Teaching the Circle

PAPER

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The immediate short-term reduction of up-front embodied carbon in the built environment is essential for meeting our global climate goals. Embodied carbon can be reduced drastically by integrating aspects of building and materials reuse into all projects. In order to prepare future architectural leaders for this challenge, academia must pro-actively teach circular building design strategies at various points in the curriculum. In particular, this paper explores the benefits and challenges of integrating circular design problems into architectural studio courses. The tools and resources presented are aimed at faculty who are somewhat familiar with circular design to begin to introduce these concepts in a studio context to undergraduate students who may have very little prior knowledge of the importance, challenges, and opportunities associated with circular building design.

EMBODIED CARBON, CIRCULAR DESIGN, AND CLIMATE CHANGE

The increasing mandate to drastically and quickly reduce carbon emissions in order to avoid the worst-case scenarios from climate change is a call to fundamentally transform the way that architects and designers approach their work. It is now common knowledge that our industry is responsible for approximately 40% of total global CO2 emissions.[1] The launch of the Architecture 2030 initiative in 2006 marked a shift in architectural practice toward greater concern and sense of responsibility for the environment. Since then, the AIA has worked to reposition architects as leaders in the struggle to combat climate change. Most notably, in 2019, the AIA re-branded the COTE (Committee on the Environment) Top Ten Measures as the Framework for Design Excellence which is now used as criteria for all AIA awards programs.[2]

Unfortunately, climate change isn't waiting around anymore. In the past two years, despite strong success in reducing carbon emissions from building operations, the effects of human-caused planetary warming have started to become everyone's lived experience. The result is a need to immediately develop and implement strategies that prioritize reductions in the up-front embodied carbon emissions generated from building materials.

> "Embodied carbon emissions are generated by the manufacturing, transportation, installation, maintenance, and disposal of construction materials used in buildings, roads, and other infrastructure. Up-front embodied carbon (also known as up-front carbon) refers to the greenhouse gas emissions released before a building or infrastructure starts being used, which are largely from manufacturing impacts. This is particularly important for reaching 2030 climate targets because these emissions will be "front loaded" in the next 10 years, unlike annual operating emissions or end-of-life emissions, which will occur later and/or gradually over time."[3]
>
> —AIA-CLF Embodied Carbon Toolkit for Architects, Part 1

Implementing widespread building and materials reuse through a circular building economy are essential actions in reducing up-front carbon emissions. According to the Ellen Macarthur Foundation's (EMF) Resources for Higher Education, a functioning circular economy does the following, "Designs out waste and pollution, keeps products and materials in use, and regenerates natural systems."[4] This concept is further illustrated in Figure 2 where the diagram shows biological and technical material flows being infinitely recycled back into a system of manufacture and use, thereby eliminating waste and reducing the up-front embodied carbon of materials used in a project.

Refocusing architectural education on reducing the short-term effects of embodied carbon requires more than just teaching the practical and scientific connections between climate change, embodied carbon, and circular design. Publications from leading circular design research teams at ZHAW School of Architecture, Design and Civil Engineering[22] and more recently from the team at the Cornell University Circular Construction Lab not only highlight robust built and theoretical case studies, but also include articles that have manifesto-like calls to action touching on the cultural and aesthetic consequences of this shift in practice. Clearly, this is a topic ripe for exploration in the academy.

The intended audience of this paper are faculty teaching undergraduate upper-division studio courses that may have some familiarity with the subject, but whose students may have little

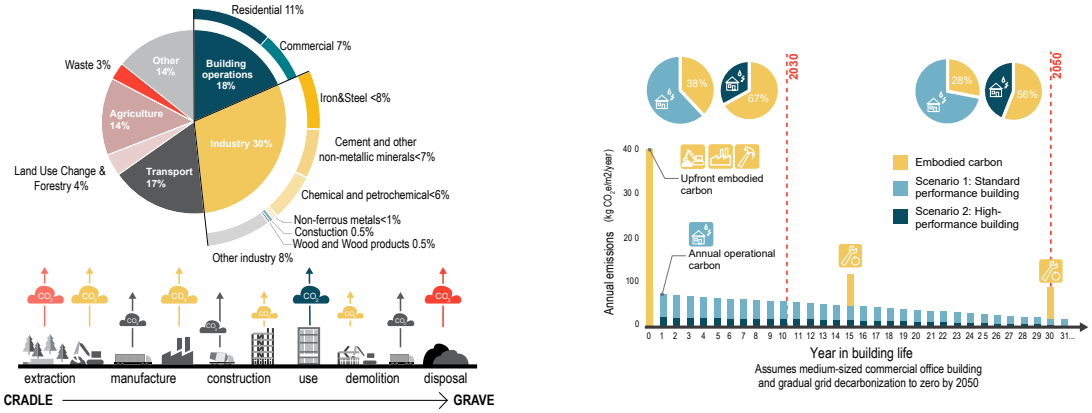

Figure 1. Three essential diagrams to help understand embodied carbon emissions. Adapted from AIA-CLF Embodied Carbon Toolkit for Architects, Part 1: Introduction to Embodied Carbon (see endnote 3)

knowledge of the role that architecture plays in contributing to up-front carbon emissions. Although seminar and design courses can explore this topic, design studios traditionally benefit from smaller class sizes where students have the opportunity to use higher order critical thinking to synthesize their learning in a design process. Furthermore, the products of studio design courses are often put on display through publication and portfolios, serving as a powerful method to communicate the program's values both internally and externally. A studio that trains students to prioritize reductions in up-front embodied carbon through circular building design strategies will develop the advocates and leaders we need in solving our climate crisis.

CHALLENGES AND OPPORTUNITIES IN THE ACADEMY

Although there are a few individuals and programs that have developed strong programs and curriculum in this area, a survey of the DEZEEN Magazine Online School Shows demonstrates that many architectural schools in the United States do not yet appear to be prioritizing teaching circular design or up-front embodied carbon reduction strategies in their undergraduate studio courses.[5] The survey looked at 24 schools in the United States with a variety of levels and design disciplines. The criteria for identifying projects was based on a single image and text and kept very broad. Projects with any evidence of circular design strategies or embodied carbon concerns were included. The survey revealed that out of 489 projects from the past 3 years, only 38 or 8% showed these indicators.

As a comparison, the AIA COTE Top Ten for Students Competition[6] has been taking place for nearly ten years. This competition specifically includes a measure to address Design for Resources, with a number of different strategies available for meeting this goal. A quick review of all 90 of the submitted projects since the beginning of the competition revealed that only 12% of projects chose to employ adaptive reuse of an existing building, and only 13% of projects indicated materials reuse. Only a very small 3% of projects described efforts at design for deconstruction.

These surveys not only reflect the way that students are taught how to manage material resources on a project, but they also reflect what kinds of studio projects they are encouraged to tackle. As the COTE survey suggests, even within schools, programs, and courses that prioritize sustainable design, integrating circular design principles into projects is still somewhat of a new idea.

Shifting to a circular building economy prompts a reassessment of the roles and responsibilities of architects in mitigating human-created waste on both a systematic and individual project scale, and consequently, it forces a reconsideration of architectural aesthetics. Based on the images in the study, there appears to be a persistence in over-celebrating modernist ideals and aesthetics, despite the known pitfalls. This value signaling needs to change. As author and professor Nikole Bouchard writes, "the modernist desire of wiping the world slate clean to work with an unobstructed tabula rasa is unrealistic and outright irresponsible. Instead… we must work with what's at hand and take on the tabula scripta"[7] She and others[8] argue that this includes opening our minds to the aesthetic prospects of collage, spolia, maximalism, and the sometimes less glamorous nature of adaptive reuse projects.

Interrogating the visual consequences of sustainable building design is not new. Authors such as Lance Hosey[9] and David Heyman[10] have both critically explored the supposed opposition between sustainable buildings and beauty. In addition to artistic concerns, the integration of circular economies, materials tracking and material markets, and widespread building salvage and reuse will have yet-unknown effects on cultural preservation, gentrification, ownership, and economic equity. As author Ken Webster cautions, "democracy and ownership are fundamentally connected."[11]

Another challenge to working on circular design projects in studio courses is the possibility that the inquiry could lead to outcomes that don't support traditional methods of design studio process and assessment. For example, if a reduction in up-front

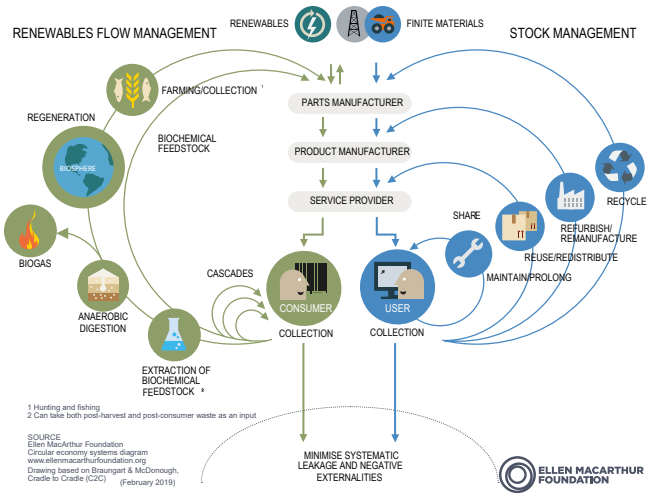

Figure 2. Butterfly diagram. Image: Ellen Macarthur Foundation

embodied carbon is a key goal, then it is uncomfortably possible that a project's solution might be a very minimal intervention, or not solved by a building at all. This, in fact, has turned out to be the case on a number of projects that the Pritzker Prize winning architects, Lacaton & Vassal have worked on.[12] The pedagogical challenge is developing studios for students to explore such nuanced decision making in architecture in a way that still communicates student ability and faculty teaching excellence. Experimenting with these new concepts in studio can be a risky proposition, especially if extra time and effort are needed to develop new partnerships, methodologies, and rubrics without the guarantee that the outcomes will be teaching portfolio-ready.

Lastly, since the time that most educators were in school, reducing up-front embodied carbon has taken a backseat to energy use reduction and other aspects of sustainable design. Even with a willingness to take on new and experimental circular design project types in studio, faculty may be challenged by a lack of readily available, undergraduate level, background knowledge, resources, and precedents to aid in teaching the subject. This is further complicated by the transdisciplinary nature of the subject. In addition to integrating typical structural, MEP, landscape, and construction knowledge into the early phases of the project, studios focusing on circular design may find they need to consult more actively with experts on local municipal salvage and waste systems, materials manufacturers, and deconstruction contractors.

Despite these challenges, it is essential that today's students are given the opportunity to grapple with the wicked problems of integrating circular design and buildings and materials reuse into their projects.

DEVELOPING STUDIO COURSES

The pedagogical suggestions in this paper are framed around circular building design strategies that directly reduce immediate up-front embodied carbon in our built environment. As such, some strategies and discussions have been purposefully omitted from the scope.

Suggestions for creating a circular design studio course are divided into the following: purpose, resources, process, and assessment which are based on Northern Illinois University's Center for Teaching and Learning Transparent Assignment Template.[13] Given the complex nature of creating a new pedagogy for a new kind of practice, this framework mirrors an effective template for developing individual assignments, and can be applied to creating a clear outline for an entire course.

Specific studio topic suggestions are based on a modified decision tree in Figure 3 entitled, "Choosing the Right Circular Approach."[14] This decision tree is particularly useful as it connects concepts of circular design to practical beginnings of a building project. Nodes along the decision tree that address rapid reductions in embodied carbon are then pulled out into the table in Figure 4. The table provides practical suggestions for developing a circular design studio's purpose, process, and assessments. A list of corresponding case studies is also provided at the end of the paper. Obviously, there is no one right way to integrate the circular design process into a design studio project. Studio projects may select a single strategy, or take on multiple strategies at a time, or consider the circular design framework as a whole. Studios may also consider working through the decision tree in Figure 3 as part of the process of site and project selection.

CLARIFY PURPOSE

Defining the purpose of the studio starts with clear and measurable objectives and includes telling students why they are completing an assignment or course, what skills and knowledge they will learn, and why it will be useful to them in the future. Clear purpose can help to motivate students that may be unfamiliar or unenthusiastic about tackling a new challenging subject in studio. For some students, it can be effective to have them interrogate their own experiences with pollution and waste, so that they can find personal connection to the topic.

Beyond the larger goal of mitigating climate change, there are a number of directions that can provide purpose for a studio focused on circular building design. For example, the studio problem can be framed as an entrepreneurial opportunity to transform waste products and materials into new products and uses through re purposing or remanufacture. Or the studio can consider the cultural consequences of preservation and building

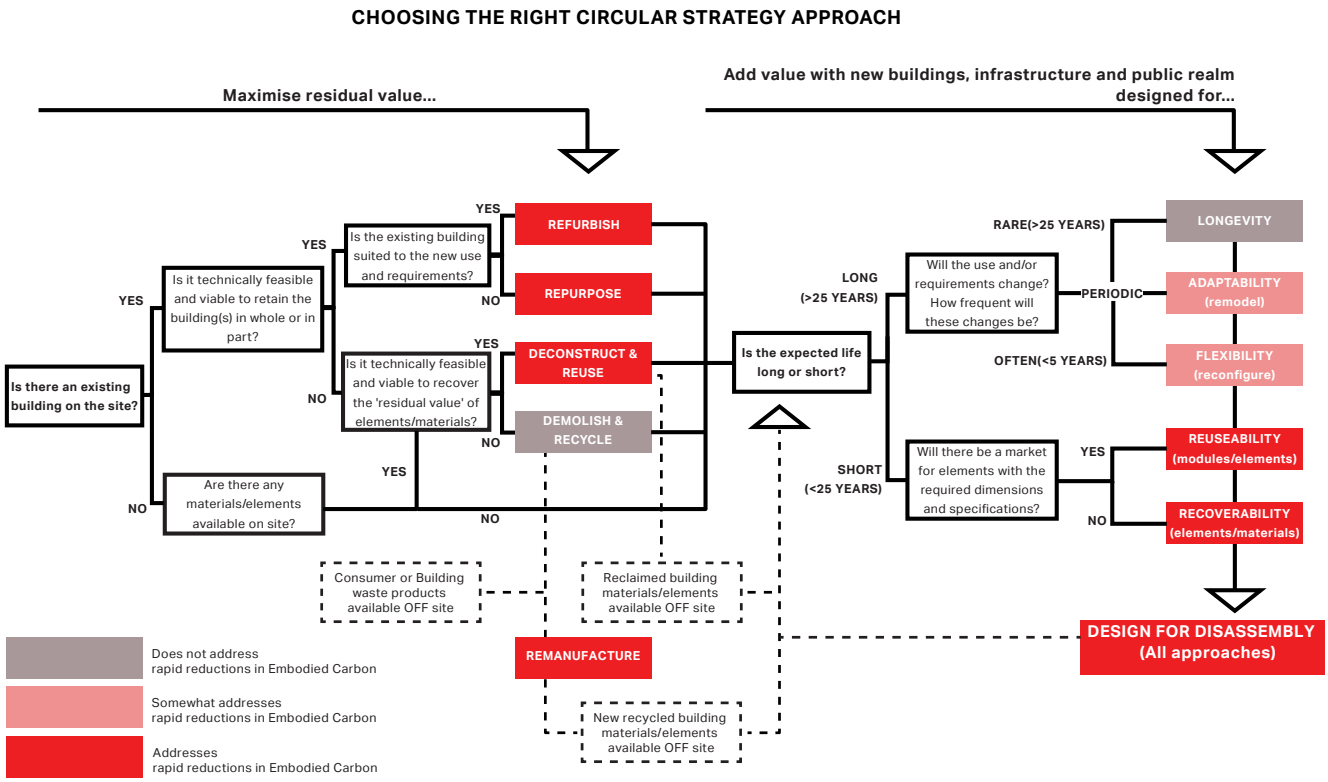

Figure 3. Decision tree to empower project teams to consider circular strategies. Modified by the author to focus on upfront embodied carbon emissions reduction strategies. Image: Mayor of London, London Assembly. Good Growth by Design Programme (see endnote 14).

reuse. Figure 4 pairs identified circular strategies with suggested questions that might create an engaging purpose for the studio.

In addition to topical purpose, reminding students that even non-research focused programs can be grounds for experimental thinking can help them focus on developing innovative processes. Undergraduate students can be guided to view themselves and their studio work as contributing to cutting-edge research, an opportunity for practice and experimentation, rather than a mandate for perfection. As a comparison, in the 1970's, early sustainable design advocates and educators such as Sym Van der Ryn, "rearticulated the meaning of practice away from the notions of expertise."[15]

Rather than emphasizing individualistic design solutions as the most important goal, the studio can become a place where the transdisciplinary, student-faculty co-creation of new purposes and the co-learning of new skills can be explored. Author and speaker Lorna Davis argues in her 2019 TED Talk: A Guide to Collaborative Leadership, "We need to move away from hero culture and toward radical interdependence in order to solve the world's most pressing problems."[16] Radical interdependence requires practice with soft skills such as teamwork, leadership, and communication. Consequently, studio course objectives and purpose statements should endeavor to promote these skills as goals of the course.

DEVELOP BASELINE KNOWLEDGE AND RESOURCES

It is important for students to contextualize circular design in contrast to our current economic thinking which is still primarily based on make-take-throw consumerism, and what Oxford economist Kate Raworth describes as, "our financial, political, and social addiction to economic growth."[17]

With that in mind, the American Institute of Architects (AIA), the Carbon Leadership Forum (CLF), and the Ellen Macarthur Foundation (EMF) have published a number of primers intended to quickly educate professionals and the public. Faculty can use these resources to teach key background concepts and vocabulary needed to understand the connections between embodied carbon and circular design. These institutions also produce easy to understand diagrams as shown in Figure 1, which summarizes a clear picture explaining how the built environment contributes to carbon emissions, and why it is important to focus on tackling embodied carbon in the short term. In addition to Figure 2, EMF and Aurp have developed a The Circular Building Design Toolkit[18]

CIRCULAR STRATEGIES

	purpose	process	assessment
REFURBISH	When is non-building is the best solution? How does an architect lead a project focused on refurbishment, repair, business and space planning?	• engage in programming • create space plan options • building asset inventory project • create as-built drawings • client interviews • embodied carbon savings calcs	• space plans • research presentations • business plans • decision trees and diagrams • maintenance plans • phasing plans
REPURPOSE	How can collaboration create a new design in harmony with existing building and community conditions? How can a project both embrace change and preserve history?	• create as-built drawings • cultural context documentation • create design options • client and community interviews • embodied carbon savings calcs	• drawings and renderings • custom details • contextual research presentations • materials diagrams • circular analysis reports • phasing diagrams
DECONSTRUCT AND REUSE	What are the considerations in creating urban materials mining systems? How do reused materials change the design process and aesthetics?	• deconstruction projects • inventory projects • map materials mining systems • research spolia studies • find salvaged materials	• material research presentations • custom details • drawings and renderings • circular analysis reports • aesthetic analysis presentations
REMANUFACTURE	What entrepreneurial potential exists in the re-manufacture of waste products? How can circular products be made from waste?	• identify untapped waste streams • propose materials mining systems • investigate materials manufacture • create circular products • investigate dismountablity	• prototypes • detail drawings and models • waste materials system map • circular analysis reports • business plans
DESIGN FOR REUSE / RECOVER	What detail and systemic issues exist in designing components for maintenance and reuse and recovery? How can building assets be managed over time?	• visit furniture manufacturers and recycling facilities • research systems of institutional asset management • start design with the details • deconstruct objects/buildings	• prototypes • detail drawings and models • material systems mapping • circular analysis reports • business plans • design built products
DESIGN FOR DISASSEMBLY	What are best practices in design for disassembly? How can buildings anticipate change and maintenance over time?	• visit temporary pavilion case studies • research systems of institutional asset management • start design with the details • deconstruct objects/buildings	• design build pavilions • prototypes • detail drawings and models • drawings and renderings • materials systems mapping • circular analysis reports

Figure 4. Circular strategies that address immediate up-front embodied carbon reductions. Image by author.

as an online tool that uses a graphic interface to illustrate a framework for selecting circular design strategies, including built case studies and challenges to implementation.

The integration of energy modeling tools into curriculum and practice has had direct positive effects on the industry's ability to reduce operational carbon in buildings. By comparison, embodied carbon calculation tools such as Kaleidoscope[19] and others have only recently been developed. In many ways, these tools feel as blunt as the early attempts at energy modeling. While it is important for students to be aware of these tools and the basic differences in embodied carbon intensity between materials, it is more fundamental to guide students toward an underlying premise that building, component, and material salvage and reuse are almost always the lowest embodied carbon options.

EXPLORE NEW PROCESSES

In addition to more familiar research processes, circular building design often necessitates engaging in the discovery, inventory, and assessment of existing buildings and materials prior to design. This step can take many forms, but interfacing at the 1:1 real-world scale with existing buildings and reclaimed materials is essential for students to fully document, analyze, and understand the material conditions they will be designing with.

When refurbishing or repurposing a building, it is typically necessary to create as-built drawings, a practical, but also enlightening step. Pairing these actions with client interviews and programming exercises may reveal that the design solution requires more creative project management and business planning than architecture. Participatory programming has the potential to lead the student down the path of authentic problem solving, rather than mandated product or building creation, opening up the possibility of a non-building solution that challenges the bounds of architectural practice.

Projects focusing on materials reuse or materials remanufacture will need to source their raw materials. Mapping of regional industry and waste flows may aid in the entrepreneurial discovery of abundant waste materials for new products, or untapped salvage material mines in the local environment. Sources might come from a student project to deconstruct a building, connections with local manufacturers or governmental groups, visits to local recycling and salvage facilities. Undergraduate students taking a studio in circular design at Sacramento State found their hypothetical source of building materials through an analysis of campus planning documents that identified specific buildings that were slotted for demolition. Using this information, students walked the buildings in order to select, inventory, and model components to incorporate into their new designs as shown in Figure 5.

Studios aiming to design for reuse and disassembly may want to consider more traditional analysis of precedent studies for temporary structures and dismountable systems. Additionally, students may benefit from the experimental deconstruction of objects in order to viscerally understand how to design a building that can be dismantled. For example, Professor Dirk Hebel from ETH Zurich had his students disassemble a vehicle in order to understand what kinds of details allow for disassembly, and later had them apply that knowledge to a dismountable housing project.[20]

In the design phase, contrary to perfecting the overall building form first, with little constraint on materials, circular design usually flips the script and forces the designer to identify the pieces before the whole. To draw an analogy to art making, circular design is more akin to the use of collage or appropriation rather than drawing or painting. Exercises in collage, or working with a pre-designed kit of parts such as children's blocks can support this new way of working. Additionally, an examination of historic precedents of spolia can help contextualize the aesthetics.

Most circular projects also require students to develop custom details to be dismountable, designed to connect materials in a non-traditional way, and often visually exposed. As a result, much of the design innovation may end up residing in the detail. Students may also find it is more logical to construct a number of prototypes at full scale, so that adequate testing of new connections can take place. This may mean that a complete drawings set is not completed until the very end of the course, if at all.

Students may also be challenged with creating diagrammatic drawings that not only illustrate the project, but also explain which components and materials are new, which are existing, and which are from reclaimed sources. Furthermore, mapping the origin of materials, their use in the project, as well as their eventual destination becomes a key part of telling the story of a circular building design.

RECONSIDER ASSESSMENT

Studio courses focusing on circular design, especially those that are experimental in nature, may require updated approaches to assessment. Faculty looking to integrate the complexity of circular design into studio courses may also benefit from the research backed, equity-minded suggestions found in the Association of College and University Educators' (ACUE's) Effective Teaching Practice Framework.[21]

Instead of focusing only on the final product, assessment in experimental courses can be designed to evaluate student effort and process. Students can be assessed on their demonstrated soft skills such as collaboration, teamwork, organization and communication and a reflection of their design process. For example, the instructors for a circular design-build studio course at ETH Zurich University integrated this task into a final "Drawing Report" as part of their Re-Use Huber Pavilions studio. The instruction was to "summarize your learning experience in text and representation."[23]

Periodic assessments such as anonymous peer reviews, co-created rubrics, and iterative reflection exercises can also help students think more critically about their process, while giving them more agency in what they want their final product to become.

When looking at the products of design studios that explore non-traditional ways of working, it can be beneficial to draw upon existing rubrics of professional practice to help students select clear metrics that they will be working toward in their projects. The AIA Framework for Design Excellence, the Circular Buildings Toolkit and other published rubrics are helpful for balancing aspects of aesthetics, building science, and community concerns in a project. One of the most challenging aspects of working with circular design is that "prioritizing materials and building reuse can significantly influence the aesthetic outcomes of the work."[24] Faculty may need to interrogate the aesthetic bias that educators and students may be bringing to the conversation and make time to have an open discussion with students about what makes a project aesthetically good.

Lastly, working with students on the exciting and under-explored possibilities of circular design is an excellent opportunity for future faculty-student collaborative research. Facilitating ways for students to remain engaged in the topic beyond the confines of studio not only supports their growth in expertise, but provides them with the incentive to revisit their studio project. This can help further develop the project as a portfolio piece, as well as aid in their ability to communicate their knowledge to future employers.

CONCLUSIONS

Shifting our cradle to grave mindset to imagining a built environment that is based on circular design principles is going to take a commitment from those of us responsible for teaching our next generation. Teaching the Circle requires bravery on the part of all design and architecture faculty to overcome the challenges of shifting culture, creating knowledge, and investing effort into doing things differently. For better or worse students look to their faculty for guidance in forming their own ethics and values regarding architecture and the world around them. In particular, the selection of studio projects they engage with has an impact on their future interests and development as a professional. The resources in this paper are meant as a soft starting point for incremental change. Even if only a fraction of them are integrated into studio projects across our nation, the cumulative impacts could be profound.

Designing with the intent of reducing embodied carbon through circular design strategies will require different methods of making in studio, but will result in actions that more closely mirror practice. Although exemplary schools in this arena seem to have the resources to prioritize large scale, multi-disciplinary, deconstruction and design-build studios, student engagement with mock ups of full-scale materials can be implemented at almost any school. In addition, existing conditions documentation through modeling and drawing serve as a baseline for working with building and materials reuse. In this respect, it is common

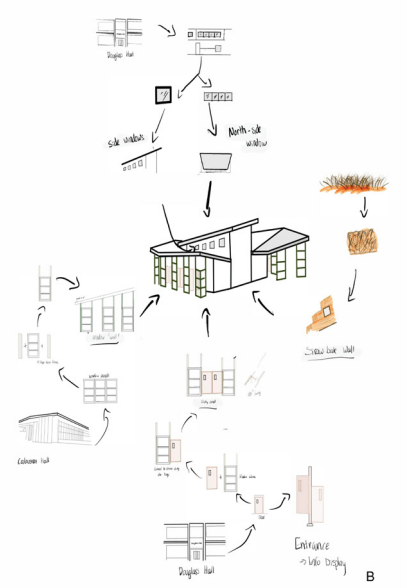

Figure 5. Material Flow Diagram. Image by Ingleng Ny

for many architects to assume the role of archivist and asset manager, being tasked with helping institutional clients catalog and assess their holdings.

Working with existing buildings and used materials is not something new to the profession, but now there is a compelling reason to ensure that all future architects are well-versed in their ability to do so. More essentially, students of architecture must learn to make the case to future clients for adaptive reuse, materials reclamation, design for deconstruction and other circular building design strategies that will help us reduce up-front embodied carbon. Studio courses not only allow students to innovate new solutions to creating a circular building economy, but provides them with the necessary practice to communicate these ideas in the future.

CASE STUDY LIST FOR CIRCULAR STRATEGIES

REFURBISH

Architects for Social Housing, Central Hill Case Study, 2018
AJDVIV, Charleroi Expo Center Case Study, 2023

REPURPOSE

Kieran Timberlake, Ortlieb's Bottling House Case Study, 2015
CHYBIK+KRISTOF, Gallery of Furniture, 2015

DECONSTRUCT AND REUSE

L'OEUF, Benny Farm Case Study, 2006
Siegel & Strain Architects, Portola Valley Town Center, 2018
Encore Heureux, Circular Pavilion, 2015
Superuse Studios, Blue City Offices, 2017

REMANUFACTURE

Sobek, Hebel, Heisel, (UMAR) Experimental Unit Case Study, 2016
Particle, Homewares Capsule Collection, 2023

DESIGN FOR REUSE / RECOVERY

John Habraken, World Bottle (WOBO) Case Study, 1962

DESIGN FOR DISASSEMBLY

RAU Architects, Netherlands Expo 2025 Pavilion Case Study, 2023
Peter Zumthor, Swiss Sound Pavilion, World Expo Case Study, 2000

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