Building to heal: chemistry for sustainable buildings

Most of the world's population is already living in urban areas [1] and it is known that the construction industry accounts for over 40% of all material extracted as well as 40% of total energy and 16% of annual water consumption. During the last century, overall global material consumption approximately multiplied tenfold, but consumption of construction minerals multiplied by a factor of 42 [2], showing a positive feedback-loop between socio-technical system evolution and its construction material requirement.

Furthermore, 50% of the building stock that will exist in 2050, mostly located in cities in emerging countries, is yet to be built. The weight of these future cities is tremendous. Quantitative analysis of the global resource requirements of future urbanization shows that without a new approach to urbanization, material consumption by the world's cities will grow from 40 billion tons in 2010 to about 90 billion tons by 2050 [3].

Following business-as-usual practices, buildings and infrastructure require resources and energy for their construction as well as during their use, but one can also turn the future challenges into opportunities. New buildings can be an opportunity for innovative solutions to mitigate environmental pressures and to generate economic growth while providing adequate, attractive and affordable housing for all. Future construction can be a way to reduce or even store carbon emissions when built with selected building materials. They can also be used as depositories of materials to be later mined. Building renovation can be a catalyst to re-activate social and economic networks in a neighborhood. Buildings rather than degrading the air quality can actually improve it as the humidity of the indoor air can be naturally controlled through earth plaster. Green façade reduces the heat island effect and provides a better air quality in the cities. Buildings can even help to reduce harmful effect of transportation through noise absorption and pollution absorption in self-cleaning façades. In a way what is the role of building materials in achieving a sustainable scenario? Can building technologies trigger virtuous mechanism to help improve not only housing conditions and environmental performances, but also the multiple aspects of the society tackled by the sustainable development goals?

To harness these opportunities and identify valuable resources, one needs to have an intimate understanding of urban dynamics [4]. Urban building stocks have been the focus of many fields of studies, from social sciences [5], geography [6], to mathematics [7], and cities have been analysed from many different angles. Cities are complex systems where natural and human processes interact to create a built environment, which in turn has its own dynamics [8].

Understanding these multiscale dynamics, tracking the appropriate materials and identify the leverage points to turn the existing system into a regenerative process is the core focus of this presentation:

- How can we transform our currently linear flow of materials through our cities towards a circular dynamic?
- How can this transformation towards circularity provide an improvement in social quality so that circular economy becomes regenerative?
- Can we measure and monitor these flows with appropriate accuracy to provide meaningful indicators in terms of policy perspective?
- Finally, can the intervention of the architects and engineers on one construction project have a wider impact and be used as a catalyst for change?

In the last decades, diverse solutions have been provided in order to align building technologies with current sustainability standards. However, despite these efforts, the objective of sustainability has proven not to be enough. A shift towards a regenerative approach, proposing to provide more positive benefits rather than trying to harm less, is then urgently needed. For instance, construction and demolition materials can be reintegrated in the flow of input materials through recycled concrete. Switzerland is ahead of others in this organization as nearly two third of demolition waste is already recycled [9]. However, excavation materials represent a much larger quantity than demolition waste. They actually represent as much as what Switzerland needs in primary material. Excavation materials can be carefully sorted and processed to produce fine and valuable gravels as well as earth material that can be promising development for earth construction. With small amount of additives, it is possible to turn this waste into a valuable construction material that would have appropriate mechanical performance as well as enhanced hygrothermal properties [10]. Another option is to increase the amount of bio-based materials in construction. This can transform the built environment in a carbon sink [11-12]. And finally, cement production even if it releases CO_2 emissions allows also to incorporate and valorize into a valuable product a large quantity of waste from other industries. In cement plants the primary materials do not represent more than 25% of the total amount of materials required (fuel included). We just need to use the right material at the right use for its right purpose. It is what we call grounded materials, a material that considering the local socio-economic context and availability of resources is offering the best opportunities.

Monitoring material flows and their regenerative values

In a world where data is everywhere, it might seem easy to monitor material and energy flows through urban systems. However, to monitor a flow, one needs to be actually willing to address this issue, and feel the need to look at this problem. To quote the pioneering American environmental scientist Donella Meadows: "*We measure what we care about, and we care about what we measure.*" Acknowledging resource, energy or water scarcity is not necessarily obvious among policy makers and the society as a whole, and a misleading indicator can be as detrimental as no measure at all: both can drive us in the wrong direction. One of the most pressing challenges regarding data monitoring is rather to create a demand. Data

already considered valuable is typically already mined: what we are lacking is data about a city's hidden value.

Trigger changes

One of the recurrent messages in sustainability conferences is that available technologies for a post carbon society are ready, but are not implemented because the current situation of our environment is not well explained to society and policy makers. This assumption – that through quantification and information, governments will engage in a transition – has not been proven right so far, as can be observed for instance from the slow progress of the IPCC (Intergovernmental Panel on Climate Change) [13]. Governments engage extremely slowly in a transition because they believe it necessarily involves a social transformation [14]. The construction sector is seen as conservative and risk adverse. Showcasing alternative materials and technological solutions while explaining current societal threats will thus not be enough to induce a change.
However, it might be important to use the power of a creative destruction when applied to construction [15]. Catastrophic events – floods, fire or earthquake – have the power to allow, during a short moment after the disaster, the local community to accept radical changes and rebuild differently. If at that moment, architects are ready to propose solutions that have been developed over a long period of time span by engineers, scientists and designers, there is a possibility to implement very fast radical changes and to design for hope. Loreta Castro (Mexico) and Stephen Lamb (South Africa) are developing engaging examples where rubbles after the earthquake were reassembled and filled a timber frame construction to provide a new community center in Oaxaca while South African invasive species causing fire and destruction were cut, chipped and used as aggregate in a new bio-concrete to provide dignified houses for people.
But when no dramatic event is happening, how to trigger changes? New attractive technologies can be used to nudge people and engage them towards sustainability without presenting these technologies as necessarily used for sustainability. The "Internet of Things" can first be attractive only to selected people (who may identify these technologies as being innovative or as providing a higher status). Yet, in fine, they may result in a significantly lower use of resources.

Looking ahead

There is a fundamental interdependence between the natural and the built environments. Unfortunately, we have reached our planetary boundaries. We know that some of the biggest transitions have been done through crises and emergencies, whether driven by political will or natural disasters, but would it be possible to achieve a smooth transition? It might be important to recognise that traditional innovation cycles, from the idea, to multiple testing loops, to prototype, validation then market release, is simply too slow. We need to start thinking about how to support ecological restoration, and how to actually reconnect to the components of natural systems. As briefly explained, technologies and products exist, and to implement them, we just need to know which future we want to build: buildings that harm the environment or on the contrary, buildings that regenerate nature and improve living qualities in our cities. A native American once alarming about the disaster of uncontrolled nature degradation argued that

The Light House in Hout Bay (Cape Town, South Africa) built by designers and builders Stephen Lamb and Andrew Lord (www.visi.co.za/this-is-the-house-that-xoma-wanted). Photo: Stephen Lamb.

before choosing our tools and our technologies, we need to choose our dreams and aspiration, because some technologies support their accomplishment while others drive us away from them.

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