PASSIVE DESIGNED BUILDINGS FOR ACTIVE CITIZENS BECAME SCHOOLS OF SUSTAINABILITY: A PROPOSAL FOR SUSTAINABLE ARCHITECTURE

J. Vives-Rego, PhD.[1], E.Uson, PhD. and J.Ll. Fumadó, PhD.[2]

1. INTRODUCTION

Sustainability has been defined as the need to preserve existing natural resources so that the earth is able to continue to provide these resources for future generations. Put more simply, a sustainable system is one that survives or persists (Costanza and Patten, 1995). In order to ensure the sustainability of architectural and building activity, it is essential that work in this field is conducted in accordance with the canons of basic ecology and, in addition, that its members seek to address certain cultural and relational characteristics that typify the way we live today.

Architecture as a discipline combines technology and art; however, with the advent of "sustainable architecture" additional concepts from the fields of ecology, sociology, and philosophy have been incorporated. Yet, the fundamental problem is that the meanings of both the classical and the new concepts remain ambiguous, their significance shifting with our cultural evolution. Hence, the traditional Vitruvian values of architecture (beauty, structure and utility) are no longer so obvious, especially when we are required to think in terms of sustainability. Although the question as to why architecture matters has been answered in a variety of ways (Glaeser, 2011), it is our contention that in the 21st century architecture will matter more than ever, because by 2050 most of the world's population will be concentrated in cities. As a result, the sustainability of dwellings and cities has acquired undeniable importance.

Two interacting forces influence all populations. One is the Malthusian dynamic of exponential growth until environmental limits are reached (Figure 1). The second is the Darwinian dynamics of innovation and adaptation that circumvent these limits through biological or cultural evolution. Nekola et al., in 2013 reported that the specific manifestation of these two forces in our current society provide the context that establishes how humans may develop sustainable relationships within our finite planet (Figure 2). Consequently, a permanent and indefinite growth is impossible due to the physical and biological imperatives of our finite world.

Biologists and architects and constructors usually inhabit different worlds. The latter innovate, deploy, and apply their techno-science based designs; the first,

1. Corresponding author. Biology Faculty, Barcelona University, Avda. Diagonal, 643, 08028 Barcelona. Spain. E-mail:jvives@ub.edu; phone: 34934021486
2. ETSAB, Polytechnic University of Catalonia, Avda. Diagonal, 649, 08028 Barcelona, Spain.

study the finite nature, propose hypotheses, and gather their evidence. And, to date, there is little to suggest that copying nature purports any advantages to architects, primarily because fully autonomous buildings or towns have yet to be built. According to the described Malthusian-Darwinian dynamic, the two critical questions that we seek to address in this paper are: i) What is the essence of a sustainable dwelling? and ii) What principles should be adhered to in making a dwelling sustainable? In other words, this study aims to elucidate the essence of sustainability in green building design implementation.

KEYWORDS
social innovation, schools of sustainability, Jevons Paradox, occupant behavior, ecological thinking in architecture

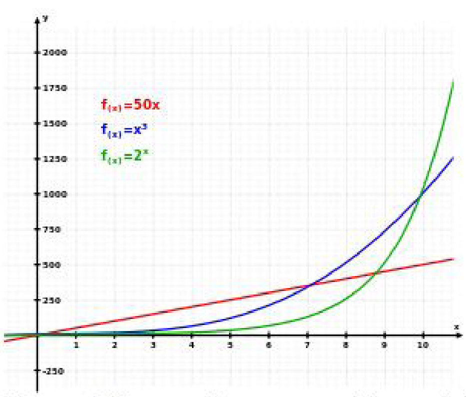
FIGURE 1: The Malthusian dynamic of exponential growth. Source: Wikipedia.

Malthusian models have the following form:

$$P(t) = P_0 e^{rt}$$

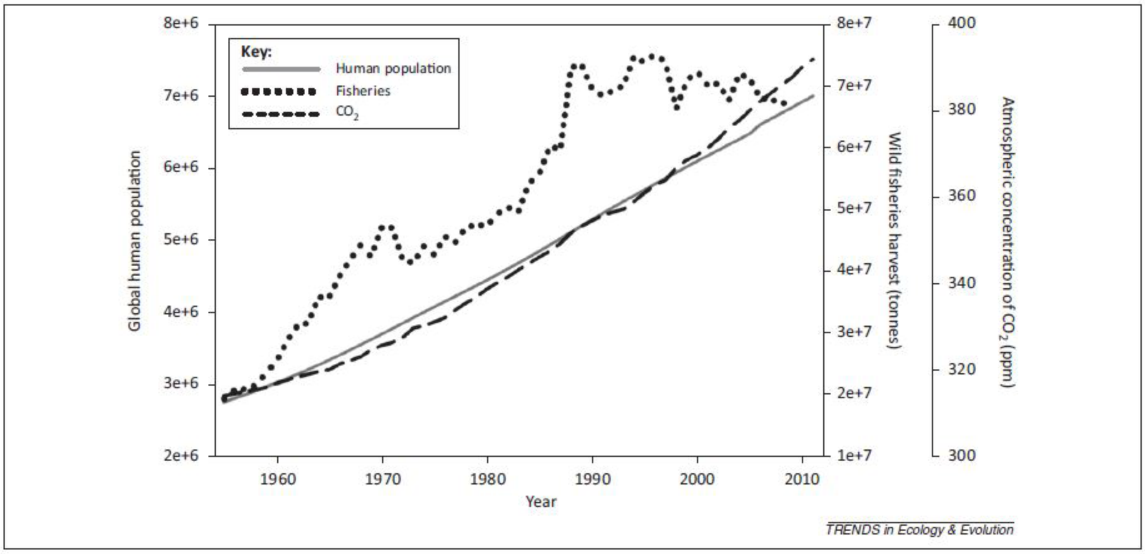
where

- $P_0 = P(0)$ is the initial population size,
- r = the population growth rate, sometimes called Malthusian parameter,
- t = time.



The graph illustrates how exponential growth (green) surpasses both linear (red) and cubic (blue) growth.
Exponential growth
Linear growth
Cubic growth

FIGURE 2: The trajectories of atmospheric CO2 and wild fisheries harvest in relation to global population since 1955. Source: Nekola et al. 2013.



2. THEORETICAL FRAMEWORK

2.1. Architecture and ecology

Salingaros (2004), among others, argues that with the exception of certain abstract ideas from living systems, ecology is not sufficiently present in modern architecture. However, a proposal that is currently gaining support in sustainable architecture is that technology should be as passive as possible and, as a counterpart to this, a building's residents need to be actively involved in its use and management, especially with regard to its energy, water, and waste systems.

Ecology is related to living systems and their relations with each other and the physical media. A living system is an integrated whole, the properties of which are determined by the relations established between its individual parts. Thus, while each part reflects the whole, the whole is always different from the mere sum of its parts. In a non-living system (in this case, in a building), the components together form the whole by means of a hierarchical structure of construction, each part of the system having its own function.

The main objective of our proposal lies within the field of social innovation, that is, what we seek to create is a community of citizens (or "schools") that can share data and decision-making tasks in a smart, innovative way, improving the quality of life of their urban community and, thus, ensuring a sustainable future. In our proposal, sustainability is learnt and acquired through practice rather than theory. The main argument underpinning our conception of sustainable buildings as "schools of sustainability" is that sustainability is more of a cultural problem than a techno-scientific or political option (Wang, 2003; Vives-Rego, 2008; Ehrlich and Ehrlich, 2013).

2.2. The Jevons paradox in architecture

A common goal when seeking to enhance sustainability is to increase the efficiency of specific practices. However, such increases in efficiency may lead to the phenomenon known as

FIGURE 3: An example of the Jevons paradox: Domestic Appliances. Source: Jevons Paradox Illustrated. Plugged-In Age Feeds a Hunger for Electricity by Jad Mouawad and Kate Galbraith. Published in the New York Times: September 19, 2009.

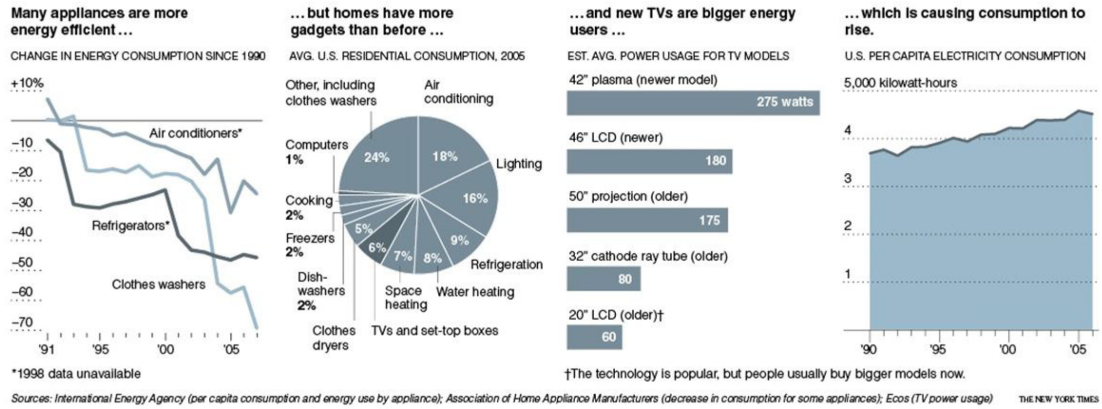


FIGURE 4: An example of the Jevons paradox: Hybrid Car. Source: http://greenimalist.com/2011/04/the-jevons-paradox/

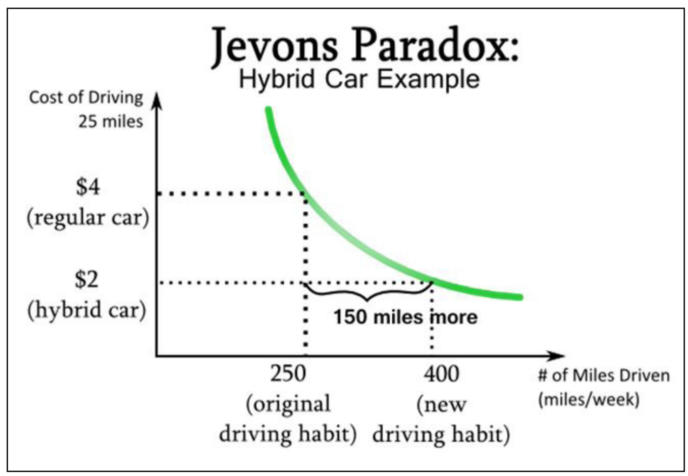


FIGURE 5: Internal view of the Brussels Environmental Headquarters (Belgium), by CEPEZED Architects. Source: http://swisspacer.com. An example of the Jevons paradox: Large Passive House Building (Space Heating Energy Demand ≤ 15 kWh/m2) fully covered with glass that has a U value of 0,8 W/m2K (0,14 Btu/hr-ft2-ºF), which means a huge budget due to the amount of glass.

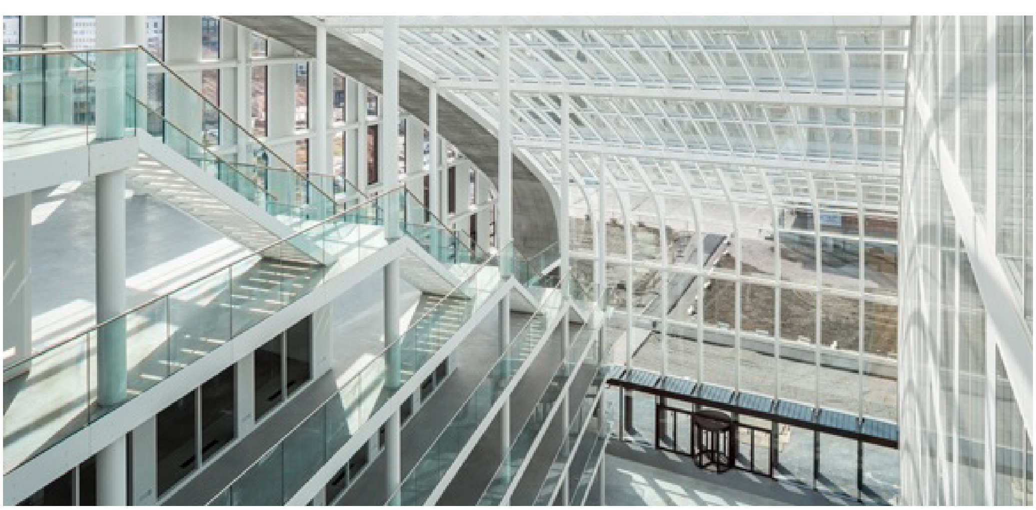


FIGURE 6: External view of the Brussels Environmental Headquarters (Belgium), by CEPEZED Architects. Source: http://pro-realestate.be.

the Jevons paradox, which occurs when improvements in efficiency to a system or process result in an increase (as opposed to a reduction) in its use. The primary cause of the Jevons paradox is the fact that technology makes access to energy, water, food or any other specific resource cheaper and easier. Our proposal incorporates the notion that "green" technologies on their own are insufficient to ensure sustainability. Rather, they must be deployed in concert with the systematic use of practices and theories of environmental sustainability, as has been reported previously, for instance, in archival practices (Wolfe, 2012).

Thus, it is found that energy consumption continues to rise, despite continuing efficiency improvements that allow the energy required per any given action to be reduced. The Jevons paradox may manifest itself in many different forms, for example: i) owing to improvements in refrigerator efficiency, consumers are able to afford more and larger refrigerators (Figure 3); ii) due to improvements in vehicle efficiency, car owners are able to drive more miles per year (Figure 4); and iii) thanks to improvements in window performance, and insulation techniques, homeowners can afford to build larger houses (Figure 5). Other manifestations include the homeowner that sells his/her old 'leaky' house and moves into a new home with higher, more advanced standards and thanks to the efficiency improvements saves 30% or more energy and water. However, if, thanks to these savings, the homeowner decides to fly abroad or to buy a second residence in the countryside or by the sea, all these sustainable gains are lost. Indeed, the savings resulting from improvements in energy or water efficiency, or simply the savings made from limiting the consumption of meat in one's diet, may, for instance, permit consumers to take more vacations, resulting in an even higher consumption of energy and other resources (Figure 6).

The Jevons paradox suggests, therefore, that people need to make a conscious choice to reduce their resource consumption in order to become more sustainable. Obvious examples include taking shorter, colder showers, using public transport, drinking tap water as opposed to bottled water, and eating less meat. By contrast, the Kuznets view of the issue is that a future marked by technological innovation and a shift to a service-and-information economy will reduce our resource consumption to such a degree that we will become sustainable without having to require people to sacrifice those things they enjoy. However, there is no evidence to back up such claims and, moreover, they rest on the assumption that Jevons showed to be false: improving efficiency is not enough.

On this point, it is perhaps revealing to note that traditional communities that have a low environmental impact and live in harmony with nature are not particularly efficient. Yet, the future of our planet is not being threatened by traditional rural communities with their old-fashioned methods of making a living, but rather by industrial economies where efficiencies are highest.

2.3. A "crisis room"

According to a forecast issued by the Intergovernmental Panel on Climate Change (IPCC), the long-term weather is likely to be "warmer, wetter and wilder". In short, we can expect more extreme weather. From the perspective of ecological architecture, this means identifying alternative approaches. Rostvik (2013), for example, presents an innovative proposal for the building of a "crisis room" that is able to withstand, and protect its occupants against, extremes of heat and cold, as well as extreme winds and extremes of intense precipitation. To achieve these goals, the crisis room would have to be compact, sited somewhere within the outer building skin (a room-within-a-room), insulated against extreme weather conditions, structurally strong, with access to the open air to ensure natural ventilation on days of extreme heat and, in the last resort, to provide an escape route.

If each dwelling was equipped with a small crisis room, then rather than having to turn the whole building into a thermos, the process of insulation could be limited to one small space. This room would have to be energy autonomous, satisfying basic energy needs from available renewable energy sources, and adapted so as to protect its occupants against both extremes of the weather scale. As Rostvik (2013) stresses, by so doing, great benefits accrue: namely, the rest of the building can be constructed to far lower insulation standards, employing less material than are required by current regulations.

In addition, we believe that a crisis room would make it clear to the building's occupants that there is a simple, efficient way to save energy. Moreover, the dual function of such spaces – crisis room and a room for daily use – does not entail any additional costs. As a matter of fact, compact design challenges of this type have always appealed to innovative architects. All in all, the proposal should result in considerable savings being made especially if the rest of the envelope is insulated with fewer layers of less resource demanding insulation.

3. OUR PROPOSAL

Our proposal is that the design of sustainable dwellings should be undertaken with the aim of creating "schools of sustainability" that permanently indicate to their occupants and visitors (them being either relatives, friends, tourists, suppliers, manufactures, public managers, etc.) the amount of resources being consumed and the amount of waste being generated. As such, energy consumption registers need to indicate renewable and non-renewable fractions; water consumption registers need to indicate reused and recycled fractions; and, waste management registers need to indicate the total production of all waste types together with the percentages that are reused and recycled. The clear and permanent display of these data should ensure that the building's occupants have, at all times, a realistic view of the consequences of their life style in terms of its sustainability. If the sustainable building is equipped with a "crisis room" as a central element of its design, the occupants would learn to regulate their energy consumption in accordance with a building management protocol that avoids the Jevons effect.

The sustainable buildings designed to become "schools of sustainability" should adhere to the following principles (Figure 7): i) the full function of the building and the behaviour of its users should be based on long-term thinking; ii) access to information about the ecological status of the building, including water and energy consumption registers, should be readily available; iii) the community of residents should be closely involved in the management of the building, while their relatives, friends and visitors should be able to understand and learn from the sustainability of the community; iv) all domestic and leisure activities associated with the dwelling and its surrounding environment should be enhanced; and v) daily commuting should be reduced and facilitated by community means. In the same way that the design of a school can contribute to the quality of environmental learning (Gislason, 2010), the design

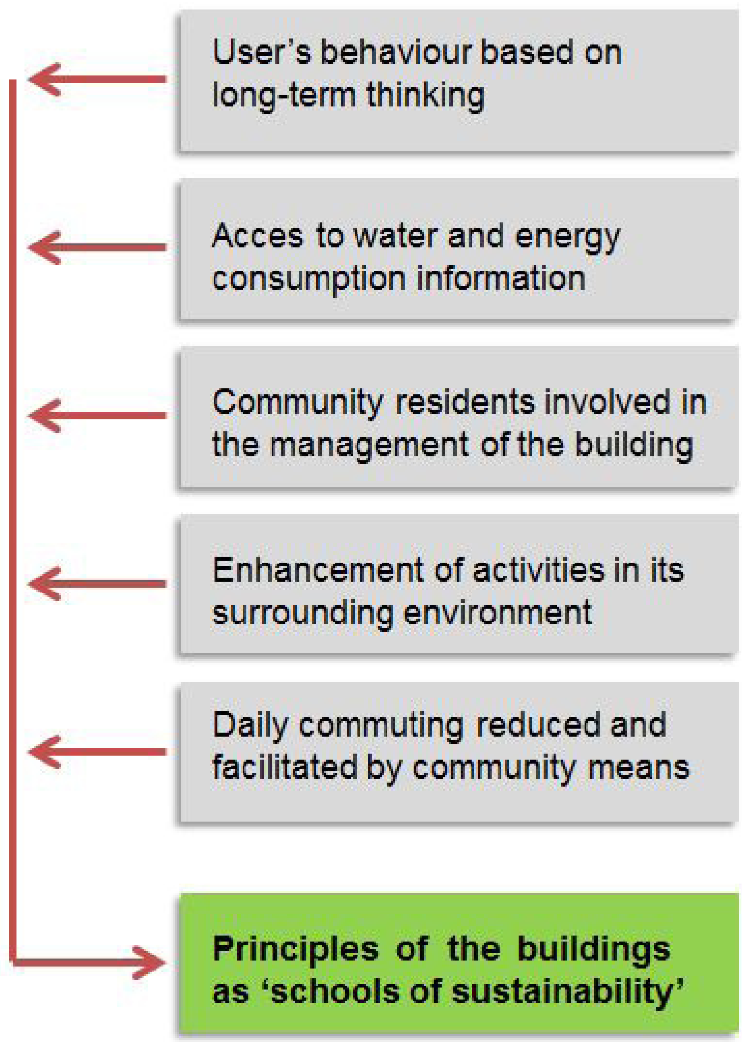
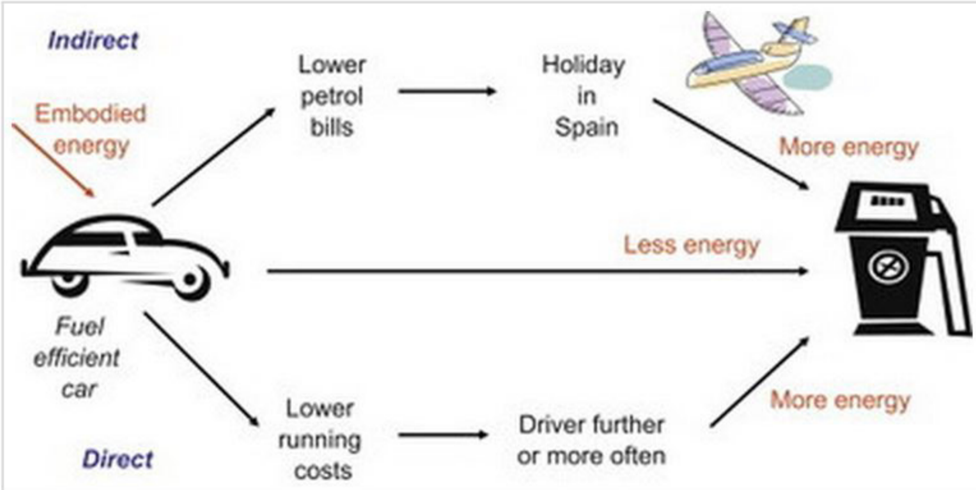


FIGURE 7: Diagram of the principles of the schools of sustainability. Source: the autors.

FIGURE 8: An example of the Jevons paradox: Homeowner Behaviour. Source: Sorrell, Steve. "Jevons' Paradox revisited: The evidence for backfire from improved energy efficiency." Energy Policy. Volume 37. Issue 4. April 2009. Pages 1456-1469.



of the dwelling should promote sustainability practices and guide the occupants' behaviour, otherwise probably neglected (Figure 8).

Our "school of sustainability" needs to be housed in a sustainable building founded on i) passive design; ii) efficient resource monitoring and control; and iii) the sustainable behaviour of the occupants, all deployed in the context of the three principles of ecological theory that define the organisation of a living system: **fluctuations**, **stratification**, and **interdependence**. The application of these principles to a sustainable building project and to the occupants' behaviour highlights the need to bear in mind a number of circumstances.

Fluctuation. Living ecosystems are not static and likewise the number of occupants in a building, their respective ages and their activities fluctuate over time as does the occupants' interaction with that building. Thus, as the number of occupants rises, they are likely to consume more resources, to generate more waste, and to subject the installations to more wear and tear. These impacts also vary according to the age of the occupants (for example, whether they include children, the middle-aged or the elderly) and the season of the year (winter, summer or holiday periods). Clearly, occupants that spend most of the day out of the building consume fewer in-place resources and generate less waste than their counterparts who spend most, if not all, of their time in the building. Ecosystems (including buildings and their occupants) fluctuate as they adapt to shifting internal and external conditions by changing their populations and rebalancing their organisation. Likewise the various component parts of an ecological building are designed to change according to such factors as the level and characteristics of occupancy and the weather conditions. Adapting a building to its environment also connects its residents with the natural processes of the urban realm. Thus, as mentioned above, living systems are not static; they are constantly having to adapt to changing internal and external conditions. Seen in relation to the first principle, that of the system's fluctuations, architecture needs to learn from living systems by focusing on the way in which a system maintains its stability while still allowing change and adaptation to occur.

Stratification. Living systems are structured hierarchically and are made up of different levels that interact with one another. Likewise, in a building, a stratification of activities takes place establishing a hierarchic steady-state in the use of the services that the dwelling provides. In practice, these levels are organized in a way that encourages optimal interaction between the different elements (for example, plants are dependent on sunlight and rain, while herbivores are dependent on these plants). Each part of the system has a role in ensuring that the ecosystem functions properly. As the building forms an environment with interdependent architectural parts, its components should allow its users to interact with them in multiple ways.

The building program is organized in line with the model of ecological stratification – compare, for example, forest stratification where each level is dependent on all of the other levels for its structural integrity, nutrients and food sources, habitat protection, and population growth and survival. A more practical example for our purposes might be illustrated by a building designed to provide food services, in which users gradually move up the various levels of the building to satisfy their food demands. Here, each level is interconnected visually and programmatically. Thus, the market occupies the building's ground floor and is the floor on which consumers enter the building, buy their goods, and where they can exit the building. Foods are prepared as close as possible to the market and so occupy the cooking school on the second floor. The prepared dishes can then be obtained from the self-service cafes or served in the restaurants on the third floor. From this floor, the patrons can look down on the cooking school and the market below, tracing the paths and watching the processes that their food must undergo before it can be consumed. The cooking students and teaching staff could be housed on the building's top floor.

The stratification of a living system, as we have seen, refers to its hierarchical structure: the various levels that interact with one another. In relation to the principle of stratification, we need to enquire as to how a building's design can emerge from the interaction between its properties and its different levels. We need to determine how the design shifts from an "imposition of order into an emergence of order". This leads us logically to the identification of the third principle in the formation of living systems, the nature of the interactions between the parts: the principle of **interdependence**. To fulfil the ecological goals of the community that inhabits the dwelling, there must be interdependence between individuals, the community, and the building's installations.

The principles of fluctuations, stratification, and interdependence indicate that the structure of a living system must be in constant change as its various levels interact with each other to create higher and higher levels of organization; yet, even when the system is in balance it continues to fluctuate so as to adapt to outside influences. In architectural terms, therefore, once a building has been constructed as a complex system, it will be perceived and conceived differently according to its context and to the people that interact with it. A building that is able to change constantly in relation to the natural and cultural processes that interact with it is a building that is being constantly created and recreated not by a single designer but by an infinite number of forces and users that come into contact with it.

We can now raise the question as to how an understanding of these three ecological principles might change the way in which we perceive and design our buildings. The principle of fluctuations suggests that buildings should be designed and perceived as places in which different cultural and natural processes interact. The building should reflect the processes that take place on site, and the more it allows the processes to be experienced as processes rather than as a representation of processes, the more it will succeed in connecting people to the reality of the site. The principle of stratification suggests that the building's organization should emerge out of the interactions between its different properties and levels. This kind of organization allows complexity to be managed in a coherent manner. The principle of interdependence suggests that the relations between the building's properties are reciprocal. The 'observer' (designer and user) as well as the site are inherent properties in the building. The interdependence between the properties is ongoing throughout the life of the building.

4. DISCUSSION, THE LESSONS TO BE LEARNT, AND CONCLUSIONS

If the Jevons paradox is accepted, sustainable architecture needs to rely on passive technology, but the occupants' behaviour is no less of a crucial element. An efficient connection between these two elements can be achieved through the establishment of a good visible monitoring system that indicates to the inhabitants at all times the balance or imbalance present in their resource consumption and which keeps them constantly aware of the consequences of their behaviour. In other words, by being "pupils" in a school of sustainability, citizens will find it easier to become sustainable. The incorporation of a Rostvik-style "crisis room" in each dwelling is a way of teaching the occupants, via their day-to-day experience, what a sustainable behaviour is or what it is not. Once a community of residents is aware that they function in accordance with the ecological principles of fluctuations, stratification, and interdependence, they will be better prepared to assume the values and attitudes needed to be sustainable. As such, a dwelling should be seen as a living organism that intelligently exchanges and stores essential resources (such as its energy) and which makes an optimal use of its waste flows. Buildings need to be seen as dynamic holistic systems, in which many factors influence a range of different impact categories, and which require complex evaluative tools that can take into account the complex relationship between energy, internal comfort, and environmental impacts.

Clearly, the role adopted by the citizen lies at the heart of our proposal. According to Onyx et al. (2012), the attitudes of active citizenship are apparently contradictory. Thus, on the one hand, they paint a picture of an active, engaged citizen, proactive and willing to work for a better world and, on the other, of a citizen that avoids active oppositional engagement in the political process. In other words, a citizen that prefers to work collaboratively with government and to work at the local rather than at the national level. Moreover, this citizen prefers to focus on concrete issues and interpersonal relations rather than on taking political action aimed at wider policy change. This citizen is, to our mind, the ideal resident to take up occupancy in our proposed dwelling, i.e. to live in a "school of sustainability."

Much of ecological design lies in the identification and revival of common sense. We seek to highlight the values of the vernacular architecture that remain applicable today as well as the traditional behaviour of occupants that is characterised by austerity in their consumption of resources. A good example in the houses of the Mediterranean is provided by their persianas (a type of roller shutter) that generate flows of cool air to provide relief against the summer heat. Recently, a new development of the traditional Mediterranean shutter, known as "persiana de Barcelona" (www.persiana-barcelona.com), has been successfully commercialised. Similarly, the "siesta" taken during the hottest hours of the day and leaving most professional and social activities for the morning and evening is a type of behaviour that should be considered afresh and imitated.

Ecological thinking in architecture takes up this idea of continuous transformation of form and applies it to construction design – seeing architectural forms in interaction with each other and with the environment rather than as separate, static objects. Ecology offers a radical path to overhaul the conceptual frameworks and methods of modern architecture, although it has often been peripheral to the principal concerns of architectural theory, design and construction. An ecological understanding of nature is important because architecture has so often situated and understood itself through its relationship with nature.

The question regarding the impact of ecological thought on contemporary architecture has been addressed by Chojecka (2013), who identifies four basic conclusions. First, the ecological conception of nature challenges established ideas about forms, form-making strategies, and engineering efficiency that are based on assumptions about nature. Second, an ecological conception of nature affects architecture by challenging the separation of things into natural and artificial categories. Third, an ecological conception of nature in architecture results in architecture being seen as an extension of nature. Fourth, and finally, Chojecka underlines an effect that results from culture being understood as an extension of nature and concerns the approaches that should be incorporated in architectural design.

According to Pedersen (2012), among others, there are two basic messages to transmit to architects as well as to the managers and occupants of buildings: i) the built environment should contribute more than it consumes while ii) remediating past and current environmental damage. Development of this kind (referred to as regenerative design) is based on mimicking ecosystem services, which become integrated within the built environment. The approach has highlighted a number of benefits, as well as obstacles that are best analysed and assessed within our proposed schools of sustainability, since here an ongoing analysis of the ecological services provided is possible.

The building of the future will not only be a dwelling but also a school of sustainability in which everybody can see and understand how dependent we are on nature and its resources. This understanding of our dependency on natural resources on a day-to-day basis will transform conventional consumers into more conscious, responsible citizens who will have as one of their primary aims a sustainable future.

According to the Global Footprint Network, (http://www.footprintnetwork.org/en/index.php/newsletter/det/new_release_national_footprint_accounts_2014), its recently published data show that the average demands of high-income countries on nature dropped sharply with the onset of the global financial crisis in 2008. In 2010, the per capita ecological footprint started to grow again only in a few high-income countries as governments began spending billions of dollars to stimulate their economies. This data seems to confirm the current view that, in general, consumption is linked to income. In this context, mention should be made of the ongoing debate that seeks to analyse the extent to which higher taxes on resources can help reduce consumption as a way of offsetting the Jevons paradox. We share the opinion of those experts from all sectors that consider that the solution to our global sustainability crisis will also require a movement towards voluntary simplicity supported by new ethics and educational values.

The importance of creating social capital in sustainable architecture is crucial. Social capital (a sociology concept) is the expected collective benefit derived from the preferential treatment and cooperation between individuals and groups. Although different social sciences emphasize different aspects of social capital, they tend to share the core idea "that social networks have value". Just as a screwdriver (physical capital) or a university education (cultural capital or human capital) can increase productivity (both individual and collective), so do social contacts affect the productivity of individuals and groups. Sustainable architecture (in particular when following the principles of a school of sustainability) is a powerful way to create social capital since it facilitates and improves the sustainable social network and the cooperation between individuals.

REFERENCES

Costanza, R. & B.C. Patten. (1995). Defining and predicting sustainability. Ecological Economics 15, 193-196.

Chojecka, N.K. (2013). Ecological thought in contemporary architecture: the impact of an ecological conception of nature. Master in architecture. School of Architecture, University of Technology, Sydney, Australia. URI: http://hdl.handle.net/10453/23557

Ehrlich, P.R. & A.H. Ehrlich. (2013). Can a collapse of global civilization be avoided? Proc. R. Soc. B. 280, 20122845.

Gislason, N. (2010). Architectural design and the learning environment: A framework for school design research. Learning Environment Research 13(2), 127-145.

Glaeser, E. (2011). Triumph of the city. The Penguin Press, New York, USA and P. Goldberger. 2009. Why architecture matters. Yale, USA.

Nekola, J. C., C.D. Allen, J. H. Brown, J.R. Burger, A.D. Davidson, T.S. Fristoe, M. J. Hamilton, S.T. Hammond, A. Kodric-Brown, N. Mercado-Silva & J.G. Okie. (2013). The Malthusian Darwinian dynamic and the trajectory of civilization. Trends in Ecology & Evolution 28, 127-130.

Onyx, J., S. Kenny & K. Brown. (2012). Active Citizenship: An Empirical Investigation. Social Policy and Society 11, 55-66.

Pedersen Zari, M. (2012). Ecosystem services analysis for the design of regenerative built environments. Building Research & Information 40, 54-64.

Rostvik, H.N. (2013) Does research results have an impact? Climate change and building insulation. Advances in Building Energy Research, 7, 1–19.

Salingaros, N. (2004). Anti-architecture and deconstruction. UMBAU-Verlag, Solingen, Germany.

Vives-Rego, J., S. Caschetto, J. Faraudo & D. Prior. 2008. Management options for the increasing demand of energy and water: is the problem soluble in technosciences only? AMBIO 37, 134-136.

Wang, W. (2003). Sustainability is a cultural problem. Harvard Design Magazine 18, 1-3

Wolf, M. (2012). Beyond "green buildings:" exploring the effects of Jevons' Paradox on the sustainability of archival practices. Archival Sciences 12, 35-50.