PROCEEDINGS

28TH INTERNATIONAL PLEA CONFERENCE ON SUSTAINABLE ARCHITECTURE + URBAN DESIGN

OPPORTUNITIES, LIMITS & NEEDS
TOWARDS AN ENVIRONMENTALLY RESPONSIBLE ARCHITECTURE

7 - 9 NOVEMBER 2012

organized by:
PLEA 2012 Local Organizing Committee

edited by:
Juan Reiser
Cecilia Jiménez
Susana Biondi Antúnez de Mayolo

PLEA 2012 LIMA PERU

in collaboration with:
PLEA International

PLEA

sponsored by:
Centro de Investigación de la arquitectura y la ciudad
Pontificia Universidad Católica del Perú

CENTRO DE INVESTIGACIÓN DE LA ARQUITECTURA Y LA CIUDAD

PUCP

PLEA 2012 PROCEEDINGS

Edited by:
Juan Reiser, Cecilia Jiménez and Susana Biondi Antúnez de Mayolo

Hosted and organized by:
CENTRO DE INVESTIGACION DE LA ARQUITECTURA Y LA CIUDAD

In collaboration with:
PLEA International

Sponsored by:

Centro de Investigación de la arquitectura y la ciudad

Pontificia Universidad Católica del Perú

Av. Universitaria 1801
Lima 32 - Peru
www.pucp.edu.pe

Design:
Gonzalo Del Castillo, Susana Biondi Antúnez de Mayolo and Braulio Miki.
Cover design:
INFINITO

november 2012

http://arch.plea.org/plea2012proceedings

Legal deposit: Biblioteca Nacional del Perú N° 2012-16250

ISBN: 978-612-4057-89-2

9 786124 057892

Swisswoodhouse, an innovative concept for sustainable modular housing

REY Emmanuel[1, 2]

[1]Bauart Architectes et Urbanistes SA, Bern / Neuchâtel / Zurich, Switzerland
[2]Laboratory of Architecture and Sustainable Technologies (LAST),
Ecole polytechnique fédérale de Lausanne (EPFL), Lausanne, Switzerland

ABSTRACT: The Swisswoodhouse concept was born out of the crossover of several lines of thought concerning issues of urban densification, flexibility of housing, adaptability of buildings and sustainable construction. The approach aims to provide an alternative to the suburban individual houses, via the integrated design of a sustainable building of 3-4 storeys high. This size is sufficient to contribute to the urban densification process, whilst to avoid the danger of anonymity present in large housing complexes. The building's concept is based on the aggregation of 22 m^2 wooden prefab modules. An entire catalogue of options has been devised, allowing for multiple combinations of apartments. On a technical level, the concept devotes a great deal of attention to energy issues and thus complies with the requirements in the vision of the 2000-watt society. This high energy efficiency is achieved thanks to high compactness; an efficient building shell; the specific use of renewable energy (solar/thermal, solar panels, geothermal) and materials whose life cycle assessment is environmentally friendly (e.g. use of native wood).
Keywords: sustainable architecture, modular housing, integrated design, 2000-watt society

1. INTRODUCTION

1.1. Residential location

In the wake of several years of research on sustainability issues, many negative consequences arising out of dispersed urbanisation have been observed. Beyond the most visible aspects in terms of consuming land and sprawling across the landscape, the spatial dispersal of urbanized sites tends to increase environmental impacts, exacerbate socio-cultural inequalities and increases infrastructural costs.

A strong relationship between low density and energy consumption due to mobility has notably been analyzed in the works of P. Newman and J. Kenworthy on automobile dependence, comparing different types of cities in the world [1]. The same tendencies were observed in other research regarding different urban conurbations in Europe such as, for example, Ile-de-France or Milan [2, 3]. Recent works on urban regions in Switzerland like Neuchâtel for example, also demonstrate that a low density tends to generate more automobile use and thereby more energy consumption for mobility [4].

Awareness of these multiple consequences has contributed to the development of territorial strategies that are able to reverse the trend. Based on a better coordination between urbanization and mobility, this approach to territorial development can be seen especially in the promotion of increased population density close to public transport, enabling a reduction in automobile dependence, by promoting the untapped potential within developed sites, and by creating or strengthening the urban polarities that are both high density and mixed [5].

The development of innovative concepts of sustainable housing is part of this process to increase urban population density. As K. Wiliams observed, an intensification of land use is a necessary condition to reach more sustainability, but it is certainly not sufficient [6]. The strategies have indeed to integrate other qualitative parameters, notably potential of inter-generational mixing and promotion of high quality of life for users. In real terms, in European countries, the challenge is to develop alternatives to the individual suburban home, which enable a reconciliation of density, housing that appeals to a variety of users and attractive surroundings at the core of the urban environment.

1.2. Evolution of housing needs

Alongside the issues concerning housing location, the concept of sustainable development involves taking a stance for a vision of a long-term equilibrium, in particular between the built environment and socio-cultural needs. In the same line, the recent demographic trends observed in Switzerland (and also in many European countries) highlight two phenomena to be considered for new housing, i.e. changing family structure and the emergence of a society that is living longer.

Throughout the last decades, the traditional family structure has been strongly challenged. Whereas a little more than half of the Swiss population lives in a family home with children, this type of household now only represents one third of all private households. Among these households with children, the share of one-parent families is increasing steadily. Households without children are the most common type of household and they are continuing to increase in number, although not as fast. These households are made up equally of young people who have left the family home and older people, owing to the fact that life expectancy has increased. These changes have a major impact on the size of households [7].

The size of households is steadily decreasing : fewer and fewer cross-generation families are living under the same roof and ever more people are living alone. This means that, according to the statistical projections, the share of households with more than two people in 2030 will not exceed 24%. So, the majority of households will comprise either a single person (41%) or a couple (35%) [8].

These changes call into question the normal practices in terms of the design and construction of housing. In fact, given the lifespan of a housing accommodation in Switzerland, a building constructed today will be faced with changing demands in the decades to come. In response to these changing socio-cultural needs, it seems relevant to plan for spatial configurations and constructive methods that offer greater adaptability in housing use.

1.3. Toward the 2000-watt society

Another fundamental issue is the balanced management of resources, in particular the creation of optimal buildings considering the local climatic conditions, based on energy efficiency design and priority use of renewable energy. For Switzerland, this challenge resonates with the vision of the 2'000-watt society developed by the domain of the Swiss Federal Institutes of Technology. On a global scale, individual human consumption is currently in the order of 17'500 kWh annually, which corresponds to a constant power of 2'000 watts. In Switzerland, current consumption corresponds to around 6'300 watts per person, across all forms of energy. The idea of a 2'000-watt society is to bring these needs down to 3'500 watts by 2050, and to 2'000 watts by 2150. Of these 2'000 watts, only 25% must be sourced from non-renewable energy sources, in order to also drastically reduce the volume of CO_2 emissions [9].

If the research carried out has stressed that such a vision is feasible in theory, considering that many potential energy savings have been identified, it has also underlined the need for continuing and convergent changes in every area of human activity : housing, mobility, food, consumption and infrastructure. In this context, housing (room heating, hot water, and lighting) and mobility account for the lion's share of total energy consumption in Switzerland today. Building sector accounts for 40 % to 50 % of total energy consumption, while mobility accounts for nearly 30 %. Given the right political and economic framework and the deployment of the best of the available technologies, researches have shown that it would be altogether feasible to increase energy efficiency in these important areas by a factor of five [10]. Designing sustainable housing is part of this view and involves the creative and rigorous consideration of these issues.

2. INTEGRATION OF SUSTAINABILITY ISSUES INTO THE ARCHITECTURAL CONCEPT

2.1. Density, modularity and flexibility

To confront the issues linked to sustainable territorial development, the objective is to create a new type of collective building, one that reconciles the needs for density and some of those features found in the private household, such as ways of personalizing space, the potential to change ownership of one's housing and the size of outdoor areas.

At the building level, the concept rests on the observation of potential for increasing population density at the core of the existing building and close to the nexus of public transport in the localities constituting the suburbs of built up areas. This analysis has led to a reflection on the optimal size for such a building. The approach aims to provide an alternative to the suburban private residence, via a design optimized in terms of a sustainable building 3-4 storey high, presented a sufficient size to contribute to the densification process, whilst avoiding the danger of anonymity present in high-rise developments.

Figure 1: Functional module measuring 22m² adapting to the different functionalities of the accommodation

The building's concept is based on the aggregation of 22m² wooden prefab modules. Each module can be deployed in a wide variety of types and uses: kitchen with or without cubby hole; bedroom with or without en-suite; two modules combined for a master bedroom with en-suite and in-built wardrobe; bedroom with loggia balcony; living room or patio (Fig. 1). An entire catalogue of options has been devised, allowing for multiple combinations of bed-sitting rooms, apartments with 2-4 rooms and penthouses across about 10 modules (Fig. 2).

Figure 2: Map of a typical floor resulting from the aggregation of various modules in three apartments with a respective surface of 50 m^2, 118 m^2 and 141 m^2.

The surface of the module therefore constitutes a unit of reference which, singly or in combination, enables the multiple needs of very different users to be met, favoring the social and intergenerational mix (young singletons, working childless couples, large families or the elderly) [11].

2.2. Integrated design and prefabrication

Via its standardized basic grid, Swisswoodhouse offers great functional flexibility not only in the planning phase, but also during the use phase and in the event of subsequent changes in needs. The real degree of this adaptability is however dependent on the construction methods of the building, especially the precise dissociation of the load bearing (fixed) and non-load bearing (adaptable) elements.

The architectural and building design has therefore included this aspect by developing a clear and simple principal, allowing a construction in prefabricated parts, mostly made from wood. The foundation stones of the building rest, on one hand, on the facades, made from prefabricated wooden elements and, on the other hand, on a central part, made from concrete prefab parts that also include all the vertical technical distributions (water, heating, electricity and ducts for controlled air exchange). The foundation stones are designed in a hybrid manner, including concrete parts in the wooden prefabricated pieces, which can meet the high acoustic requirements (Fig. 3).

The technical installations follow the same logic and are designed so as to be able to be integrated into the construction elements and be mostly prefabricated. Secondary elements complete the catalogue of modules that make up the apartments, notably a system of balconies that meets the objective of offering several kinds of outdoor space. The latter are designed in such a way that they can be fixed to the façade subsequently. Concerning the stairwells and lifts, these are also part of the surface area corresponding to one of the modules.

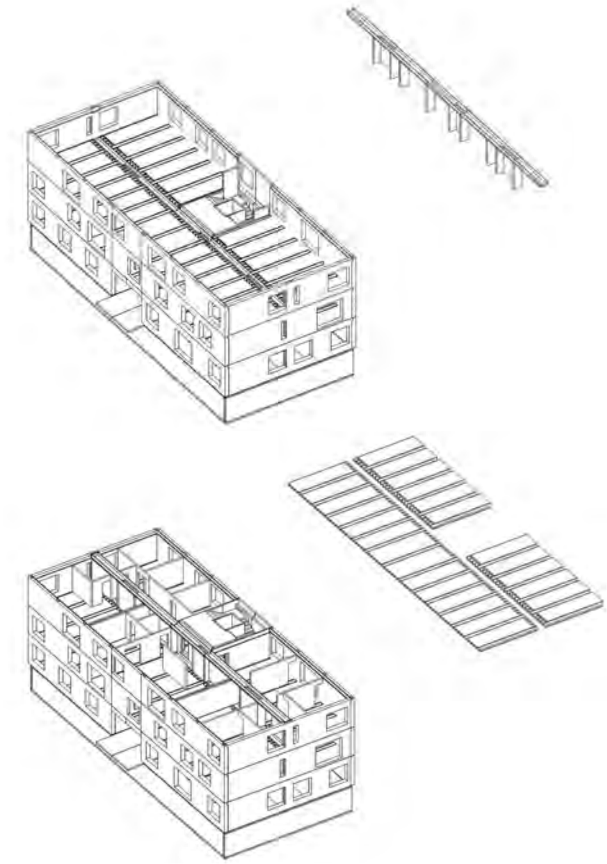

Figure 3: Axonometric projection of the construction principles of the building.

The abundant use of wood here offers several benefits to meet the high targets in terms of sustainability. On the one hand, wood resolves certain construction details in the simplest way, by removing some of the thermal bridges in the joins between vertical and horizontal elements. Furthermore, regarding embedded energy, this approach allows recycling of an abundant local resource that is currently underexploited in Switzerland. The result is environmental impacts with a downward trend, as much in terms of non-renewable primary energy (NRE) as in equivalent CO_2 or SO_2 emissions.

Several variants have been studied regarding the architectural expression of the building, in order to develop a register that is compatible with the modular design of the apartment, and the adaptability of the building, as well as the option to have installations in different contexts (Fig. 5 and Fig. 6).

Figure 5 : Visualization of a Swisswoodhouse building implemented on an urban site.

Figure 6 : Visualization of three Swisswoodhouse buildings generating a new urban polarity.

3. RESULTS

3.1 Energy efficiency and ecological construction

To meet the targets of the 2'000-watt society, specific studies have allowed for the share of energy specifically available for housing to be estimated (materials, heating, electricity and inferred mobility) at 840 watts per person over a total of 2'000 watts per person. By considering an average value of 60 m^2 per person, the resulting maximum limit value of primary energy is 122.2 KWh/m^2a [12].

Regarding the materials, the concept is based around the abundant use of wood, care taken in the construction methods and a choice of materials that meets the requirements of Minergie ECO label, which corresponds to a high standard of ecological construction in Switzerland. Given the chosen building principles, the primary energy limit value for materials can be met. The results obtained here tend to coincide with those obtained elsewhere for other buildings that were part of other research [14, 15].

Table 1. Limit value for primary and final energy for a home that is compatible with the performance requirements inherent in the 2'000-watt society. The conversion factors between primary and final energy are taken from Ecoinvent 2.01 [13].

	Primary energy [KWh/m^2a]	**Conversion factor**	**Final energy [KWh/m^2a]**
Materials	**27.8**		
Use	**66.6**		**30.5**
Heat	12.5	Heat Pump = 1.9	6.6
Ventilation	6.9	CH Electricity = 3.0	2.3
Domestic hot water	11.1	60% Solar = 0.9	6.0
		40% Heat Pump = 0.8	3.6
Lighting and appliances	36.1	CH Electricity = 3.0	12.0
Mobility	**27.8**		
Total	**122.2**		

Regarding the energy for heating, domestic water and electricity, given a hypothesis based on the use of a heat pump and solar thermal collectors, the resulting limit value for final energy is equivalent to 30.5 KWh/m^2a (Table 1). However, we must mention that when considering the ambient heat, the conversion factor between primary and final energy can vary by a factor of 2 where there is a heat pump, and so can have a significant influence on the final energy to be considered. The same applies if the electricity consumed is not from the normal network, but includes a greater share of renewable energy (e.g. photovoltaic).

Taking these considerations into account, additional analysis has stressed that, as a minimum, the building must meet the requirements inherent in the Minergie P label regarding indoor climate and domestic hot water to be considered compatible with the 2'000-watt society targets, meeting the current highest Swiss energy standard [16].

The research has shown that these energy use requirements are achievable for the Swisswoodhouse building through the simultaneous integration of the following main measures (Fig. 7) : high performance thermal outer shell with better air-tightness (Table 2), consideration of direction in the percentage of opening of the facades, removable exterior solar protection (with regulator), highly efficient technical installations (heat generation, electrical appliances), efficient lighting (fluorescent lighting or energy-efficient bulbs) attention paid to the lift and the standby of electrical installations, and use of renewable energy to meet all needs (heat pump linked to geothermal probes, solar thermal collectors for domestic hot water and photovoltaic installation).

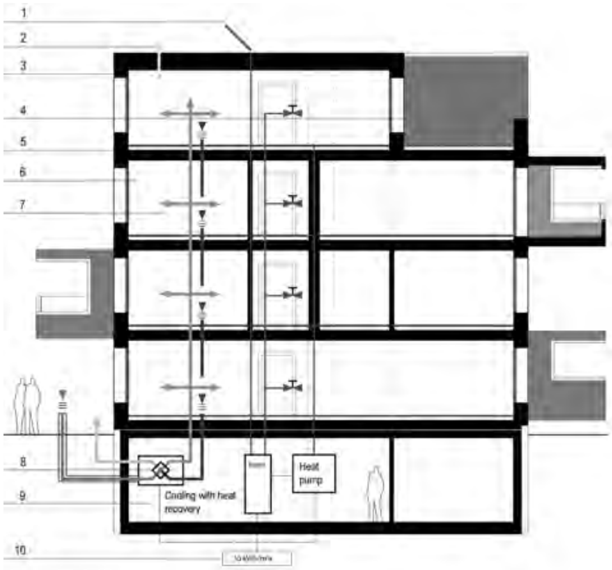

Figure 7 : Measures of Swisswoodhouse's energy efficiency (1= solar captors, 2= low need of heating energy, 3= high air tightness, 4 = high performance thermal outer shell, 5= A / A+ / A++ household appliances, 6= heat-insulating glass, 7= heat distribution, 8= controlled residential ventilation, 9= heating requirements, 10= final energy consumption).

Table 2. Values obtained for a Swisswoodhouse building with an Energy Reference Area (ERA) of 1'562 m2 installed in the region of Luzern (Switzerland).

Parameters	Values
Basis of calculations	
ERA	1 562 m^2
View factor	1.20
Suppl. for thermal bridges	10 %
Air exchange	0.7/h (standard)
Indoor temperature	20 ºC
Shade	Horizon 24º
Climate data	Lucerne
Glazed part	10-40% (average 23%)
Outer shell values	
External facades	U = 0.10 W/m^{2}K
Ground floor foundation stone	U = 0.12 W/M^{2}K
Roof	U = 0.09 W/M^{2}K
Windows/glazing	U = 0.50 W/M^{2}K
Windows/frames	U = 1.10 W/M^{2}K
Heating needs	
Minergie-P limit value	15.3 KWh/m^{2}a
Swisswoodhouse value	14.9 KWh/m^{2}a

Regarding mobility, the calculations made show that compatibility with the values matching the 2'000-watt society can only be achieved by mostly using public transport and through active car pooling. Therefore, sites for building that are in close proximity to public transport stops (train, tram, underground, bus) must be favored. An estimated calculation has been made more particularly for a 2-person household living in an apartment with a 120 m^2 Energy Reference Area (ERA). The limit of 27.8 KWh/m^{2}a per person for inferred mobility means that 3'335 KWh/a can be consumed for their mobility, the same as an average daily distance of 15km in a eco-friendly car (100 km to 3 liters) or 23 km by train (Table 3) [12].

Table 3. Calculations relating to the mobility of a 2-person household living in an apartment with a 120 m^2 Energy Reference Area [12].

Transport	Km/y/flat	Km/y/pers	Km/day/pers
Car 100 km /10 lt	3,400	1,700	4.5
Car 100 km / 3 lt	11,200	5,600	15
Train	16,600	8,300	23
Airplane	3,700	1,850	5

3.2. Socio-cultural and economic parameters

With a view to a sustainable architecture, the research also analyzed socio-cultural and economic parameters. In this sense, a building that is adapted for processes of urban densification, which meets a high-energy standard and which offers constructive and ecological features is part of a long-term economic vision. The calculations carried out in common for different Swisswoodhouse configurations have shown that the gross return for such a building is less than 5%, or just under common practice.

However, the reflection in terms of investment must also consider the following additional parameters which play a role in the financial soundness of the operation but which are difficult to put a figure on :

- particularly short planning and building time, of around 4-6 months, which enables a reduction of related costs,
- optimal adaptation to needs and requirements of users thanks to enhanced flexibility,
- minimization of operating costs thanks to the building's high-energy efficiency,
- minimization of costs of adapting the apartments to new needs,
- anticipation of the change in framework conditions in terms of costs related to energy and the environment.

An analysis of Swisswoodhouse was also carried out using the ESI property assessment method developed by the Centre for Corporate Responsibility & Sustainability of the University of Zurich and incorporating elements relating to sustainability.

The assessment was carried out using the alpha version of the ESI-Tool and showed that the design allowed for a high level response to the various criteria being considered: flexibility and multi-use, energy & water independence, accessibility & mobility, health, safety and comfort (Fig. 8).

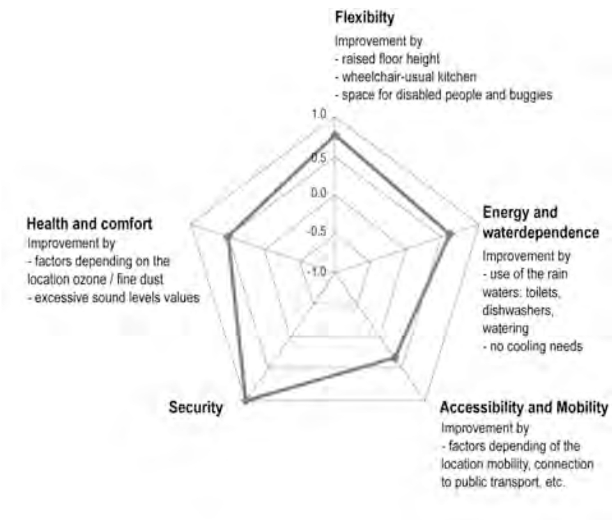

Figure 8 : Overall view of the assessment carried out using the ESI property assessment method.

4. CONCLUSION AND PROSPECTS

On the one hand, the research has allowed for the development of an innovative concept for modular housing and on the other hand, to demonstrate that the latter is compatible with the energy requirements inherent in the long term vision of a 2'000-watt society. With its characterizing simultaneous consideration of environmental, socio-cultural and economic criteria, Swisswoodhouse is clearly part of a perspective on sustainable architecture.

Following a research phase that gathered a wide cross-disciplinary team, the goal is now to proceed to the building phase of a first prototype building. The aim is to increase the density of a plot of land that is well served by public transport, and this first build will enable all of the parameters developed during research to be tested, and on site monitoring of the building's performance to be carried out.

Today, the prototype is ready to be built and, with a view to this, an application for a building permit has been lodged in a district located in the region of Luzern (Switzerland), where the plan is to increase the population density of a plot of land overlooking a waterway and which is well served by public transport. The planned configuration is a three-storey building with a penthouse, in total 16 accommodations of diverse types. This build will enable the research to continue and, during a prototype build, to check the values obtained by the calculations and simulation tools (monitoring).

ACKNOWLEDGEMENTS

Swisswoodhouse is an initiative begun by the architectural firm Bauart (W. Frei, S. Graf, P. C. Jakob, E. Rey, Y. Ringeisen, M. Ryter) and the construction firm Renggli AG in Sursee. This project involves numerous associated partners, in particular the engineering firm Reuss Engineering, Makiol + Wiederkehr and Pirmin Jung, as well as several research partners such as the IBB from the ETH in Zurich, the EMPA in Dübendorf, the BFH-AHB in Biel and the HEIG-VD in Yverdon-les-Bains. The research project has benefited from the financial support of the Swiss Federal Environment Office (BAFU), the Swiss Federal Energy Office (BFE) and the Commission for Technology and Innovation (KTI / CTI).

REFERENCES

1. Newman P., Kenworthy J., (1999). Sustainability and cities : overcoming automobile dependence. Washington, Island Press.
2. Fouchier V., (2005). "La densité urbaine dans le projet de territoire : quelle contribution au développement durable ?". Lausanne, Conference, 10th March 2005.
3. Camagni R. et al., (2002). "Forme urbaine et mobilité : les coûts collectifs des différents types d'extension urbaine dans l'agglomération milanaise". RERU, 1, p. 105-140.
4. Rérat P., (2005). "Etalement, fragmentation, mobilité : analyse des tendances de l'urbanisation dans la région de Neuchâtel". Urbia, 1, p. 41-60.
5. Rey E., (2011). "(Re)construire la ville autrement". Tracés, 17, p. 7-10.
6. Williams K., (2000). "Does intensifying cities make them more sustainable?" in Williams K. et al., Achieving sustainable urban form. London, Spon, p. 30-45.
7. OFS, (2008). Les familles en Suisse. Rapport statistique 2008. Neuchâtel : OFS.
8. OFS, (2009). Forum Ecoparc 2009. Quelques données de l'Office fédéral de la statistique. Neuchâtel, January 2009, p. 3.
9. Novatlantis, (2011). "The 2000 watt path. Reducing energy consumption and CO2 emissions to enhance our quality of life" in Smarter Living. Moving forward to a sustainable energy future with the 2000 Watt Society. Novatlantis : Villigen PSI, March 2011, p. 8-9.
10. Jochem E. et al., (2004). Steps towards a sustainable development. A White Book for R&D of Energy-Efficient-Technologies. Zurich : CEPE / ETH Zurich and Novatlantis.
11. Lüthi S., (2008). "Swisswoodhouse - von der Vision zum Projekt". Bau & Architektur, 6, p. 10-12.
12. SIA, (2008). "Valeurs cible A et valeur cible B" in Objectifs de performance énergétique SIA. Zurich : SIA, Documentation D 0216, p. 42-46.
13. Ecoinvent. [Online], Available : http://www.ecoinvent.ch [17 April 2012].
14. Kochenz M., Pfeiffer A. (2005). Potenzial Wohngebäude : Energie ung Gebäudetechnik für die 2000-Watt-Gesellschaft. Zürich : Faktor.
15. Rey E., De Herde A. (dir.), (2006). Régénération des friches urbaines et développement durable : vers une évaluation intégrée à la dynamique du projet. Louvain-la-Neuve : Université Catholique de Louvain, PhD Thesis.
16. Reuss Engineering et al. (2008). Swisswoodhouse. Grundlagen der 2000-Watt-Gesellschaft. Gisikon, Report WP 1, December 2008.
17. Meins E., Burkhard H.-P., (2009). ESI Immobilien-bewertung - Nachhaltigkeit inklusive. Zurich : University of Zurich, Center for Corporate Responsibility and Sustainability.