the material characteristics of wood, featuring both ease of processing and a certain level of strength, present high potential for sustainable production and high-efficiency utilization. Beginning with the forestry industry that produces lumber, if the timber industry and the construction industry devise ways to utilize timber effectively, and furthermore, if the recycling market matures, more efficient material utilization will be promoted. "Sustainability" can be established only if all phases from production to consumption become economically profitable. Thus, to maximize the environmental value of Japan's rich forest resources as a material "timber" resource, we named our concept of construction for promoting economic circulation, thereby contributing to the sustainability of forests and society, "Circular Timber Construction," as a term signifying the timber-type circulatory construction often used in recent years.

0.2 Concept of Circulation between Resources and Capital

The production and distribution of timber in society is often likened to a river, and forestry as the starting point is called "upstream"; the timber industry processing materials is called "midstream"; and the construction industry consuming materials is called "downstream." In this paper, we define the circulation as a continuous cycle in which resources flow from upstream to downstream, with capital flowing from downstream to upstream.

In recent years, capital inflows into the timber market have begun with the following three points in the background.

1. Expansion of ESG investment
→ Increase in the use of timber
2. Increase in Mass/Tall Timber structure
→ Increase in demand for laminated wood with a large cross-sectional area
3. Soaring overseas resource prices
→ Increase in demand for domestic timber

If the above is continued, business expansion and job creation as described in the following three items will be anticipated in midstream.

1. Expansion of timber supply
→ Capital Investment for increased processing capacity and yield rate
2. Boosted production of high-value-added laminated wood with a large cross-sectional area
→ Introduction of new processing machinery
3. Streamlining of supply channels
→ Development of preferred production and processing mills locations

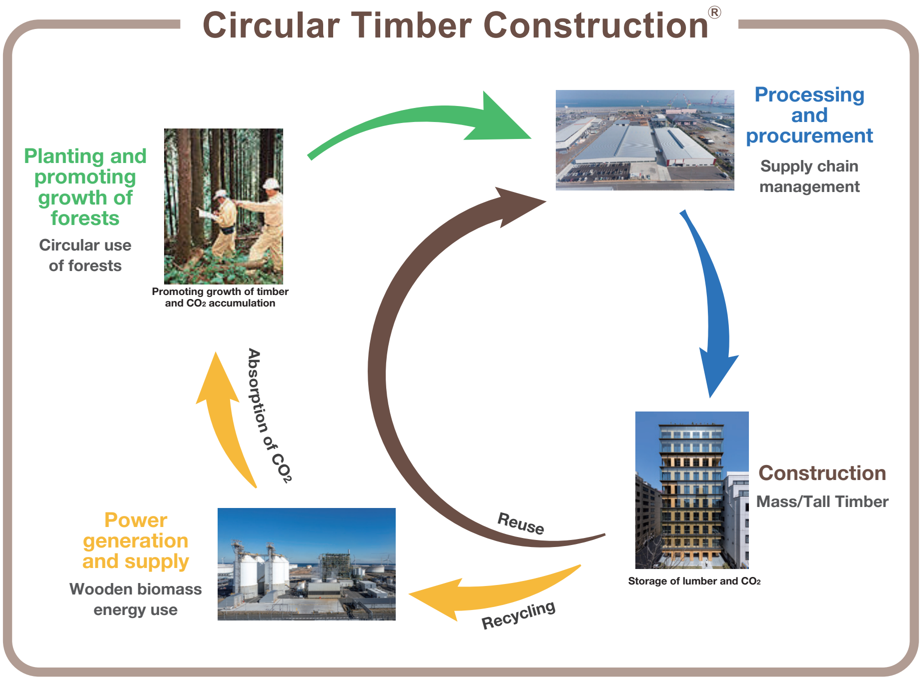

Figure 0.1: Basic Concept of Circular Timber Construction

If midstream activities are vitalized, capital will eventually be returned upstream, leading to a healthier forestry industry from the business point of view and preservation of the national land, as shown in the following three items.

1. Expansion of raw wood supply
→ Expansion of investment and job creation
2. Implementation of reforestation
→ CO_2 fixation and land conservation
3. Rebalancing of tree planting species
→ Planting forests in view of demand and ecosystems

The chain as described above is the basic flow of resources and capital in the Circular Timber Construction aimed to be achieved at the moment.

0.3 Issues in Circulation and Economic Feasibility

While the chain shown in the previous section is the basic structure of Circular Timber Construction, there are issues in the upstream, midstream, and downstream areas, respectively, to realize the above and to create further circulation. First, in the upstream area, the following two major issues have been identified.

1. Reforestation is an investment in the future more than 30 years from now, and cannot be done without a long-term vision for upstream and midstream.
2. Currently, planted forests are mainly Japanese cedar ("*Sugi*"), but it is necessary to plant tree species other than *Sugi* for high strength timber based on strategic analysis.

Next, in the midstream, the following two issues have been identified, because detached houses have been the main market for a long time, and the bulk of timber supply has been dominated by imported materials.

1. Determining whether engineered wood products, particularly structural glued laminated timber (GLT), cross-laminated timber (CLT) and/or Laminated Veneer Lumber (LVL), is likely to see long-term demand
2. Exploring locations for production and processing mills suitable for optimizing supply routes from mountainous areas to cities

In particular, the second point should be verified proactively. While upstream locations of forests and downstream locations of cities are inevitably fixed, midstream locations are relatively flexible, and streamlining of supply routes can be achieved by the midstream, rather than upstream or downstream.

Finally, in the downstream area, although opportunities for active use of timber have been growing in recent years, the lack of a market for reuse and recycling of building materials after dismantling and the lack of stockyards for reused materials are current issues in terms of extending the carbon fixation period in timber. These are not only important from the perspective of long-term use of resources, but also as venues with economic value as new markets.

When it becomes a business field of "beyond downstream" going farther from the downstream, Circular Timber Construction can be realized not only as a sound flow of capital and resources, but also as a construction of a scheme in which the resources themselves are circulated.

These are the issues and possibilities from upstream to downstream, and the significance of Circular Timber Construction.

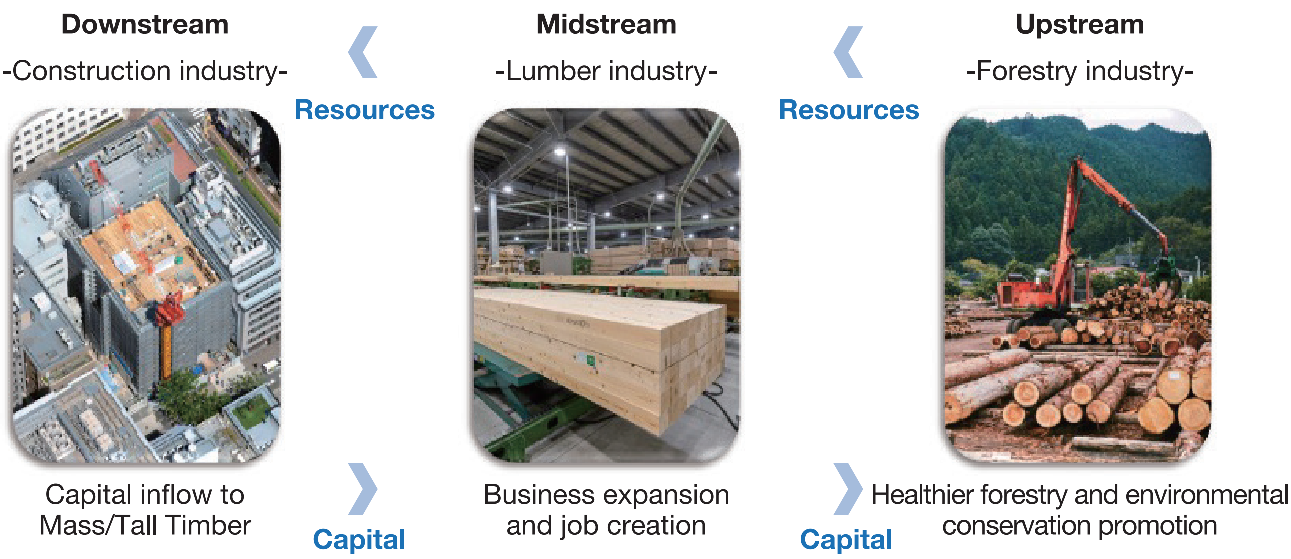

Figure 0.2: Basic Flow of Resources and Capital in Circular Timber Construction

Chapter 1

Upstream analysis —Ideal Forestry Resources To Be Supplied from Mountains—

1.1 Status of Forest Growing Stock in Japan

According to the Food and Agriculture Organization of the United Nations (FAO) Global Forest Resources Assessment 2020 (FRA 2020), 68.4% (approximately 25 million hectares [ha]) of the land area of Japan is forest, only behind Finland's 73.7% (approximately 22 million ha) and Sweden's 68.7% (approximately 28 million ha) among developed countries (OECD member countries). Of these 25 million hectares, according to a survey by the Forestry Agency, there are approximately 10 million hectares of planted forests and approximately 15 million hectares of natural forests, as shown in Figure 1.1

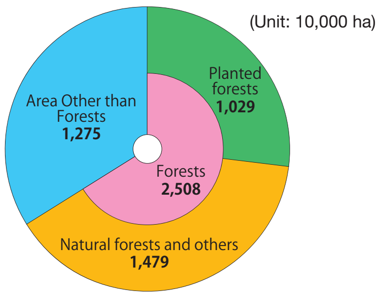

Figure 1.1: Breakdown of Land Area and Forest Area

In fact, this area of 25 million hectares has remained almost constant from the 1960s up to the present. However, overall, the forest growing stock has increased for more than 50 years due to the growth of trees, although there have been increases and decreases due to felling and planting. As shown in Figure 1.2, the forest growing stock, which was 1.89 billion m^3 in 1966, was estimated to be 5.24 billion m^3 in 2017, and planted forests are largely responsible for this increase.

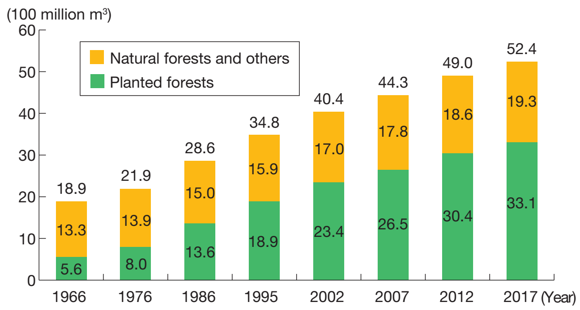

Figure 1.2: Change in the Forest Growing Stock

In addition, Japanese cedar ("*Sugi*") accounts for 44%, Japanese cypress ("*Hinoki*") 25%, Larch ("*Karamatsu*") 10%, pine tree species ("*Akamatsu*", "*Kuromatsu*", "*Ryukyumatsu*") 8%, Abies sachalinensis ("*Todomatsu*") 8%, and broadleaf trees 3% (Note 1). In terms of area, Japanese cedar ("*Sugi*") accounts for half, but from the growth rate, the majority of the above forest growing stock is planted forests, and half is comprised of Japanese cedar ("*Sugi*").

1.2 Advanced Aging in Forests in Japan

Figure 1.3 shows a table that classifies the area of planted forests whose age is clear by age class (a unit of five years of tree age; for example, Age Class 10 is 51 to 55 years old). The figure shows that the age 50 years or older accounts for exactly 50%. Most of the tree species used in the planted forests are Japanese cedar ("*Sugi*"), and while their growth rate varies depending on the region, they grow sufficiently for felling as timber in about 30 to 50 years (7 to 9 age class.) In other words, about 70 to 80% of the planted forest area has reached a state suitable for felling as materials.

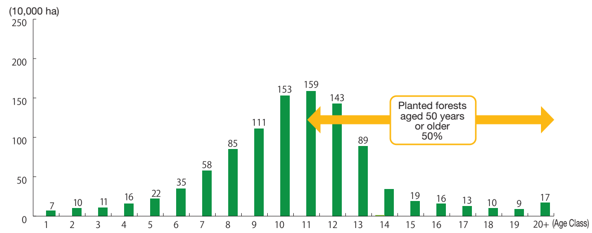

Figure 1.3: Age Class Composition of Planted Forests (2017)

Japan has abundant forest resources, and over the past 50 years, the growing stock, or timber in the forests, has continued to increase. This in itself may seem like a very good thing, but it can also be said that trees that have grown enough and can be used as building materials are left in the forest without felling. This is not just a lost opportunity. Figure 1.4 is a graph showing the amount of CO_2 absorption by tree species by forest age, and as can be seen from this graph, the amount of CO_2 absorbed by cedars that make up most of the planted forests rapidly declines in age 30 to 50. This tendency is evident in conifers, particularly in Japanese cedar ("*Sugi*"), and from the perspective of forests for carbon offsetting, it is effective to rejuvenate cedars that are older than 40 years by felling for utilizing and planting new trees.

As can be seen from the above, at least half of the Japanese cedar ("*Sugi*") in planted forests, which account for much of the forest growing stock in Japan, are approaching the time of felling from the viewpoint of CO_2 absorption capacity as materials, and, in other words, are aging.

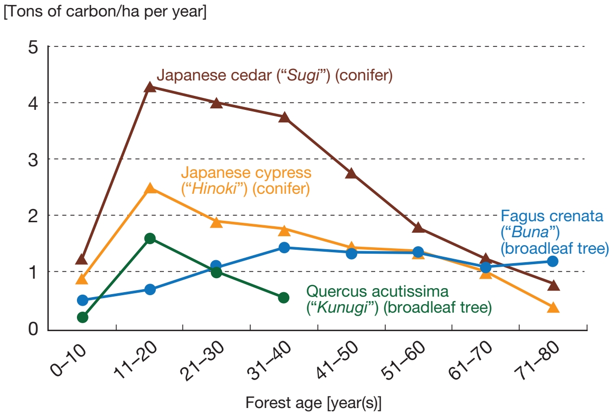

Figure 1.4: Amount of Carbon Absorption by Tree Species and Forest Age

Category	Total demand					Amount of domestic wood use				
	2014 (Result)	2019 (Result)	2020 (Forecast)	2025 (Forecast)	2030 (Forecast)	2014 (Result)	2019 (Result)	2020 (Target)	2025 (Target)	2030 (Target)
Total construction use	40	38	—	40	41	16	18	—	25	26
Sawnwood	28	28	28	29	30	12	13	15	17	19
Plywood	11	10	11	11	11	3	5	5	7	7
Total non-construction use	36	44	—	47	47	8	13	—	15	16
Pulp and chips	32	32	31	30	29	5	5	5	5	5
Fuel wood	3	10	7	15	16	2	7	6	8	9
Others	1	2	2	2	2	1	2	1	2	2
Total	76	82	79	87	87	24	31	32	40	42

Figure 1.5: Targets and Results (as of 2020) of the Amount of Domestic Wood Use Set in 2016

1.3 Forest Wood Use Policy

In consideration of the situation described in the previous sections, the Forestry Agency has set quantitative targets for expanding the use of domestic timber over the next decade based on the scenario of increasing demand for timber structures in its “Promotion of Forest and Forestry Reforms” (April 2018) in order to “transform forestry into a growth industry and to promote appropriate forest management.”

In addition, as shown in Figure 1.5, in the Annual Report on Forest and Forestry in Japan (Fiscal Year 2021), the target amount equivalent to roundwood for 2030 was shown to be 26 million m^3 for domestic use such as construction materials. In other words, an increase of 8 million m^3, or 1.4 times the 18 million m^3 in 2019, is aimed at.

In the next and subsequent chapters, we will clarify what this level means, whether the target value is achievable by the construction industry, and possible issues. In the “Promotion of Forest and Forestry Reforms,” an expansion of 10 million m^3 compared to 2015 is targeted, while the more recent Annual Report on Forest and Forestry in Japan (Fiscal Year 2021) aims for an increase of 8 million m^3 compared to 2019, so the numerical figures are different. In this report, we quantitatively examine the latter target value of 8 million m^3 and refer to the former demand expansion scenario for breakdown.

[Source]

Note 1: Annual Report on Forest and Forestry in Japan, Fiscal Year 2019, p. 54

Figure 1.1 : Annual Report on Forest and Forestry in Japan, Fiscal Year 2017, p.14, Data I-1

Figure 1.2 : Annual Report on Forest and Forestry in Japan, Fiscal Year 2021, p.54, Data I-2

Figure 1.3 : Annual Report on Forest and Forestry in Japan, Fiscal Year 2021, p.54, Data I-1

Figure 1.4 : Learning Museum of the Forest and Forestry, a graph of “Calculation based on Nagano Prefecture Regional Forestry Planning Major Tree Species Stand Volume Table”

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Figure 1.5 : Annual Report on Forest and Forestry in Japan, Fiscal Year 2021, p. 20, Data for Feature 2-5

Chapter 2

Analysis of Relationship between Upstream and Downstream —Quantitative Consistency between Supply and Demand—

2.1 Scenario for Expanding Use of Domestic Wood (1) Improvement in Wood Self-Sufficiency Rate in Low-Rise Residential Buildings

We will estimate the implications of the expected expansion of 8 million m³ (Note 2) according to two demand growth scenarios and quantitative consistency with the current situation in the downstream (domestic construction market) area (Fig. 2.1).

The first scenario is an increase in the domestic self-sufficiency rate in the existing wooden housing market. In the future, the supply of low-rise timber houses with one to three stories is expected to decrease, and the only way to increase demand in this market is to increase the domestic self-sufficiency rate of timber supply. The domestic self-sufficiency rate in 2018, before the "wood shock," was about 45%, but the "Promotion of Forest and Forestry Reforms" estimates that the domestic self-sufficiency rate will increase to two-thirds (about 67%) in 10 years (Note 3).

According to the scenario, improving the domestic self-sufficiency rate in the existing low-rise timber housing market is expected to account for 30% of the total demand growth (Note 2), and approximately 2.4 million m³ of the 8 million m³ increase is expected to come from the increase in wood demand for domestic low-rise housing.

2.2 Scenario for Expanding Use of Domestic Wood (2)-A Creation of New Demand for Domestic Wood in Low-Rise Non-Residential Buildings

The second scenario is to create new wood demand by switching from the currently supplied reinforced concrete (RC) and steel-framed buildings to timber structures.

First, as a volume zone where timber structures are expected, low-rise non-residential buildings with one to three stories can be mentioned. The scenario estimates that by increasing the current ratio of wooden low-rise non-residential buildings from about 10% to 60% over 10 years, 30% of the total demand growth will be achieved. This is equivalent to approximately 2.4 million m³ of 8 million m³ (Note 2). The estimate states that it is necessary to increase this timber structure ratio by 50%, in other words, to make one in two new low non-residential buildings wooden, based on a domestic self-sufficiency rate of 70%, a yield rate of 50%, and average volume ratio of 0.2 m³/m². Since it is generally said that the volume ratio of wooden houses using conventional construction methods is 0.2 m³/m², the scenario means switching to the equivalent of all-timber low-rise non-residential buildings (Fig. 2.2).

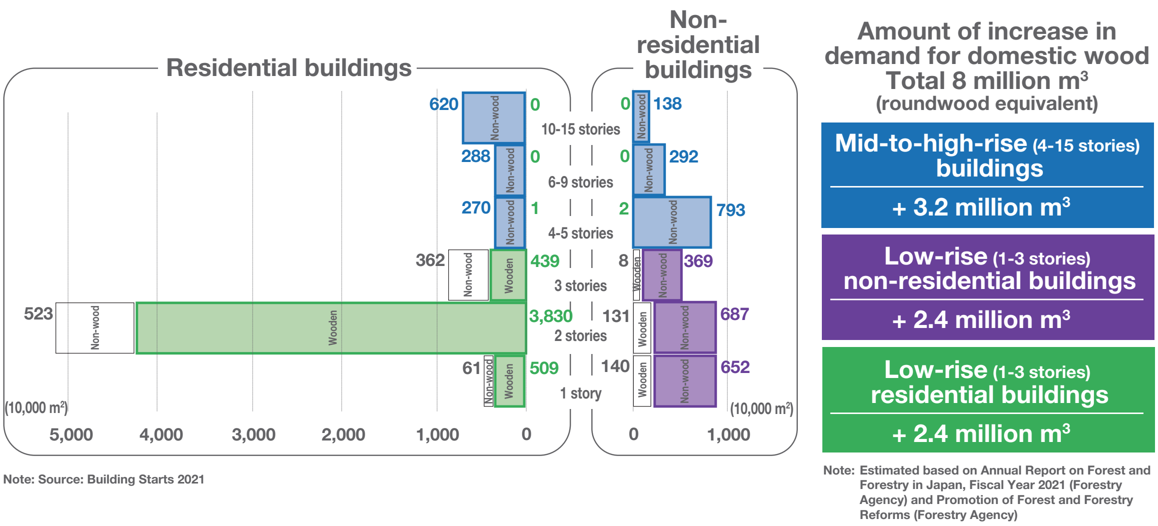


Figure 2.1: Breakdown of Use and Scale for Expansion of Domestic Wood Use (+ 8 million m³)

	Amount of increase in wood demand (Roundwood volume)	Yield ratio	Domestic wood ratio	Average volume ratio	Target market scale (2021)	Required ratio of wooden structure
Low-rise non-residential buildings (1-3 stories)	+ 2.4 million m³ *1	50% *1	70% *1	0.2 m³/m² *1	17 million m² *2	Approximately 50% *3

*1: Estimated value based on "Promotion of Forest and Forestry Reforms" (Forestry Agency)
*2: Building Starts 2021
*3: Required ratio of timber structure X = Demand for wood (roundwood volume) 2.4 million m³ x Yield rate 50% ÷ Domestic wood ratio 70% ÷ Average volume ratio 0.2 m³/m² ÷ Target market scale 17 million m²

Figure 2.2: New Demand for Domestic Wood for Low-Rise Non-Residential Buildings

Promoting timber structures with a volume ratio of 0.2 m^3/m^2 or more is required, and for this purpose, timber structures need a construction method that is competitive with other conventional construction methods such as reinforced concrete construction and steel frame construction. In the future, construction methods that can realize a long lifespan equivalent to steel frame construction and construction methods that can realize timber structures at low cost will be needed. Taking an example from Obayashi Corporation's efforts, there are development of "Omega Wood," a wooden material with a large cross-sectional area using fastening appliances without secondary gluing, and the "Shin'ei Kumano Worksite" (Fig. 2.3), utilizing "Omega Wood" for low-rise non-residential wooden buildings. In addition, in order to utilize wood resources more efficiently, it is also necessary to improve the yield rate and extend the service life.

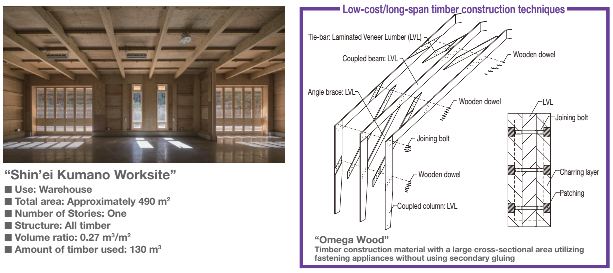


Figure 2.3: A Non-Residential Low Timber Case

2.3 Scenario for Expanding Use of Domestic Wood (2)-B Creating New Demand for Domestic Wood for Mid-to-High-Rise Buildings

Mid-to-high-rise buildings with 4 to 15 stories, which are currently rarely made of wood, are also expected to be converted to timber buildings. While the barriers to timber structures are higher for mid-to-high-rise buildings than for low-rise non-residential buildings, if the method is established, mid-to-high-rise buildings will lead to expanded timber demand.

"Promotion of Forest and Forestry Reforms" expects that 40% of the total demand growth will be achieved by making 25% of mid-to-high-rise buildings with timber in 10 years. When converted to a target value of 8 million m^3, the use of domestic lumber is expected to expand by approximately 3.2 million m^3 (Note 2). In this scenario in which one in four medium- and high-rise buildings is made of timber, the use of wood timber will be promoted based on the average volume ratio is 0.4 m^3/m^2 (Fig. 2.4). 0.4 m^3/m^2 implies twice the amount of timber used as compared to conventional wooden houses, but the majority of current tall timber has a volume ratio of less than 0.1 m^3/m^2, so there is a quantitative inconsistency with the scenario. In order to achieve this high material load ratio, it is essential to establish a method that uses thick paneled materials such as CLT, which uses a large amount of wood as an infill material for floors and walls, and effectively utilizes the size of the material volume as heat insulation and factory workability. For example, one example of these initiatives is the "Obayashi Corporation New Umeda Dormitory" (Fig. 2.5), which uses the CLT unit construction method to increase the amount of timber use and to achieve labor-saving and low-costs.

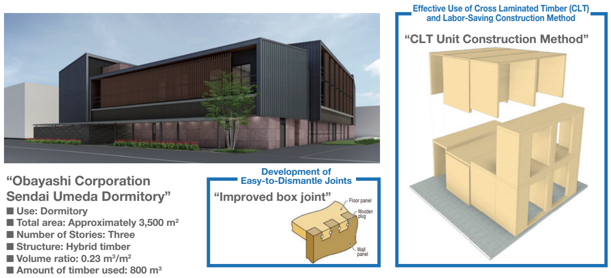


Figure 2.5: Tall Timber Case 1

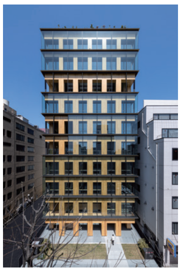
In addition, in "Port Plus" (Fig. 2.6) by Obayashi Corporation, the first tall/all-timber fireproof building of its kind in Japan, was realized by using the three-hour fireproof wooden column/beam "Omega Wood (fireproof)" and the high-load-bearing wooden column/beam joint "rigid cross joints," and the result of assuring all timber represents a very high volume ratio. In this way, one way is to use "more" timber in one building. In addition, it can also be said that the ability to build timber structures with the same service life as steel-framed and reinforced concrete structures will "extend" the period for timber use in structures and carbon fixation.

At the same time, it will be necessary to use timber in at least part of "more" buildings, based on the percentage of materials used. If it is necessary to convert non-wooden structures to structures with at least partially wooden interiors, attempts to structurally hybridize wood planks that also serve as formwork with reinforced concrete should be promoted at the same time, as in the case of the Tamadic Nagoya Building (Fig. 2.7).

	Amount of increase in wood demand (Roundwood volume)	Yield ratio	Domestic wood ratio	Average volume ratio	Target market scale (2021)	Required ratio of wooden structure
Mid-to-high-rise buildings (4-15 stories)	+ 3.2 million m^3 *1	50% *1	70% *1	0.4 m^3/m^2 *1	24 million m^2 *2	Approximately 25% *3

*1: Estimated value based on "Promotion of Forest and Forestry Reforms" (Forestry Agency)
*2: Building Starts 2021
*3: Required ratio of wooden structure X = Demand for wood (roundwood volume) 3.2 million m^3 x Yield rate 50% ÷ Domestic wood ratio 70% ÷ Average volume ratio 0.4 m^3/m^2 ÷ Target market scale 24 million m^2

Figure 2.4: New Demand for Domestic Wood for Mid-to-High-Rise Buildings



"Port Plus"
- Use: Training site
- Total area: Approximately 3,500 m²
- Number of Stories: Eleven
- Structure: All timber
- Volume ratio: 0.57 m³/m²
- Amount of timber used: 1,990 m³

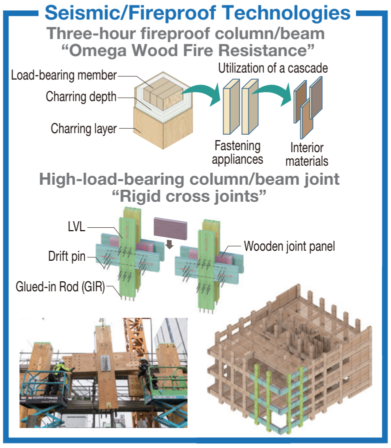


Figure 2.6: Tall Timber Case 2

"Tamadic Nagoya Building"
- Use: Office
- Total area: Approximately 3,800 m²
- Number of stories: Six
- Structure: Wooden interiors
- Volume ratio: 0.15 m³/m²
- Amount of timber used: 560 m³

Figure 2.7: Tall Timber Case 3

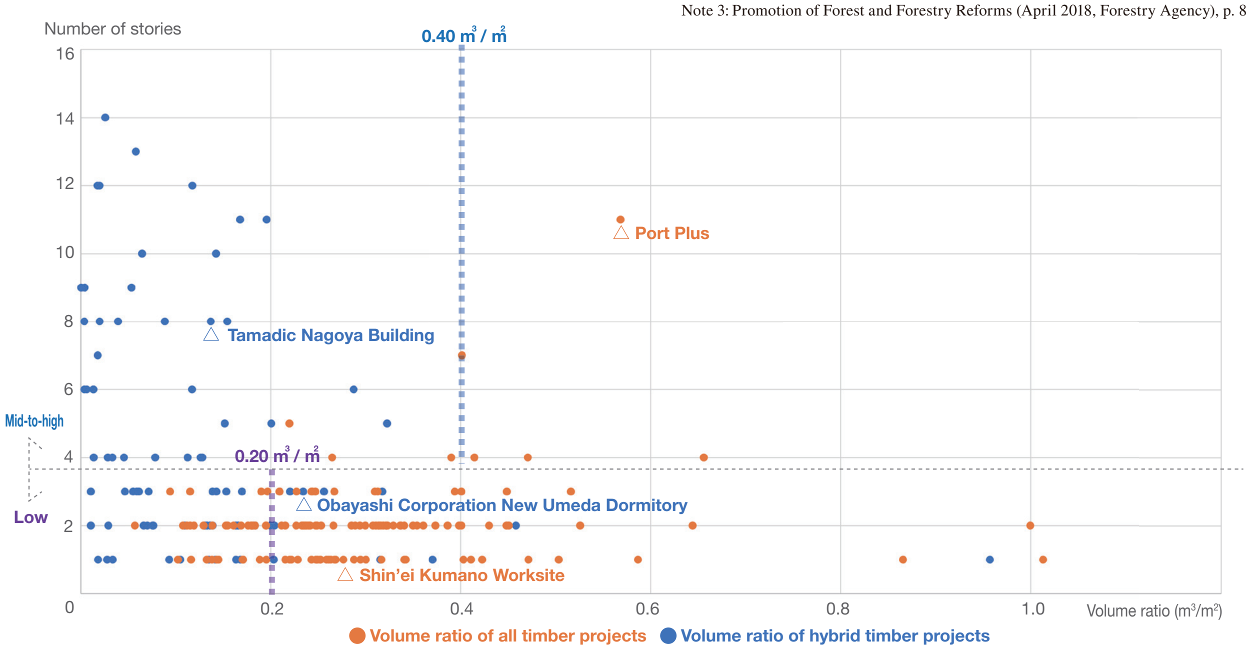
2.4 Volume Ratio Analysis in Timber Structure Market

We will analyze the consistency of the amount of new demand for domestic wood that the Forestry Agency expects to see in the construction market as compared with the amount of wood built and used in wooden buildings to date.

Fig. 2.8 shows the relationship between the number of stories and the volume ratio (m^3/m^2) of 210 cases (*) of leading all timber and hybrid timber (*) projects in recent years. In low-rise timber structures (one to three stories), all-timber structures are often seen, and it is considered quite possible to make wooden structures with an average volume ratio of 0.20 m^3/m^2 assumed by the Forestry Agency. Meanwhile, in tall timber structures (four stories or more), the only case where the average volume ratio exceeds 0.40 m^3/m^2 is Port Plus, which is an all timber structure. The volume ratio of hybrid timber structures also tends to be smaller than that of low-rise timber structures.

Clearly, the material volume ratio of 0.40 m^3/m^2 assumed in the demand growth scenario of "Promotion of Forest and Forestry Reforms" cannot be easily achieved. In order to achieve this, the challenge is to create a situation where all timber and hybrid timber structures with a high volume ratio are cost competitive, and it is also essential to enable a breakthrough of converting the use of "more" timber into value in terms of the supply chain and technical aspects such as "fireproof" and "seismic resistance."

[Source]
Note 2: Annual Report on Forest and Forestry in Japan, Fiscal Year 2021, p.20
Targets and Results for the Amount of Domestic Wood Use as per the Basic Plan for Forest and Forestry
Note 3: Promotion of Forest and Forestry Reforms (April 2018, Forestry Agency), p. 8



* Scope of analysis: (1) Projects whose amounts of timber used are published in the "Mass/Tall Timber Data Base"
(2) Projects whose amounts of timber used are published in the Investigation Report on the Leading Projects for Sustainable Mass/Tall Timber
(3) Projects whose amounts of timber used are published in CLT Pilot Project Case Report

Figure 2.8: Relationship between the Number of Stories and the Volume Ratio in Recent Timber Cases

Chapter 3

Downstream Analysis —Material Characteristics of Timber required in Tall Timber—

3.1 Type of High-Strength Timber Required in Tall Timber Structures

In order to expand the use of domestic timber, we will analyze the tree species and strength of wood required in the promotion of tall and mass timber structures from interviews with engineered wood manufacturers and the case of Port Plus, which is an all-wood, tall-timber fireproof case.

To meet the seismic resistance standards of the Building Standards Act of Japan, the wood used in the structure of mid-to-high-rise buildings (four stories or more) must be high-strength wood with a strength grade of E120 or higher (E: Young's modulus). To achieve high strength in wood, engineered wood (laminated wood, CLT, LVL, etc.) is required because the performance of the engineered wood is evaluated according to strength characteristics and grade and it has high dimensional stability. Engineered wood is selected according to the tree species and origin of the raw material, and is classified by strength testing of the sawn wood in the primary processing, and strength is assured by secondary processing.

In general, domestic tree species that can supply E120 or higher are pine species such as larch ("*Karamatsu*") produced mainly northern part of Japan (north of Nagano). If this is manufactured as a frame material, it can be used for columns and beams in tall timber structures. In addition, Japanese cedar ("*Sugi*") which accounts for most of the forest growing stock in Japan, is about E70 on average, and is not strong enough for columns and beams of tall timber structures. Therefore, it is more suitable to be manufactured as Cross Laminated Timber (CLT) for use as planar materials, to be used in walls and floors in tall timber structures (Fig. 3.1).

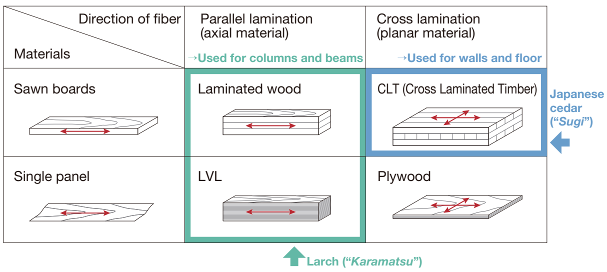


Figure 3.1: Types of Engineered Wood

3.2 Tree Species of High-Strength Timber and Strength Occurrence Rate

In Chapter 2, we described that domestic wood use expansion of approximately 3.2 million m^3 is expected in mid-to-high-rise non-residential structures, but in reality, the conditions of the tree species and origins of high-strength timber that can be supplied in Japan are limited. In order to increase demand, it is crucial to understand the conditions of wood, which is a natural material, and to design structures with as appropriate wood strength as possible. Therefore, we interviewed manufacturers of CLT, Laminated Veneer Lumber (LVL), and laminated wood about the tree species and strength occurrence rate of wood.

As shown in Fig. 3.2, the strength occurrence rate of wood of E120 or higher (E: Young's modulus of elasticity) was found to be more than 80% in larch ("*Karamatsu*"). For Japanese cypress ("*Hinoki*"), L100 or higher accounted for more than three-quarters, and for *Sugi*, L80 or higher had an occurrence rate of one half (L: laminar's Young's modulus of elasticity) (Note: The Young's modulus for elasticity represents the strength of a single panel for *Karamatsu* and the strength of laminar (sawn board) for *Sugi* and *Hinoki*.)

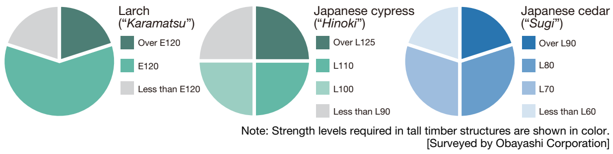


Figure 3.2: Timber Strength Occurrence Rate by Tree Species

3.3 Analysis of Port Plus, Yokohama Training Site of Obayashi Corporation

Based on the above interviews, we compared the strength occurrence rate of wood and the part, tree species, and strength of the wooden components of Port Plus, which is an 11-storey high all timber structure, and examined if the design strength was set appropriately. The timber used in Port Plus is as follows:

- **Columns and beams**
  - **→ LVL**
    Domestic larch ("*Karamatsu*") and Larix gmelinii ("*dafurika karamatsu*") of Russian origin
    E120, E100, E90
- **Small beams**
  - **→ LVL and laminated wood**
    Domestic larch ("*Karamatsu*")
    E120
- **Floors, walls**
  - **→ CLT**
    Japanese cedar ("*Sugi*")
    Different grade composition Mx60

As for the LVL of columns and beams, larch ("*Karamatsu*") of E120 or higher accounts for 80%, so it is safe to say that the strength design was generally appropriate. As for the CLT of floors and seismic walls, it was confirmed that they were manufactured with sawn boards of L60 or higher, which is the lower limit of the Japanese cedar ("*Sugi*") strength occurrence, and were confirmed to be evenly used.

3.4 Setting Design Strength in Mid-to-high-rise (4-15 stories) structures

From the interviews, it was found that more than 80% of Larch ("*Karamatsu*") can be used for the columns and beams of tall timber structures by designing E120 as the maximum level. When building taller timber structures, it is not possible to simply increase the design strength, for example, to E130 and E140, and it should be noted that the cross-sectional dimensions will also increase. Since Japanese cypress ("*Hinoki*") has a strength occurrence rate of about 50% at L110 or higher, it can be an alternative option for columns and beams currently made for the most part of larch ("*Karamatsu*"). While laminated wood and CLT of Japanese cypress ("*Hinoki*") are common, its LVL has limitations in that there are few manufacturing mills for its LVL and the designing with its strength conditions of around L110 to 125, which is a little weaker than larch ("*Karamatsu*").

For floors and walls, the first choice is Japanese cedar ("*Sugi*") CLT, and if higher strength is required, then Japanese cypress ("*Hinoki*") CLT should be used.

By understanding the timber that can be supplied based on the tree species, origins, and strength, and designing with appropriate strength, domestic timber will be used in various applications to achieve expansion in demand.

Chapter 4

Issues of Location in Wood Distribution System —Streamlining Processing and Distribution of Resources—

4.1 Wood Mileage

Wood mileage is a numerical value of the environmental impact of transportation, determined by multiplying the amount of lumber transported by "Wood Miles," which is the transportation distance from the lumber origin site to the consumption site. While Japan is a developed country, it has abundant forest resources on its own land, and this Wood Mileage can be reduced by effectively designing the circulation of upstream forests, midstream wood processing, and downstream timber construction. In addition, as demand for tall timber structures expands, not only from the above viewpoints, but also for the rational circulation of capital, the question of "from where, by what route, and how to procure" will become increasingly important in the future. However, a platform has not yet been developed.

4.2 Resource Distribution by Tree Species (Japanese Cedar [“*Sugi*”], Japanese Cypress [“*Hinoki*”], and Larch [“*Karamatsu*”])

As mentioned in 3.1 "Type of High-Strength Timber Required in Tall Timber Structures," the main domestic tree species used for building structural materials are Japanese cedar ("*Sugi*"), Japanese cypress ("*Hinoki*"), and larch ("*Karamatsu*"). If you look at the distribution of the top prefectures in terms of growing stock of planted Japanese cedar ("*Sugi*") by age class, it can be said that cedar is a tree species that varies depending on its origin, and although there are regional differences in its properties, Japanese cedar ("*Sugi*") can be obtained in various places.

Meanwhile, when looking at the distribution of the prefectures with the highest growing stock of planted Japanese cypress ("*Hinoki*") by age class, the distribution is narrower than that of cedar, and concentrated in the west of the Chubu region. Japanese cypress ("*Hinoki*") is easier to dry than cedar, has a more easy-to-use appearance, and is easier to obtain in volume terms. Although growth is slow, the price of raw wood has fallen to a level that is not much different from cedar, so it may become an option for the structural material in tall timber structures.

Finally, when you look at the distribution of the top five prefectures by age class of planted larch ("*Karamatsu*") growing stock, the production areas that have enough growing stock to provide as a material are limited, and in Honshu, they are concentrated in the Kanto-Koshinetsu region. Larch ("*Karamatsu*") is originally a material that has difficulty in shape stability and workability, but it has become easier to use thanks to the efforts and ingenuity of the producing areas. It is an attractive material in terms of strength, and strategic planting may be necessary in the future.

4.3 Distribution and Production Capacities of Timber Production Sites and Processing Sites (GLT, CLT, LVL)

If we illustrate the amount of forest growing stock in each prefecture by tree species, the location of wood processing mills that can address medium- to large-scale wooden buildings, and the wooden construction potential according to the construction area in one map, we can see that the large supply and demand centers are not necessarily close together.

Considering secondary processing such as GIR, drift pins, and steel plate insertion, the options for processing mills will be further limited. The sites with large demand for tall and mass timber structures, which we have seen in the previous chapters, are concentrated in the metropolitan areas around Tokyo, Nagoya, and Osaka. If the procurement destination is set close to the construction site, the technology that can be used may be limited, and this is currently increasing the Wood Mileage of tall timber. Meanwhile, if we visualize the movement route of timber from the material production area to the metropolitan area based on the road network, we can see that there are several nodes on the route. These logistics nodes are close to the metropolitan areas, which can provide a clue to determining the location of a processing mill. In order to promote the use of downstream timber, it may be effective to establish several accumulation bases (wood industrial complexes) in Japan that can perform the processing necessary for tall timber as "relay sites" connecting sites of origin and construction sites.

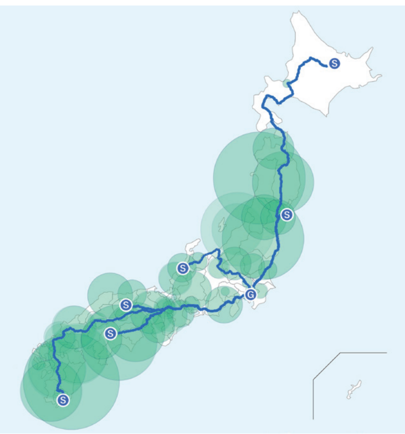


Figure 4.1: Resource Distribution Map of Japanese Cedar ("*Sugi*")

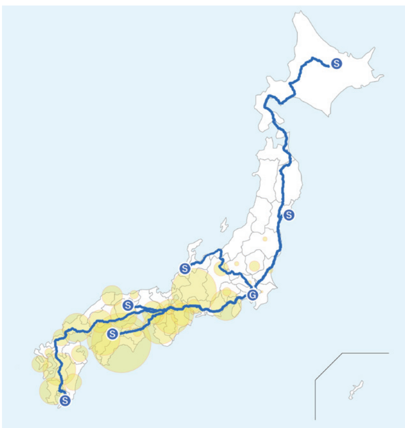


Figure 4.2: Resource Distribution Map of Japanese Cypress ("*Hinoki*")

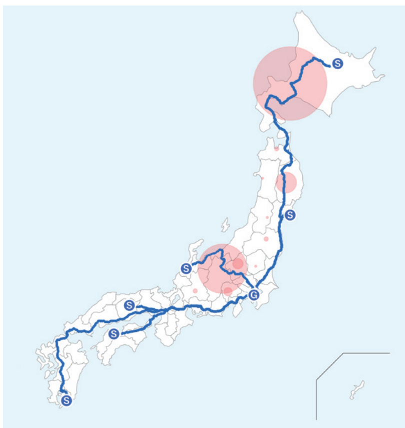
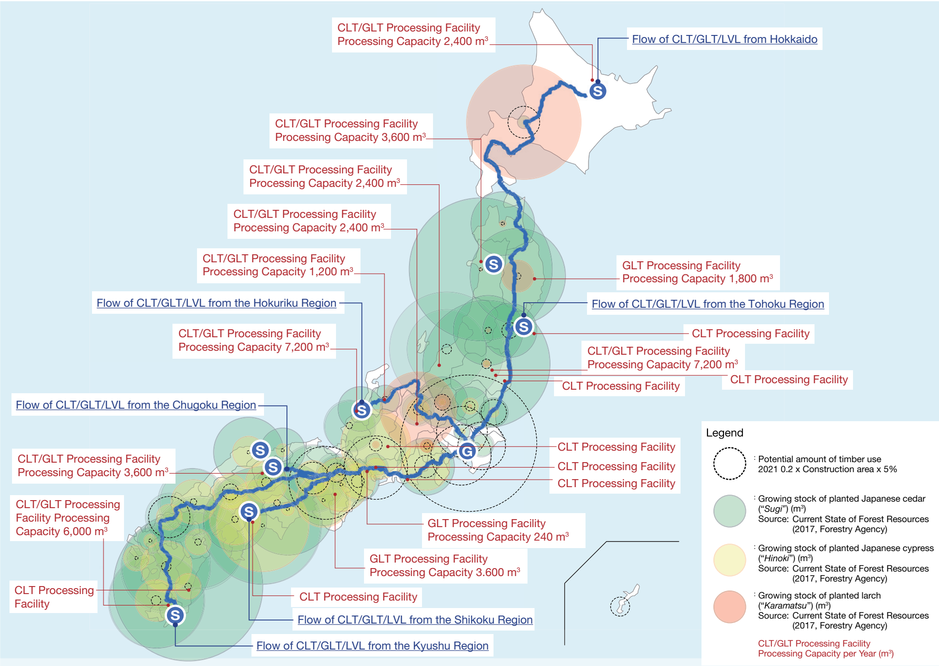


Figure 4.3: Resource Distribution Map of Larch ("*Karamatsu*")

The route of transfer from the starting point ("S"), which is the production facility in each region, to the goal consumption site ("G"; tentatively set as Tokyo Station), was visualized using a blue line.



[Source]
CLT production sites:
List of CLT Manufacturers in Japan (JAS-Certified Mills of Japan Cross Laminated Timber Association members)
Japan Cross Laminated Timber Association (July 14, 2022)
https://clta.jp/document/

Glued Laminated Timber (GLT) production sites:
List of tall and mass timber contractors
Japan Laminated Wood Products Association (March 2022)
https://www.syuseizai.com/

LVL production sites:
List of JAS Certified Mills, single panel laminated materials
Japan Plywood Inspection Corporation, 2022
https://www.jpic-ew.net/db/ichiran.pdf

GLT processing sites
List of tall and mass timber contractors
Japan Laminated Wood Products Association (March 2022)
https://www.syuseizai.com/

CLT processing sites
List of CLT processors
Japan Cross Laminated Timber Association (July 14, 2022)
https://clta.jp/document/

Figure 4.4: Distribution and Production Capacities of Timber Production and Processing Sites

4.4 Wood Industrial Complex Concept

In this report, we have presented the situation where the national government is promoting the reforestation of forests aged 50 or older, and the target amount of domestic timber use has been set for felling the woods accordingly. However, this target amount of use was formulated in 2016 for 2030, and is only up to 14 years into the future. So what will happen in 20 or 30 years?

The age class composition of the planted forests in 2017, which coincided with the formulation of this target amount of use, is shown in Figure 1.3 above. So, for example, in 2037, that is, 20 years from the state shown in Figure 1.3, the composition simply shifts to the right by 20 years (four age classes). The area of forests aged 50 (age class 10) at that time will be as shown in Figure 4.5.

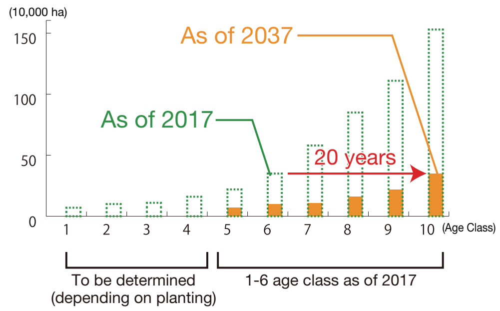


Figure 4.5: Age Class Composition of Planted Forests (2017)

[Source] Created by the authors based on Figure 1.3

It is not certain whether in 2037 there will actually be areas of forests aged more than 50, that is, forests that were aged 35 or older in 2017, but even if they are not completely felled, the act of "felling the abundant forest resources to use wood" will not be able to continue in the near future, as is evident in Figure 4.5. If we envision a future in which forest resources may decline, the following three factors will be crucial.

(1) "Maximization of yield" of timber resources

(2) "Maximization of the period length of use" of timber resources

(3) Maximum reuse of timber resources

First, the new technology is required to realize (1) and (2), and market establishment is necessary in addition to the technology to realize (3). With both of these in mind, the "Wood Industrial Complex Concept" proposes a site which plays a comprehensive role in assuring timber processing technologies, as a stockyard necessary for the reuse market, and reprocessing. This will be a key in promoting Circular Timber Construction.

Toward Circular Timber Construction
—Mass timber strategy and quantitative analysis for "more" and "longer" use of wood—

Roundtable —After reading the report—

Mariko Yamasaki (Nagoya University)
Yutaka Goto (Chalmers University of Technology/ Tohoku University)
×
Yosuke Komiyama (Kyoto University)
Sho Ito, Shun Takayama, and Mari Ota (Timber Design and Construction Department, Obayashi Corporation)

After reading the report

Komiyama: Dr. Yamasaki and Dr. Goto have kindly read the report we prepared from Chapters one to four. In this roundtable discussion, I would like to have your feedback on the report and have a discussion to enhance understanding of the content.

Goto: I felt that the report was described in an easy-to-understand manner and had much information. Information that is familiar to those who are engaged in specialized research on wooden structures is summarized in a way that is easy for general people to understand. I would encourage you to develop it further not only for the purpose of Obayashi Corporation's business, but also into something that could be a message to society.

Obayashi Corporation: The government's target of the amount of lumber use appears simple figure if you look at the numbers alone, but if you think about it carefully, we learned from this report that you can't reach the target unless you use a tremendous amount of lumber. It is a level that cannot be reached unless there is a switch to wooden structures, not simply by wood interior finishes.

Yamasaki: There are many new topics that have not yet been published in textbooks, and I thought they were highly valuable as data. Wooden buildings and circularity are international topics, but if we talk about forests, the topic is unique to each country. The timber industry in Japan is undergoing a transformation towards non-residential construction. Who will take the initiative? Stronger recommendations and requests may do the trick.

Goto: When I read the report, I felt that materials and capital flows were mixed between the upstream and the downstream. Essentially, there should be more talk about the reuse and recycling of materials themselves, and I think that has not been explored yet in depth.

To achieve the balance between the carbon absorption rate and the carbon emission rate

Goto: The figure of "Age Class Composition of Planted Forests (2017)" in Chapter 1 is important. If a stable supply of timber is established, the distribution of forest age classes should be stabler and more even, but if you look at the area distribution, you can see that there are few 0 to 5 age classes. If trees are planted continuously, the forest area can be recovered, but you can see that the forest area that will reach the appropriate age in 50 years will be less than it is now.

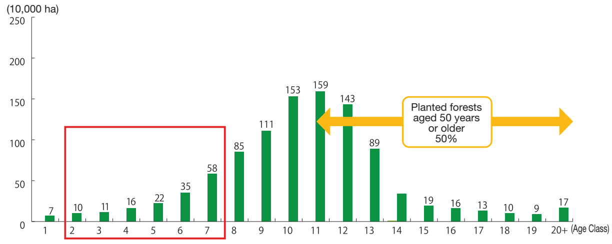


Figure 1: Age Class Composition of Planted Forests (2017)

Obayashi Corporation: Timber is abundant now, but in the future, when there are no mature forests and the supply becomes less, the significance of "wood industrial complexes" will increase as a venue to reprocess timber stocks in cities and reuse them effectively.

Yamasaki: To add a little more so that readers won't misunderstand, it is true that the area in the red frame in the figure "Age Class Composition of Planted Forests (2017)" will shift to the right in 50 years, but in many cases, "trees that can be used now" will still be usable 50 years from now. Therefore, the bigger problem is that there may be no more people to produce trees than that there will be less planted forest area.

Let's consider the need for reuse from another perspective. The cycle diagram between wooden structures and forests commonly distributed in the world signifies the carbon circulation. Therefore, it is also important to consider whether the speed of carbon absorption and the speed of carbon emission are balanced. If timber is burnt as fuel, the carbon storage period in timber will be very short. This is the important meaning in using timber in buildings that can store carbon for a long time. However, since in Japan buildings have a short lifespan, it is not possible to extend the period until timbers are burnt unless some form of reuse is introduced. Therefore, reuse can be said to be a way to extend the carbon storage period in buildings in order to establish a longer cycle.

Let's say it takes 50 years for a tree to grow to a usable size for building materials. To achieve carbon balance, the lifespan of buildings (the period during which timber continues to store carbon in the building) should be considered in view of the yield rate. Fifty years is divided by the yield of the forest, but not all of the forest area can be used for building materials. With so much cut felled but unused timber left, the yield of the forest should be less than 50%. When we consider "production period of timber / (yield of forest × yield of timber) = lifespan of a building," if, for example, the yield of the forest is about 10% and the yield to be used as a building material is about 40%, the period during which carbon should be stored in the building will be 50/(0.1 × 0.4), exceeding 1,000 years. This is not realistic, so you have to try to change at least one of the numbers. Both numbers represent challenges and need to be improved.

How Can Timber Structures Be Reused?

Obayashi Corporation: At what level should we set the goal for reuse? It is likely we can increase the recycling rate for low-rise timber structures with a high material volume ratio, whereas tall timber structures are more complicated and difficult in terms of joints. Most of the wood members of Port Plus are joints, and even if they are dismantled, the recycling rate will probably be low. So, areas with high potential are the low-rise timber volume zone manufactured in view of 3Rs and the tall timber volume zone designed with a focus on using more timbers than on 3Rs, I presume.

Yamasaki: Even in low-rise timber structures, there is currently almost no construction of detached houses using reused materials. Waste timbers are used for wooden biomass power generation. The dismantled parts are collected at intermediate treatment facilities, but if many wood members from tall timber were transported in the future, it would be necessary to build cascades while expecting future technological development. For example, I think it is possible to separate the materials in some ways while breaking up the members with some metal parts in the wood. The ideal first option is to reuse it as a member for the same purpose, and the second option is to collect at least wood for use as wood chips and recycle them into some board type building materials. The frame of the column and beam may be reused for board materials and used for flooring. Or, even if not as building materials, the materials can be reused for pellets.

Komiyama: How do we find value in constructing buildings with reused materials that could also be used in areas other than architecture, such as civil engineering structures and furniture? Morality alone is not enough.

Goto: If it takes 50 years for engineered wood to be dismantled, the barrier in its reuse and recycling lies in, for example, the issue of whether we can handle the material in the same way as virgin wood, considering that it has been subjected to loading over the years. It seems technically feasible to make chips into boards, but there is also a problem whether it is economical to use reusable materials that have been collected. In an age where longevity is sought after, it is time to reconsider in the first place why buildings have to be dismantled.

Obayashi Corporation: When the purpose of the building is changed, there has scarcely been the idea of reusing the building itself, and until now the established practice has been to scrap and build. A business model for maintenance has not been established.

Therefore, regardless of the size, in Japan, in the case of a wooden office building, the depreciation period will end in 24 years, and the residual value will be very low. The building may not be demolished as soon as the depreciation is over but at most the building's life is about 50 years.

Possibility of Wood Reuse and a Material Passport

Goto: If we assume that building's value is lost in 24 years, it may be a good idea not to make the building too robust, or at least make it easier to dismantle. "designed for deconstruction" is a field that will attract attention around the world. There may be a distinction between buildings that have cultural value and should be used for a long time, and buildings that are focused from the beginning of construction on ease of dismantling and should be circulated earlier.

Obayashi Corporation: In this report, in addition to "secondary processing" to manufacture the necessary components for tall and mass timber structures, we envision a "Wood Industrial Complex" as a facility that functions as a "stockyard" for reusing dismantled wooden building members and distributing those materials.

Yamasaki: When you go to an intermediate treatment facility, you will find dismantled materials in storage waiting to be turned into chips. It would be desirable if the intermediate treatment facility could become a stockyard for reuse, but for that purpose, legal arrangements are necessary.

Komiyama: In that case, could the material passports being discussed in Europe be a solution?

Goto: Since we submit a confirmation application of plans, elevations, and cross-sections in two-dimensional drawings, the current situation is that building permits are granted even if you do not write down each and every member. In the future, if we get permission with a digital twin, we will technically be able to track members. However, in wooden structures, especially on a small scale, details are often changed depending on the on-site judgment, so the question is how to allow that. Currently, even in Europe, it is difficult to convert existing stocks with a long age into data, and research is being conducted to estimate materials by taking photos.

Yamasaki: Wood itself has variations in strength, so how to guarantee the strength of that material is also an issue. However, ICT makes it easier to manage variations. In today's terms, it is respecting diversity. It is difficult to track down chips due to the use of cascade, so it is easier to manage materials with reuse. Technological development in recent years has focused on robustness such as in high-rise buildings, but we must not forget the ease of dismantling wooden buildings have. I think both can coexist.

How to Create Timber Structure Market

Obayashi Corporation: The current market for wooden buildings is for detached houses with a relatively uniform scale and format, and if we want to provide a stable supply for tall and mass timber structures, we will need to make a large investment in new infrastructure.

Yamasaki: 80% of one- or two-story houses are still made of timber. In the housing market, most of the horizontal members such as beams and girders are imported, and it is difficult to domestically produce them because of the existing market. Rather, it may be easier to create a completely different field. I think it is possible in the future that the mid- rise scale structures from four to seven stories will be replaced entirely by timber structures.

Goto: I agree that the volume zone of future timber structures will be mid-rise. Meanwhile, we should also look at the disparity between upstream and midstream. Due to the pandemic, contractors that have to buy materials are having difficulties, but I hear that processing companies that own forests have survived because they were able to contain the rise in prices. Vertical integration is also a business model.

Yamasaki: Not all forests in Japan need to adopt this management method, but I think that a business model that takes advantage of the characteristics of a major general contractor will become a breakthrough in the business world surrounding forestry, lumber, and construction.

Obayashi Corporation: When processing companies own forest resources, does that mean that processing companies are investing capital in those who are engaged in forestry?

Goto: In Sweden, some companies have forests, and also engage in lumber sawing, secondary processing, and construction. Half of the timber they handle comes from their own forests, and the other half comes from local individual forest owners. They also provide consultation on forest management.

Yamasaki: In the case of a company in Tenryu, Hamamatsu, the company does not own its own forest, but as a company, it knows what kind of trees grow in the local forest and watches them grow, so they know what kind of trees can be obtained at a given period. If everyone knows what will happen when a tree grows, they can predict the future and return as much as possible to the forest owner. So this company plays a role in telling downstream what kind of trees will emerge in the future and how to cut this forest to return the money. This is also a way of doing things continuously. In this way, it would be interesting if the downstream actions and the midstream actions match well. Will Obayashi Corporation also own forests?

Obayashi Corporation: Owning a mountain is holding inventory, which is a risk which Japanese general contractors are not good at managing. Whether it is steel or concrete, the general contractor is not responsible for procuring raw materials or manufacturing and processing products. We do not buy directly from manufacturers, but rather indirectly from processors and trading companies. General contractors do not have the expertise to take on the risk of demand fluctuations and the risk of raw material procurement, so that is the biggest problem. Going midstream would still be a challenge right now.

How to Establish Downstream to Upstream Circulation in Business

Obayashi Corporation: What about the situation in afforestation in Europe? Is afforestation operated systematically in view of supply and demand?

Goto: In Sweden, 70% of the national land is forest, and about 70% of it is a forest that is constantly managed by humans. The volume is on the rise, and the age class distribution is even. In Sweden, there was a time about 100 years ago when forests were reduced due to overfelling. Therefore, about 100 years ago, a law was enacted stipulating that if you cut one tree, you should plant two. Today, if you cut one tree, you plant four. Although thinning is implemented, the volume of the entire forest is on the rise.

Yamasaki: Twenty years ago, when the use of domestic timber was at its nadir, there was no discussion of forest resources. The focus of discussion may vary depending on what lies ahead of the increase in wood use rate and how far into the future you envision.

Obayashi Corporation: I hear that Japan is also trying to accelerate the felling cycle by introducing "Elite Trees."

Yamasaki: When talking about forests, we need to assume that the whole of Japan may fall into an unbalanced state. My forecast is that forests in Japan will be divided into forests as industrial sites and forests as landscapes. In the former, sustainable forestry may be achieved by forestry managers who can plant trees continuously. However, most forests may fall apart before that happens, and will become a sort of background. Is that what we hope for? What should we do to reduce such forests? I think it depends on whether the people there see forests as resources. If upstream, midstream and downstream stakeholders discuss together what kind of trees to plant while seeing the forests as resources, forestry will become viable in such an area. On the other hand, people who don't consider a forest to be resources may even think of managing them as garbage cleaning. I hear 90% of the resources are thrown away in such cases. When considering how to teach them to see it as a resource, I think there are many things that a general contractor like Obayashi Corporation in the downstream can do, and there is a possibility of saving the midstream. The upstream doesn't have any spare capacity, so it cannot change itself. Even if Obayashi Corporation can't save all the forests in Japan, why not think about saving at least one or two forests now?

Obayashi Corporation: When we started working on timber construction, we realized that we didn't have any know-how. The timber industry was seen as a "black box," and there was an opinion within the company that it was too early for us to get involved in it. Therefore, we need to create a foundation for a viable long-term business.

Goto: Clearly, this does not mean that there will be no trees in the mountains in the future, but it is certain that resources will taper off, so in order to prevent this from happening, I think it is necessary to circulate money to encourage people to work upstream, and to create incentives for tree planting.

Yamasaki: In Japan, if resources dwindle, we may simply return to imported materials. In the future, many forest owners may not plant "conifers" as they are now aware that "conifers" are difficult to handle. Our needs are less likely to be understood by producers in the mountains, and there is also the issue of whether the monoculture of Japanese cedar and Japanese cypress is good for forest cultivation, so next, they may choose to plant tree species other than conifers, which are currently the mainstream of building materials. However, from the architectural point of view, this undermines sustainability. In order to prevent this from happening, we need a business model that provides incentives for environmental and ethical causes. If Obayashi Corporation can be a driving force that economically promotes circulation between the construction industry and timber production, it will be invaluable.

Obayashi Corporation: Taking this report as a good opportunity, we aim to convey the message focusing on both "more" and "longer" use of wood. Thank you very much for coming here today.

First Roundtable: December 12, 2022, on Zoom
Second Roundtable: January 30, 2023, on Zoom

Chapter 5

Conclusion —Social Issues and Goals in the Construction Industry—

Finally, the issues and the goals of the construction industry identified in this report are summarized from the perspective of the Wood Industrial Complex Concept and Circular Timber Construction.

5.1 Social Issues 1 —Decarbonization—

I believe the driving force behind the global attention on trees is carbon offsetting. From the viewpoint of increasing the amount of CO_2 fixation and reducing emissions, the following five items are the main issues.

1) Expansion of carbon fixation in forests

If there are two possible options, increasing the forest area and rejuvenating older forests, planting trees after felling would be a prerequisite rather than increasing the area since Japan already has forests covering 67% of its land. Therefore, the promotion of felling and assurance of reforestation are issues.

2) Promotion of non-residential timber structures

Since the number of housing building starts, which were the main use of the materials, is expected to decrease in the future, the challenge is to expand demand by constructing non-residential timber buildings, and to encourage felling and reforestation. In recent years, tall and mass timber structures have been promoted, but in terms of quantity, further expansion is necessary.

3) Long-span use of timber

Timber structures not only consume wood, but also play a role in fixing carbon in the form of timber for a long time and with a large capacity. In addition, when the timber reuse and recycling market is developed, the fixation period will be further extended. One of the challenges is to develop the method and market.

4) Improvement of yield of wood processing

The challenge is to improve the yield, which is currently said to be about 50%. The remaining 50% can be effectively used as biomass fuel, for example, but it returns to carbon dioxide in a relatively short period of time, so from the viewpoint of carbon fixation, it is more desirable to use timber as a material for as long as possible.

5) Streamlining timber transportation routes

In order to reduce CO_2 emissions from transportation, it is desirable to have a timber processing mill at a geographical midway point between the mountains and the construction site. It is necessary to locate the mills of domestic laminated wood with a large cross-sectional area and secondary processing mills with appropriate production capacity in consideration of the geography of both material sites of origin and the cities with large construction volumes.

5.2 Social Issues 2 —Economic Vitalization—

In order to continue the decarbonization strategy, economic feasibility is essential. Issues related to trees can be discussed in various ways from the viewpoint of the economy and industry. From the perspective of the construction industry, which handles trees as timber, the following two issues can be raised.

1) Sustainable afforestation expansion (timber production)

If the area of young forests in Japan continues to be small and the supply of large quantities of lumber continues without sustainable afforestation, the cycle of “felling abundant forest resources to use trees” may not be able to continue in the near future. In order to prevent a future in which forest resources may decline, planned reforestation is crucial, and looking to the future, leveling the entire age distribution of forests is also an issue.

2) Maturity of the reuse and recycling market

One example of how to balance the rate of carbon uptake in forests with the rate of carbon emissions in the construction industry is the maturity of the market for reprocessing and reusing wood. As a new business, such reuse and recycling can have economic effects, and it can also be a measure, even though temporarily, for the future when forest resources may taper off until reforested trees grow.

5.3 Goals in the Construction Industry —Today—

No reforestation or development of new processing mill sites will be promoted without reliable demand for lumber. Therefore, downstream trends are important, and the construction industry is particularly expected to play an important role. Also, fueled by public promotion of timber structures, the following items are common goals for the construction industry to disseminate timber structures.

1. **Improvement of elemental technologies such as seismic resistance, durability, fire resistance, and weather resistance**
2. **Exploration of economical design methods based on yield and material characteristics**
3. **Presentation of architecture that communicates the attractiveness of timber**

5.4 Goals in the Construction Industry —Future—

In order to solve various social issues, cooperation between upstream and downstream is necessary, and movements aimed at this collaboration are beginning to occur in various industries. Based on such a situation, this report presents the "Wood Industrial Complex Concept." The goal of the concept is to build a tall and mass timber construction supply chain. The role it should play is as follows.

1) **Abundant and economical production of high-strength timber required for tall and mass timber construction**

2) **Improvement of distribution channels through appropriate locations in view of material sites of origin and consumption sites**

3) **Based on the information obtained by consolidating processing and distribution, optimizing the manufacturing process, reducing losses, and improving yield.**

4) **By having wood reprocessing and storage functions, the supply chain also functions as a recycling and reuse site.**

5) **High-efficiency energy conversion of wood waste discharged at processing mills by concomitantly installing a biomass plant**

The reuse of parts for tall and mass timber structures is an issue that should be examined in the future in the development of both the reprocessing market and design methods. Information on "in what condition should the members be dismantled to enable reuse" is necessary, but there is currently no reprocessing market itself, and knowledge of this is still scarce in Japan. In general, the dry construction method is easier to dismantle than the wet construction method, but the laminated wood itself contains wet adhesive in the material. Therefore, it is believed to be effective to at least eliminate secondary gluing between laminated woods. In Port Plus, which was also introduced in this paper, the columns and beams have a three-layer configuration of LVL, but each layer of LVL is not bonded by secondarily gluing and is fixed in a dry state. CLT used for walls and floors is considered reusable as a material, except for the ends used for structural joining and the surface to which the coating is bonded. However, as with steel frames and reinforced concrete, it is currently not permissible under the Building Standards Act to directly reuse a structure once it has been used. Since the barriers are lowered for areas other than architectural structures, it is necessary to include, in the Wood Industrial Complex Concept, an appropriate cascade utilization strategy for "long-term use of timber" in conjunction with the growth rate of the forest (Figure 5.1). The construction of such a base will lead to an increase in production capacity in the midstream, and a new recycling business will also come into the scope. In the downstream as well, in addition to ensuring a more stable supply of materials, the development of architectural plans and technologies intended for reuse will be promoted by collaborating with recycling bases. Therefore, it is desirable that both the midstream and the downstream will cooperate to promote the initiative.

In addition, the Wood Industrial Complex Concept requires a variety of know-how, such as wood processing technology, biomass power generation technology, and skills to identify the needs of the construction industry. As an example of a move toward this goal, Obayashi Corporation has been operating multiple biomass power plants, and in February this year it started a capital alliance with Cypress Sunadaya, a timber manufacturing company (Figure 5.2).

In fact, in addition to the main issues discussed in this paper, there are a wide range of issues that need to be addressed, and there are aspects that have not even been recognized as issues yet. Still, we believe that starting with a movement that connects the downstream and the midstream will lead to the realization of the Wood Industrial Complex Concept and eventually Circular Timber Construction. In the future, if each industry can move forward step by step while sharing the same goals, it will be possible to make maximum use of the resources of forests in Japan and build a framework that can make a significant contribution to both the environment and the economy.

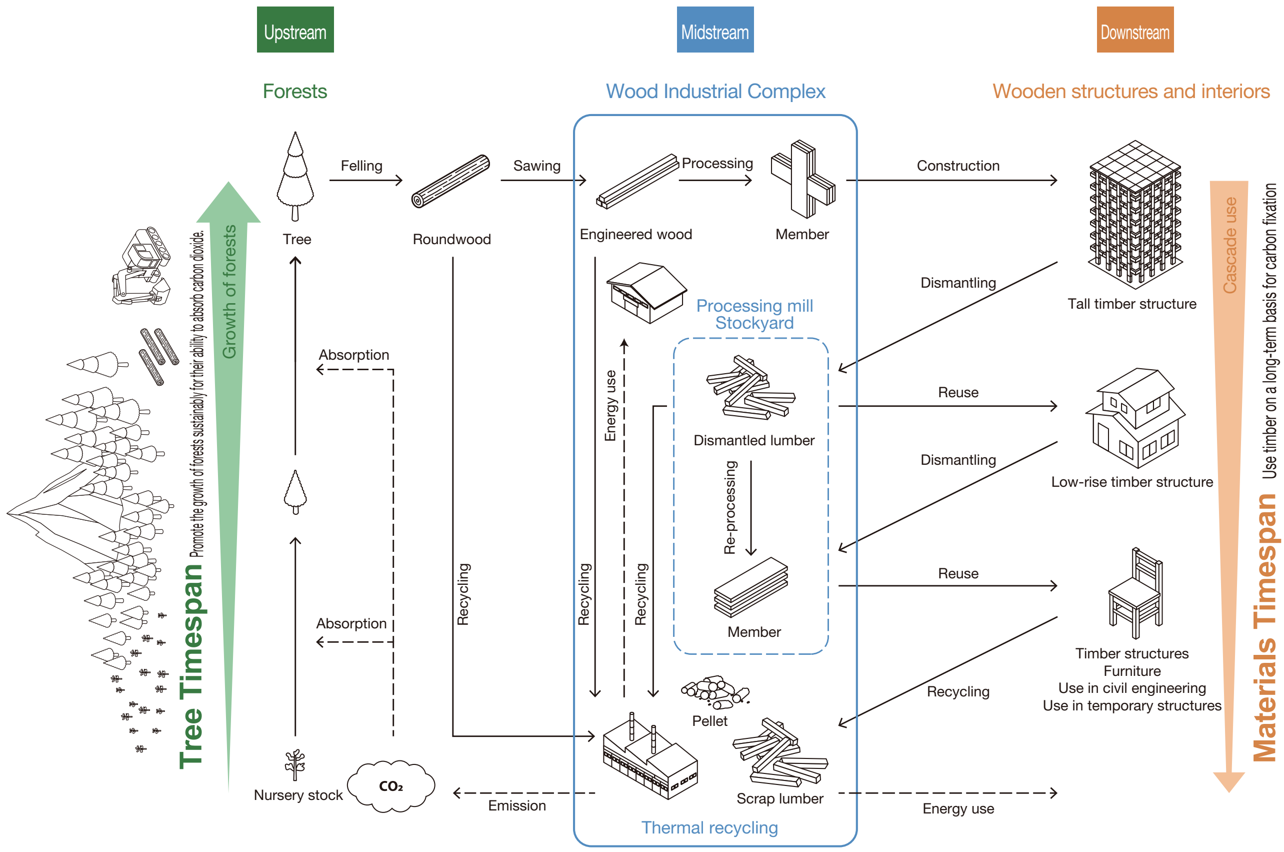


Figure 5.1: Timber Resource Circulation Diagram

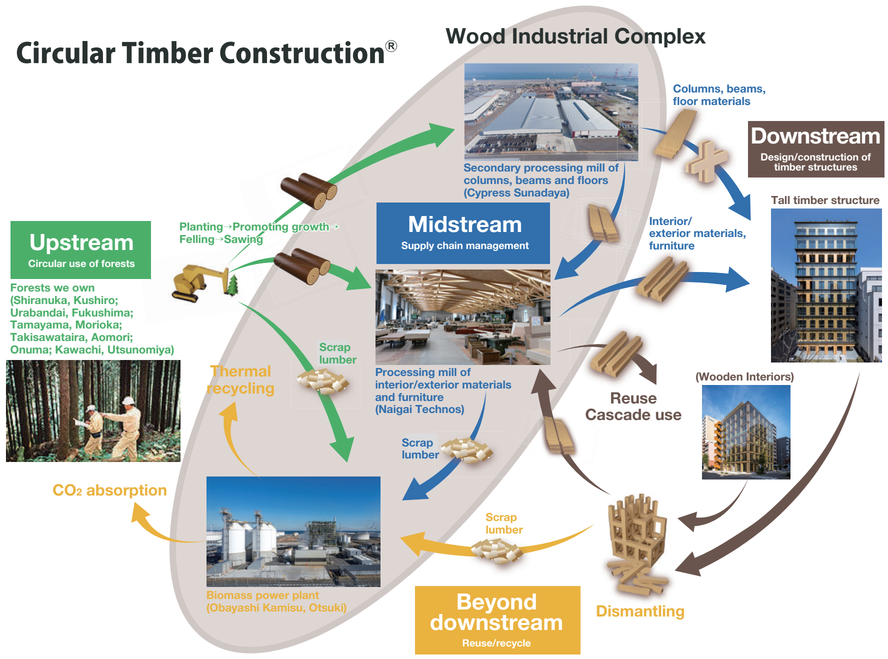


Figure 5.2: Concept of Wood Industrial Complex

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