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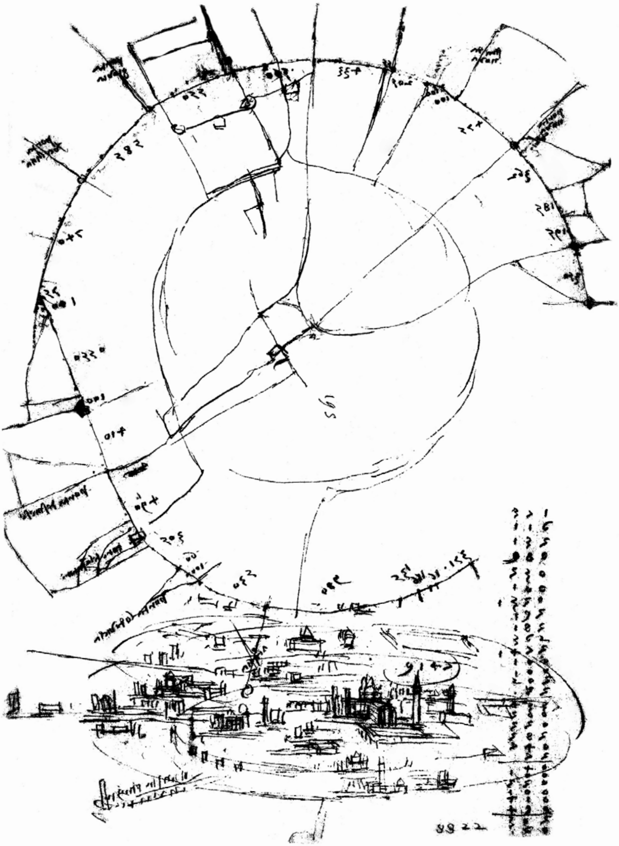
Towards (R)evolving Cities

Urban fragilities and prospects in the 21st century



Towards (R)evolving Cities

Urban fragilities and prospects in the 21st century

FEDERICO CINQUEPALMI

UNIVERSITÀ DEGLI STUDI FIRENZE | DIDA DIPARTIMENTO DI ARCHITETTURA

This volume is the result of thirty years of studies and research on policies and technologies applied to the environmental, energy and building sectors, with particular focus on processes and phenomena related to urban systems: research and studies carried out in some of the main academic centers in Italy and abroad, namely the IUAV university of architecture in Venice, the National Research Council (Consiglio Nazionale delle Ricerche - CNR), the Sapienza University of Rome, the National Agency for New Technologies, Energy and Sustainable Economic Development (Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile - ENEA), the National Institute for Environmental Protection and Research (Istituto Superiore per la Protezione e la Ricerca Ambientale - ISPRA), and the US National Oceanic and Atmospheric Administration (NOAA), as well as United Nations Educational, Scientific and Cultural Organization (UNESCO), Food and Agriculture Organization (FAO), Organization for Economic Co-operation and Development (OECD), the University of Massachusetts (Boston) and Cambridge University. The research and studies have found concrete applications in the policies of the Italian Ministry of the Environment and Protection of Land and Sea, and the Ministry of Universities and Research, from 1999 until today.

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Cover: Leonardo da Vinci (1452 - 1519), Atlantic Code (Codex Atlanticus), folio 199 (reverse). Plan of the city of Milan with indication of city gates (top) and bird's eye view of the city of Milan (bottom).
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EVOLUTIONARY CITIES: FROM THEORY TO PRACTICE

Approaching cities theoretically, taking inspiration from scientific disciplines such as thermodynamics and evolutionary physics, brings clear benefits. First, it allows for a deeper understanding of sustainability in the light of the second principle of thermodynamics and the concept of entropy; for instance, it becomes clearer that living organisms perform more efficiently than anthropic systems in terms of resource use and waste production. Second, it lays the basis for a common language that can be shared horizontally by experts with different backgrounds and thus encourage transdisciplinary cooperation; in order to face the closely interrelated environmental, social and economic problems, architects, biologists, geologists, engineers, environmental scientists, and other specialists are called upon to join their competences in a coordinated action and discover coherent practical solutions for building increasingly integrated and sustainable systems. Third, it shows the limits of the most commonly used planning and management approaches that focus prevalently on spatial and structural issues; rather it highlights the need for systemic views, exploring internal and external interactions, flows and dynamic processes. To give an example, typical Master Plans are considered largely obsolete tools, unable to handle the emerging needs of local communities due to quick social and climate change or technological innovation in our connected world. As proved by thermodynamic laws, time, more than space, is the crucial variable and increases the need for integrated planning practices that embed multiple parallel activities, widely shared policy-making with long term perspectives, inclusive programs and actions engaging multiple actors at all stages, from design to execution and management.

Ilya Prigogine, theorist of evolutionary physics, explained the general behaviour of complex dynamic systems such as living organisms and ecosystems, as well as economic and social systems, through thermodynamics. He defined these systems as *dissipative structures* for their capacity to structure themselves into coherent ordered forms depending on the capacity of the system to capture the energy and material inflows from the external environment and, contextually, to generate entropic outflows in the form of waste, heat and other emissions. Dissipative structures have the capacity to self-organize, making "order out of chaos", adapting and interacting with the surrounding environment, and behave as coherent systems, each with its own identity, that is more than the sum of its parts. Prigogine himself, together with Isabelle Stengers[1], stated that the simplest example of a dissipative structure that could be evoked

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[1] Prigogine I & Stengers I. *La Nouvelle Alliance. Métamorphose de la Science*. Gallimard, Paris 1979.

by analogy is the city. Cities therefore can be interpreted as ordered structures with their functions, dynamics and metabolism.

In the book titled *City out of Chaos*, which explores new approaches to the knowledge and management of urban systems interpreted as dissipative structures, Pulselli and Tiezzi[2] highlight the importance of the models and diagnostic tools that make it possible to visualise and quantify the dynamic processes that take place in cities and their evolution in time. The graphical language for system modelling used by Howard Odum[3] is one example. It allows representing real systems by visualizing interactions among main components and energy and material sources.

Representation in a diagram provides a synthetic description of stocks of resources and their flows throughout the transformation processes occurring within an observed boundary. In particular, Figure 1 shows a vision at a glance of the dynamics of a wide urban system. Sectors of activity, such as nature-based systems (bullet-shaped: agriculture including forestry and animal husbandry) and anthropic systems (rectangles: industry including electricity generation and manufacturing; cities including settlements and infrastructures), are indicated as crucial processes supported by a set of sources classified as natural (circles in the left side: sunlight, wind, rain), market-based (circles at the top: energy, materials, food

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[2] Pulselli R M, Tiezzi E. *City Out of Chaos. Urban Self-organization and Sustainability*. WITpress, Southampton UK 2009.

[3] Odum H T. *Environment, power and society*. Wiley, New York 1971; Odum H T. *Systems ecology*. Wiley, New York 1983.

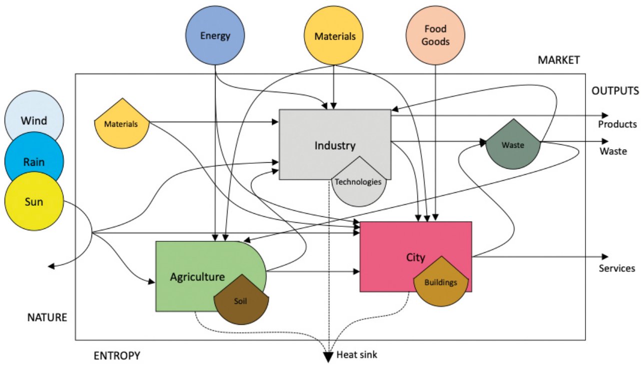

Fig.1. Energy system diagram of a generic urban system based on the graphical language by Howard Odum.

and goods) and stocks, being quantities stored within the system (stock symbols: materials from quarries and mines; soil; technologies; buildings). Energy and material flows are defined by arrows. The arrows that point down, converging towards an entropic sink, indicate that, with each transformation, part of the energy is degraded in the form of heat, following the second principle of thermodynamics. This "macroscopic" vision clearly shows cities as a combination of connected processes that ultimately depend on resources directly deriving from the environment (left side). The city's autonomy is based upon the recognition of this inescapable dependence.
The simulation diagram gives a coherent representation of the various elements of an urban system and describes the general functioning of a city in the light of the thermodynamics of dissipative structures. The formation

and subsistence of the whole, services and urban functions that generate general outputs (namely society, economy, culture), are processes that absorb resources from the external environment and dissipate entropy, in the form of heat, waste, refluent water, and atmospheric emissions. Once the importance of these dynamic processes as crucial factors in urban management is proved, it is clear that it is desirable to use innovative methodologies and tools to collect data, estimate quantities, elaborate indicators and inform urban design practices based on deeper knowledge and increased awareness.

Quickly moving from theory to practice, one representative example of a tool that has been used for this purpose is the carbon accounting framework tested by the *Ecodynamics Group* at the University of Siena[4]. The basic greenhouse gas inventory methodology has been applied to cities and city neighbourhoods to evaluate the intensity of emissions (a form of entropy) generated by the urban functions. The added value consists in the opportunity to tackle multiple variables including energy demand, waste production, water use and material flows for different sectors of activity and, through specific emission factors, express impacts in the common unit of tons of equivalent carbon dioxide (CO_2eq).

The carbon accounting framework has been used to show the impact of energy and material processing in cities and neighbourhoods and is used to inform urban policies and

[4] Pulselli R M, Marchi M, Neri E, Marchettini N, Bastianoni S. "Carbon accounting framework for decarbonisation of European city neighborhoods". *Journal of Cleaner Production* 208 (2019) 850-868.

design, for example for implementing mitigation measures in the various sectors of activities to avoid emissions and achieve a low carbon society. Although this monitoring tool is partial and not exhaustive, it helps to guarantee the robust scientific coherence of planning and design practices by focusing on dynamic processes and their measurements; moreover, it can support awareness-raising initiatives targeting citizens and stakeholders engaged in participative processes. The outcomes concern many urban design issues operating at different scales, from that of the community to the individual level, and promoting different strategies, from structural and technological solutions to policymaking and behavioural changes. In the framework of the European project CityZen, a series of participatory workshops were carried out in ten sample cities. The travelling workshop involved an international team of academics, specialists in urban design, energy transition and environmental accounting. During the course of each workshop, each of which had a designated location, the team of experts visited the urban area under study and interacted with administrators and citizens to gather their concerns and identify their main needs and aspirations. At the end of several study and co-design sessions, the team produced a plan for the radical transformation of the city in a medium- to long-term perspective. In practice, the outcome of each workshop was the vision of a desirable sustainable, energy self-sufficient and carbon-neutral city by 2050; to this end, each action in the plan was measured and sized according to the actual feasibility of the interventions and the expected mitigation effects.

There is extensive documentation on the results obtained during CityZen roadshows[5]. One of the most significant experiences was carried out in Roeselare[6], Belgium, a city that has been working on an innovative urban climate plan for some time and to which the administration has dedicated a specific office. During the five days of the workshop, the action of monitoring emissions served first to guide and then to verify the activities of sustainable urban planning and energy transition.

Starting with a collection of site-specific data, the first step concerned the estimate of the city's overall impact in its current state, taking into account the main sources of emissions: energy consumption for residential use and urban mobility, waste management and water resources (it is understood that this estimate is partial and overlooks other important factors that contribute to determining the carbon footprint of an urban system, such as food supply, consumption of goods acquired from the market, the costs of facilities and infrastructure, industrial, craft and agricultural activities). For the

[5] van den Dobbelsteen A, Martin CL, Keeffe G, Pulselli RM, Vandevyvere H. From Problems to Potentials—The Urban Energy Transition of Gruž, Dubrovnik. Energies 2018, 11, 922. Pulselli RM, Maccanti M, Marrero M, van den Dobbelsteen, Martin C, Marchettini M. Energy transition for decarbonisation of urban neighbourhoods. A case study in Sevilla. In Passerini G. Sustainable Development and Planning X 893-901 2018. Pulselli RM, Maccanti M, Neri E, Patrizi N. Planning neighbourhood decarbonisation in Mediterranean cities. Quaderni di Urbanistica 3. 20, 2020 15-22.

[6] Pulselli R M, Broersma S, Martin C L, Keeffe G, Bastianoni S, van den Dobbelsteen A 2020. "Future City Visions. The Energy Transition Towards Carbon-Neutrality: lessons learned from the case of Roeselare, Belgium". *Renewable & Sustainable Energy Reviews* 137 (2021) 110612.

city of Roeselare, with more than 61000 inhabitants, the emissions measured correspond to approximately 320000 t CO_2eq on an annual basis. In addition to the measurement of the emission value, which would be puzzling for a non-expert audience, the communication of the results played an important role in the entire participatory process. In order to make the measured carbon footprint understandable and accessible to all, the emission value was expressed in spatial terms, representing a virtual forest area that could absorb an equivalent amount of CO_2. The virtual forest offsetting Roeselare's emissions corresponds to 23700 hectares, four times larger than the area of the municipality itself (6000 hectares).

The representation in Figure 2 shows the proportions of this equivalent forest area in relation to the size of the municipality and the shares allocated to the various emission sources. This image is the result of a simplification of a more complex calculation model in order to deliver a very clear message: the set of processes within the selected sectors of activity has significant environmental impacts and the equivalent forest area represents in an effective way the current challenge to be faced in order to reach the objective of a carbon neutral society by 2050, as expected by Europe. The second step of the process is therefore to determine every possible measure to reduce the extent of the equivalent forest, i.e. the amount of greenhouse gases emitted. The final outcome of the workshop is a sequence of actions for decarbonisation, for each of which the effects in terms of emissions avoided are visualized and appreciated.

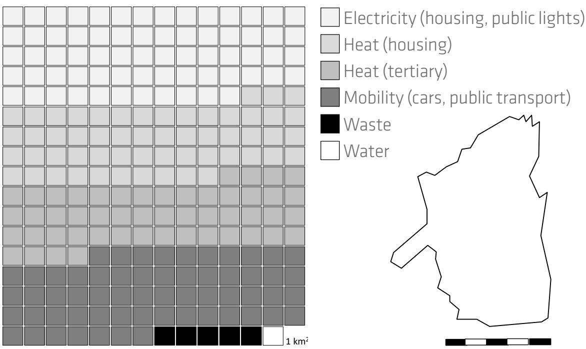

Fig. 2 Representation of the virtual forest offsetting greenhouse gas emissions of the municipality of Roeselare (Belgium), compared to the administrative boundaries, and the corresponding emission sources.

The mitigation actions discussed and then approved in Roeselare cover various possible solutions. Information and awareness-raising campaigns were planned to induce changes in individual behaviour regarding energy (energy savings in homes and workplaces), mobility (reduced use of private cars) and waste (reduction, reuse, differentiation), but also shared community policies on urban regeneration, circular economy, and community-based agriculture. Other measures concern the implementation of technological solutions from the scale of the individual building (energy saving, passive ventilation, nature-based solutions, renewable energy sources and storage systems, rainwater recovery), to that of the neighborhood or the whole city (smart grids and district heating networks powered by various renewable sources, integrated sustainable mobility systems, nature-based solutions at urban scale, integrated waste and waste water management systems). A further long-term scenario assumed a complete transition to electric power (air conditioning of buildings with heat pumps; electric mobility) considering, in addition to the benefits of a definitive abandonment of fossil fuels, the need to meet a greater demand for electricity consumption through new generation plants from renewable sources and integrated smart grids capable of supporting intermittent production and consumption. For every single action envisaged in this decarbonisation plan, potential benefits were estimated, quantified in terms of emissions avoided and therefore of portions of forest area progressively subtracted from the initial equivalent forest area, until its extension is reduced to zero. A clear observation arises from the experience of Roeselare: the scenario that emerges implies the creation of a new way of functioning and a new landscape of the urban system in which the combination of individual behaviour and new technologies profoundly changes how the city is perceived and experienced. Above all, the integrated approach shows that the energy transition is not merely a technological or infrastructural issue. For example, electric mobility can never be achieved through a complete replacement of the existing fleet of cars, but to be sustainable it will require a radical change in the mobility system towards integrated networks, intermodal exchanges, public transport and shared vehicles, bicycle and pedestrian infrastructures and limited mobility for private vehicles; in short, social and business models completely different from the current ones will have to be hypothesised, with a radical reduction in private mobility in favour of a widespread and capillary organisation of integrated transport.

The experience of the CityZen roadshows has shown how urban planning and programming practices must have a multiple value, not limited to the regulation of homogeneous spaces and zones as in current Structural Plans. From now on, it will be crucial to integrate different competences, e.g. combining design actions with assessment in order to predict the effects of proposed measures and assess their feasibility. In addition, participatory and civic involvement practices will play a crucial role, which in turn will be able to draw on the contributions of experts and specialists provided that simple and straightforward communication is developed. It is conceivable that, in the future, all planning will be the subject of coordinated and shared action by multiple actors within an articulated process of comparison and verification.

Accounting frameworks, monitoring methodologies, and mediation models are examples of tools that drive the transdisciplinary work of more scientifically oriented planning and design processes. These are needed to face the challenges and achieve the objectives of the Agenda 2030 of the United Nations (i.e. Sustainable Development Goals) or the European Green Deal. It is certainly to be hoped that, in the future, monitoring operations will be structured in an increasingly efficient manner, and that we may reach deeper knowledge of the processes that take place within an urban system and of the quantities of energy and material that they involve. The analogy between urban systems and living organisms that we have identified brings us to this conclusion; it underlines the importance of overcoming the emphasis on structural and spatial aspects and turning our attention more to the *metabolism*, rather than to the *anatomy*, of urban systems.