Rethinking Wood

Markus Hudert, Sven Pfeiffer (Eds.)

Rethinking Wood

Future Dimensions of Timber Assembly

Birkhäuser
Basel

Table of Contents

Foreword

Klaus Zwerger

"Rethinking Wood" evokes two quite different reflections. The first involves a return to wood as a material characterized by its inhomogeneity. Its optimal use demands respect for the uniqueness of every single piece. A respect that can only grow out of extensive background knowledge and experience with this material—a never-ending process as the best artisans and artists discover throughout their working lives. With every new piece of wood, they face the intrinsic challenge of rethinking how to best bring its unique qualities to light. This is a highly idealized representation. Of all artists, sculptors have perhaps been the most uncompromising in their pursuit to shape their works in alignment with the unique form of natural materials. An endeavor that both tested their attention and demonstrated the breadth of their talent through their flexible response to the raw material at hand. Artisans, such as carpenters and cabinetmakers, on the other hand, were denied such considerations as they were bound by economic concerns. And yet, the responsibility of selecting the most suitable piece of wood for a specific purpose, and particularly when cutting joints to ensure that the reduced cross-section is not carelessly weakened, lay entirely in their hands. Historical objects offer examples of both impressive attentiveness and gross negligence. Sculptors' concerns and means of expression have profoundly changed. Artists are acutely sensitive to social change. They would be the first to know that only a few people remain who stand to gain something from the material reflection described here that has become foreign to them. But developments are not consistently sequential. Not every path taken leads to completely new fields. Fortunately, there are artisans who still feel connected to, or have newly discovered this idea.

The second reflection follows a completely different perception of wood. For the inexperienced, it is highly difficult to estimate the properties of this material, and this in turn has set in motion an effort to control it. In the process of transforming wood to wood plastic composites, many of its positive properties remain intact. The partial elimination of the properties considered negative has reinforced the impression that this was a positive development.

Over centuries, architects, engineers, and non-professionals have laid a great deal of groundwork in this area, both theoretical and practical. Roof constructions had to span ever larger distances or surface areas. The practice of simply enlarging the beam cross-sections soon reached its limits in more ways than one. Growing massiveness increased the weight to such a degree that such beams could no longer bear the additional load of the roof constructions that they were meant to carry. On the contrary, there reached a point when they, too required support. A rise in construction led to a noticeably significant reduction in timber resources. Competition between those who could afford the few existing exceptional pieces was predictably limited. If the required dimensions were no longer available, craftspeople had to come up with alternatives. Large timber traders and wood factories have not been in existence for very long. The rise in prices triggered by ever diminishing supplies spurred developments, such as truss frames and strut frames. Other innovative approaches, such as the hammer beam construction, proved unviable.

Churches and temples could benefit from gaining an undisturbed view of the alter from all directions. Heavily loaded wagons could be easier to move around in barns if there was no danger of striking any supporting pillars. Bridges had to enable the transport of loads from one bank to another without support. Both interlocking beams and the Chinese "woven" arch bridges extended the reservoir of natural materials. Liu Yan (Liu 2018) has established that similar development approaches had existed in Europe. Log buildings play with the idea of turning a linear material into a two-dimensional one. The observation that two similarly aged trees merge together when they stand in each other's way was first used by landscape designers as a source of inspiration. Meanwhile, companies are now growing furniture to order. Efforts haven't stopped there. Scientists are trying to grow branches of different trees into a network. This is a case of re-thinking wood with a view to expanding its scope of application. The desire to overcome material-specific limitations mentioned in the first reflection served as a source of inspiration for developing products that cannot be manufactured with naturally grown wood, at least not in serial production. If we were to place the two reflections in temporal order of appearance, the second reflection initially acquires solely positive attributes: the material no longer dictates the form of the product; now it's the desired product that determines the development of how the material should be reshaped.

The title the editors have chosen is strongly focused on this second consideration. In their collection of contributions, however, there is room for reflection on my first line of thought. If we allow for both reflections, then the title "Rethinking Wood: Future Dimensions of Timber Assembly" encompasses the never-ending story by human standards of one of mankind's most important building materials.

Trees offer a variety of products, wood being the primary usable resource. No one uses bark or bast nowadays. It has become increasingly difficult to find places where leaves are used to cover roofs. However, the moment we say that wood is the primary usable part of a tree, it becomes immediately evident how one-sided and limited this view is. Trees produce oxygen and bind CO_2. Is this also not useable?

Trees reduce the risk of erosion. Trees are the habitat for many other animals, a significantly valuable function given the world's looming nutrition problems. Thus, this too is useful.

Humans have become increasingly dependent on wood. Numerous analyzes on the manifold and ever intensifying utilization of wood over the centuries have shown this. For a short period, we trusted seemingly more efficient building materials to such a degree that wood was reduced to mere shuttering material in construction. Only in building interiors did it remain a valued material—nothing could replace the warmth and comfort it exudes as it burns in an open or acoustically perceptible fireplace. But wood has experienced an amazing renaissance, making major strides to regain a remarkable status.

This would not have been possible had we continued to use wood in the same way for millennia. Other building materials may have had a strong influence on this. But stone, clay, and iron could no longer sufficiently satisfy user needs. The processes of breaking down the material, re-composing it, and adding substances to it have increasingly homogenized an inhomogeneous material. In addition to making the material easier to process by less experienced craftspeople, it was now possible to do so using machines that were no longer restricted by the limitations of human power. Machines work tirelessly, with greater precision and speed. That these developments "affect our built environment and the way we produce architectural space"[1] is beyond question. The historic building materials wood, clay, and stone have created a formal canon that has undergone few fundamental changes throughout history. Even though our growing experience in dealing with the material combined with improved tools have enabled us to resolve our current needs more effectively, this has followed previously known patterns.

One of the principle thrusts in wood construction was to continually reduce the volume of the material required. Another was to replicate construction designs originally developed in stone and clay building. Wood scarcity drove Philibert de l'Orme and David Gilly to their innovation. Friedrich Zollinger worked in response to the housing shortage after the First World War. Frei Otto was a student fascinated by phenomena that can be observed in nature. He had recognized that there is no better teacher. They all paved the way for curved roof surfaces made of rod-shaped pieces of wood. It was, however, only the development of wood plastic composites that finally made it possible to produce curved beams of any dimension. Cabinetmakers of the Baroque era had demonstrated how to shape thinly cut wood. Flat plywood panels can be easily transformed into curved surfaces. With wood plastic composites, the two-dimensional directionality of wood

---

1. Quote from the preface of this book's editors.

is seemingly no longer a restriction. And yet despite this, the task remains the same. Be it flat elements or linear ones, these must not exceed certain dimensions, otherwise they can no longer be transported and manipulated. The individual elements must still be connected to the building.

Transporting building materials has always been a logistical challenge and quite often a hurdle. And yet built structures have been mobile for at least a thousand years. Insofar as it was feasible, wooden buildings were constructed and produced on site. The connecting components were laid flat on the ground, trimmed to size, and respectively labeled. At dizzying heights, they were then assembled to roof trusses over churches and palaces rather quickly and requiring little adjustment. It was absolutely common practice to relocate buildings. Many were dismantled for this purpose, a feat only made possible by using detachable wood joints (Zimmermann 2007).

Just as this development affects our environment and the production of architectural space, it is clear that the development of new wood construction materials has an "impact [...] on our culture."[2] The way we tackle and solve our current tasks and problems shapes our culture. This is a gradual process. Artificial materials hardly ever emerge from a flash of genius; rather their development is a result of the cooperation and competition of many minds from both economics and science. This is reflected in the wide range and diverse content of the contributions in this book. The human spirit can hardly be reined. In that sense, development can neither be stopped nor questioned. Reflective considerations are always permissible; not only because they are fundamentally interesting, but because they make us aware of the temporal constraints of cultural currents. Hermann Phleps (Phleps 1959) wrote that "(ornamental multiplications of constructive bracing in the framework) spelt the decline of timber construction." A verdict he may perhaps wish to reconsider in light of screen-printed, ornamental patterns on the many high-rise smooth glass facades or wood-clad concrete walls.

In using wood as a raw material for wood-based materials, there is no reason to differentiate between trees that have grown in the rainforest and those on plantations. The selection criteria are cost-efficiency and reproducibility according to demand. This example alone shows the impact both on our culture and our understanding of it. Some structural engineers are aware of the "gap between reality and practice." Civil engineer, Bruno Ludescher knows that the growth conditions of trees have a significant impact on the quality of their wood. But, as Bruno Ludescher puts it (Ludescher 2015), "how should we correctly comply with this empirical data?" We cannot reliably judge

---

2. Quote from the preface of this book's editors.

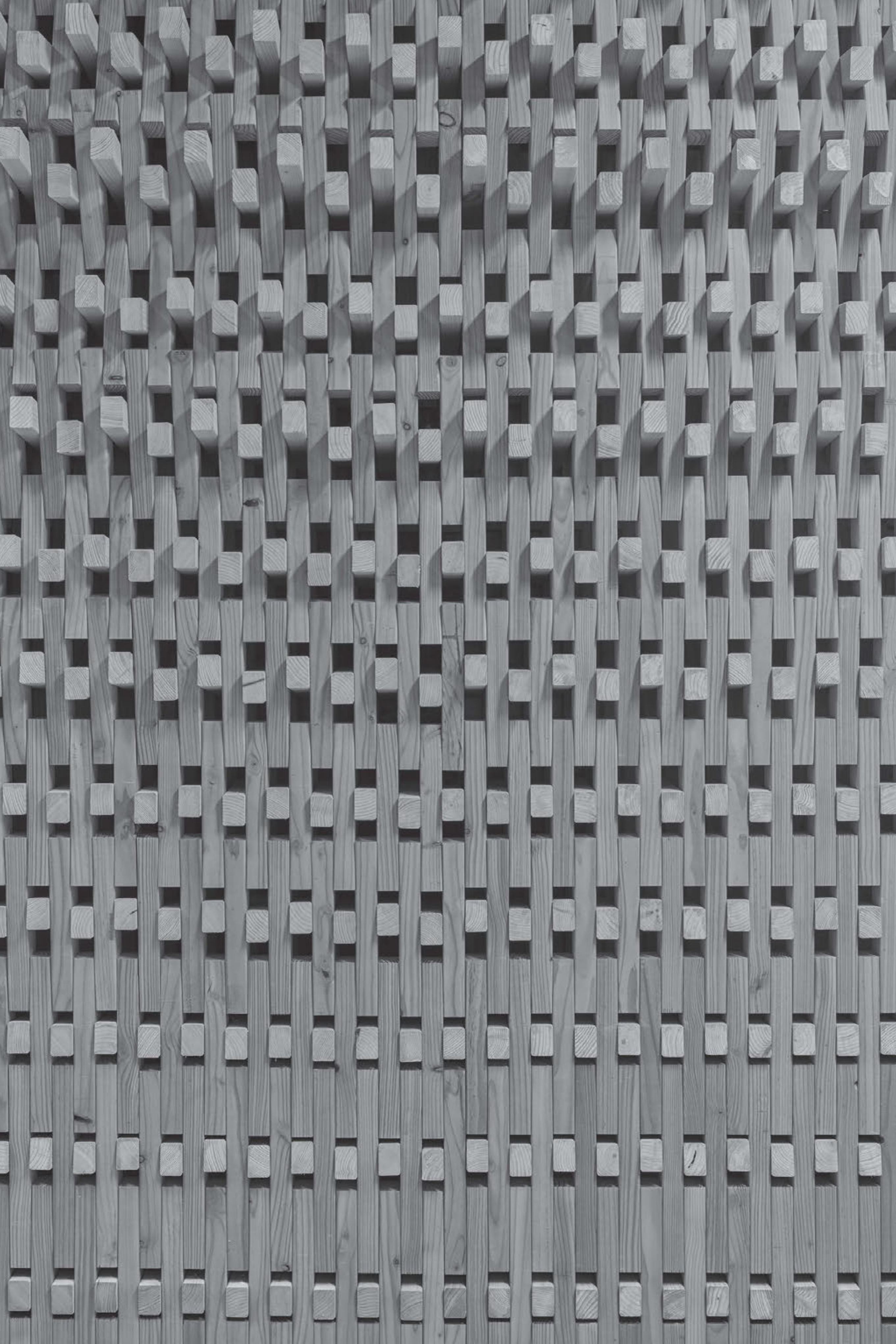
this development, as captivated as we are by its course. Perhaps this is a task for later generations.

I am fascinated by the wealth of ideas expressed in the examples presented here; from the consistency and outcome of intellectual achievement and perseverance to their implementation. We can look forward to seeing which of these ideas will prevail and which proposals will spark transformation or become the starting point of something new. Research, development and testing new ideas are prerequisites for improvement. That many approaches remain unsuccessful should not discourage anyone from bravely daring to taking the leap. But allow me to make a few critical observations that go beyond this material's current usefulness.

We cannot expect everyone to see trees as more than a source of wood. Many don't even make that association. One consequence of the devastation that Europe suffered in the twentieth century was the questioning of traditional taboos, which brought about enormous improvements. But where there is light, there is shadow. Many a liberation has been ruthlessly carried out on the backs of others. In the euphoria of seemingly limitless growth, we have severely overexploited our natural resources. Many a liberation has left a vacuum. In our pursuit of self-actualization, we have failed to respect our neighbors, leading us to hit limits we can't quite handle. Disoriented, we seek stability in mindfulness and the like. But where is the mindful understanding of the source of our existence, an awareness of the fact that our survival depends on a nature that makes our lives possible? Repeatedly misusing the term sustainability will not ensure our continued existence. It speaks for the editors that they have also dedicated two contributions on this topic.

To err is human. New developments do not arise without mistakes. Yet, regrettably, mistakes are often only detected in the application. But should they not be corrected as soon as they are discovered; and not only when they are acknowledged as such? Should we not examine the consequences of our actions much sooner, in order not to commit as many errors in the first place? The production of wood plastic composites could promote the short-term profitability of monocultures, against better judgement. By stating that the forest grows faster than trees are taken from it in volume may lead to an apparent positive CO_2 balance. However, in the longer term, such statements could become meaningless statistical number games. Should we not be critical when all the CO_2 bound in the forests is expelled again when we clear them, transport the wood to gigantic factories, refine it, and transport it again over even greater distances to the most remote construction sites? Thonet's example shows that scarcity sometimes stimulates more innovative behavior than abundance. The company built its factories in the midst of purchased forests to minimize transport routes in at least one direction. We are not proposing this as a conceptual blueprint for today's major producers of wood-based materials. What we need today is completely different ideas. Innovations cannot be copied. Luckily, there are architects who are not afraid to take issue with and act on the use of non-regional building materials and resources, even if it comes at higher cost for their clients. The supermarket mentality of being able to afford everything because it is cheaply available, rather than sacrificing many other needs for the sake of quality, is understandably a reflection for a minority, reserved for those who are concerned and—it must be said—can afford it. Building ecologically and sustainably does not only depend on the choice of building materials. Is not thinking globally and acting locally also a worthwhile principle in the building industry?

Many architects are already investing a great deal of brainpower and design time in developing construction methods that facilitate a clean separation of the various construction materials used after the expiry of the building. Students write diploma theses on this subject. The awareness that wooden components glued with plastics do not simply return residue-free into the natural cycle when they are left to decay has led to a reflection on alternative, residue-free wood composites. This begs the question: Are product developers allowed to be content with the fact that distributors of their new products are using high-budget marketing to hide and lie about product deficits? Are ethical questions not appropriate or even necessary here? Despite our fascination for new developments, should we not investigate the consequences of our actions as intensively as we pursue goals to optimize nature according to our ideas? Business-focused entrepreneurs make no room for such ifs and buts. So, the first responsibility remains with the developers. It must also be taken into consideration in the development process. Because let's face it: no one – and especially not those working with wood – wants to be accused of being shortsighted.



Preface

The popularity of wood as a building material has been thriving over the past several years. Digital design tools in combination with numerically driven fabrication processes have made many of the outstanding examples of contemporary wood architecture we see today possible. However, developments in material engineering have made an equally important contribution. Whereas traditional timber construction exclusively used components made of solid wood, timber construction, as it is referred to today, relies mainly on wood-derived products.

These products are basically reorganized and reassembled forms of previously comminuted natural wood. The application of different strategies of reorganization on the material level, using for example veneer strips, chips, or particles as basic raw material, has led to a large variety of timber-derived products with new mechanical, physical and geometrical properties. These in turn have enabled structures with bigger spans and unlocked new possibilities and challenges regarding their assembly.

New materials, such as wood foam, and new processes and applications for material derivates, such as cellulose and nano-cellulose, continue to be developed and explored, opening up new potentials regarding digital fabrication. Consequently, this has led to a number of questions and challenges: What will wood assemblies on different scales look like in the future? How will they affect our built environment and the way we produce architectural space? And how big will the impact be on our culture, and our technological knowledge and progress?

This publication seeks to explore and answer these questions by bringing together a collection of recently built projects, seminal research projects, and critical theoretical perspectives, which, among other things, invite the reader to rethink the current rapport between hylomorphic and morphogenetic design approaches. It suggests that digital technology and material driven practices, connected in an intricate web of mutually dependent relationships, can drastically change our ways of thinking about architectural design as a form of cultural expression.

The book addresses the above-mentioned topics and questions in five parts: Concepts and Perspectives, Joinery Culture, Digital Processes, New Materials and Applications and Reapproaching Nature. Each part begins with an introduction that briefly summarizes the individual contributions as well as puts them into context with recent and future developments in the respective fields. Whenever applicable, these introductions also highlight crosslinks between contributions and topics of different parts.

The first part, Concepts and Perspectives, brings together thought-provoking essays and concepts that address the notion of sustainability and challenge our understanding of the building material wood. The reader is encouraged to see beyond the isolated individual wooden component, and to understand it in the context of the ecosystem from which it emerges, which is the forest. Moreover, this part presents strategies, such as wood cascading and Design for Disassembly, that could lead to a more material-efficient use of wood and help maintain a balanced and sustainable forestry. It offers perspectives and speculations on the future of forestry and wood construction both in Europe and Southeast Asia.

Technologically processed wood-based materials have expanded the horizon of possibilities for architects and engineers. The downside of these artificial composite materials is that they are difficult to recycle. Whereas the need for skilled carpenters and manual joint carving is diminishing, there is an increasing demand for experts who could help transfer traditional timber construction knowledge and joint configurations into modern practice. Hence, the projects presented in the second part, Joinery Culture, address the adaptation of traditional joinery knowledge to modern fabrication processes and vice versa.

Part three discusses the integration of wood properties into computational design procedures as well as the resulting economic and social implications of Digital Processes. Pioneering research at ETH Zurich, Stuttgart University, and EPFL, as well as by other stakeholders like Design to Production, has paved the way for the next generation of researchers and practitioners. The projects presented here illustrate the current shift from process-specific CNC machines towards more flexible and versatile tools that push the boundaries of what is buildable. Harnessing the power of computation, they not only involve sophisticated design and fabrication processes, but have also started to include the modelling and analysis of the material behavior.

The fourth part introduces new wood-based materials as well as new applications. Unlike most wood products available today, the examples featured here do not, at least in principle, rely on adhesives. Based on the general approach behind engineered wood and wood-derived materials as well as some of the featured examples, the introduction to this part also provides an outlook on new concepts of materiality. Moreover, it predicts a future in which architects and designers will have a bigger say in the design of wood-based and bio-materials. It remains to be seen whether this will impact the degree to which materials are designed towards a specific application and the degree to which they are used as design drivers themselves.

Finally, but no less important, part five, entitled Reapproaching Nature, presents approaches that explore the potential of using naturally grown and living wood as well as new ways of exploiting the properties and behavior of natural wood as design drivers. Here, the growth parameters of living organisms themselves become integral design drivers for buildings with a novel and unique architectural expression.

Dealing with custom-grown building components and the appropriation of natural form and material morphology, the projects and concepts featured in this final part of the book belong to the forerunners of an increasingly dynamic movement.

The different contributions of this book address, on various scales, a wide range of aspects regarding the building material wood. Despite their heterogeneity, they all move beyond established ways of understanding and using wood. Enabled and driven by new material developments, fabrication processes, and a renewed interest in the potential of natural wood, these approaches are pushing the boundaries and opening up new dimensions of timber assembly. Each of the contributions highlights different constituents of this new agenda, mapping out future developments for an old and familiar material, while maintaining links to cultural and historical aspects. Despite its familiarity, it seems there remains much to be discovered about this material and its different forms.

Currently, many of the featured approaches remain of interest only to academic and specialist circles. But not for much longer. With this publication we aim to make them accessible to a wider audience, including students and professionals in the fields of design, architecture and engineering, as well as to the interested public.

The editing and publishing of this book were made possible thanks to the generous support of Aalto University's Department of Architecture, the Department of Civil Engineering, the Chair of Design of Structures, as well as the Wüstenrot Stiftung. We are indebted to all guest authors and their valuable contributions to this publication. Moreover, we would like to express our gratitude for the advice and consulting from our colleagues and friends.

Markus Hudert and Sven Pfeiffer, 2019

Concepts and Perspectives

The steady rise in wood's popularity as a building material over the past decade puts it well past being a 'new' phenomenon. Wood has become a veritable alternative to concrete and steel, at least in many parts of Europe and North America. Reason enough to closely examine some of the causes – as well as assumptions – behind this material's popularity. In the context of climate change, the main argument for using wood typically is the fact that it is a renewable resource and that it stores CO_2. Hence, one could argue that wood deserves the grade "sustainable" more so than other materials.

Tatry forest. Photo: Dominik Slomka (cc)

The sustainability of wood, however, is not absolute. What is often overlooked is that all-natural wood is hardly used in contemporary building construction. In this context, and as the fourth part of this book points out, one should bear in mind that the use of engineered wood and wood-based materials, the production of which typically involves adhesives, is not entirely unproblematic. Moreover, the fact that wood is a renewable resource does not mean that its availability is unlimited. Its sustainable production requires a well-balanced and sustainable forestry. In addition, we need to think of more resource-efficient ways of using wood in buildings.

In his thought-provoking essay, Kiel Moe shows that wood fulfills many of the criteria that we would define as desirable goals when developing a new building material. More importantly, he encourages us to rethink established notions, and hence question our general understanding of wood and in particular its use as a building material. He suggests that in order to be truly sustainable, we need to unthink or abandon the ubiquitous yet rather narrow understanding of wood in building construction and architecture that typically disregards the ecosystem behind it, namely the forest. In architectural design, the relational and reciprocal dependencies between the components involved, as well as the relationship between the parts and the whole, typically play an important role. Moe argues that we need to expand this systemic way of thinking to materials and energetics as well.

As mentioned earlier, wood is a renewable but not an infinite resource. In this context, Mark Hughes highlights the necessity of using wood in a more resource-efficient way. One strategy of achieving this is the *re-use* or *cascading* of wooden elements that are embedded in already existing buildings.[1] The concept of *cascading* is comparable to that of *down-cycling*: a building component is re-used several times, for iteratively less demanding purposes. The approach of *Design for Disassembly* (DfD) aims at improving the ease of recovery of the constituent elements of future buildings. Similar to Moe, he suggests that sustainability must not be sought in building construction and components alone. It must extend to the forest, which is the ecosystem behind the building material wood.

In comparison to central and northern Europe and North America, the renewed interest in wood is only just emerging in large parts of Asia. The region's booming economy and the high volume of new building construction would make the potential impact of using more wood tremendous. Michael Budig discusses the current situation and future possibilities of building with tropical timber in Southeast Asia.

---

1. A relevant and promising reference regarding current developments in the area of material re-use in building construction is the project *Mine the Scrap*, developed by Tobias Nolte and Andrew Witt of Certain Measures. As part of this project they developed a software tool that scans scrap elements from demolished buildings and rearranges them into new architectural envelopes (Nolte and Witt 2016).

Moreover, he presents the results of an architectural design study that he conceived and carried out at Singapore University of Technology and Design (SUTD), which aimed to increase the awareness of tomorrow's architects and designers regarding the qualities and potential of this building material in this region of the world. In the long run, the aim is to cultivate a higher and more widespread appreciation of wood, as well as an increased use, and hence a likewise increased value of this material, thereby helping prevent the clearing or torching of tropical forest areas.

Although wood is probably the most sustainable building material currently available, there are still many things we can learn – and some things that we should unlearn – about it. The authors of this part introduce different approaches that address our complex relationships to this resource, including research into forestry and systemic thinking. Instead of focusing on isolated solutions, we should expand our goal of an increased sustainability to a larger scale, to material and energy flows. The available volume of wood for construction is limited as it relies on a sustainable and balanced forestry. With new approaches, like *wood cascading* and *Design for Disassembly*, we can help to keep this balance intact.

Think Like the Forest: Maximizing the Environmental Impact and Energetics of Building Timber

Kiel Moe

If we were to design a building material from scratch today, certainly some of its key characteristics would be that it:

- captures carbon, rather than emits it, during its production
- has production and extraction processes that can augment the cultivation of biodiversity
- does not require fossil fuel consumption for its production, extraction, and processing
- is renewable at the scale and rate of human consumption
- is based on a cellular solid material architecture that can modulate both heat and humidity in a single material
- has a thermal diffusivity between that of insulating foams and dense thermal masses
- has a thermal emissivity lower than human skin
- fosters good health and air qualities, and is certainly not toxic
- is fireproof for construction
- has a construction ecology readily mapped and quantified
- has a knowable and negotiable political ecology
- has forms and scales of unequal ecological and economic exchange we can readily address
- is capable of enabling small-scale economies
- is, as Ivan Illich would say, "convivial" i.e. it is easily workable with simple tools by everyday people
- is open source: its core intelligence is non-proprietary
- incorporates feedback as it adjusts and adapts to changing conditions

The above is a partial list of properties we might associate with wood. No human-derived material/energetic system approaches the nuanced complexity and efficacy of the processes that make "trees" and thus the building material we call "wood". Wood is a 400-million-year-old material that has evolved and assembled a set of relationships and system properties that we, as human beings, have only begun to understand (Kohn, 2013). Surely there are many more relationships and properties than we have yet to comprehend; or perhaps simply cannot, or may never, comprehend. Thus, more than designing a new material, or even a new material process, what the world most needs today is:

- a new way for humans to fully understand a material (like wood)
- a new process for acquiring knowledge about a material (how we might research and teach "wood" architecture)
- a new way to understand material processes (not merely as engines of commodification and product-making)
- and, perhaps most importantly, the way a material relates to the world in the fullest possible sense; not just to some discrete component-object in that world (such as a "building")

Together, this would constitute an "advanced" conception and use of wood. In this regard, though, we must acknowledge that architects have been trained, literally, not to see the forest for the trees, nor even to see the trees when it comes to wood. Even worse, architects typically have little idea of what wood is, or what it does or could do, much less what forest do or could do. Too often construed as the simplest—perhaps most banal of building materials—wood is typically presented as rudimentary in construction courses and textbooks, and thus too often perceived to be in need of new methods and processes. So within the abstract domain of "wood", it is easy for architects to get lost in the recent proliferation of contemporary claims about timber construction, processes, and possibilities, which are indeed important in themselves and worthy of our interest. However, it pays to recognize that the most important and advanced thinking about "wood" is not, yet, in the building industry.

The reality is that there is no such physical thing as "wood," just as there is no such thing as "a tree." There is the forest: that amazingly complex and vital set of relationships and processes from which modern western minds vainly attempt to isolate the idea of a tree, or the even more abstract concept of "wood." We might have a loose, abstract association around a set of materials and properties that we might describe as "wood." Or we might collectively hold in our minds an abstract, children's comic book illustration of a tree. These isolating abstractions are violent abstractions that already do epistemic and ecological damage in the very way that we conceive of and name them; to say nothing of the way architects further abstract and externalize wood. We need a conception of wood, like forest, that alludes to the complex and vital set of relationships and processes that are inextricable from the "wood" we use in buildings.

To understand wood—indeed to *rethink* wood today—is often to think about wood for the first time in a serious way. To rethink wood and its assemblies in architecture today, likewise, is to rethink what we think an assembly is and what it can do. Not just building assemblies, but all the socio-bio-geophysical assemblages that presuppose those building assemblies (Bennett, 2010). To rethink wood, we need to question our assumptions about assemblies such as trees, as much as the forest, and certainly wood's complex, sublime relationship to civilization and the planet as a world system. We need to think about building environments in relation to living environments in entirely new ways. This requires us to understand the specificity of what we call wood and all it actually does and can do in the simultaneous assembly of both living environments and in building environments. As one starting point, it probably means dropping the abstractions we use to externalize the consequential dynamics of "wood" in our pedagogical and professional spheres.

The degree to which architecture might attain what we once associated with "sustainability" is the degree to which architects will not merely build with wood, but rather finally understand the deep ecological implications of building with living materials. In the case of wood construction, a homeorhetic relationship with living systems will only be understood—and indeed will only be possible—when we understand that *building and assembling forests is as important as building and assembling architecture*. We need to grasp how related and potentially mutual these acts of building in fact could be. To build with timber we need to foster timber first. For only then might we understand what it actually means to build a world, rather than just consuming our abstractions of the world—like wood and fuel—to build even more abstract buildings.

Once we begin to understand the larger set of relationships and processes that encompass what we call "wood," we will understand that we are merely re-directing the hardened edge of one of the earth's most evolved and astonishing dissipative structures. And herein lies the ostensible purpose of this contribution to this book: to address the energetics of building with timber. As it turns out, understanding "wood" as a unit of living systems such as trees, forests, and people is an excellent way to learn more about energy and energetics.

Wood offers lessons on energy because it is a clear example of our chronic problem with energy: we confuse and conflate fuel for energy. We ubiquitously use abstract nomenclature (like fuel) for much more exacting and rich energetic processes. The fate of the world is trapped in that dangerous abstraction. Given our fuel-centric ontology of energy, we are not trained to see the larger dissipative structures of energy cascading through the universe and our planet. We are epistemically and methodologically misguided in this way about energy in our culture. Rethinking wood can help us relearn what energy is, and what energetics might offer us as a way to act in the world.

Energetics

Just as we are trained not to see the forest for the trees, or the trees for the wood, we are likewise trained not to see the dissipation of energy through the vast array of nested dissipative structures and systems throughout the universe and in our living planet. We only see and commodify fuels as specific forms of energy and discuss their relative "efficiency"; in a similar way we are trained to see wood beams and panels, and discuss a few of their structural or thermal properties as abstract entities. To learn to see the forest for the trees and its wood is itself a lesson on how to see energetics beyond the abstraction of fuel. To learn that lesson would engender far greater and further-reaching impacts on collective dynamics like energy consumption and biodiversity than any far smaller, instrumental claim about the thermal capacities of wood in buildings, or their carbon sequestration dynamics. These behaviors, properties, and dynamics related to timber building are important, but their relationship to a larger set of energetic and ecological processes are imperative to understand. If we are at all serious about the core concept of sustainability, we need to grasp and hold onto these larger, paramount lessons about energy and forests. In building science, more than ever before, we need to think on a macro-scale rather than a micro-scale. We need to get out of the lab and studio and into the field and forest. This contribution is but a sketch of what some of these lessons might be as we collectively continue to think about how we can maximize the environmental impact of building with wood.

Wood

"Wood" is the by-product storage media of our planet's most astonishing and effective energetic process: photosynthesis. As autotrophs, flowering plants like trees have evolved over hundreds of millions of years to absorb diffuse and low-quality, but extremely abundant formations of energy—sunlight—and mix it with diffuse and "simple" compounds like water and carbon dioxide. One of the products of this photosynthetic process is cellulose sugar. These sugars are channeled into the supple solid mass structure of the woody plant-tree; the bulk material that we use as timber building components.

As the plant grows, it is effectively a 3D printer (Craig, forthcoming 2019). It deposits cellulose material as it grows up towards sunlight, while simultaneously building a vertical vascular structure that it uses to circulate water and other compounds throughout the dendritic organization of the organism. This vascular structure effectively makes the tree a pump that links the ground to the atmosphere, locking carbon into the soil and either emitting moisture into the atmosphere or into the soil. (In this regard, it is not surprising that wood is an ideal material to not only structure a building, but also to modulate its humidity and moisture content, while also addressing the thermal behavior of the building (Hameury 2005)). The expanding horizontal girth of this vascular mass increases its capacity as a pump, but also its structural capacity, thus permitting the organism to grow taller and thus produce more branches and leaves. As such, this organism steadily increases its intake of more and more carbon, sunlight, and water through this growth, in order to support further growth. The net result is an organism that evolved over 400 million years to maximize the intake of simple compounds and diffuse energy—like water, carbon, and photons—in ways that process and mix them to produce more complex compounds and trophic relationships with adjacent species, including humans, through its modes of feedback reinforcement. It is, in short, a model of thermodynamic optimism and ecological generosity; a stark contrast to the pessimism of our current model of isolating, "self-sustaining" survivalism (Braham 2011).

We can marvel at the seeming "simplicity" and sheer effectiveness of this highly evolved organism. Nevertheless, the above description is merely emblematic. It is, itself grossly abstract and inadequate to offer insight on the far more and ingenious evolutionary adaptations and mutualities that particular species co-evolve in particular places. This requires thinking of wood beyond the tree, and the tree beyond our nascent understanding of how it relates to the forest of larger bio-geophysical processes and histories. For instance, if we currently consider wood as only the above-ground portion of the tree, then what are we omitting? Dr. Suzanne Simard from the University of British Columbia points to the intensity of the rhizosphere activity as part of forest communication and metabolism that presupposes "wood" production. As one example, forests metabolize decayed salmon brought into their milieu by bears and wolves using nitrogen from the decayed fish to signal other trees through fungi, trade nutrients, and fix carbon (Simard 2018). Or consider the lifetime study of tree "architecture" in the tropics led by Francis Hallé that helped scientists to understand the tree as a community, rather than as an individual (Hallé 1978). Even our ignorance and abstractions of a particular tree species, such as Gingko biloba can be re-examined. The Gingko is a living fossil that survived both the dinosaurs and the atomic bomb through its structures and intelligence (Del Tredici 1991). If we are in fact motivated by survival, then attention to expert species might be advisable. Such examples and models of study are replete with possibility for design, as elucidated by Rosetta Elkin's advocacy for bringing the vitality of plant life back into the profession of landscape architecture (Elkin 2107). Erwin Thoma offers some insight for architecture, but models of design are indeed scarce in this regard (Thoma 2014).

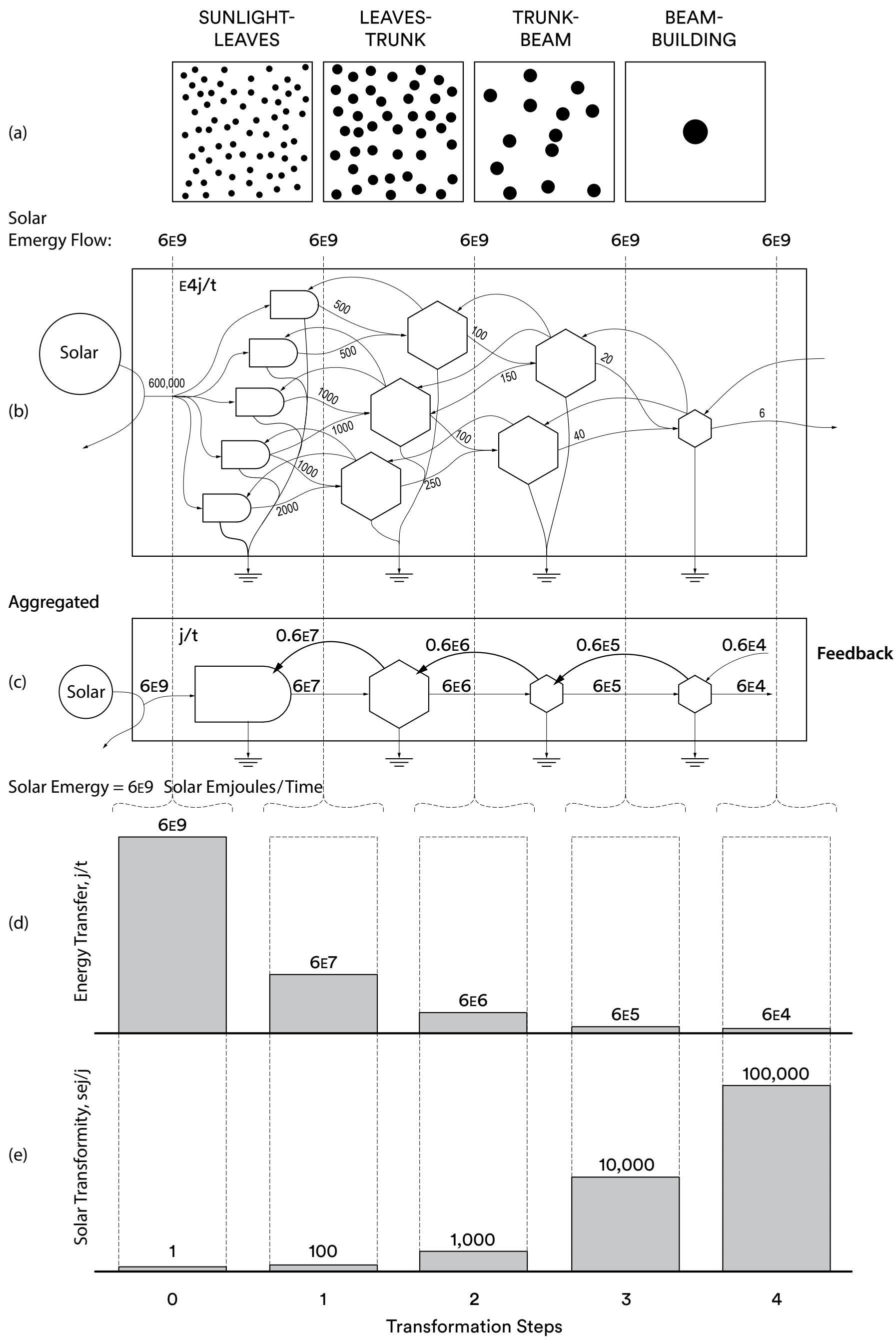


Figure 1. “Wood” is the temporary, captured state of a cascade of low-quality but abundant energy inputs and more scarce, high-quality outcomes and feedbacks. Systems ecology diagrams track the flow from the sun to, in this case, the leaves, branches, and trunks to building components and buildings; tracking the material formations that emerge to dissipate this exergy along the way. The diagrams also track the feedback of material, energy, and feedback that flows back through the system and gives it structure. This is called design. The illustration is drawn by the author, based on Howard T. Odum, Environmental Accounting: EMERGY and Environmental Decision Making, New York, John Wiley and Sons, 1996.

Energetics of wood

We will never understand "wood" unless we begin to grasp the seeming simplicity and effectiveness of the *energetics* of this organism that produces wood. Woody plants are unmatched as a dissipative structure in how they have evolved to degrade available energy gradients. Consider the cascade of its energetics (Figure 1). Low-quality energy enters the organism, and higher-quality formations and concentrations of that energy emerges as that intake energy cascades through the system again and again as feedback. To cascade and feedback energy in this way, trees have developed mutualities with adjacent species at all trophic levels to further dissipate the available energy. At some point it is sheer hubris to isolate one species from its obligates. For example, humans breathe the "waste" products of these organisms—oxygen—while these organisms transpire our "waste" carbon dioxide. But that carbon dioxide-oxygen cycle is ambiguous without considering the mutualities that presuppose the "tree" in the soil conditions that host the growth of the flowering plant, the tacit agreements with other species to spread seed, or the capacity of the tree trunk to host thousands of species and organisms once the "tree" has died and has fallen to the forest floor. This is where our abstractions of "tree" and "wood" become more pronounced; and where they do the most harm.

Why would we fetishize the "tree" its upright living state over its next state of supporting life in other ways on the forest floor or in an apartment building? How can we abstract "wood" from the rich, vital complexity of these long-evolving processes? How can we abstract "biomass pellet fuel" or "R-value of wood" from this complexity? Each of these abstractions has their use and purpose, but we must recognize that we habitually fail to link insight on individual abstractions and studies to the larger context from which we abstract. This failure to link our study of isolated abstractions in architecture to larger systems is at the core of our most "unsustainable" practices and beliefs.

Forests as dissipative structures

One simple, but illustrative measure of the energetic effectiveness of the dissipative structure we call a forest comes from landscape ecology. Landscape ecologists Jeffrey Luvall and H. Richard Holbo studied the level of radiation emitted by varied patches of landscape (Luvall and Holbo 1991). The patches were all in the same region, so they received similar levels of solar insolation. The results were that an old growth forest emitted lower temperatures than a quarry, an agricultural field, or a new growth forest (Table 1). The quarry merely exhibits the simple absorption and re-radiation of that solar energy from the stone mass and surface. Very little work is extracted in this landscape patch and it has no mechanisms for further productive dissipation.

In contrast, the old growth forest does more work, having evolved a more sophisticated dissipative structure and organization. This is be-

	Quarry	Clearcut	Douglas Fir Plantation	Natural Forest	400 year old Douglas Fir Forest
K^* (watts/m^2)	718	799	854	895	1005
L^* (watts/m^2)	273	281	124	124	95
R_n^* (watts/m^2)	445	517	730	771	830
T (°C)	50.7	51.8	29.9	29.4	24.7
R_n/K (%)	62	65	85	86	90

K^* = incoming net solar, L^* = net long wave out going, R_n = net radition transformed into nonradiative process at surface, R_n/K^* = percent of net incoming solar radiation degraded into nonradiative process. [excerpted from Jeffrey Luvall and H. Richard Holbo, "Thermal Remote Sensing Methods in Landscape Ecology," in Quantitative Methods in Landscape Ecology, eds. Monica G. Turner and Robert H. Gardner (New York: Springer-Verlag, 1991), 127–52.]

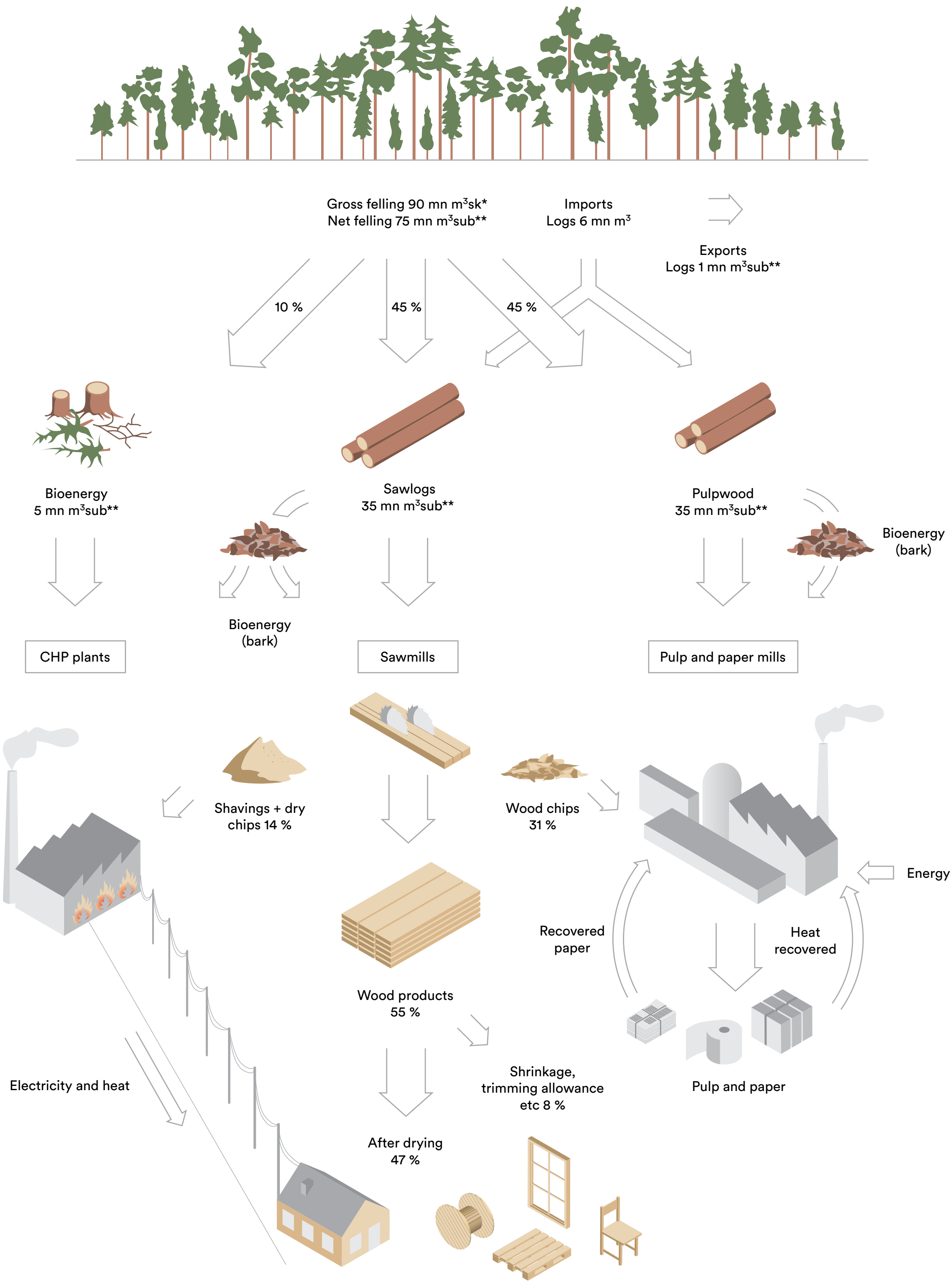
Table 1. Radiation emitted by varied landscape patches. Excerpted from Jeffrey Luvall and H. Richard Holbo, "Thermal Remote Sensing Methods in Landscape Ecology."

cause over time the old growth forest has developed highly integrated and diverse systems that put the same energy input to work in complex ways—such as in the growth of diverse flora and fauna at many trophic levels. In short, an old growth forest reflects a set of highly evolved, complex interrelated systems that cascade and dissipate the same solar energy more effectively through their structure and organization. More work is extracted from the same solar gradient as more living processes tap into that gradient. This is not solar energy as a "fuel." This is a complex organization of coupled living systems that collectively work towards exuberance, abundance, and vitality from the lowest quality inputs. A directly analogous exuberance and vitality ought to be the purpose and aim of design.

What we call "wood" is one of the most complex and vital of building materials, primarily because it is living material that is part of living systems. No single person knows all it is capable of doing or should be doing, not only in architecture, but also in the ecology of our planetary urbanization. However, there seems to be no more important or ambitious task for those who make claims on how to couple environment and architecture than attaining non-abstract, non-externalizing conceptions of "wood." It is a profound first step towards rethinking wood.

As we rethink wood we must finally grasp the hierarchy of energy and other life-sustaining processes inherent to what we call wood, tree, or forest. We can then finally begin to understand how to maximize the environmental impact of specifying wood in contemporary construction. But in doing so, we might finally recognize that we would not be specifying wood per se (thinking like a wood beam), but rather we would always be specifying a vast assembly of nuanced processes and properties that in aggregate could, if adequately understood, meaningfully adopt the adjective "sustainable."

We need to evolve far more sophisticated dissipative structures as the basis of our energetics in architecture. What we once called wood is an important part of that dissipative structure design. But hopefully, as inhabitants of the world, we soon forget the bizarre abstraction of "wood" as a precondition of how we come to borrow the hardened edge of the world's most sublime energetics—forests—as we build with forest-based cellulose materials. In doing so, we would come to think, and act, like the forest.


Gross felling 90 mn m³sk*
Net felling 75 mn m³sub**
Imports
Logs 6 mn m³
Exports
Logs 1 mn m³sub**
10 %
45 %
45 %
Bioenergy
5 mn m³sub**
Sawlogs
35 mn m³sub**
Pulpwood
35 mn m³sub**
Bioenergy
(bark)
Bioenergy
(bark)
CHP plants
Sawmills
Pulp and paper mills
Shavings + dry
chips 14 %
Wood chips
31 %
Energy
Recovered
paper
Heat
recovered
Wood products
55 %
Electricity and heat
Shrinkage,
trimming allowance
etc 8 %
Pulp and paper
After drying
47 %