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# NEGENTROPY HOUSE : A SUSTAINABLE BUILDING DESIGNED THROUGH AN INTERDISCIPLINARY APPROACH

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## ABSTRACT

The interdisciplinary project "Negentropy House" aims to apply the well known principles of non-equilibrium thermodynamics (entropy growth control through the use of external energy flows) to the building construction sector. This self-regulation mechanism, observed within living organisms, is intended to be applied to the design, the construction and the operation of a new EPFL building (a guest house).

In order to achieve the practical implementation of these principles in the different building project phases, a list of "Sustainability Criteria" was established, together with associated target, threshold and veto qualitative and/or quantitative objectives: they make up a concrete and detailed specification for each building project phase.

An overview of the first results of this interdisciplinary project, including a presentation of these criteria together with some practical building aspects, is given in this paper.

## RESUME

Le projet interdisciplinaire "Negentropy House" a pour but de traduire certains principes de base de la théorie de la thermodynamique hors-équilibre (modération de la croissance de l'entropie interne par l'utilisation de flux extérieurs d'énergie) au domaine de la construction. Ce mécanisme d'auto-régulation, propre aux êtres vivants, sera ainsi appliqué à la conception, à la construction et à l'exploitation d'un nouveau bâtiment de l'EPFL (maison d'hôtes sur le site d'Ecublens).

Afin de mettre en œuvre ce principe dans le cadre des différentes phases de projétation du bâtiment, une liste de "critères de Développement Durable" a été établie, auxquels ont été associés des valeurs-cibles, limites et de veto : il constitue ainsi le cahier des charges du projet.

Les premiers résultats de ce projet interdisciplinaire, ainsi que les conséquences pratiques de ce dernier en ce qui concerne la réalisation de ce nouveau bâtiment, sont présentés dans cette communication.

## INTRODUCTION

The building sector with the related infrastructure (city networks, access roads, etc.) is responsible for half of the overall energy consumption in Switzerland (more than 800 PJ in 2000), corresponding to greenhouse gas emissions of more than 5 Tons-equivalent $CO_2$ per capita [KNS96]. In spite of the considerable efforts dedicated to energy conservation

measures within buildings since the seventies, the perspective of climate changes pleads today for a "Factor 4" further reduction of the current building specific energy consumption to achieve a sustainable development in this sector [Wei96].

A coherent approach to achieve this global challenge can be foreseen in the application to the building sector of the growth regulation mechanisms of the living organisms, which control their internal production of entropy (a physical measure of disorder) by an optimal use of external energy flows (e.g. solar radiation for plants, natural food for animals, etc.).

These well known principles of non-equilibrium thermodynamics [Odu83] are intended to be applied to the design, construction and operation of a new EPFL building (a guest house). The challenge was addressed within an interdisciplinary project (the"Negentropy House" project) [Neg01], which aims at the practical implementation of these principles in the different building planning phases. An overview of this project is given hereafter.

## METHODOLOGICAL APPROACH

In summer of the year 2000, an interdisciplinary project team was set up (cf. article front page), involving representatives of the following disciplines and fields of expertise (in brackets):

- building physics (renewable energies, bio-inspired technologies)
- civil engineering (management and logistics)
- environmental engineering (ecosystemic research)
- architecture (building design, sociology).

Included in a broader research programme (see Figure 1), which involves a novel approach for the building sector (ecosystemic modelling, bio-inspired technologies), the first phase of the "Negentropy House project" was initiated by addressing the conception of the new building.

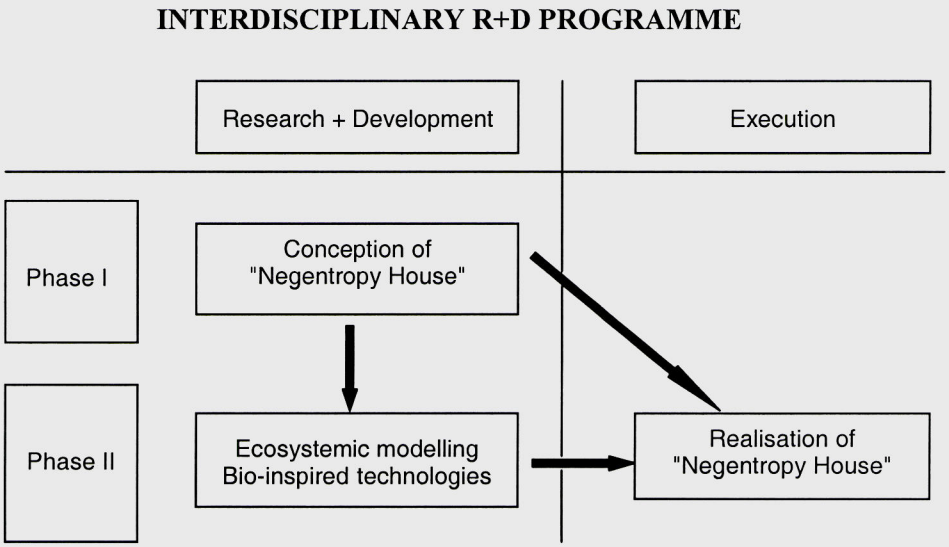


Figure 1: Structure of overall interdisciplinary R + D programme on sustainable buildings, including "Negentropy House" project

Within this first conceptual phase, a holistic approach was used to outline the principal building specifications according to the requirements of sustainable development. Following the definition of the Rio Conference en 1992, three different aspects of sustainability were considered (ecology, economy and sociology), in order to proceed to:

- a first analysis of the notion of intemporality in architecture, which is necessary to address a "sustainable architectural design" of buildings,
- the elaboration of "criteria of sustainability" for the design, construction and exploitation of the new building,
- the choice of the most appropriate site on the EPFL campus for the building implantation,
- the analysis of the operational constraints of the project, including both financial and social aspects.

All these considerations were developed and consigned within a common written document given by reference [Neg01]; they were followed by practical recommendations for the execution for the upcoming project phases.

Among those points, the elaboration of "criteria of sustainability" was certainly the prevailing action undertaken within the first project phase. It lead to the setting up of a list of such criteria, defined with corresponding target, threshold and veto values, which makes up the main body of the building specifications.

## ASSESSMENT OF "SUSTAINABILITY CRITERIA"

The list of "sustainability criteria" was established for practical reasons following a recent publication of the Swiss Society of Engineers and Architects (SIA) given by reference [SIA01]. According to this document, a list of generic criteria was used (cf. Figure 2), which was developed further for this specific building project.

| **Ecologie** | | | |
|---|---|---|---|
| **Matériaux** | **Energies** | **Sol / Paysage** | **Infrastructures** |
| Matériaux non polluants | Energie totale, y compris la construction | Surface / Sol | Transports |
| Ressources renouvelables | Energie d'exploitation | Paysage | Déchets ménagers |
| Déchets de construction | Possibilités d'optimaliser l'exploitation | Aménagement des alentours | Eau /eaux usées |
| Recyclage des matériaux | Recours aux énergies renouvelables | Gestion de l'eau | |
| Provenance / exploitation | | | |
| **Economie** | | | |
| **Substance du bâtiment** | **Coûts d'acquisition** | **Coûts d'exploitation et d'entretien** | **Flexibilité** |
| Substance construite | Prix du bâtiment | Coût total optimum | Conception de base du système constructif |
| Site | Prix du terrain | Coûts d'exploitation | Possibilités de changement d'affectation |
| Programme des locaux | Frais financiers | Coûts d'entretien | Interchangeabilité des éléments |
| Qualité d'équipement | Coûts externes | Coûts externes | |

| Societé | | | |
|---|---|---|---|
| **Bien être** | **Utilisation** | **Esthétique** | **Collectivité** |
| Sécurité | Fonctionnalité | Aménagements intérieurs | Offres dans le voisinage |
| Climat intérieur | Flexibilité, utilisation individualisée | Aménagements extérieurs | Espaces semi-publics |
| Lumière, bruit, vibrations, ondes électromagnétiques | Sphère privée | Espaces extérieurs | Espaces publics |
| Polluants, odeurs | | Impression de l'ensemble des aménagements | Coexistence |
| | | | Participation |

Figure 2: Generic sustainability criteria used to assess the specifications of the project

This development was carried out, starting from the different groups of generic criteria, represented by (3 x 4) blocks of Figure 2. Each generic criterion was than refined by specific subcriteria, to which some figures of merit were attached. Based on qualitative or quantitative appreciation methods, each figure was linked to specific values defining:

- a threshold value, which has to be overpassed by the corresponding subcriteria,
- a target value, which ideally should be reached,
- a veto value, which can in no way be accepted.

Figure 3 illustrates the specific subcriteria and figures, corresponding to the generic criteria "Bien-être" (Well-being), defined for sustainable development. Reference [Neg01] gives the complete list of criteria and figures established for the project. They make up detailed specifications for the building design, construction and operation, which will be used to support the design team during the upcoming phases of the project.

## OPERATIONAL ASPECTS

Several important constraints, linked to operational aspects of the project, had to be considered beside the "sustainability criteria". These different practical elements, presented in detail in reference [Neg01] and in favour of the project, can be summarised in the following way:

Market study

- About 75% of EPFL academic guests are single persons, staying in most cases less than one month at EPFL (more than 85% of the guests' sojourns are shorter than three months).
- A building of 30 rooms with a majority of single rooms could benefit from a high rate of occupation.
- No facility of this type exists in the surroundings of the EPFL campus, however hotel rooms must be considered as possible competitors for the guest house.

Business plan

- The costs calculation, based on current interest rates (4.5% for a mortgage) and a 40 year long amortisation period, shows reasonable construction costs (450 – 500 CHF/$m^3$ SIA).

**SOCIETE**

**1. Bien-être**

Le but premier du bâtiment est d'assurer un environnement intérieur agréable : les autres objectifs sont subordonnés à cette exigence. L'ensemble des règles ne pouvant pas être exhaustif, l'architecte doit avoir en permanence le souci du confort de l'occupant, cela dans la conception du bâtiment et aussi des installations techniques.

| | Valeur limite | Valeur cible | Veto | Références |
|---|---|---|---|---|
| **Sécurité** | | | | |
| Incendie : au moins les exigences de l'ECA | = ECA | = ECA | < ECA | ECA |
| Intempéries : possibilité de ventiler durant les intempéries | Sans risque de dégâts | | Probabilité de dégâts | |
| Effraction | Sécurisation des ouvrants | | Aucune sécurisation des ouvrants | |
| Modération du trafic sur le site (chicanes) | | Si possible | | |
| **Climat intérieur** | | | | |
| Confort thermique raisonnable (valeur de PPD moyenne) | PPD < 20% | PPD < 10% | PPD > 25% | SIA 180 |
| Masse thermique suffisante répartie : constante de temps du bâtiment | > 150 h | > 200 h | < 50 h | SIA 180 |
| Protections solaires efficaces | g < 0.20 | g < 0.15 | g > 0.35 | SIA 180 |
| **Eclairage, acoustique, ondes électromagnétiques** | | | | |
| Eclairage naturel suffisant (facteur de lumière du jour moyen) | D > 2.5% | D > 3% | D < 2% | |
| Isolation acoustique suffisante entre logements | R' > 55 dB | R'> 50 dB | R' < 50 dB | SIA 181 |
| Isolation acoustique suffisante vers l'extérieur | R' > 35 dB | R' > 40 dB | R'< 30 dB | SIA 181 |
| Niveau de bruit des installations | < 35 dB | < 30 dB | ➢ 40 dB | |
| Distribution électrique en étoile (absence de boucles) | oui | oui | | ORNI 99 |
| Système de distribution électrique principal loin des lits | oui | oui | | ORNI 99 |
| Mise à terre systématique des appareils | oui | oui | | ORNI 99 |
| **Polluants, odeurs** | | | | |
| Perméabilité à l'air de l'enveloppe, ouvertures de ventilation fermées | $V_{a4}$ < 1 m/h | $V_{a4}$ < 0.5 m/h | $V_{a4}$ > 2 m/h | SIA 180 |
| Ventilation adaptée en présence d'occupants | 30 m3/h pers. | 40 m3/h pers. | < 20 m3/h pers. | |
| Intensité maximale due à la présence de Radon | < 200 Bq/m3 | < 60 Bq/m3 | > 400 Bq/m3 | OFSP 96 |
| Teneur maximale en formaldéhyde | < 0.05 mg/m3 | < 0.03 mg/m3 | >0.15 mg/m3 | CAD 96 |
| Pourcentage d'insatisfaits de la qualité olfactive de l'air après 2 mois | < 20% | < 10% | > 50% | |
| Contrôle allergènes / acariens | | | | |
| filtration pollens (si ventilation naturelle : filtre électrostatique) | | oui | | |
| pas d'humidificateur installé | | oui | | |
| pas de moquette/ éviter "refuges" pour la poussière | | oui | | |
| Création de zones "non fumeurs" | Une seule "zone fumeurs" | Tout le bâtiment "non fumeurs" | Pas de règles | |

Figure 3: Specific subcriteria for the group of generic criteria "Bien-être", with corresponding figures of merit

- Monthly renting costs are apparently competitive for the market (1000 CHF/ month for a single room), when assuming a reasonable vacancy rate (lower than 20%).
- The construction costs per cubic meter unit and the mortgage rate are the most important elements of costs calculation, as shown by a sensitivity analysis (Pareto diagram).

Construction site

- Among three possible construction sites on the EPFL campus, the one chosen is partly built and allows re-using existing concrete slabs and wells.

This preliminary project phase was completed by establishing a list of innovative products and technical developments which could contribute to the achievement of the project goals. An overview of existing buildings, characterised by high energy performance and/or low environmental impacts, was carried out as well in order to define the final detailed objectives of the project.

## CONCLUSION

The interdisciplinary project "Negentropy House" aims to apply the self-regulated growth mechanisms of living organisms (entropy growth control) to the construction sector. As a first step, it is intended to apply these principles to the design, construction and operation of a new EPFL building (guest house).

The elaboration of a list of "Sustainability Criteria", defined specifically for this building, is certainly the most important outcome of the first project phase. These criteria, linked to corresponding figures of merits, will be used to define the specifications of the building for the upcoming phases of the project.

Accounting also for operational aspects, it is expected that the new building will take maximum benefit from natural energy and material fluxes (solar radiation, renewable materials, etc.), and contribute to achieve sustainable development in the field of construction.

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