

# LESO-PB

## **A Low Environmental Impact Anidolic Facade**

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# A LOW ENVIRONMENTAL IMPACT ANIDOLIC FACADE

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## ABSTRACT

The building of the Solar Energy Laboratory (LESO) was erected in 1981 on the campus of the Swiss Federal Institute of Technology of Lausanne, in order to allow "in situ" testing of experimental solar facades. In 1998, the building was the object of a significant restoration and a new southern facade was designed and built following the principles of sustainable development. This article describes the principles that guided this work, and presents the results obtained with regard to energy consumption, daylight and comfort.

## 1. INTRODUCTION

Built in 1981, the Solar Energy and Building Physics Laboratory (LESO-PB) of the Swiss Federal Institute of Technology of Lausanne, is a 3 levels building offering 9 physically independent units; each one being equipped with a heating system, an energy meter, an automatic system that measures air exchange between units and with the outside /CAR89/ and a data acquisition module. This equipment made it possible to measure simultaneously and under same climatic conditions up to 9 facade elements (surface 20.2 m<sup>2</sup>) and achieve the objectives defined for the building, which included:

- a) to allow in situ measurement and evaluation of solar and/or high insulating facades,
- b) show ways to use best daylight and passive gains in an office building,
- c) offer a working space to the staff of the laboratory.

From 1982 to 1995, 15 facade elements were analysed in terms of energy and comfort /LESO85, JLS87a, JLS87b, JBG88/. In 1997, it was decided to replace the whole set of elements with an unique and homogeneous facade, taking into account the requirements of sustainable development, namely:

- use of low environmental impact materials and techniques,
- drastic reduction of the use of non renewable energy,
- increase of daylight sufficiency and better use of natural and artificial lighting,
- improvement of the summer comfort using night cooling.

## 2. CONCEPT OF THE NEW FAÇADE AND TECHNICAL INSTALLATIONS

Considering the above listed requirements, studies have been made and the following elements have finally been selected as decisive principles for the new façade (Fig 1):

- a) Choice of wood as a renewable and low impact material.
- b) Selection of a building system that allows a high thermal insulation and an efficient protection against bad weather of the outdoor wood elements.
- c) Integration of anidolic devices /COU99/ to achieve a homogenised daylight distribution: reducing the daylight factor close to the window and increasing it in the rear part of the room.
- d) Design of openings that allow in summer efficient natural ventilation during the night with minimised risks of somebody breaking in or flooding.
- e) Choice of appropriate sunshades to control daylight and solar gains.

In its initial state, the LESO building was already characterised by an non renewable energy consumption (heat and electricity: 190 [MJ/m<sup>2</sup>]) four times lower than the average of comparable buildings. This value slightly increased due to extension of the computer fleet. Electric contributions cover about half of the heating requirements; therefore, improvements due to the new façade were mainly expected from reduction of artificial lighting needs and improvement of summer comfort.

In parallel, the luminaries of the whole building were replaced by recent, more effective models and the traditional electric installation was replaced by an EIB electrical bus system that gathers all



technical installations on a single wire. Each room is equipped with a set of sensors (presence, window opening, temperature and indoor lighting level), controls (heating, lighting and blinds) as well as switches for light, blinds and heating set point.

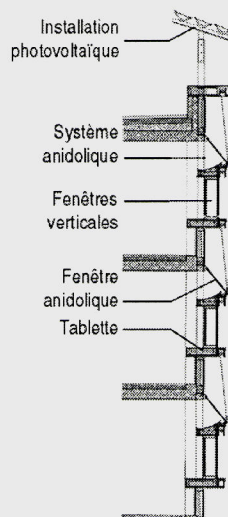
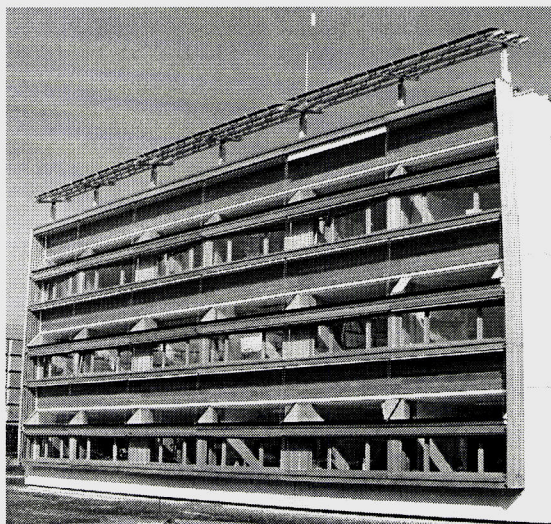


Figure 1

a) General view of the facade, which includes the inclined anidolic elements, the windows composed of a fixed central part and a turn-tilt casement window on each side as well as the wood backplate well protected against rain. On the top of the facade, a 3.2 kW grid-connected photovoltaic installation has been installed.

b) Cross section of the facade.

Currently, there is only a proportional integral regulation set on heating based on indoor temperature and a set point fixed by the user. But the final goal is to allow a PC to control all technical installations and set up a high-level regulation on heating, blinds, and artificial lighting in the whole building, as well as on night cooling through the control of two bus-connected velux windows on the roof. This system should allow a better energy and comfort management, while leaving to the occupant the possibility of adapting the lighting intensity and the heating set point or operating the blinds.

### 3. BUILDING PERFORMANCE ANALYSIS

#### 3.1. Energy assessment

Measurements were taken, from October 1999 to March 2001, in order to establish a detailed thermal assessment of the building. They were supplemented by numerical simulations.

##### 3.1.1. Natural and artificial lighting

The integration of anidolic elements to the southern facade and the replacement of the luminaries made it possible to appreciably reduce the artificial lighting requirements. Figure 2a) compares the daylight factor profiles related to traditional and anidolic frontage. In the back part of the room daylight sufficiency during working hours, passes from 10 to 38%. That is to say, an average savings in artificial lighting between 14 and 28%, depending on the place of work and the occupant behaviour.

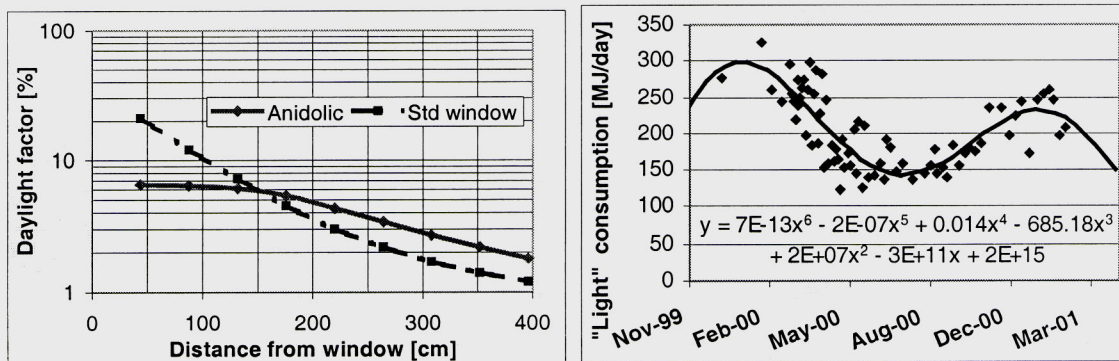


Figure 2 a) Daylight factor profile measured in a room equipped with the anidolic facade and in an equivalent room equipped with a traditional window. b) Evolution of "light" consumption of the building.

The building has two electric circuits: a "light" circuit (220V: the illumination and personal computers), and a "force" circuit (220/380V: heating and big devices). Figure 2b) shows the evolution



of the "light" consumption. The requirements in illumination are very low from June to August; thus, personal computers average consumption reaches 120 [MJ/day] or 1.8 [W/m<sup>2</sup>].

Considered period	Installed power [W/m <sup>2</sup> ]	Average power consumed [W/m <sup>2</sup> ]	
		in december	on the year
01.06.99 to 31.05.00	19.5	2.65	1.43
01.06.00 to 31.05.01	9.0	1.6	1.0

Table 3 Savings on the illumination resulting from the replacement of the luminaries.

Following the replacement of the luminaries, the requirements in illumination passed from 35.3 [GJ], for the period from 1.6.99 to 31.5.2000, to 24.7 [GJ] for the period from 1.6.2000 to 31.5.2001, that is to say an economy of 30%. Table 3 shows the evolution of installed (-50%) and called powers.

### 3.1.2. Requirements in heating

In southern and northern part of the building, heating requirements are, respectively, met by electric and water radiators. Figure 4a) shows the evolution of these two consumptions, respectively "force" and "heat". As heating is switched off in summer, the average consumption of the machines connected to the "force" current reaches 125 [MJ/day] or 1.85 [W/m<sup>2</sup>].

#### Energy signature

The energy signature is obtained by referring the total energy consumption of the building according to the outdoor temperature (Fig. 4b)). Two segments of line are thus obtained:

- Below 13°C (heating interlocking temperature), the right-hand side segment slope is proportional to thermal losses. Thus, specific thermal losses reach 0.72 [W/m<sup>2</sup>K].
- Above 13°C, called power lies between 4 and 6 [W/m<sup>2</sup>]; it corresponds to the needs:
  - of illumination (vary a lot with season): from 0.3 to 2.3 [W/m<sup>2</sup>]
  - of measuring computers and apparatus: 1.8 [W/m<sup>2</sup>]
  - of the server and machines: 1.85 [W/m<sup>2</sup>]

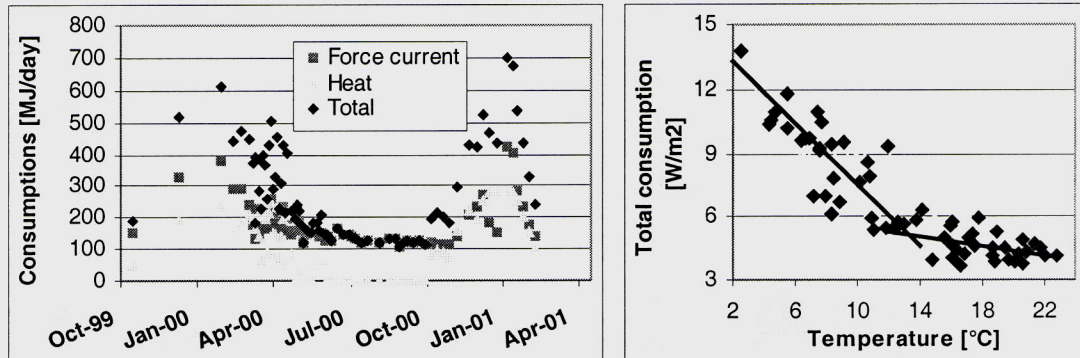


Figure 4 a) Evolution of "force" and "heat" consumptions of the building. b) Signature of the building over the period from October 1999 to March 2001.

#### Numerical modelling

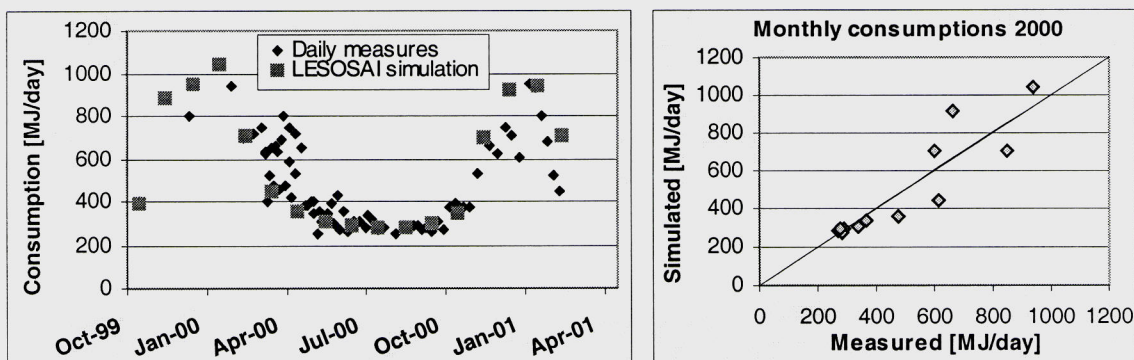


Figure 5 a) Comparison of weekly measured and calculated consumption. b) Monthly calculated consumption brought back to measured consumption.

To go deeper in the analysis a simulation of the building was conducted with the LESOSAI /LESOS/ software which is based on a stationary thermal model. Figure 5a) and Table 6 show a comparison between measured and calculated consumption; will figure 5b) shows that there is no marked tendency towards an over or an under evaluation of the measured values (average relative variation 13.7 %).

		Measures	Simulation	Units
Heating season	Specific thermal losses			
	Energy signature	0.72	xx	W/m <sup>2</sup> K
	Detailed assessment	xx	0.79	W/m <sup>2</sup> K
	Rough requirements in heat	xx	287	MJ/m <sup>2</sup>
	Useful gains			
	persons	xx	-6	MJ/m <sup>2</sup>
	lighting and devices	xx	-70	MJ/m <sup>2</sup>
	solar gains	xx	-136	MJ/m <sup>2</sup>
	<b>Net requirements in heat</b>	<b>76</b>	<b>75</b>	MJ/m <sup>2</sup>
Year	Other requirements and gains			
	Lighting	42	xx	MJ/m <sup>2</sup>
	Computers & machines	129.4	xx	MJ/m <sup>2</sup>
	Photovoltaic installation	-15.4	xx	MJ/m <sup>2</sup>
	<b>Total energy index</b>	<b>232</b>	<b>xx</b>	MJ/m <sup>2</sup>

Table 6 Principal elements of the energy assessment of the LESO.

Figure 7a) and 7b), respectively, presents the building thermal losses and useful gains distribution. Because of orientation and poor quality (double glazing and metallic frames), the “other windows” (46% of window surface) have a less favourable energy balance. Alone solar contributions through windows cover 47% of the requirements in heat for the building.

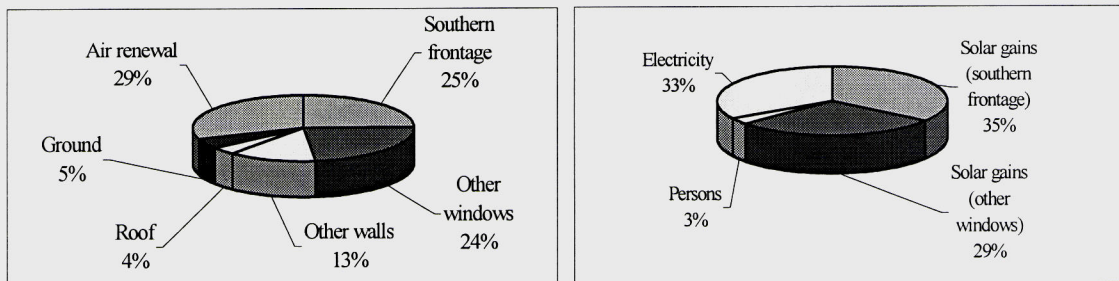


Figure 7 a) Distribution of the building thermal losses (Total: 226 [GJ/year] or 287 [MJ/m<sup>2</sup>year]. b) Distribution of useful heat gains for the building (Total: 166 [GJ/year] or 212 [MJ/m<sup>2</sup>year]).

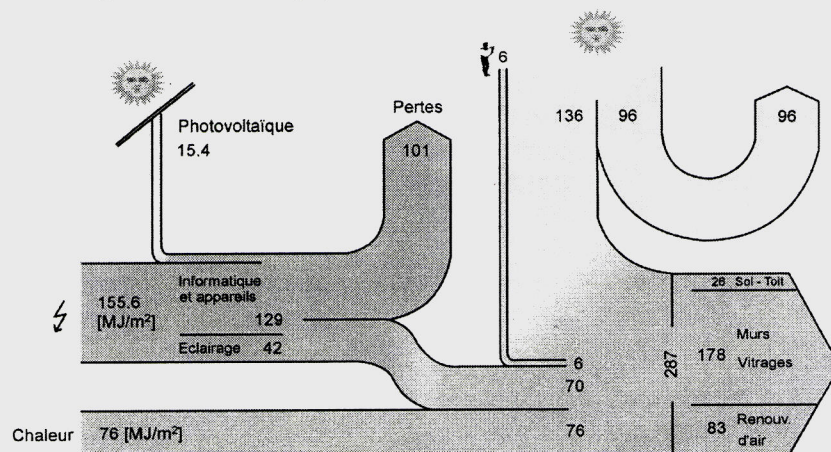


Figure 8 Diagram of Sankey for the whole building.

Lastly, figure 8 presents the diagram of Sankey of the whole building. The high consumption of data-processing equipment, measuring apparatus and machines leads to significant rejections beside heating period. A share of the solar contributions (41%) is also rejected, following the use of the blinds and window opening by the occupants.



### 3.1.3. Contributions of the photovoltaic installation

Of a peak power of 3.2 kW, the photovoltaic installation which dominates the southern frontage adds up a surface of 28.2 m<sup>2</sup> panels. The annual production, which completely consumed on the spot, added up 3315 kWh during year 2000, that is to say 1036 [kWh/kW<sub>p</sub>]. Figure 8 shows the daily and monthly current production. It will be noticed that the production of electricity during the season of heating (1<sup>st</sup> October to 30<sup>th</sup> April) accounts for 41% of annual production.

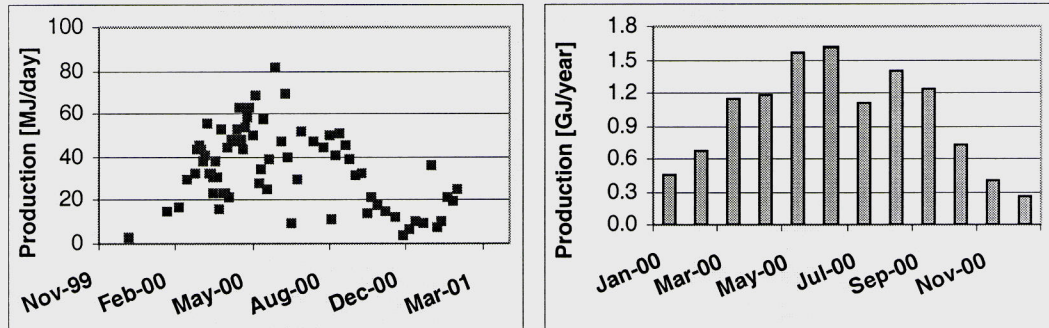


Figure 8 Daily a) and monthly b) evolution of the photovoltaic installation electric production.

### 3.1.4. Thermal comfort

The quality of the building's envelope insulation and of the new frontage glazing ensures a high thermal comfort during heating season. Consequently, the study of thermal comfort concentrates only over the summer period. During this season, interior climate depends a lot on the occupant management of solar protections and openings. The windows, with French frames, allow an effective night ventilation and the storage of this freshness thanks to the significant thermal mass of the building.

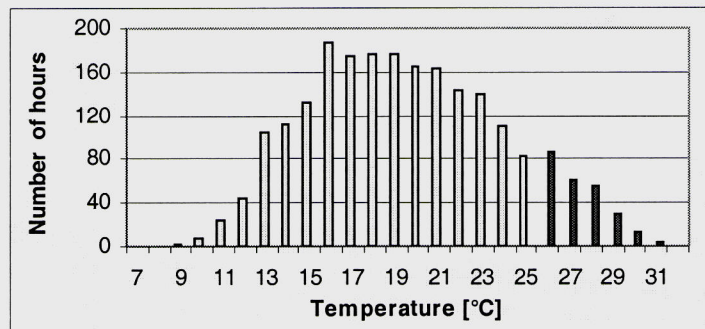


Figure 9 Histogram of the outside temperatures measured during summer 2000.

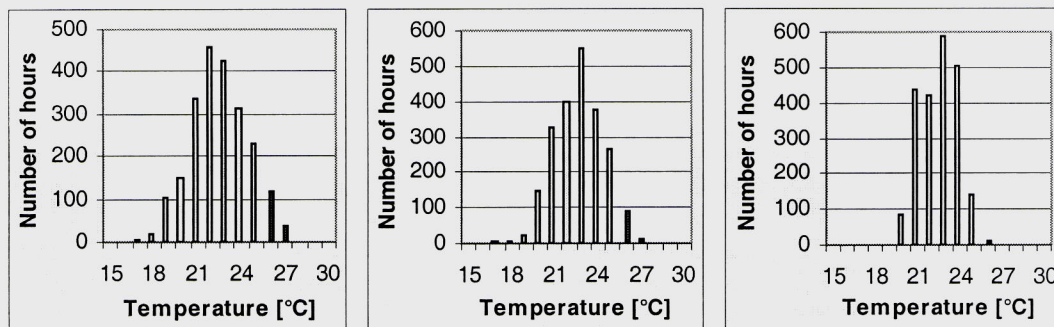


Figure 10 Histogram of the interior temperatures, measured in 3 rooms of the building, respectively located at the ground floor, the 1<sup>st</sup> floor and the 2<sup>nd</sup> floor, during the same period.

Figure 9 and 10 give the temperature histogram, respectively, for the outside and a set of rooms measured during summer 2000. The outside temperature exceeded 26°C during 243 hours, that is to say the 11% of time. Throughout the same period, the interior temperature was more pleasant:

according to the behaviour of the occupant and the room considered, the number of overheating hours (more than 26°C) added up from 11 to 157 hours, that is to say 0.5 to 7% of time.

In the stair-well of the building, one observes a clear stratification of the temperature: on the ground floor level the temperature never exceeded 26°C, whereas on the second stage level this limit was exceeded during 3% of time.

#### 4. CONCLUSION AND RECOMMENDATIONS

From the strict point of view of energy, the new frontage leads to a positive net assessment: solar gains useful for heating (58 GJ) being slightly higher than the thermal losses of the frontage (56.5 GJ). With that, it is advisable to add the increase of autonomy in daylight which represents an average saving in electricity of 8 [MJ/m<sup>2</sup>year]. The requirements in heating for the building are thus very weak since they do not exceed 76 [MJ/m<sup>2</sup>].

If the requirements in heat are very weak, the electric consumption (informatic and measuring equipments and machines) is significant; annually it reaches 129 [MJ/m<sup>2</sup>], that is to say a little more than half of the overall consumption of energy. This consumption contributes to internal gains during the winter, but leads to thermal loads during the summer: so it should be reduced. There for, it is necessary to take account of future energy consumption of new equipments: for example, the replacement of the tube screens by flat-faced screens "tft" could reduce the building electric consumption from 8 to 10 [MJ/m<sup>2</sup>year]. Moreover, it is essential switching off, completely, equipments when those are not used.

Finally, the geometric complexity of the anidolic frontage leads to a developed surface appreciably more significant than for traditional plane frontages; but, in terms of life cycle assessment, it still favourable due to a large use of wood /HED99/. This complexity brings however advantages which can not be neglected, namely:

- Better quality of interior lighting (homogeneous level of illumination in the room).
- Higher thermal Comfort
- Increase in useful interior volume
- Protection against the bad weather of the external parts out of wood
- Aesthetic quality of the whole frontage.

#### THANKS

We make a point of thanking very sincerely:

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