
Figure 9: Bathroom with water tank and accessories


Figure 10: Living room


Figure 11: Finished house

**4.2.2 Surroundings realisation**

Surroundings on the second wood board base have been made at 80% with reusable materials. (Cardboard, paper, wood, dry plants) (cf. figure 12).


Figure 12: Surroundings creation

**4.2.3 Power sources integration**

Some power energy supplies were installed, to illustrate green energy production and management, according to specifications given in § 3,(cf. figures 13 to17):

- Hydrogen fuel stack kit including solar panel, electrolyser, hydrogen and oxygen tanks, (from H-tec company) [18]


Figure 13: Solar and hydrogen fuel cells

- Stirling motor [19], with mechanical transmission belts, dynamo and cement mixer assembled at Enseirb-Matmeca
- Wind generator (anemometer Vaisala company given by "Météo France" connected to a three phases brushless mini generator)
- Solar cells (roof integration) and hand made motorised solar tracking system [20]
- Solar water pump for cycling water in the pool (Opitec)


Figure 14: Reversible Stirling engine, transmission arm, cement mixer


Figure 15: Wind generator (anemometer)


Figure 16: Tracking Solar panel

#### 4.2.4 Electrical heating of the house

In addition with these auxiliary energy sources, a 10V DC power supply will be installed under the house to power the electrical heater (floor heater and ceramic heaters). The design will be done during student's project.


Figure 17: Solar water pump, river and pool

## 5. First assessments

### 5.1 Work assessments

The realization of the house model and surroundings took more than 1500 cumulated hours of work, of which 150h for the specifications definition and feasibility study (ENSEIRB and Craiova University). Around 1000h devoted to the practical erection of the house by the pupils and professors of the Chambery College. The realization of the surroundings and installation of the various energy sources represented more than 300h at ENSEIRB-MATMECA. Around 50h were dedicated to promotion, advertising, and opening ceremony organisation.

As we must show as well as possible, an ethical behaviour and respect ourselves the sustainable development concept, the project was completed with a minimum budget (labour costs excluded). Raw materials and various basic devices represented a few hundred euros as indicated in table 2. Syporex (AAC), insulators and wood pieces were salvaged materials.

| Material and devices | Price (€) |
|---|---|
| Wood board 80x100cm | 80 |
| Building material | 50 |
| Chemical resin and glue | 50 |
| Surroundings material | 100 |
| Hydrogen fuel electrolyser and stack | 500 |
| Solar cells | 180 |
| Solar pump and pool | 40 |
| Stirling engine | 450 |
| Sundries | 30 |
| Total | 1480 |

Table 2: Project cost

### 5.2 Human assessment

It was a nice individual and collective human experience with ultra motivated teenagers. Indeed, some of them were in "school failure" or had strong social or family difficulties. Over passing their problems, they worked all together with solidarity and enthusiasm in a multi thematic and federating project. Four professors of College Chambery used this project all over the year, as illustration for their courses and for supporting collective pupils work:
- Professor of mathematics (sizing, scaled drawings works…),
- Two Professors of building technology (walls, insulation and house manufacturing),
- Professor of art and technology (house surroundings creation and design).

Despite the lack of sponsor and heavy technical means for this project, it was an opportunity for sharing human values, and mainly to show that it is possible to obtain "incredible" results with nothing, when working together with humility and strong motivation.

### 5.3 Collateral consequences

Thank to advertising and communication around this project, it allowed to get in touch with other local University colleagues and private companies and to start collaborations. Thus, four students from Enseirb Matmeca electronic department found training period within Sumbiosi project (part of solar decathlon challenge 2012) with possible promise of job opportunities after that.

### 5.4 House model promotion

The house model has been awarded by town hall of Talence city as the best scholar realisation of the year in sustainable development education thematic [21]. Figure 18 shows the opening ceremony with the mayor and local politics representatives, press in june 2011.

Figure 18: awards ceremony

The house model should be exhibited during the next sustainable development workshop in the "maison de l'éco-citoyenneté" in Bordeaux (eco citizen house).

Moreover, negotiations are in progress with French educational kits designer and retailer SORDALAB [23] and APRIT/Didacsol association [24], for industrialising the small house prototype and offering it for sale or public exhibition.

## 6. Future work

First phase of the project is finished. The second phase will consists in electrical wiring of the model and design of various electronic equipment, connection and management of power energy sources to supply the house. Many future Enseirb-Matmeca student's projects will be devoted to this work as indicated in the next paragraph.

### 6.1 Futures student's projects ENSEIRB-MATMECA

The green house model will support al lot of students projects for the next two years: following electronic equipments are going to be studied:
1° Weather station including pressure, temperature humidity, wind speed measurement sensors and electronic conditioning circuits.
2° Multi "green" power supply, to power the house:
- Roof solar panel, battery charger, with its charge and discharge low power management circuit.

- Hydrogen fuel stacks and hydrogen production management ($H_2$ level control and over heating safety control)
- Mobile solar panel and its solar tracking system (low voltage supply analogue feed back loop)
3° Garden "lighting":
- Low consumption LED switching circuits powered from solar battery previously designed.
4° House electrical heating and temperature control:
- Power ceramic resistors (to match the true ceramic electrical heater) controlled by a PWM switching feed back loop and integrated temperature sensor circuits.
5° Water recycling circuit and water pump management circuit. (Switching "on" and "off" criteria)
6° Canadian well and fresh air flow management. (Electronic control of fan supplied by the hydrogen fuel stack).

Once this second phase ended, a third phase of experimental measurements and characterisations will be started: heat losses and thermal behaviour in different house configuration will be investigated using infra-red thermography which becomes now a mass market technology. (Cf. the air thermography campaign [22] done in 2009 over the whole city of Bordeaux to check buildings and houses thermal losses).
After full validation tests, we should be able to propose and to introduce an integrated "sustainable development" practical lessons in first year study at ENSEIRB-MATMECA.

### 6.2 Possible evolutions

New accessories such as solar water-heater and other simple home automation systems will be added. A scaled parabolic solar dish and its tracking system should also be studied. A scaled -one meter high – modular solar tower kit (APRIT association collaboration) will be designed and installed to complete solar energy management aspects. Finally, a third base might be joined for garden, pool and water cycle illustration.
A full monitoring of the house model by a miniature home automation system and computer should be studied in the near future.

Second and third phases of the project, (theoretical electronic designs and practical results) will be described and detailed in near future publications.

### 6.3 Repeating the experience

A similar 1/20 scale house with environment-friendly insulation based on wood structure might be created next year. The same size will make this second model compatible with the common base and surroundings. A new academic partner will be associated in this project: "Lycée technique Saint Nicolas, Paris" Thus, global performances of the two models will be easily compared.

## 7. Conclusion

The first step of this innovative sustainable development project of miniature house was completed successfully thanks to the motivation and the implication of all. We checked the first functionalities of the house. Electronic design and wiring for house energy management will be realized step by step, next year, during a second project's stage. Through this multi thematic, multi competence project, we federated sciences, technology, creative arts, hand work but more especially we tried to merge sciences, humanism and humanity. The famous french writer F. Rabelais still said in 1532 "Science without conscience is the ruin of the soul". We hope that this project will help to stir the conscience to the need for sustainable development [25], [26], [27]. We hope to extend collaborations to other local schools to promote sustainable developement among the young pupils and students.

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Batiecolo [28] 9, Allée Félix Nadar, 33700 MERIGNAC and Bio-Médoc habitat, 8 rue A. Castaing, 33160 St Médard en Jalles.

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