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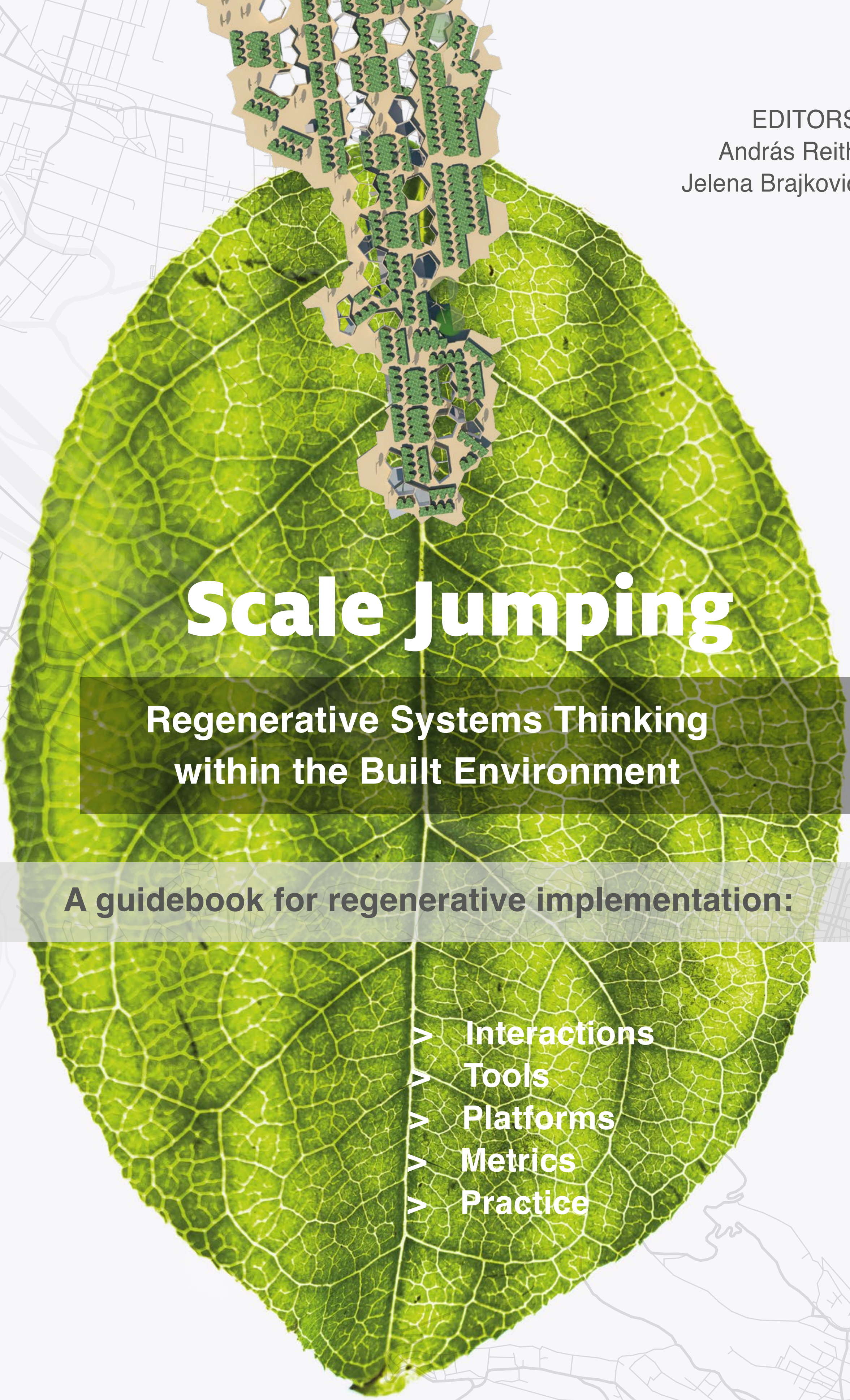

Scale Jumping

Regenerative Systems Thinking within the Built Environment

A guidebook for regenerative implementation:

> Interactions
> Tools
> Platforms
> Metrics
> Practice

RESTORE
REthinking Sustainability TOwards a Regenerative Economy

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SCALE JUMPING ›››

Regenerative Systems Thinking within the Built Environment

A guidebook for regenerative implementation:
interactions, tools, platforms, metrics, practice

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IMPRESSUM

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Scale Jumping: Regenerative Systems Thinking within the Built Environment.
A guidebook for regenerative implementation: Interactions, tools, platforms, metrics, practice

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6 Energy

By Rosa Romano, Emanuela Giancola, Elisabetta Palumbo, Antonino Marvuglia

From Nearly Zero Energy Buildings (NZEB) to Positive Energy Buildings (PEBs) and Positive Energy Districts (PEDs)

In many industrial and highly populated countries, research into high energetic consumption within most cities, is promoting the concept of "Low Carbon Cities". Its primary concept has to date been on ways to reduce the impacts of current energy consumption in transportation and buildings. Energy is the lifeblood of economic development and modern society. In contemporary economic developments, energy tends to become a significant political, social, and economic objective (Popescu *et al.*, 2019). According to The World Energy Outlook 2018 (IEA, 2018), based on current and scheduled policies, projected energy demand in 2040 will have grown by more than 25%.

The "low carbon city" concept is complemented within the broader notion of regenerative city. Through the potential of recent scientific-technological advances and 'smart' innovation, a regenerative city not only preserves environmental stocks, but moreover restores and regenerates these from previous losses (Axinte *et al.*, 2019).

In so far as it may, a regenerative city needs to make careful use of energy and harness renewable energies to power buildings and activities.

Promoting restorative actions for urban regeneration necessarily requires some reflection on productive renewable energy technologies (PV, solar thermal panels, geothermal, biomass, etc.) that can be integrated into the building envelope and/or urban districts to reduce human environmental impact.

Renewable energies not only help to decrease the building energy consumption to zero, but also the emissions of CO_2 and other climate-altering substances, throughout the life cycle of the building, with a view to continuously protecting the environment and its resources.

Over recent years, many European Community programmes have funded (micro to macro scale) renewable energies within the building sector, to overcome the **nearly Zero Energy Building (nZEB)** target, introducing the new concepts of **Plus Energy Buildings (PEBs)**. Especially the "Buildings design for new highly energy performing buildings"[1] call, focused on development and demonstration of applied solutions, which significantly reduce the cost of new buildings with at least 'nearly zero-energy' performance levels, whilst significantly accelerating the speed with which these buildings and their systems find a way into the mainstream market. The innovative solutions should address the challenge to move towards a 'Positive Energy Building" (PEB) standard on a large scale with demonstration projects that go beyond the "traditional" 'nearly-zero energy' buildings" levels, to the point where buildings are active contributors to energy production and environmental quality in particular when new neighbours are planned (*e.g.*, Positive Energy Districts).

PEBs can, in fact, produce more energy than they consume and supply energy to other nearby buildings, creating a system of inter-connected units at neighbourhood level, aiming at least to achieve energetic neutrality or, in extreme cases, energy positivity (Magrini *et al.*, 2020).

Moreover, a PEB not only aims to harness renewable energy (*e.g.*, electricity, mainly from photovoltaic systems, rather than from wind turbines or other sources), but it must also pay attention to the purpose and distribution of excess resources upstream (Cole and Fedoruk, 2015).

Rather than an individual and isolated PEB, it is interesting to scale jump to the concept of a **Positive Energy District (PEDs)**, composed of several interconnected buildings at neighbourhood level, contributing

to the energy supply through a “smart” distribution of energy networks. The spread of these types of buildings would have positive implications for the three spheres of sustainability:
- Environment, reduction of CO^2 emissions thanks to the use of clean energy from Renewable Energy Sources (Directive 2009/28/EU);- Society, forming a solidarity-based community, working towards the common purpose of energy support;
- Economy, compared to the initial investment in smart grids and integration of RES in buildings, users can count on economic savings in energy costs.
In 2017, the EU launched the “Positive Energy Districts and Neighbourhoods for Sustainable Urban Development” programme, in order to achieve its ambitious energy objectives. The programme forms part of the SET Plan Action 3.2 “Smart Cities and Communities”, which aims to support the planning, deployment and replication of 100 PEDs by 2025 with the support of 20 Member States.
In line with the SET Plan Action 3.2, specific recent initiatives on the study of PEDs may be mentioned, which were recently launched, such as the Cost Action CA19126 - Positive Energy Districts European Network (Cost Action CA19126) and the International Energy Agency (IEA), EBC Program - Annex 83 - Positive Energy Districts.

Embodied energy versus Operational Energy

However, is it enough to focus on current energy consumption alone? Analysing the current energy consumption of a city alone can lead to the conclusion that urban areas, in particular densely populated ones, are relatively efficient, largely because per-capita current energy consumption is lower than in dispersed urban or suburban arrangements. However, what is not measured as part of the energy impact of urban areas is the built space itself — the streets, pavement, buildings, utilities, tunnels, etc. — that are required to maintain such a dense arrangement of humans. In addition, the energy used to manufacture the array of consumer goods and services that urban residents purchase and their onward transportation for sale is not taken into account either.
Embodied Energy (EE) is the sum of all the (direct and indirect) energy required to produce goods and services, whether environmental or economic in nature. It is different from the direct energy measurement of energy consumption. EE refers to the energy consumed by all other products and services used to process and to manufacture the product, as well as to maintain it. For example, in the literature on building and construction engineering, EE refers to the energy embedded in all products and services used by a building from its design, construction, useful life (maintenance and replacement) up to final demolition (recycling and reuse), in other words the EE consumed throughout the whole life-cycle of the building (Dixit, Culp & Fernández-Solís, 2013; Dixit, 2019). It differs from energy consumption throughout both the useful life (operational energy) and the construction phases of the building, concepts that only reflect the direct energy that is consumed.
Scientific literature has shown the need for appropriate analysis metrics and weighting systems to properly characterize nZEB and the importance of the EE an indicator in a building energy analysis. Giordano *et al.* (2017) assessed whether EE is a valuable indicator that should be included in building energy analysis along with Operational Energy (OE) and if they can both be taken into account at an early design stage. The EE and OE assessment presented in this scientific work was carried out considering the International Energy Agency (IEA), Solar Heating & Cooling Program, Task 40, Annex 52, and the IEA, Evaluation of Embodied Energy and CO_{2eq} for Building Constructions, Annex 57.

Furthermore, the paper shows that EE increases, because of the use of energy-intensive materials, while the OE calculation is influenced by the solar gain, the shadowing factor and the heat transfer factor.

Current legislation within European Countries aims at Zero Emission Buildings, mainly through OE minimization (Tingley & Davison, 2011). However, an nZEB building can not always be defined as a Zero Carbon Building (ZCB), even if it is true that optimization of the useful life phase can lower CO_2 emissions, because it cannot be guaranteed that the materials and components chosen during the construction phase have as low an impact from the environmental point of view.

Accordingly, future NZEB implementations must address proper balance metrics and a weighting system. So far, only very few countries have introduced requirements pertaining to EE, mainly due to the lack of national and agreed EE databases for building materials. Furthermore, a weighing scale among energy analysis factors requires investigation.

Finally, the discussions on EE and OE should be extended to Embodied Carbon (equivalent carbon dioxide emissions).

LCA VS eMERGY

The crucial issue that needs to be addressed is the identification of a balance between the different energy consumption sources and their related environmental impacts, considering a life cycle perspective.

A recognized, suitable and standardized (ISO 14040:2006 and ISO 14044:2018) method for measuring environmental sustainability over the whole life cycle is **Life Cycle Assessment (LCA)**. Although still difficult to apply at district level, the use of LCA for environmental impact assessments of construction products and buildings in the last 25 years has been increasing.

Therefore, it is evident that the design and operation of both buildings and urban districts should be inspired by LCA principles and possibly, for a fuller connection with nature, the assessments obtained with the principles of LCA are complemented by those made using **Emergy** (spelled with an “m”) analysis (EMA).

The concept of Emergy, initially developed by American ecologist H.T. Odum in the 1980s, is defined as the total available energy (exergy) of one kind that was required (used up) both directly and indirectly in either making a product or offering a service.

Emergy is based on a donor-side (*i.e.*, nature-oriented) perspective, as opposed to the traditionally human-oriented perspective on which LCA-based assessments are founded. Known as a **paradigm shift**, emergy implies that EMA estimates of resource value should not only be based on resource scarcity and the consequent extraction costs for humans (as with LCA), but also on the global effort by nature (called also geo-biosphere work) that make those resources available. EMA could even be imagined as an alternative way to define circularity indicators.

While LCA are traditionally used to assess the sustainability of products and policies, Emergy is more suitable for assessments of a region or an ecosystem, where there is a clear interface between the antropho-sphere and the natural systems and the study of human activities is well embedded within the contextual contribution of natural capital. Emergy aggregates energy and matter flows of a different nature into a common numeraire, which express the amount of **equivalent solar energy** invested by nature in the production of a unit quantity of a delivered resource.

The appealing features of EMA are: its internally consistent “donor-side” theory of value; the common numeraire for all inputs and processes (both natural and human-dominated). Its negative characteristics are: it is harder to explain the rationale for the inclusion of resource formation processes, and the complex language needed for its communication is never easy.

In some areas, the application of EMA will be sub-optimal, when:

1. Assessing the “eMERGY cost” or “sustainability” of individual products and systems taken in isolation from the larger system in which they are embedded (e.g., a single car, one computer, etc.);
2. Replacing monetary costs on the scale of the (local) economy;
3. Assessing individual technosphere systems in general whose temporal and spatial scales are much smaller than those of resource (re)generation.

The approaches based on LCA and EMA are therefore, to some extent, complementary and can sometimes be integrated.

The critical concepts set out in the present text - “Energy Positive District”, “eMergy”, “low carbon and resilient city”, “life cycle vision”- are interconnected with the wider research topic “Restore Energy Pattern” through complementary relationships that are neither linear nor hierarchical (Fig. 1.1.9).

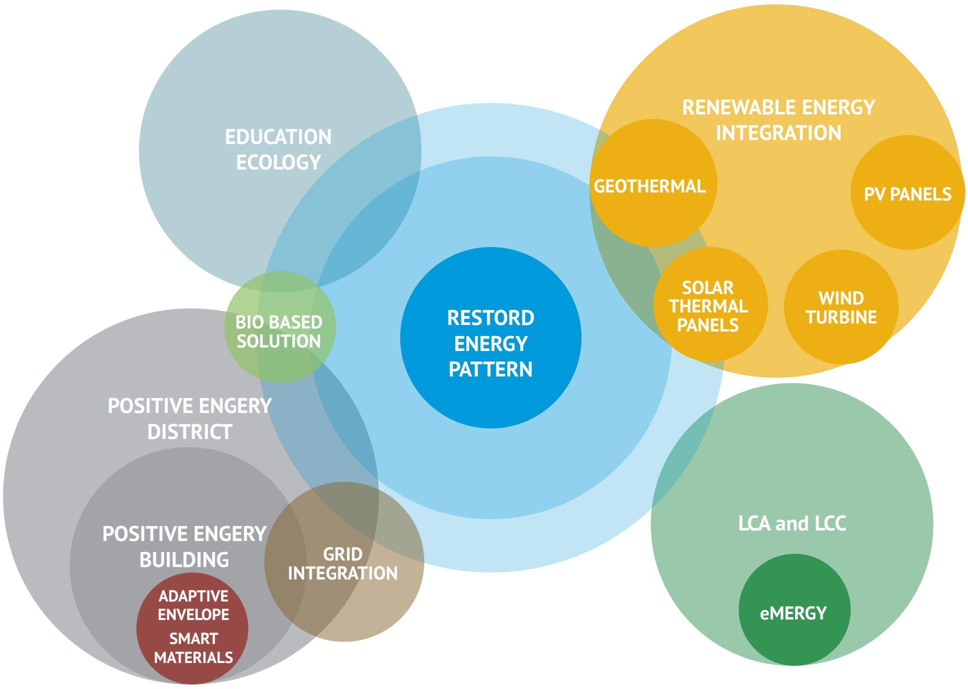

Figure 1.1.9. *Conceptual diagram of Restore energy pattern. (Source: Antonino Marvuglia).*