Design Strategies in steady-state systems

Matteo Clementi

Building Environment Science and Technology Dept., Politecnico di Milano
E-mail: matteo.clementi@polimi.it

ABSTRACT: This paper addresses the problem of working out consistent design tools able to cope with the sustainability requirements for building.
The term sustainable refers to the definition of strong sustainability (as) given by Herman E. Daly and specifies a system that is able to preserve natural capital within an economic system subject to a stationary energy flow (the solar energy).
The methodology presented hereby applies, in an environment design building context, the thermodynamic analysis introduced by Howard T. Odum, indicators as emergy, ecological footprint and Life Cycle Assessment.
The target is a tool that may help the designer to reach a better understanding of the complex set of connections between local natural resources and buildings in different points of their life cycle and to optimize these connections more easily through an interface code between design procedures and thermodynamics analysis.

Keywords: emergy, ecological footprint, strong sustainability, sustainable architecture, LCA.

1. PRINCIPLES

The study presented hereby is the work in progress of a second year PHD thesis, which analyses and implements building design tools able to steer architect choices towards sustainability. The term sustainable refers to the definition of strong sustainability given by Herman E. Daly.

He defines four basic principles to explain the term strong sustainability.

1: sustainable yield principle: the resources withdrawal rate from an ecosystem should be at least equal to its own regeneration rate.

2: Absorption capacity principle: wastes production rate should be equal to the natural absorption capacity of the ecosystem.

The regeneration and absorption capacity defines the natural capital and not to maintain those capacities has to be considered a natural capital consumption and therefore not sustainable [1].

3: Carrying capacity principle: the aggregate load has to be brought back to the right level not to exceed the natural carrying capacity.

4: Replacement Principle: No-renewable withdrawals of resources should be offset by an equal quantity of renewable ones, in order to replace them on the long-term [1] [2].

Pursuing those principles presupposes the acceptance of a steady state economic system, intended as a system based on a limited and renewable resources budget.

The awareness of the limited supply of natural services, implies to recognize the global population right to take advantage of the same services amount.

The evaluation of a project in the “strong sustainability” sphere, implies the same problem.

In fact, to be addresses as sustainable the project contribution to the life style general impacts has to improve wellbeing conditions towards equal right to the planet services .

2. TOOLS

2.1 Requirements

The sustainability principles imply the use of specific tools able to meet specific requirements:

1) They have to be able to deal with the combination of different disciplines, so to assume alternative scenarios of development which could involve different consumption strategies. In practice, the impact assessment of man related activities on the services supplied by the environment, need to gather the dynamics activated by consumption categories. In this way it is possible to understand which is the building design contribution on the general impact of consumer.

2) They have to be able to show the material culture, generated by the design process, as a flows activator. Flows have to be assessed in relation to the context where emissions and withdrawals take place.

3) They have to be able to quantify the flows.

4) They have to be able to locate them, so to understand which kind of ecosystem they will deal with and so assessing the specific carrying capacity.

2.2 Organization of information.

Referring to the demand presented at point 1, in the specific case of architecture, the designer is invited to see the project as a service design opportunity.

The sustainability principles fulfilment imposes to look at the objects (architecture included) as service flow activators, that connect man and the ecosystem through a complex set of relations more or less eco-consistent. To reach this objective implies a basic rule about the information layout: the sustainability of a building has to be evaluated referring to the services supplied to the user and referring to the characteristics of the area where all flows effects fall.

In this way the design supply to the general impact of the user lifestyle can be evaluated, and a constructive comparison can take place among the consumption categories: dwelling, feeding, transportation and services .

To look at the material artificial context as a set of flows connections, generates a codethat can be shared by different disciplines so to create scenarios of integrated development related to a particular lifestyle and a specific context.

2.3 Representation

The fulfilment of the second requirement is possible through the use of an analytical tool, conceived by Howard T. Odum to show how the work of nature and society can be evaluated on a common basis. This tool, now used in quantitative ecology and ecological economics, allows to represent a building as a complex network of flows. It uses energy system diagrams to represent anthropic dynamics inside an ecosystemic context, both local and global. Therefore it allows to understand specific interactions between biosphere related dynamics and those related to human activities.

In this way an object can be represented as a flows operator inside a network of nodes that exchange materials and energy to each other.

The methodology allows to classify the internal nodes of the system according to the different role they play in the ecosystem. So It enables to relate the analysed dynamics to the basic principles of sustainability.

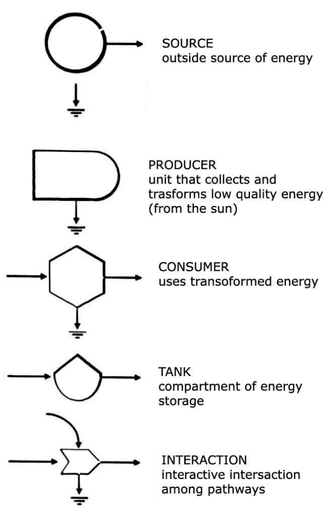


Figure 1: Energy system simbols [4].

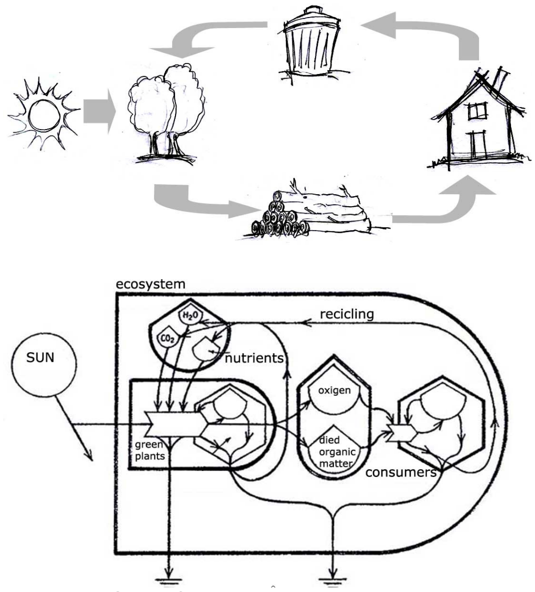
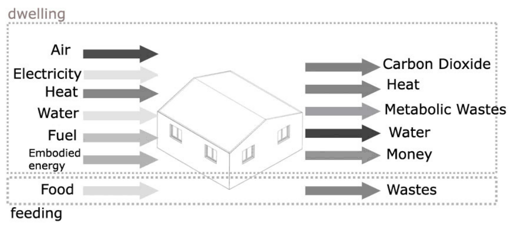


Figure 2: Simplified ecosystem diagrams.



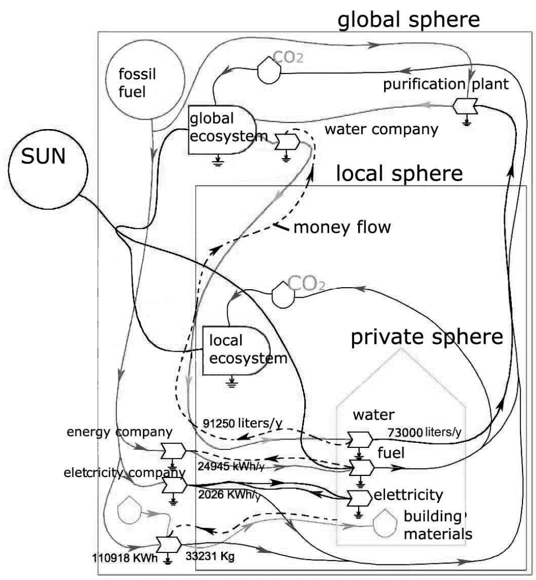


Figure 3: Main flows involved by a dwelling, represented through the use of energy system diagrams.

2.4 Quantity

The third requirement expresses the need to check the sustainability principles by quantifying energy and material exchanged by nodes.

So the representation of the process through the energy system diagrams has to be necessarily followed by the quantification of energy resources and material exchanged by the nodes, in such a way as to verify the balance conditions.

In the building context this task requires to solve two peculiar questions: data availability and ability to manage and quantify complex data set.

a) As far as the first one is concerned, the presented methodology adopts the Life Cycle Analysis tool, even if not completely. It follows LCA procedure till LCIA step, the Life Cycle Impact Assessment, and it excludes the last part of the procedure about data interpretation. In this way it will be possible to access to useful existing databases especially about the Environment Product Declaration (EPD) of building materials and components [5].

Using this tool up to the LCIA stage, allows to simplify data management, reducing the amount of different data according to the main environmental impact factors, but still keeping the quantitative characteristics of them.

Environmental impact factors permits to express, through the same unit of measurement, different amounts of material and energy according to the main common impact they generate. In the Danish LCA tool, EDIP96, for instance, the environmental impacts like NRE (No-Renewable-Energy), GWP (Global Warming Potential), AP (Acidification Potential) and EP (Eutrophication Potential) are espressed in terms of equivalent amount of energy or material, kg of CO_2, SO_2 or NO_3. In this way we are still able to assess the exchanging rate between the nodes of the system, so to verify the sustainability principles fulfilment and apply indicators such as the ecological footprint and emergy.

b) About the second task, the question related to dynamics quantity and management is taken on by an integrated use of a dynamic modelling software and computational sheets.

Their functioning can support the quantification of an energy system diagram, so to calculate how a flow can vary in time and how it is influenced by feedback actions.

2.5 Location

The requirement about the dynamics location is related to the conditions shown in the third principle, as also in the second and first.

Its fulfilment takes place by giving the possibility to geo-reference the interaction nodes of the energy system diagram.

This is allowed by the use of a Geographic Information System, a GIS, adding information about withdrawal and emission coordinates related to the main dynamics.

The benefits related to the use of it are:

a) A starting point towards evaluating the conciliation between environmental and economic sustainability, by means of quantifying the specific dynamics (money included) and to put them in relation with the context.

This happens checking the project economic fall-out in the specific area, evaluating imported or exported economic flows.

b) Geo-referenced information allow to check the carrying capacity of the local internal ecosystem and at the same time to understand which amount of natural services has been supplied by external ecosystems.

c) together with the possibility to quantify the internal dynamics of an area it allows, furthermore, the use of synthetic indicators of sustainability related to the emergy analysis, based on the distinction between local flows (renewable and not renewable) and imported ones.

They can furthermore give an help on estimating the internal ratio between renewable and no-renewable resources involved in the project.

d) A much more effective impact assessment related to the local and regional sphere: for instance, in the case of Eutrophication Potential it enables to connect the amount of drawn substance to the real capacity of the involved basin; the same can happen if it is a matter of eco-toxicity indicators, giving the possibility to relate the flows to the real conditions of the local ecosystem (as happens in the case of Nature Planner as support to the LCA Dutch tool EcoIndicator99).

3. STRATEGIES

After proposing principles and tools, it is required to adopt design strategies so to address design choices towards the accomplishment of the principles set out above.

The natural world has always been subject to a steady supply of solar energy, this remark open to a wide range of analogies.

For instance the Lotka's maximum power principle could give advices about the main target. It says, in fact, that the survival of a species in an ecosystem is related to its own ability in maximizing the internal flow keeping the balance conditions of the ecosystem resources.

Furthermore, the ecological concept of development gives interesting suggestion towards the strategy to be adopted. It is, indeed, useful to understand how an organism maximize the internal flow: minimizing outputs, minimizing wastes and so the entropy of the system.

Going back to the consumption categories, and, in particular to dwelling, this strategy could be interpreted as follows:

a) Maximizing renewable local input considering an equal use of natural global services.

b) Minimizing general entropy of the system.

c) Readmitting the output flows as input resources inside the same category or between different consumption categories.

4. APPLICATION

ELaR (Ecodynamic Land Register)

The application of the study is meant as an integration among the tools mentioned above, on a common structure based on the land register (ELaR is the acronym for Ecodynamic Land Register).

The tool will be applied in a mountain area in the central Italy, inside the Gran Sasso ad Laga Mountains National Park, characterized by a strong depopulation trend since the second half of the last century. This phenomenon has generated a wide network of abandoned villages.

Such a peculiar situation has given birth to the proposal to create new sustainable services for tourism.

The application target consists in the possibility to evaluate and support the different proposal of settlement renovation, according to their eco-consistent features, so to evaluate how they affect the lifestyle of the single user (tourist or local inhabitant) . At this state of the research the consumption categories taken into consideration are feeding and dwelling, the main drawing categories according to the ecological footprint assessment.

ELaR gives the possibility to check design proposals from different point of view, concerning the services supplied by the building and their general impacts on natural context.

The use of energy system diagram, supported by computational tools, allows to quantify the different flows activated by the single building inside the land parcel.

In this way the information about the building, in terms of flows activated during its entire life-cycle, can be related to the local natural environment, so to check, through the use of a GIS, the interaction level between the building and the local free available resources.

The land parcel establishes a link among different elements:
- the building, represented as a set of input and output flow;
- the local natural resources with the different climatic, biological factors, etc;
- the number of persons who lives inside the parcel.

In this way it will be possible to use ELAR as a design tool able to activate strategies on different scale.

At very local scale, inside the land parcel where the building stands, consumptions could be minimized using renewable local resources, such as sun, rain and wind, already present in the input-output database.

At a local scale it is possible to check which circuits of material and energy are completely contained inside the analysed area, as biomass supply for heating, or organic local growing for feeding, etc.

At the global scale participation to green house effect can be measured together with other LCA related impact factors, as well as consumption of global resources through the use of synthetic indicators like the ecological footprint and emergy.

Furthermore the representation through input and output flows related to a land parcels enable an easy dialogue among different discipline. In relation to the activity housed in the parcel an architect will be involved in the case of dwelling, an agronomist if is a matter of farming, or in other cases an environmental engineer or a landscape ecologist.

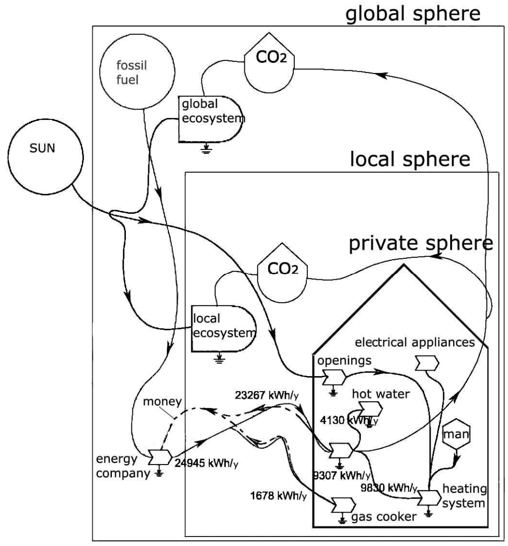


Figure 4: First of a series of images, that show a comparison between dynamics activated by two different kind of building proposal for the same area.

The first is representative of the local contemporary building practice (average practice) and the second is characterized by more eco-consistent features (eco-consistent practice). Above, an energy system diagram of the dynamics activated by the fuel consumption per person in the first case (average practice).

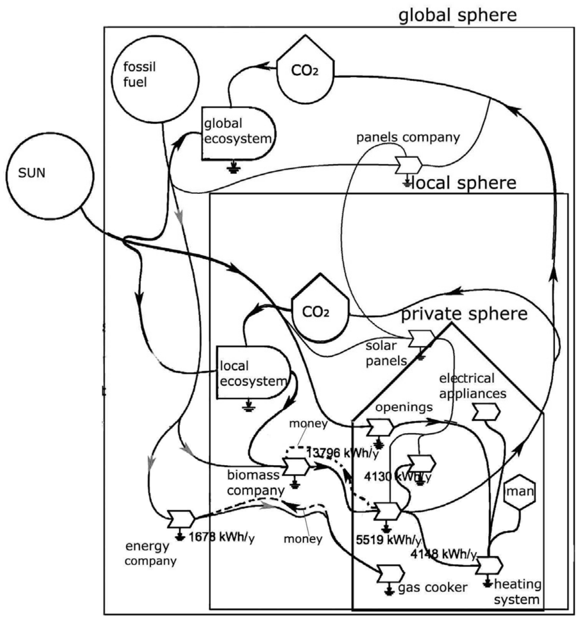


Figure 5: Energy system diagram of the dynamics activated by the fuel consumption per person in the second case (eco-consistent practice).

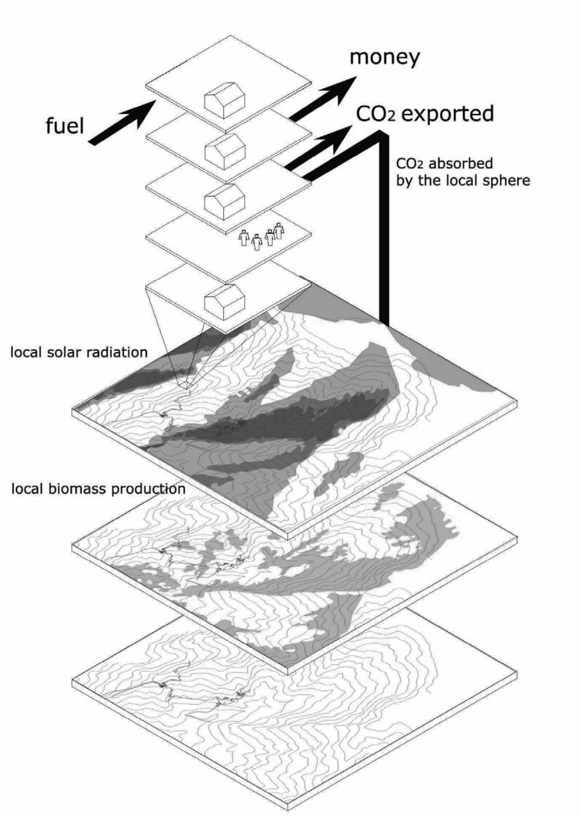


Figure 6: Dynamics activated by the fuel consumption in the first case (average practice) in relation to the local context.

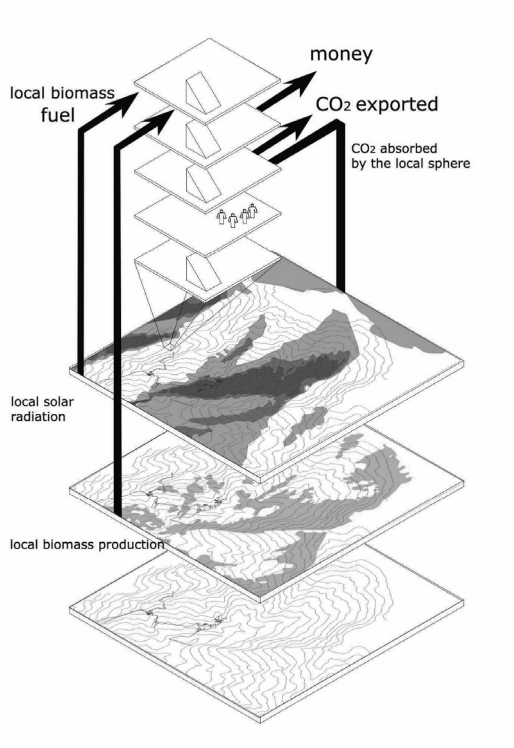


Figure 7: Dynamics activated by the fuel consumption in the second case (ecoconsistent practice) in relation to the local context.

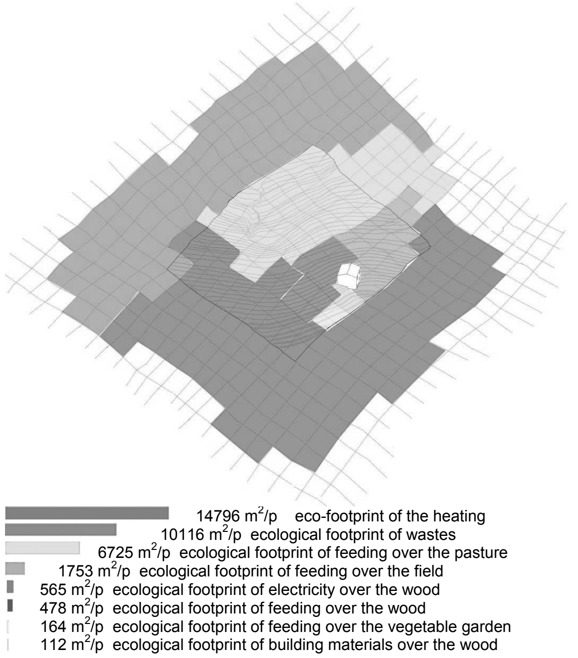


Figure 8: Local ecological footprint per person of the main flows activated inside the parcel in the average building practice . The carrying capacity of the local sphere is of 115 persons. Above the same quantities on a ten meters module grid.

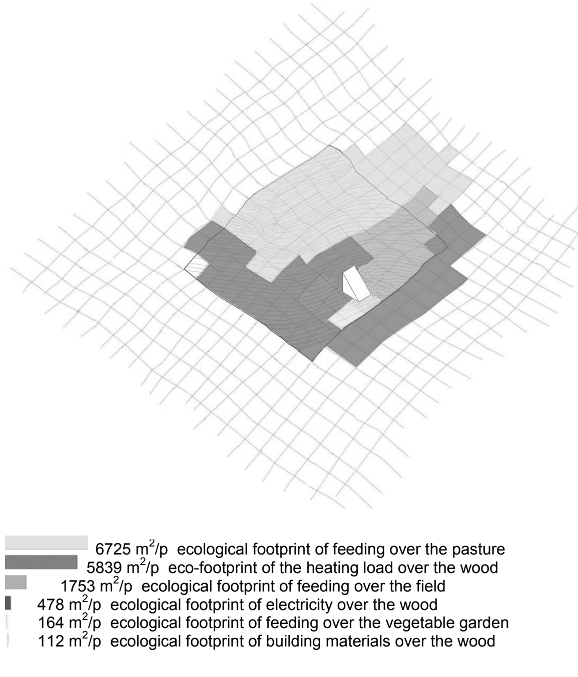


Figure 9: Local ecological footprint per person of the main flows activated inside the parcel in the eco-consistent practice. The carrying capacity of the local sphere is of 267 persons. Above the same quantities on a ten meters module grid.

All the activated dynamics, through the use of the common tool, can be involved in a general calculation of internal balance of the specific area.

The access through a GIS to this kind of information enable to check ecological balances on local scale and to assess the potential autarchy level of a specific area, so as the amount of local resources, imported and exported ones (money included) directly involved by that lifestyle.

The tool enable to access the set of connections activated by the cultural material inside the parcel, and in the same time allows to check the relations set with the other parcels in terms of land needed to absorb wastes and regenerate resources.

For instance, in the case of a residential parcel, it activates input and output flows related to dwelling and feeding.

By an eco-dynamic point of view, that land portion has specific requirement in term of demand and offer, it will involve other land parcel with the specific task to absorb wastes and regenerate resources in different amounts and locations according to the consumer choices.

The positions of the involved parcels enables to assess the imported and exported flows in relation to a specific area.

In this way checking the general development conditions of the settlement will become possible, quantifying the single inhabitant use of natural services.

Such evaluation of sustainability allows to define action priorities inside the main consumption categories, so to orient design choices toward the reduction of the amount of services supplied by the local environment and, in the same time the maximization of the carrying capacity of it.

Essential conditions to reconcile environmental and economic sustainability.

REFERENCES

[1] H. E. Daly, Oltre la crescita, l'economia della sviluppo sostenibile, Edizioni di Comunità, Torino 2001.

[2] E. Tiezzi, N. Marchettini, Che cos'è lo sviluppo sostenibile? Le basi scientifiche della sostenibilità e i guasti del pensiero unico, Donzelli, Roma, 1999.

[3] N. Chambers, C. Simmons, M. Wackernagel, Manuale delle impronte Ecologiche, Edizioni Ambiente, Milano 2002.

[4] H.T. Odum, Environmental Accounting, Emergy and Environmental Decision Making, John Wiley & Sons, 1996.

[5] Baldo G.L., Analisi del ciclo di vita LCA. Materiali, prodotti, processi, Edizioni Ambiente, Milano 2005.