energy data• simulation games • city building games

Playing Energy Landscapes. Reconnecting Architecture, Data, and Scales

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Abstract

The climate crisis has heightened the relevance of architecture due to its substantial impact on energy consumption and carbon emission. However, such relevance is conveyed by means of simply numerical values that are derived from data and communicated through digital tools that cannot be examined or questioned. They become labels that frequently serve to certify that a particular abstract objective has been successfully accomplished. Such *landscapes of energies* flatten out any distinctions between architecture and urban environments. The article describes the development of a simulation game that defies this prevailing pattern. The game alludes to the historical legacy of simulation games centered around ecology and economy, while adopting a lighthearted and exploratory attitude towards data and energy. By engaging in gameplay, the simulation experience allows users to easily understand its mechanics while also reconnecting the different dimensions of architecture and the urban environment.

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The impact of architecture on the climate is mainly measured in quantities and abstract entities.

The scale of data
Amid the ongoing climate crisis, architecture has discovered a new relevance, which is best reflected by two repeated figures from conference to publications: *30%* and *80%*. Both recur over and over and refer to the share of the CO2 emissions (construction and services) and waste produced by the building industry, reflecting architecture's enormous impact on the environment and the climate. However, the discipline's newly regained relevance has an obvious downside which is also reflected by these two numbers: the impact of architecture on the climate is mainly measured in quantities and abstract entities. It is essentially a matter of energy consumption, consequential emissions and their impact on the climate – mere numbers and statistics that pave the way to performances' optimization and protocols to conform to. "Good" architecture is then a matter of achieving certain goals and a positive eco-balance (*Ökobilanzierung*). It is measured and assessed through environmental impact points (UBP: kg/m2 effective energy related surface), greenhouse gas emissions (THGE: kg CO2-eq/m2 effective energy related surface) or grey energy (kWh oil-eq./m2). The calculations of these data are highly complex and often performed by digital tools and by specialized firms. In Switzerland, the main instrument to calculate emissions and grey energy is the KBOB-list, a governmental standard which is periodically revised. It is based on the different degree of impact on health and environment and through the revision, these different influences are weighted differently. In the first edition of 1990, the major weight was on ozone layer depletion (50%), while in the last edition this accounts only for 2%. Here climate change accounts for 38%, while back in 1990, it only accounted for around 4%. The calculation of these factors in their various interdependencies, is highly complex and can only be done through digital instruments, such as Greg, Lesosai, Co2mpass or Ecotool, just to mention some of the most popular ones. These tools allow for a calculation of several parameters – first of all of energy consumption, production and greenhouse gas emissions – and are the foundation of Swiss building-standards such as GEAK, Minergie and SNBS, which attest and label buildings. Here again, every standard has a different

set of parameters that they include in their evaluation (SNBS being the most holistic) and which change over time.
For architects the struggle is twofold: on the one hand, they have no control on the tools and on the operations that these perform, as they are given, on the other hand, energy-consumption and its consequences – such as greenhouse gas emissions – remain ungraspable entities that have no relation to the *real* world of architecture. As for the first point, these tools appear to be *black boxes* that are fed with data – square meters of floor, square meters of window surface, tons of concrete etc. – and based on this, they generate results, that will tell if a building conforms to a certain goal or not. Obviously, this tells nothing about the architecture of the building and its qualities. As for the second, these numbers and these percentages are totally abstract and difficult to relate to a particular scale of architecture. They are a linear or non-linear sequence of numbers and as such potentially endlessly scalable, without a real point of reference. Consequently, sustainability is – also – a matter of numbers and this must be reflected by the discipline. The results are "landscapes of energies" that make no distinction between the scale of a house, a quarter, a city or an urban landscape and as such, between architecture and urban environments. Multiscalarity, which is the possibility to change and work on different scales, is then suspended and scales *flattened*.

The scale of the planet
In the context of sustainability, the issue of scale has gained momentum, as it became more and more clear that the relationship of human beings to their environment, and their impact on it, must be retaught in the terms of its magnitude. Indian scientist and historian Dipesh Chakrabarty has made an argument for the need of a new *regime of historicity* through the concept of anthropocene but mainly through the concept of planet and planetary (Chakrabarty, 2021:68). The planet is then a new category to think sustainability, opposed to the notion of globe (and of globalization), with the latter being a humanocentric construction, while the planet *decenters the human* (Chakrabarty, 2021:4). Among the many references Chakrabarty builds upon, there is also the distinction

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made by Martin Heidegger, between *Erde* and *Welt* in his attempt to define the nature of artworks. *Erde* then is something that can be "manipulated", while *Welt* is given (Heidegger, 1977). This reference is telling about the fact that these different scales have a long tradition and have been used to explain other contents. In his book Chakrabarty includes a dialogue with Bruno Latour and his plea for a return to earth, which appears to be antithetical to the position of Chakrabarty, at the same time it covers the same issues of a "New Climatic Regime" including the question of human-nature relationship or global inequalities (Latour, 2018:16). For Latour the question of the scale at the center of his movement from close to far:

Whereas urban spaces had traditionally been designed by arranging *voids* and *solids*, only abstract diagrams could grasp this new and vast scale.

> We must face up to what is literally a problem of dimension, scale, and lodging: the planet is *much too narrow and limited* for the globe of globalization; at the same time, it is too big, infinitely too large, too active too complex, to remain within the narrow and limited borders of any locality whatsoever. We are all overwhelmed twice over: by what is too big, and by what is too small. (Latour, 2018: 1)

This struggle and search for the *right* scale of sustainability, resonates with the history of architecture and the discipline's struggle towards the horizon of its operations and that which is still manipulable through its means, such as plans, diagrams or models. By no way the struggle with scale is new to the discipline, as it rises now again in the context of the landscapes of energy. In fact, it is something very peculiar to the history of the discipline. In the wake of industrialisation in particular, cities exploded and sprawled into a suburban dimension, losing their previous contours and size. For architects, this marked a dramatic change in their profession and the tools they were accustomed to. This transformation is particularly evident in two competitions: the 1910 Groß-Berlin competition and the 1919 Greater Paris competition, where, alongside a more traditional scale (1:5,000, 1:10,000), new and larger scales emerged (1:60,000 and 1:40,000 respectively) that challenged the conventional way of designing urban spaces. Whereas urban spaces had traditionally been designed by arranging *voids* and *solids*, only abstract diagrams could grasp this new and vast scale. The introduction of ever-larger scales overthrew all theoretical attempts to wrest control of this scale: in the German Ruhr region, for example, a new regional scale emerged that obliterated any attempt to maintain the notion of a contained *city*. The engineer Robert Schmid presented a study, in a 1:100,000 scale, for the development of the newly created *Siedlungsverband Ruhrkohlebezirk* coal-mining settlement district (Schmid, 1912). The study marked the birth of a new discipline: *Landesplanung* (state planning) which was later to become *Raumplanung* (spatial planning). In this context, architect Gustav Langen introduced the concept of *Landschaft* (landscape) to describe this new form and scale of urban design. He posited that a geographical point of view should integrate into architecture (Langen, 1912). The consequence of this development was the incorporation of a multiscalar perspective on architecture. The recent call for *planetary urbanisation* (Brenner, 2014) in the context of architecture and urbanism, has further extended the space of observation and action to ever-larger scales, leaving architects puzzled and insecure about their possible interventions and means. In this sense, the periodical resurgence of the notion of *territory* may well represent an attempt to reclaim lost agency, as it was the case in the 1970s when the term became fashionable in Italian architecture or again nowadays (Aymonino, 1964; Gregotti, 1966; Topalović, 2018).

The contemporary data-based *landscapes of energy* constitute a new challenge for architecture.

Landscapes of energy

Building on a century-old tradition of responding to ever-increasing scales, the contemporary data-based *landscapes of energy* constitute a new challenge for architecture in that, in addition to their expanding scale, they are – if possible – even more abstract than large-scale *space*. Energy is expressed through charts and graphs rather than plans and perspectives. Energy and emissions are measured and expressed in data, constituting the basis for models and simulations. The discussion about the climate crisis and its impact on human life is based on simulations and projections. Among the most famous – and probably most controversial – simulations in this arena are those developed by Jay Forrester, professor at MIT's Sloan School of Management, which the Club of Rome used to develop the scenarios published in the seminal "The Limits of

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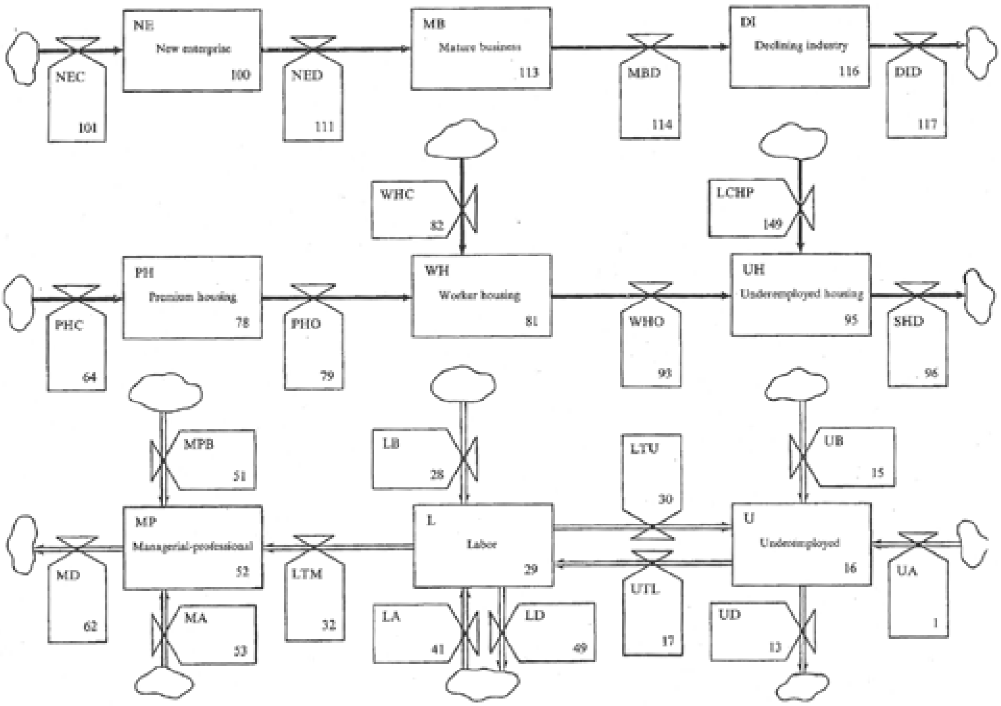

Fig. 1 - Jay Forrester, "Diagram. Model for an urban area", 1969. Source: J. W. Forrester (1969), *Urban Dynamics*, p. 16.

Growth" in 1972 (The Club of Rome, 1972). Forrester went on to apply his theory of system dynamics on urban environments and published his research in 1969 in his book "Urban Dynamics" (Forrester, 1969) in which he described the development of a city as an economic model with a corresponding life cycle and identified business and housing as the main levers of its development. To explain his model, Forrester mainly relied on diagrams visualising the interdependencies between the different factors and levers. He also included a rather hapless perspective of his *ideal city*, revealing just how abstract his understanding of the urban scale was and how much he struggled to complement the structure's scale with a corresponding physical model. The representation resembles rather to an abstract data sheet, than to an urban environment. Two things appear relevant in this context. Firstly, at the time, the climate crisis was not discussed in terms of energy (consumption and production) to the extent that it is today, but more in terms of resources and pollution. In "The Limits of Growth," energy is only discussed in passing and in relation to pollution (The Club of Rome, 1972: 71).

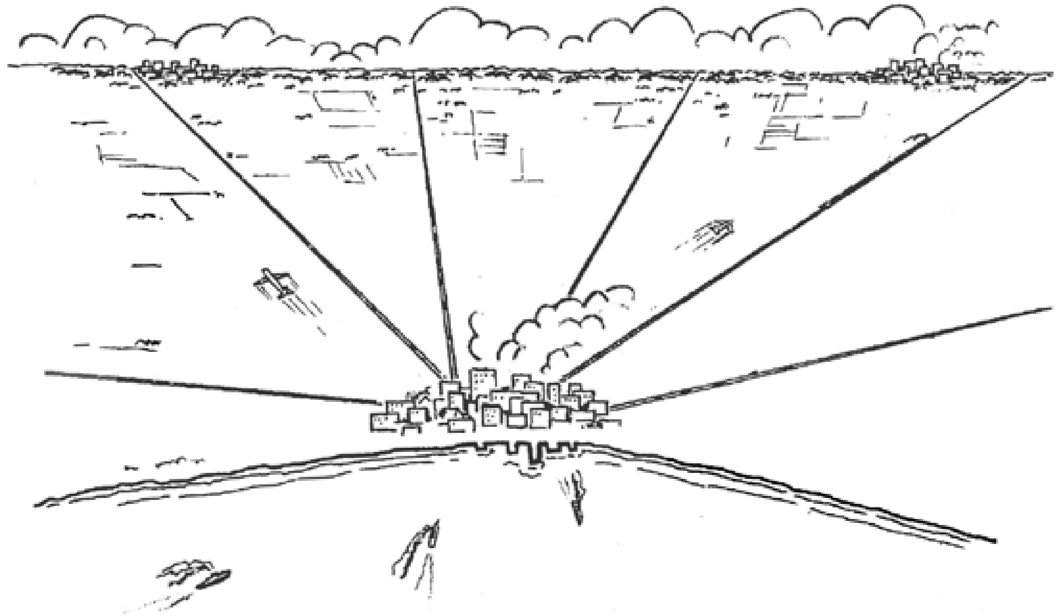

Fig. 2 - J.W. Forrester, "Urban environment", 1969.
Source: J.W. Forrester (1969), *Urban Dynamics*, p. 15.

Secondly, there was a general discontentment at the time towards these models and simulations and the related emerging technologies, which from the start were heavily criticised on the grounds of lacking or insufficient data (Edwards, 2010: XVIII). Proponents of the environmentalist counterculture of the 1960s and 1970s were critical of the *top-down* technology that had emerged from military founded research during and after World War II:

> Between 1945 and 1965, digital computers revolutionized weather forecasting, transforming an intuitive art unto the first computational science. Unlike many scientific revolutions, this one was planned. Numerical weather prediction became the civilian showcase for a machine invented in wartime to support specifically military needs. Scientists conceived and carried out the first experiments with numerical forecasting in the earliest days of electronic computing, years before commercial computers became widely available, as a joint project of American military research agencies and the US Weather Bureau. A principal architect of that project was John von Neumann, who saw parallels between the science of nuclear weapons and the nonlinear physics of weather. (Edwards 2010: 6)

The pedagogical value of games started to be recognised and games at the intersection of simulation and ecology emerged in this period.

The focus of the discussion, among the scientific community as well, at the time was on the accuracy of these projections, the model used and the available data.

Eco-simulation games
Against this background, the significance of games and game-playing as alternative approaches to dealing with data while maintaining a critical stance towards the associated technology was growing considerably. At the same time, the pedagogical value of games started to be recognised and games at the intersection of simulation and ecology emerged in this period. However, they typically focused on the scarcity of resources and not on energy, mainly adopting a management perspective. Not least, the motivation behind these games was how to deal with data. Buckminster Fuller developed one of the most influential games of the genre. In 1969, he realised his "World Game," which he had already started working on in the 1940s. The game was based on *dymaxion maps*. It was

> […] an attempt to turn a technocratic apparatus of data analysis, systems modelling, scenario building, computer technology, and information design – the stuff of Cold War military strategy – to more egalitarian ends to meet human needs. (Stott, 2022: IX)

The players had to deal with the scarce resources of the world and find ways to distribute them more equally by modelling scenarios. The aim was not to win but to find solutions and gain literacy around complex systems, data and world problems. The "World Game"

> was driven by a fantasy of a cybernetic architecture of total information, the cybernetics of the Seminar were characterized by an *ontology of unknowability*. (Stott, 2022: IX)

Fuller's approach was influenced by the biologist Ludwig Von Bertalanffy's General Systems Theory (GST) John von Neumann's game theory and based on the notion of the world as *Spaceship Earth*, a metaphor that would gain much momentum at the time (Ward, 1966). The implicit assumption of the metaphor was that the earth could be controlled and its mechanisms understood – which is the purpose of the game – but we are yet to learn how:

> Now there is one outstanding important fact regarding Spaceship Earth, and that is that no instruction book came with it. It is worth noting that there is no instruction book for successfully operating our ship. (Buckminster Fuller, 2008: 60)

The “World Game” was a typical product of its time, with both a fascination with and critical stance towards computer and cybernetics, and the attempt to use them to solve environmental problems. Data was negotiated and played out in the game and as such made tangible in its influence on the game world. A World Game Institute was created in 1972 to disseminate the game and the insights it provides.

The “World Game” was a mix of tabletop and digital games. Several other game experiments emerged in its heyday, notably the “Sumerian Game,” whose history has been the subject of many investigations and myths. Developed between 1962 and 1967 by IBM under the direction of Bruse Moncreiff and supported by the New York State Education Department, it was aimed at Sixth grade children and based on an IBM mainframe. It was connected to an IBM 1050 terminal and a slide projector (Wing, 1967). After receiving some background information about the Sumerian culture, the children would assume the role of Lagash, the ruler of a Sumerian city-state and be put in charge of its resources. They would be tasked with deciding how to distribute the harvest to feed the population and plant new crops. The projected slides would serve as a visual aid to support the players’ decision-making and show the consequences of their decisions. It is noteworthy that Mabel Addis, one of the first female video game designers, played an essential role in this project and is credited in the game.

A third game worth mentioning is “Ecogame,” aimed at teaching economics – and, indirectly, ecology – and developed by Georges Mallen in England around the same time. Mallen had worked for Gordon Pask, one of the most prominent cyberneticians of the time. He and his System Research Ltd developed, among other things, SIMPOL (SIMulation of as POLice system), a project about decision-making in crime investigations.

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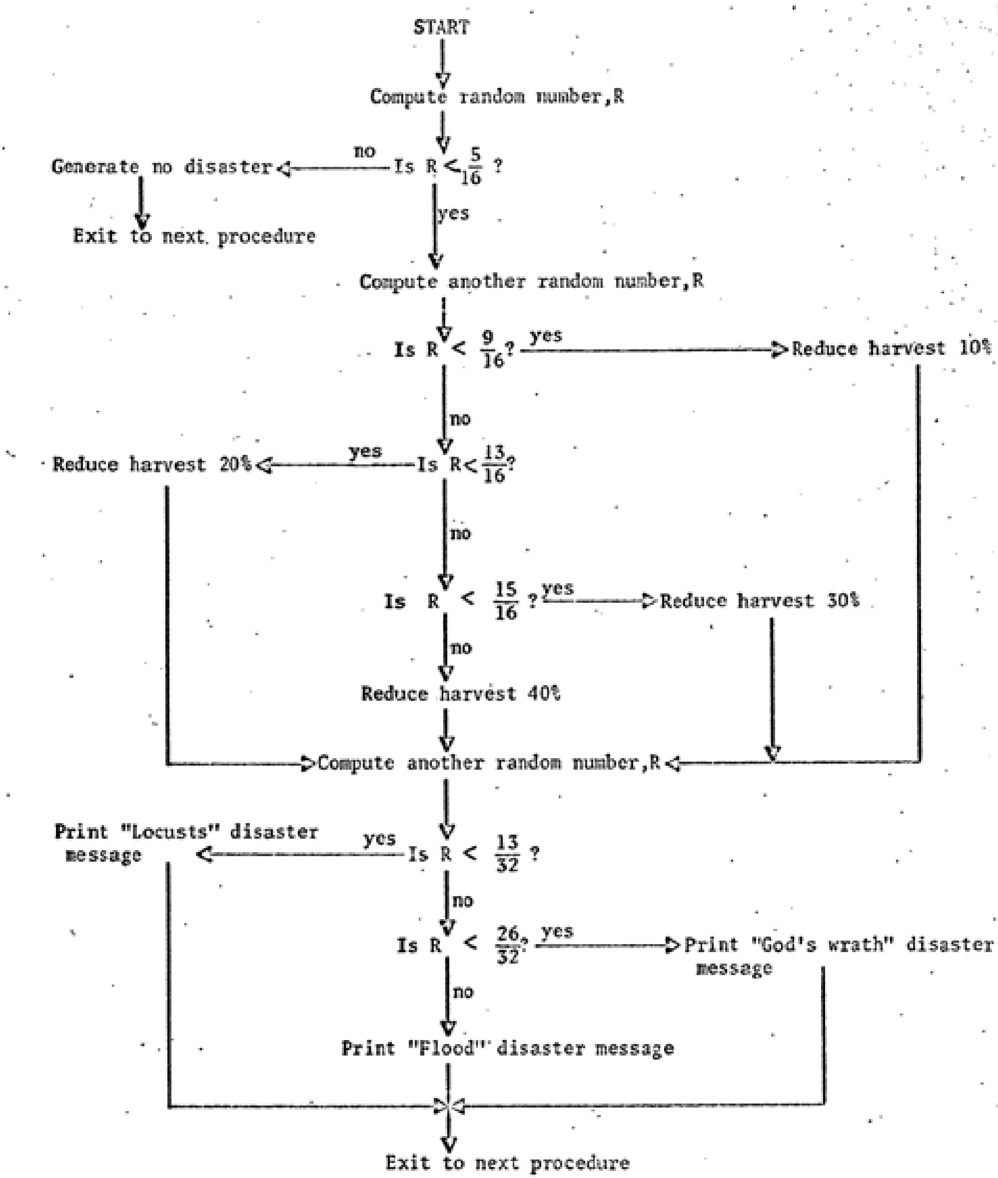

FIGURE 4. NATURAL DISASTER GENERATION PROCEDURE

Mallen had previously cooperated with Cedric Price on the "Fun Palace," and after leaving Pask, he founded his own company, System Simulation Ltd with Mike Elstob. One of their first commissions in 1969 was designing a game to be displayed inside a "Buckminster Fuller type geodesic dome" at the Computer 70 trade fair (Mallen, 2017: 197). He developed the "Ecogame," which could be played by groups of three players who had to make decisions for a model economy. According to these decisions, a slide projector connected to the computers (as in the "Sumerian Game") would display corresponding images:

> The heart of the game was a system dynamics model that I developed of an hypothetical national economy which was controlled by three players seated at three Tectronix terminals each with slide projectors projecting images of how the model economy was faring on to screens suspended above the terminals. These images were photographs collected or taken by Anthony McCall. So, for example, if the model economy was performing well and creating wealth, colourful images of happy citizens, elderly folk or families at play were selected. If, however, the economy was being run down, black and white images of dole queues or civic unrest would be selected. So spectators could see how things were going by the mood of the projected images. We called the system "Ecogame". (Mallen, 2017: 193)

The game was used again by the Centre d'Etudes Industrielle (CEI) in the context of the European Management Forum held in January 1971 in Davos (a precursor to the current World Economic Forum). Both "World Game" and "Ecogame" would put the economy at the forefront and rely on abstract diagrams and, conversely, projections of real-life pictures, thus bridging abstraction and concrete representation.

Along with these games, another type of simulation game emerged at the time. It focused on urbanism and urban environments, such as "Metropolis" (1964) by Richard D. Duke and the subsequent "METRO game/simulation" (1967), "CLUG – Community Land Use Game" (1966) by Allan G. Feldt, who had worked on "Metropolis," and "INHABS" (Instructional Housing and Building Simulation) by Cedric Green (1967). The purpose of these games was for players to learn how to deal with the complexity of cities. They were primarily used in a classroom setting. However, they were also used to bring relevant stakeholders to the board to play different roles. These were mainly

Fig. 3 - The Sumerian Game, "Example of generation procedure", 1967. Source: R. Wing (1967), *The production and evaluation of three computer-based economics games for the sixth grade*, p. 30.

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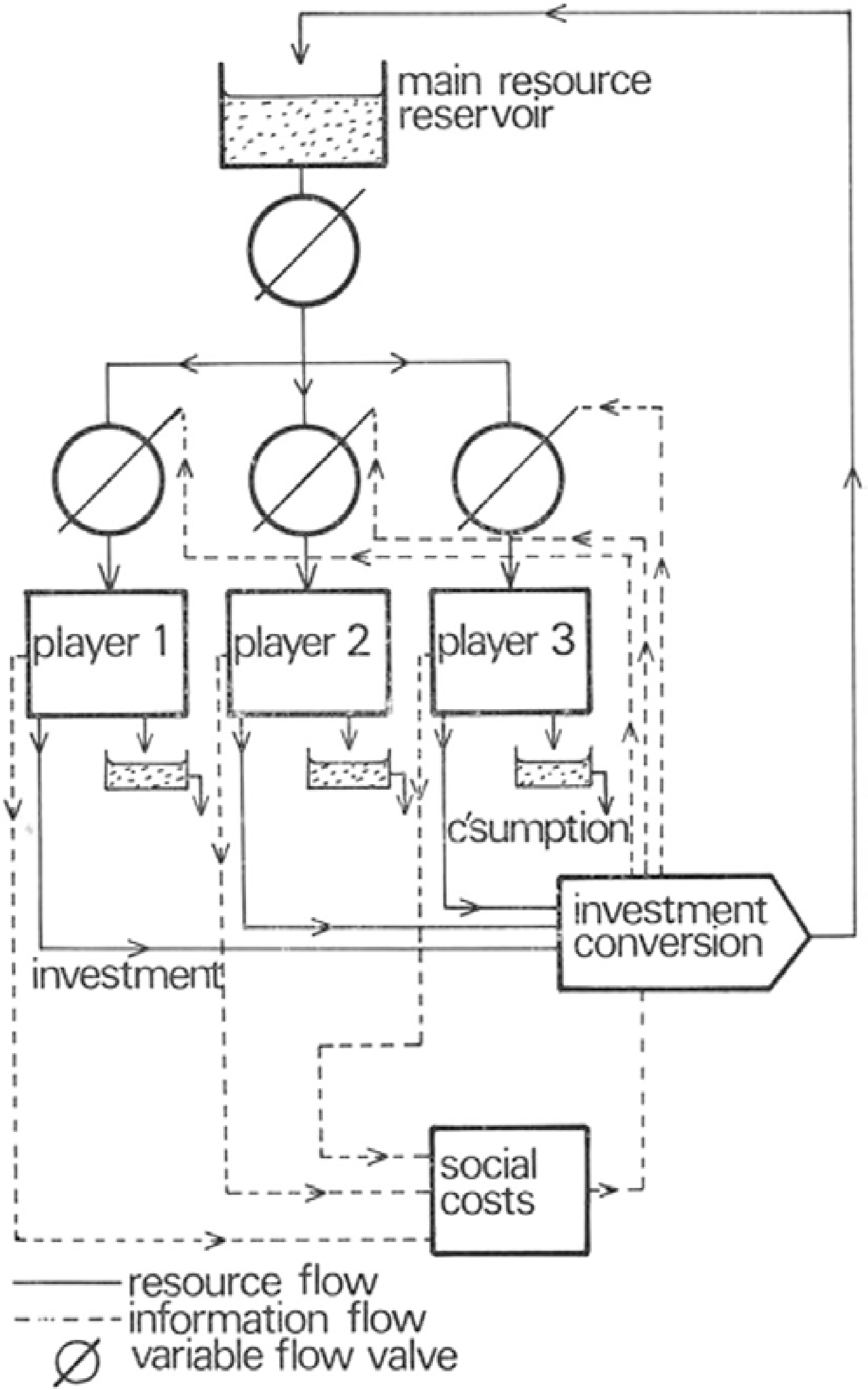
main resource
reservoir
player 1
player 2
player 3
c'sumption
investment
conversion
investment
social
costs
resource flow
information flow
variable flow valve

analogue games, but soon extended to computer programs that could register and process the players' input. Duke, who like Stuart Marquis is considered to be one of the pioneers of urban simulation games, would later question this path from analogue to digital:

> It was a time when a significant number of planners believed that it was possible to model a major metropolitan community as a predictive, scientific tool to evaluate various proposals affecting the community [...]. This later proved to be a rather simplistic view, limited in theoretical content and technology. (Duke, 2000: 80)

"Metropolis" and other urban simulation games did not focus on ecology, but they still centred on limited resources, and compared to the "World Game" and "Ecogame," they had a clearly defined urban scale. "Metropolis" famously took the city of Lansing (the capital of Michigan) as its reference. With around 100,000 inhabitants in 1960, the city was fairly large-scale. By comparison, the other games tended to focus on idealised, smaller towns.

Generally, architects started to take an interest in games in the 1960s, as alternative approaches to dealing with physical reality and the limitations of their profession. In the words of architect Juan Pablo Bonta, editor of a 1979 issue of the "Journal of Architectural Education" dedicated to games:

> Architects and architectural educators are becoming interested in gaming. There is a philosophical reason: since the collapse of the modern movement, we are no longer sure that the architects' values, stylistic preferences or prejudices are better than anyone else's. In abandoning the messianic role, we fabricated for ourselves, we can see architecture as a transaction between groups with different goals and values-the users, the owners, government, labor, industry, public opinion, architects themselves. Like war, business and politics, architecture can be seen as a game in the widest sense of the term. The principles of gaming theory are applicable to it and they can cast light upon aspects of the profession overlooked before (Bonta, 1979: 1).

This tells us that there is a tradition of architects applying methods of gaming in their practice.

Fig. 4 - Economic flow diagram for "Ecogame", 2017. Source: G.L. Mallen (2017), *A journey - crossing boundaries, Interdisciplinary Science Reviews*, p. 199.

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Net Zero: A sustainable construction simulation game, 1990-2050

The pioneering experiments mentioned above were later translated into commercially successful games such as “SimCity” (1989), “Big City” (1999) or “Cities: Skylines” (2013), which all focus on having fun rather than learning and which build on a model of constant growth. However, the first version of SimCity already featured pollution, the option of a car-free city, and the principle of limited resources, which extended to money, land, energy and connections. Subsequent games put ecology in the foreground, such as “City Rain” (2010), “Anno 2070: Das Spiel mit der Ökobilanz” (2011), “Block’hood” (2017) or “Save the Earth” (2023), but the fun factor remained at the heart of things. These games all oscillate between a large scale – the world – and a small scale: the blocks. There is no in-between scale. Once more, ecology is mainly understood in terms of balancing resources rather than energy.

In line with this tradition, we are developing a new simulation game called “Net Zero: A sustainable construction simulation game, 1990-2050.” The idea is to create a game that moves energy consumption and production to the forefront and is oriented towards teaching school children. In the game, the player is responsible for an average Swiss city of 20,000 inhabitants and tasked with spending funds in a way by which net-zero emissions can be attained by 2050. It is based on different projections and goals developed in Switzerland and around the world, all of which have a 2050 net zero target.

The focus is on buildings, infrastructure, and green spaces. Emissions, energy consumption levels, and waste management are constantly displayed and made visible to the player. Houses are grouped according to their date of construction, alignment, orientation, and the corresponding type of insulation and heating system. According to Swiss statistical data, 31% of buildings in Switzerland are pre-war buildings, 21% were built between WWII and 1970, 33% between 1970 and 2000, and 15% were built more recently. Each of these types are associated with a specific consumption of energy and production of CO_2. Aspects such as densification, re-use of building materials and biodiversity are also integrated. Embodied energy is also part of the

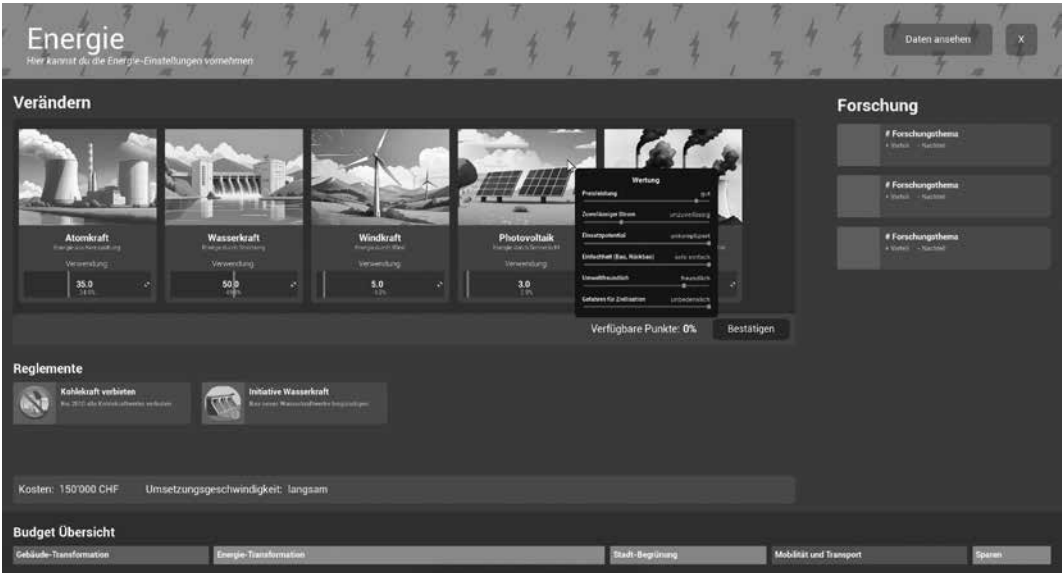

Fig. 5 - Tool box, "Net Zero: A sustainable construction simulation game", 1990-2050. © Andri Gerber, Pascal Areggger.

equation, meaning the player should avoid destroying structures whenever possible. The game's goal is to find ways to make the complex interdependencies within urban planning understandable for children aged 14 to19, who will be playing the game in the classroom. The game follows the "Education for Sustainable Development-ESD 2" approach, which suggests that children should learn to reflect on sustainability and come to their own conclusions. This way, sustainability is no longer a topic only accessible to experts, but a learning process open to all of society. This approach aligns with the "emancipatory approach" coined by Arjen Wals (Wals, 2011). Sustainability is a matter of knowledge-building through action and interaction rather than passive information-gathering.

One of the game's main ambitions is to reconnect the different scales that constitute the *energy landscape* and to make their differences graspable for the player. Three scales are represented in the game: the single house, the urban district, and the city. Energy consumption and production, CO2 emissions, and waste production are constantly displayed on each scale and seen in relation to each other. The game will show different ways to display energy levels. Using infrared thermography, the player will be able to see which houses and districts are losing energy due to poor insulation, and the contribution trees make to cooling a single house or district.

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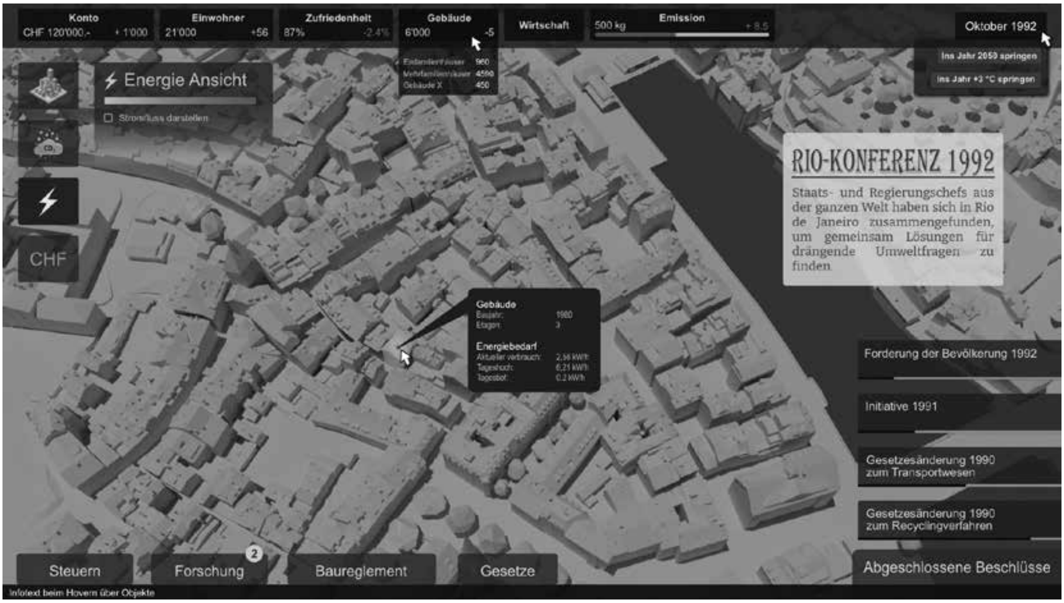

Fig. 6 - Mockup, "Net Zero: A sustainable construction simulation game", 1990-2050. © Andri Gerber, Pascal Aregger.

The player will be able to visualise how their city is doing and what kinds of improvement they are achieving with their actions at any point. This aspect of visualization is key to the game and will allow to better understand the consequences of decisions. Players can simultaneously intervene in a single house, a group of buildings (e.g., the category of pre-war houses) or a district. The data is always available and displayed in relation to a comprehensible unit. Data and energy are not abstract entities in this game but part of a whole. The player understands by which means and choices to manipulate these factors and what results will likely yield. Their actions will have an impact that can be visualized and contextualised. In school, the children will play on their computers or tablets while the teacher sees all their screens displayed on a dashboard, allowing them to discuss the children's different strategies.

We decided to develop this game not only to create a pedagogical tool to create awareness, but also to regain control over the *black box*, that is the digital model by designing our own model with our own rules. The rules and mechanics of the game are on display rather than hidden, meaning the player can intervene at any time during the game and witness the effects of their decisions. It is what makes this type of game so powerful: unlike the *black box* programs

with simple input and output, this game allows the player to intervene and change the course of the game whenever they wish.
In her book and exhibition dedicated to games in architecture, Mélanie van der Hoorn underscores how players are simultaneously in power and powerless:

> A game is a form of empowerment: players can grasp and control situations that remain inaccessible in normal life. At the same time, the developer also exerts a considerable influence on the course of the game through the material and rules, in which he embeds – consciously or not – messages and ideologies. (van der Hoorn, 2022: 86)

To achieve this condition is the goal of our simulation game.
Designing a game like this is a means of regaining control over the mechanism within. Of course, a game is always just a reductive copy of reality, but deciding what is worth copying always rests with the designer. Models and simulations do not have to be passively accepted; they can be designed so the player can manipulate them at will. Sustainability, then, is not only a matter of resources but also of energy, and energy can be understood as an element that ties the different scales of our lived-in-spaces together.

Sustainability is not only a matter of resources but also of energy, and energy can be understood as an element that ties the different scales of our lived-in-spaces together.

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