Build a solar model for an nZEB refurbishment

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VLS 500 is a building of social housing, built in 1974 and located in La Rochelle, France. With the envisioned integration of solar PV production, VLS 500 should be the first social housing building of France, retrofitted with the nZEB performance.

Keywords: Social housing – refurbishment – photovoltaic – solar collectors – district heating – prefabrication.

Site description and climatic relevant aspect

The building is located in the city of La Rochelle, on the French Atlantic Coast, with geographical coordinates: 46°09'07.09"N, 1°07'00.07"W and an altitude above sea level of 7 m. Under Köppen's climate classification, La Rochelle features an Oceanic climate. Seasonal weather is made of mild dry summer period and mild and humid winter periods. The characteristic values of the climate are summarized in **Table 1**.

Table 1. Climatic relevant aspect of La Rochelle.

ISO 877-1:2011 classification	Marine west coast climate
Physical information	La Rochelle (France)
HDD (Base 18°C) /CDD (Base 22°C)	2068/21
Average Annual Air Temperature	13.0°C
Average Annual Relative Humidity	80.6%
Rain amount (mm)	755 mm
Solar Irradiation	1 337 kWh/m²
Average Wind speed (m/s)	4.2 m/s

Fetch distance from the ocean is less than 4 km, with a yearly sunshine duration of 2200 hours per year, La Rochelle is the most isolated place of France's Atlantic coast.

Rupella-Reha Project

Supported by the Social Housing Agency of the urban area of La Rochelle (www.office-agglo-larochelle.fr) and managed by the University of La Rochelle (Tipee Plateform), Rupella-Reha is one of the award-winning projects launched by the French Environment and Energy Management Agency (ADEME) in 2011. This project involves retrofitting three buildings of the Social Housing Agency, located in three different districts of the city, with a global approach (indoor air quality, thermal, acoustical and visual comfort, solar energy systems). VLS 500 is one of these three buildings with an objective of 35 kWh/m².y (primary energy consumed on site). Its retrofit started in 2013 and the design phase ends at the beginning of 2016. Further to this period, the works will last eighteen months and will be completed by a monitoring period of two years. The design team is mainly composed of the architect "Cointet et associés", engineering companies "ITF" and "Atmosphère" and the University of La Rochelle. Cointet et Associés are the project manager for the Social Housing Agency, in charge of design and economic parts. ITF and Atmosphère are in charge of improving envelope and building systems. Eventually, the University of La Rochelle is the project manager for ADEME.

Figure 1. The district of Villeneuve-les-Salines.

VLS 500, from the seventies to a 21th century building

VLS 500 was built in 1974 displaying a cubic geometry (**Figure 1**). Because of its layout similar to the others buildings of Villeneuve-les-salines, VLS 500 is a distinctive architecture of this district.

The building is composed of four blocks (**Figure 2**) of flats with sixty-four residential units and less than one hundred occupants. Two blocks have six floors above the ground, while the two others are limited to four floors (**Figure 3**). The net conditioned floor area is 4 900 m² and the glazing percentage (overall window-to-wall ratio) is 20%.

Envelope thermal properties

In France, as most of buildings built in the seventies, the VLS 500 envelope was built out of prefabricated components. For the four blocks, each component of the building envelope (external walls, internal partitions, slabs and roofs) was developed with the same materials and according to a unique sequence of material layers. In spite of a detailed study about the building before retrofit, many physical characteristics or materials remain unknown.

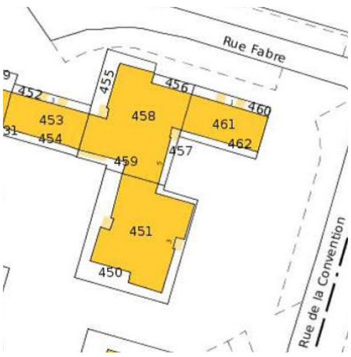

Figure 2. The four blocks of VLS 500.

To improve the thermal performance of the envelope, the design team proposed several retrofit actions. Reinforcing thermal insulation of external walls and windows was advocated using prefabricated externally insulated element to address the occupied site issues. This new layer is hitched to the current external wall, enlarging the total thickness from 25 cm to 40 cm (**Figure 4**).

Figure 3. A four and six floors block.

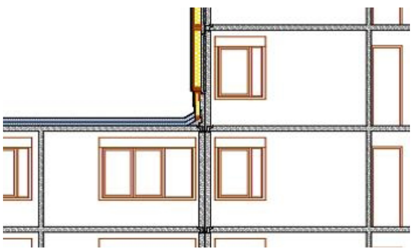

Figure 4. Prefabricated wall hitched to current external wall.

This prefabricated wall will include the new windows and will improve the airtightness because of this optimized assembly process. Moreover, because of retrofit intervention is done with the occupants inside, this technology permits a shorter intervention and a site less noisy.

Characteristics of the building components before and after retrofit are described in the following **Table 2.**

Building Systems

VLS 500's HVAC systems are not the usual systems employed for social housing buildings construction, for years in France. Only the ventilation system can be qualified as "standard" with natural ventilation strategy based on stack effect. From 1974, the heating and the DHW systems are connected to the district heating system of Villeneuve-les-Salines (distributing pressurized hot water

Table 2. Thermal characteristics before retrofit.

<table>
<tr><th></th><th></th><th>Before retrofit</th><th>After retrofit</th></tr>
<tr><td rowspan="3">External wall</td><td>Construction</td><td>From exterior to interior: reinforced concrete (7 cm), polystyrene (4 cm) and reinforced concrete (14 cm).</td><td>From exterior to interior: 15 cm of insulation (fiberglass) in a wood frame, the current external wall (25 cm)</td></tr>
<tr><td>Thickness [m]</td><td>0.25</td><td>0.40</td></tr>
<tr><td>U-value [W/m²·K]</td><td>0.731 (estimation)</td><td>0.2</td></tr>
<tr><td rowspan="3">Flat roof</td><td>Construction</td><td>From exterior to interior: Gravel (5 cm), extruded polystyrene (5 cm), reinforced concrete (14 cm)</td><td>From exterior to interior: Gravel (5 cm), Polyurethane (20 cm), reinforced concrete (14 cm)</td></tr>
<tr><td>Thickness [m]</td><td>0.25</td><td>0.39</td></tr>
<tr><td>U-value [W/m²·K]</td><td>0.689 (estimation)</td><td>0.122</td></tr>
<tr><td rowspan="3">Ground floor slab</td><td>Construction</td><td>From exterior to interior: Reinforced concrete (14 cm)</td><td>From exterior to interior: Reinforced concrete (14 cm). insulation</td></tr>
<tr><td>Thickness [m]</td><td>0.14</td><td>—</td></tr>
<tr><td>U-value [W/m²·K]</td><td>3.692 (estimation)</td><td>0.256</td></tr>
<tr><td rowspan="2">Walls between the internal environment and unconditioned spaces</td><td>Construction</td><td colspan="2">From exterior to interior: reinforced concrete (9 cm), insulation (5 cm), reinforced concrete (9 cm)</td></tr>
<tr><td>Thickness [m]</td><td colspan="2">0.23</td></tr>
<tr><td rowspan="3">Intermediate slabs</td><td>Construction</td><td colspan="2">A unique layer of reinforced concrete (14 cm)</td></tr>
<tr><td>Thickness [m]</td><td colspan="2">0.14</td></tr>
<tr><td>U-value [W/m²·K]</td><td colspan="2">2.495 (estimation)</td></tr>
<tr><td rowspan="2">Internal partitions</td><td>Construction</td><td colspan="2">A unique layer of bricks (10 cm).</td></tr>
<tr><td>Thickness [m]</td><td colspan="2">0.10</td></tr>
<tr><td>Thermal bridges resolution</td><td>Specific features adopted in reducing thermal bridges through building envelope</td><td colspan="2">A specific attention was given to balconies' thermal behaviour in order to reduce thermal bridges. A certain number of balconies will be destroyed.</td></tr>
<tr><td>Airtightness</td><td>n50 [1/h]</td><td>Six residential units tested: results from 1.4 to 4.39</td><td></td></tr>
<tr><td rowspan="2">Window 1</td><td>Typology</td><td>Single glazing with wood frame</td><td>Double glazing (argon) with PVC frame</td></tr>
<tr><td>U-value windows [W/m²·K]</td><td>4.95 (estimation)</td><td>1.4</td></tr>
<tr><td rowspan="2">Window 2</td><td>Typology</td><td>Double glazing with PVC frame</td><td></td></tr>
<tr><td>U-value windows [W/m²·K]</td><td>2.9 (estimation)</td><td></td></tr>
<tr><td>Shading</td><td>Type of solar shading</td><td colspan="2">Louvered shutter</td></tr>
</table>

to 2 136 flats). This district heating system is one of the first in France. Otherwise, a part of DHW is produced by solar collectors installed on the roof (flat plate collectors).

Because of VLS 500 is a pioneer building for using renewable energy technologies (RES) in the 70's, the design team highlighted pro-arguments to the Social Housing Agency in order to rise the amount of RES to aim a nZEB performance. This increase of RES has become possible for two reasons: a special wood frame is built on the current roof to support 465 m² of photovoltaic panels (65 kW_{peak}) and the ten years old solar collectors are replaced by evacuated tube collectors (thirty-five units).

Figure 5 displays the solar study to optimize productivity of photovoltaic panels and solar collectors.

During the period of time in which the heating system is switched on, the surplus of hot water produced by these new collectors shall be used to preheat water for heating system. During the switched off period, the surplus is injected in the district heating to avoid overheating (**Figure 6**). Except the solar thermal power

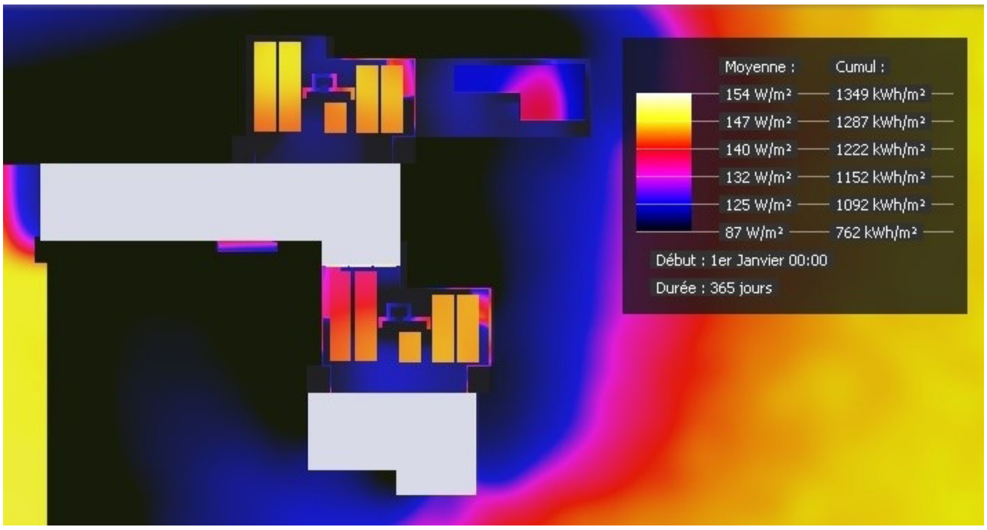

Figure 5. Improving RES by a solar study.

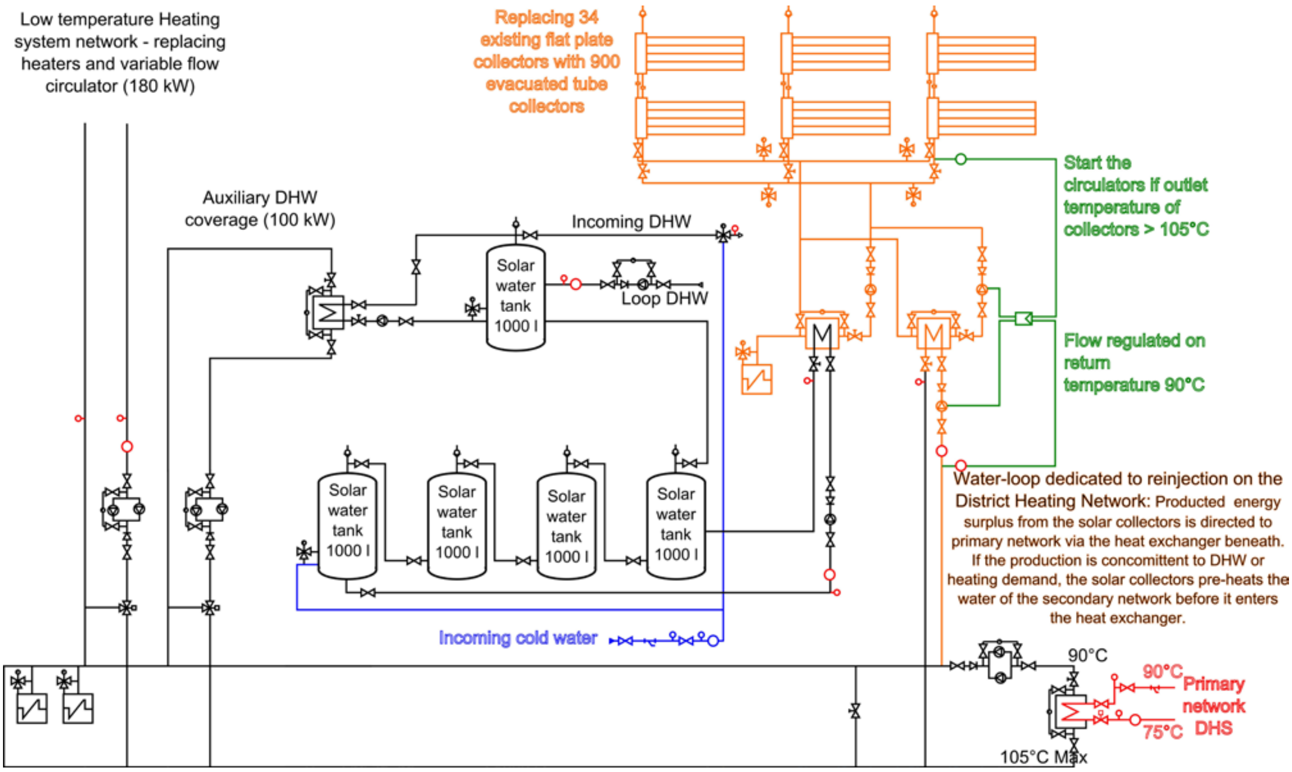

Figure 6. Schema of solar collectors.

stations, this combination was never used before in France on building retrofitting operations.

As the same time as these RES actions, the heating system is updated and the ventilation system is modified to a hybrid strategy powered by low-pressure mechanical ventilation systems.

Figure 7 displays an architectural view of VLS 500 after retrofit.

Figure 7. VLS 500 after retrofit.

Energy performances and economic aspects

In accordance with the French Thermal Regulations (RT 2012/RT-ex 2005), building energy performance after and before retrofit has to be calculated with a legal computation engine, specific to refurbishment operation. Also, the Effinergy association is the only French institute to deliver nZEB certification for new constructions. Therefore, the energy performances of VLS 500 are calculated with the legal computation engine and compared to French nZEB criteria (**Table 3**).

For this most ambitious project of the Social Housing Agency, 2 477 000 € are invested (excluding tax) for retrofit intervention, 108 000 € to replace solar collectors and 172 000 € for the PV installation (wood frame and panels). Apart from the income with selling kWh produced through PV system to the French Electricity Company (EDF), the cost for energy operation of the building will be about 15 k€ per year whereas it reached 43 k€ per year before retrofit intervention, corresponding to annual savings of 28 k€. ■

Acknowledgement

The authors greatly aknowledges Denis Rubé, Brice Maurange and Floran Castets for their contributions to the project.

Table 3. Energy uses before and after retrofit.

Energy uses & renewable energy before retrofit	
Total energy uses (Primary energy calculated with national conversion factors) (kWh/m^2.y)	135.11
Space heating (kWh/m^2.y)	109.27
Hot water (kWh/m^2.y)	14.63
Ventilation (kWh/m^2.y)	0
Lighting (kWh/m^2.y)	7.54
Auxiliary (kWh/m^2.y)	3.68
Renewable energy produced on-site: solar collectors (primary energy)	53 534 kWh
Energy uses & renewable energy after retrofit	
Total energy uses (Primary energy calculated with national conversion factors) (kWh/m^2.y)	44.04
Space heating (kWh/m^2.y)	23.41
Hot water (kWh/m^2.y)	10.01
Ventilation (kWh/m^2.y)	1.88
Lighting (kWh/m^2.y)	7.03
Auxiliary (kWh/m^2.y)	1.71
Renewable energy produced on-site: solar collectors (primary energy)	78 348 kWh
Renewable energy produced on-site: PV technology (primary energy)	157 160 kWh
Total energy uses nZEB Criteria (Primary energy) (kWh/m^2.y)	10.14