EMBODIED CARBON COMPUTING

— Fostering Transparency for a new Circular Economy

The building industry is one of the world's largest polluters, accounting for 38% of all global emissions (UN EP, 2020) as well as for 30% of the global waste (OECD, 2020)—all while the building stock is predicted to double until 2050 (UN DESA, 2018).
In case we continue constructing and operating the built environment as we are now—mostly on finite resources and inequitable ownership—we are steered towards climate catastrophe (Rockström, 2009).

To fight the climate crisis, a radical, systemic transformation (Meadows, 2018) of the industry is inevitable. Instead of short term thinking and profit-driven limited liabilities, we need to transition to a system of holistic life cycles, allowing us to understand and manage buildings from their supply to removal chains—as well as everything in between.

All solutions are already at hand (Hawken, 2017); we now need to implement them. This is where computation can help us translate new approaches into effective action.

In this essay, I will be looking into the application of computing within the built environment and specifically, at the potentials—and pitfalls—of using advanced technologies for mapping complex life cycles of new developments that employ regenerative materials to build a global carbon sink (Churkina, 2020). With the gained in-depth insight, systemic interdependencies can be made visible to various actors along the entire value chain. I see transparency and knowledge transfer as crucial to inform both bottom-up and top-down change towards the overall transformation of the building industry.

In order to understand the potential for optimisation, we first of all need to get an overview of two underlying methodologies:

Next to drastically reducing operative emissions, which often seems to be the core focus within the current debate, we need to tackle the grey emissions that occur during construction. To do so, we must fundamentally rethink the way we build today. Here, timber and other renewable materials play a vital role. Biogenic building materials store carbon during their growth and retain it throughout their entire life cycle—unless the building or its components burn down or rot. With using these materials in construction, we are able to mitigate carbon, while reducing emissions of conventional production methods significantly through substitution (Dieren, 2022).

This mitigation potential is extended by advances in prefabrication, where computation and robotics allow for ultra-precise and hyper-individual production (Schodek, 2004).

Combined with modular designs, construction times on site can be cut drastically whilst also reducing the noise pollution on site.

Life Cycle Assessment is the systematic analysis of the potential environmental impact and the energy consumption of products throughout their entire life cycle. Before each analysis a system's boundaries—e.g. cradle to grave or cradle to gate—are defined as different boundaries are useful depending on the product and the objective of the analysis. The environmental impact is evaluated on the basis of the emissions and resource expenditures of a product or process (Dieren, 2022; Vogtländer, 2014).

Sustainable building is not an easy task. Relevant know-how is difficult to obtain, access, and scale. Hence, a qualified consideration of sustainability criteria during the design phase is highly complex (Dieren, 2022).

The determination of complete ecological data through Life Cycle Assessment goes beyond the scope of usual competition entries and feasibility studies within the architectural profession. The advanced design and the determination of structural components are the basis for a Life Cycle Assessment. At the same time, the continuous comparison with LCA data provides an important basis for decision-making during the design phase. This complexity can only be solved by intelligent real-time tools and need to become an integral part of the planning process (Dieren, 2022).

Current LCA databases appear to be very broad and non-specific to our application. The current data quality is not sufficient for enforcing or successfully governing a carbon tax. Creating more granular data is challenging due to the immense complexity of the respective value chains (e.g. wood to city).

Buildings could become material banks and store not only carbon but also their materials' economic value over time; whereas currently, the highest value increase is generated through speculations around the building land—mostly generating profits for real-estate investors whilst driving up rent for tenants without adding any actual value.
When building with regenerative materials that store carbon on an urban scale, it will become critical to catalogue the elements and materials used. Without a reliable, granular quantification of what our buildings are made from, it will be impossible to govern a necessary future (international) carbon price (Strefler, 2021; Roolfs, 2021).

A material bank's catalogue could contain data on each element—so called material passports (Göswein, 2022)—such as material, dimensions/mass, origin, certification, history of use, individual footprint, embodied carbon, composite property, recycling potential, waste potential, expected life span, material value, mounting compatibility, suggested application, and many more.
The deep knowledge of all elements within a building including their respective specifications would form the basis of a whole new (circular) economy with a tangible material value. It would incentivise the industry to think about materials as a precious commodity instead and promote resource efficiency.

As we are looking into more lightweight, modular building construction when building with regenerative materials, material banks could foster adaptive building configurations. Buildings could be extended or reduced based on actual needs, allowing for a trade between existing developments or a circular re-use of materials for new developments.

I propose an integrated, intelligent material bank specifically for future buildings made from regenerative materials. Such a tool should convey crucial knowledge on two levels: it lets users assess the footprint of future and current buildings and their individual elements (compute) and tangibly explains the underlying principles and mechanisms of sustainable construction (learn), as Living Systems' Timber Computer (Schrage, 2022) demonstrates in prototypic manner.
In order to achieve this, we need to employ a blend of advanced technologies: Smart Dust could help identify elements and track circular value chains, Visual AI could help catalogue existing building stock or act as a controlling instance on the building site. Yet, all that data needs to be handled and made sense of. Here, Machine Learning could help determine the footprint of our future buildings based on the data collected and form an ever-growing, self-learning catalogue of building elements.
Advanced computation is the only way to drastically increase the granularity of the data available. An integrated, tangible solution has the potential to make a fundamental difference in how we perceive buildings. In addition, it has the capacity to extend such benefits to a wide audience within the general public, outside of siloed expertise of specialists or niche academic research.

A tangible solution—e.g. embedded into existing planning tools—would allow architects, planners, and city-makers to unravel the Urban Metabolism of a city (Ferrao, 2013), understanding the global systemic interdependencies along the entire value chain, and help position their own role and scope within it. A holistic understanding paired with quantifiable data will create agency and guide design and planning decisions towards effective climate action.
Fostering transparency through a user-friendly, low-threshold front-end has the potential to raise awareness not only amongst professionals. Forming a new economy around building materials and making it tangible, provides opportunity for broader participation in value creation, posing a chance to rewrite a fundamentally new narrative around building ownership, shifting from a few to many. This will actively engage citizens by boosting their environmental consciousness when seeing their own house's role and hence, has strong potential to eventually trigger policy change.

Ultimately, gaining deep insight into where the components of our buildings come from, where they are stored and where they go next, is critical for a successful circular economy within the building industry.

Besides the immense potential of using computation to understand, manage, and communicate the complexity of embodied carbon within our future buildings, such application would not come without risks.

It might be that essential regenerative resources—such as timber—are not available in the desired quantities in the specific region. It is critical to use regional materials from sustainable sources to keep emissions from transport low. Yet, this requires the transformation of the entire value chain—e.g. of how we manage our forests (Costanza, 2014) which will take time. However, an integrated transparent impact measurement system will provide the data necessary to conduct such a transformation—and is eventually applicable to all relevant materials in any region.

There is a certain risk of the new economy being created to be owned by a few actors instead of many, which could foster speculation around the material values made tangible, which would heavily increase the injustice in the real-estate market even further. Noone wants parts of their building to be sold when material prices surge.
The more important it is, that the underlying system is peer-reviewed and owned by an independent, non-profit governing body, such as a data collective (Bartolomucci, 2022). A way to also prevent unethical data use is to open source the code of the solution and be transparent about its underlying mechanism and incentives (Monge, 2022). This should also reduce the risk of mistrust and manipulation of the data.

Generally, we may guess that technology, in theory, is neutral. In practice, however, it follows the ideology of its creator—intentionally or unintentionally. If used wrongly, it becomes a tool of control (Scott, 1989) or political repression (Morosov, 2011). We can either distance ourselves, or take an active part in shaping a future, which does not only favour its elitist financiers. In the most extreme case—if we keep sitting still, a “Superintelligence" might emerge and replace humans as the dominant life-form on Earth (Bostrom, 2014).

Yet, why don’t we use the momentum of the ongoing gold-rush of urban tech (Florida, 2020) as a chance to rebuild it based on principles that serve our planet (Latour, 2018) as well as a diverse range of its inhabitants. This would allow us to actually build cities for people (Gehl, 2010). We could embed indigenous philosophies such as “kin” (Haraway, 2016) or “Lo-TEK” (Watson, 2019) from the start. All while using technology mindfully and use less of it to save cost and resources (Nagler, 2021).

Ultimately, we have no choice but to work with what exists. A system cannot be changed from the outside. In order to transform it, we need to bend the existing – towards a system that respects the planet's boundaries, serves the common good, sustains life at scale, and nourishes the future.

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