Concrete experience of collaboration between secondary school and university in a sustainable development project: design of a realistic small scale house to study electronic and thermal aspect of energy management.

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Abstract: A full academic year was required to complete the first phase of this innovative realistic small scale house design to introduce sustainable development concept in an electronic engineer school. A few ten young pupils from 12 to 14 years old and their secondary school professors, 5 students and researchers from ENSEIRB-MATMECA engineer school, members of University of Craiova Romania, were involved in this project with the help of the national French agency ADEME (Agence de l'Environnement et de la Maitrise de l'Energie), and MNE of Bordeaux (Maison de la Nature et de l'environnement). While the small scale genuine materials house was realised by the secondary school's pupils, electronic and energy management system are designed at ENSEIRB-MATMECA and Craiova University, This 1/20 house model in now operational for practical lessons (renewable energy study, energy saving, infrared thermography measurement…) and for supporting electronic projects at ENSEIRB-MATMECA.

Key words: Sustainable Development, Didactical model making, Low power electronic, Renewable energy systems

1. Introduction

1.1 ENSEIRB MATMECA engineering school short overview

The project was initialized at ENSEIRB-MATMECA school: The "Ecole Nationale Supérieure d'Electronique, Informatique et Radiocommunications de Bordeaux" (ENSEIRB) is one of the oldest French graduate engineering schools, known as 'Grandes Ecoles' in France. It was founded in 1920.
ENSEIRB has developed with the growth of information and communication technologies. A Computer Science Department was created in 1986 to complement the original Electronics Department. The expansion has proceeded in year 2000, with the development of a new Department of Telecommunications. Mathematic and mechanical department joined ENSEIRB in 2009, to merge in an biggest entity ENSEIRB-MATMECA. ENSEIRB-MATMECA is now member of IPB (institute polytechnique de Bordeaux) strongly linked to the Bordeaux 1, Science and Technology University.

2. Project situation

2.1 National collaboration

This project was carried out through national collaboration with "the House of the Nature and the Environment" (MNE) of Bordeaux, national french organism ADEME (Agency of the Environment and the Control of Energy) France, the ENSEIRB-MATMECA (33400 Talence), the colleges Chambéry (33140 Villenave d' Ornon) and Henri Buisson (33400 Talence) (professors and pupils) for the realization of the small scale house.

2.2 International collaboration

Thanks to a bilateral European collaboration with Faculty of electromechanical and environment engineering (Craiova university-Romania), it was possible to establish academic connexion on sustainable development, to refine the project definition and to find common scientific and pedagogical goals.

2.3 Sustainable Development context

2.3.1 Necessity of sustainable development

Since Rio de Janeiro conference (1992), Kyoto protocol and agenda 21 definitions [1], the necessity of a harmonious development is now admitted by a majority of scientific and political personalities. Even if sustainable development is a complex concept, which concerns a wide range of social, scientific, economical and environmental issues, each of us is able to do something for humanity evolution [2].
The good debate is not to know if "sustainable development is gadget or a necessity". In fact, we do not have anymore choice. The future of our planet, and thus our human life is concerned. A radical cultural change is needed in engineering education to embrace broad skills, environmentally aware attitudes, knowledge and fundamental values, human behaviour, as well as a sense of ethical responsibility [3], rather than the narrowly focussed "technical excellence" which is traditionally accepted as good engineering education definition.
Such is the formidable stake for which the generations present and future must devote all their energies. "All the remainder is only pure petty and poor occupation of the human spirit."[4]
If each people do not raise its own level of conscience and of responsibility, the Nature will force us, willy-nilly. Elsewhere, the climate changes might be the first steps towards a great re-sequencing of our planet [5]?
In fact, the good question is first an individual question: "how each of us, we can do something for in our daily or professional life". Do not wait political or/ and institutional initiatives. Start first by individual action.

2.3.2 Education to sustainable development state of art in Bordeaux IPB and Craiova universities

Since the environmental problems are mainly consequences from a too strong belief in the traditional engineering, the starting step for a human society in harmony with our environment could be in training the students in the spirit of caretaking for Nature, building awareness and understanding the human industrial society as a part of the whole living world on Earth. A highly professional specialist, with availability for focusing on a paradigm shift, accepting the framework of Cleaner Production as human moral obligation, must be the higher education purpose worldwide. However, French and Romanian current teaching regarding sciences for sustainable development is not yet very developed [6] even if sensitizing efforts are done in many primary schools [7]: Climate changes, power saving, green "behaviour" are discussed with young pupils who are maybe more receptive than adults. In higher education, some French technical university departments offer specialisations with a reduced number of students: Thus, a few French Technological University Institute IUT (2 years of study) [8] started formation in this field (St.Malo, Pau, Bordeaux cities etc.). Some punctual actions are done in ENSEIRB-MATMECA such as conferences on green energies involving private local companies. ENSEIRB-IMS labs works on electrical vehicle development. But, there is not yet official program from French ministry of education and no well structured global approach for sustainable development teaching [9], [10]. Consequently, pedagogical tools for practical lessons are not really available [11]. And no sensitizing courses are given in our IPB Bordeaux institute engineer schools.
Situation in Craiova University (Romania) is a little different: Within the University of Craiova, the Faculty of Engineering in Electromechanics, Environment and Industrial Informatics aims in formation of specialists who could control the various knowledge needed for understanding the global vision of Sustainable Development. The Faculty is integrated into the European higher education structures through a TEMPUS Program, funded by The European Union and supported by PHARE. Laboratories have been equipped with modern education equipment. Teachers have been undergoing training in universities in France, Belgium, Italy and Spain. Also, students, especially from the Environmental Engineering specialization could accomplish part of research education abroad. The European Programme 1999-2010 ERASMUS Scholarship students allowed research international collaboration, since the mobility were bilateral, more students from European Union (Ecole des Hautes Etudes d'Ingenieurs, Lille, Université de Bourgogne IUT Le Creusot, Université Catholique de Louvain la Neuve) achieving project development stages in this faculty. With regard to the research projects in the Environment field, within the University of Craiova a Platform for interdisciplinary research – innovation, training and knowledge transfer had been achieved for the time period 2008-2011, which entails the Faculty of Electrical Engineering, the

Faculty of Engineering in Electromechanics, Environment and Industrial Informatics, the Faculty of Physics, and the Faculty of Horticulture. The main purpose in creating Tehnoplat Oltenia research platform is related to ensuring necessary conditions for salvation of geosystems, ecosystems and species, by establishing the adequate management of sustainable development of socio-economic systems through an interdisciplinary approach to agricultural, electrical and environmental traits of human world. Also, an important Grant research project must be taken into consideration, “Research on the development of an intelligent sustainable rail vehicle, in condition of transportation safe, comfort and efficiency”.

Thus, even if the situation is a little different in Bordeaux and Craiova universities, it appears that important efforts must be done to promote sustainable development education like it should be done everywhere. This necessity for ENSEIRB School is particularly illustrated in the next paragraph.

2.3.3 ENSEIRB-MATMECA state of art

A recent opinion poll among ENSEIRB-MATMECA students showed that around 40% are not aware or not really involved in sustainable development (See table 1). More than 60% do not know job opportunity in sustainable development field (cf. table 2).

Personnal student’s behaviour	percentage
Do concrete daily actions	64%
Do some time concrete actions	24%
Do nothing for sustainable development	12%

Table 1: Student’s sensitivity to sustainable development

Student’s future job wishes	percentage
Want to work in sustainable development field	20%
Do not know	60%
Do not want to work in sustainable development business	12%

Table 2: Student’s future jobs wishes

Lastly, only 49% of the students would like to see included a specific sustainable development teaching in engineer school.

Whereas the national statistic and predictions for the next ten years show a strong progression of jobs creation in sustainable development field [12], job opportunities in green business seems to be still fuzzy in student’s mind. Thus, this questioning confirms that a big work of awareness and education is required in our electronic engineer school.

2.4 Aim of the project

According to the previous paragraph, the project started through an individual questioning of a few teachers: What can we include in our research field and/or pedagogical thematic to have a concrete action in sustainable development, while respecting the mains scientific fields of our engineering school?
Thus, the « small scale green house » project was born.

2.4.1 Social and cultural aims

As local actors in sustainable development are often scattered and work alone, the first aim of this project was to build connexion and links between different motivated people. It was also the opportunity to merge various competencies and knowledge for a common goal.

2.4.2 Technical aim

The expected aim was to build a modular model of house with true construction materials and its “green” power generation system. Once finished, the model will be used as:

- demonstrator (exhibition in town halls or sustainable development events)
- pedagogical support for practical lessons and electronic projects, for sensitizing engineering students in first and 2nd year study. In particular, it will allow the design of electronic devices such as electric heating, temperature control, management of multi source energy (solar, wind, hydraulic, hydrogen), low consumption lighting system. Thermal measurements using infra-red camera with emissivity correction and other temperature sensors will be performed during practical lessons a well as insulator material thermal characterization, solar cells ratio measurement etc.

The chosen scale (1/20) makes the model big enough for ergonomic uses and small enough to be carried or moved easily. Moreover, standard and cheap electronic parts and COTS (components out of the shelf) components can be used for the future electronic equipment design student’s project.

The second goal was a social and human one’s; to establish connexion between local strewn people with the same sensitivity to environmental problems and to federate energies on a multi thematic project.

2.5 Interest of the work.

Small scale model cartoon houses exist in private architect offices and in the national agency ADEME [13]. They explain new available green technologies for individual and collective buildings.
There exist also « green houses » full scale (1:1) demonstrator created by the French ENSAM engineer school for solar decathlon challenge [14] (which is obviously not easily transportable). And theoretical works are still done on this subject [15].
However, pedagogical, genuine building materials and fully functional (thermal and electronic aspects) small scale modular house do not exist till now (neither in France nor in Romania).

It is thus an innovative work which will give place to many multi thematic projects fully compatible with the ENSEIRB-MATMECA and Craiova university main goals.

3. Project specifications

3.1 Generalities

The miniature house must be manufactured according to the true technical rules of the architect, building trade, carpenter, plumber, painter, roofer, solar, solar installer and so on.
The choices of raw materials are done according to the traditional building in south west France and give priority to passive insulation and classical material (too expensive phase change materials excluded).

3.2 Small scale house technical specifications

1° Square house, one floor 10m x 10m, (i.e. 50 cm x 50 cm at 1/20 scale),

2° Total surface wood board on ground: 80cm x 100cm, 18mm thick (compatible to be transported through doors and corridors)

The house will be located on one side of the mechanical support and on 20cm high piles to allow an easy access under the house where some electronic devices will be installed. Easy electrical wiring and a place to an inclined "garden" (cf. figure 1).

3° The house must comprise 3 independent parts according to a concept of "turned over shoes box" (cf. figure 2):

Part 1: external walls in Autoclaved Aerated concrete (AAC) (scaled thickness: 2.5 cm), also known as Autoclave Cellular Concrete (ACC) [16] (which was invented in the mid-1920s by Max Ginsberg). This material has excellent insulation properties thanks to the air micro bubbles contained. Surface aspect: rough coat or smoothed. (Small brick sawn and cut in a big AAC block)

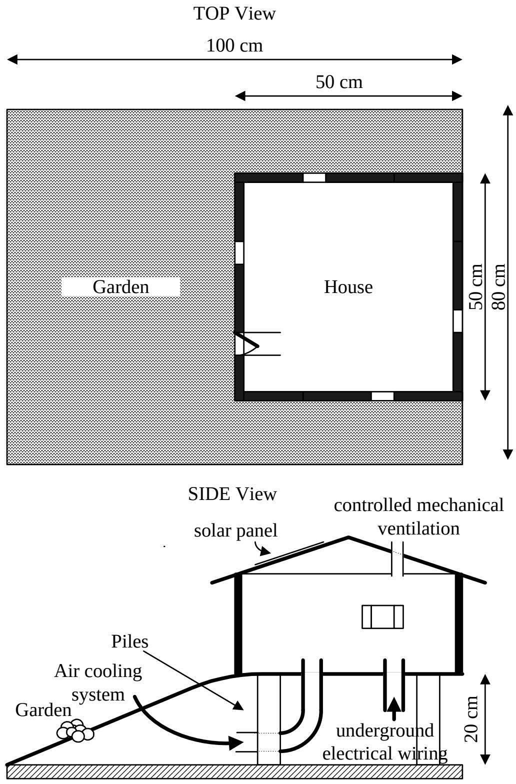

Figure 1: House implantation

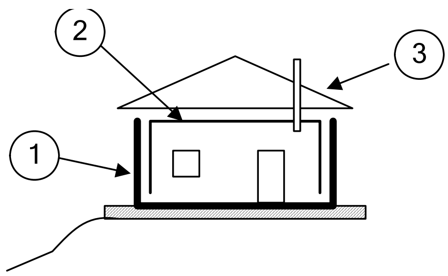

Figure 2: Modular encasable insulation

Part 2: removable interior insulation double wall and ceiling, encasable by the top inside the external walls.
Three types of insulators will be used to be able to make practical thermal performances comparison:

-Polyurethane (1cm thickness+aluminium coated). A polyurethane is any polymer consisting of a chain of organic units joined by urethane links. The thermal conductivity is between 0,023 and 0,028 W/m.K. [13]
- Polystyrene insulator, with a thermal conductivity # 0,039 W/m.K.
- Cork panels (thermal conductivity # 0,04 W/m.K).

Part 3: two slopes roof, removable and encasable, frame: local pine tree wood; terra cotta tiles or equivalent.

4° Windows and esthetical elements,
The openings will be carried out on the external frame part 1 and in opposite on part 2.
- 1 main door (wood)
- 1 glazed normal size windows by main frontages. Window frame in white extruded PVC, wood shutters, brass shutter's fastening.

One of the windows will be equipped with double glazing removable [17] assembled with slides on part 1 (cf. figure 3). (width: #7 cm, height #7cm, lintel # 2 cm).

Thus, this window might be opened or single glazed or double glazed, for energy losses comparative studies.

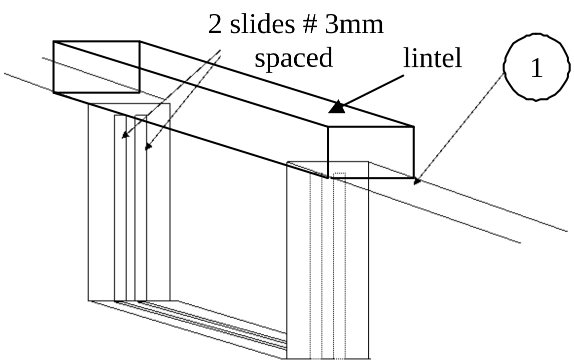

Figure 3: Double glazing window

5° House bottom surface
- Three opening (3cm diameter) in the floor for underground electrical wiring, and a fourth one for fresh air flow circulation and control (cf. figure 4).
- Four stoppers to close theses opening when not used.
- Esthetical aspect ceramic tiling or equivalent.
- Optional floorboard for a floor heating system.

6° Interior installation
It must be as simply as possible to have an easy access to electronic circuits. (i.e no partition inside). Only a bathroom and living room will be installed to illustrate plumber, tiler and painter action.

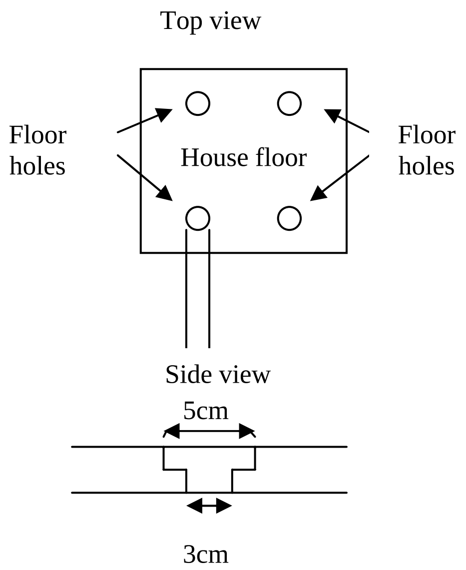

Figure 4: Ground holes localisation

- One chimney with circular vertical conduit 20 mm diameter, (type PVC) till the top of roof (to simulate an air extractor).

7° Roof
- Removable pitched roof (slope 33%, like in true roof in southwest of France) with pine tree wood parallel roof truss, rafter and batten. It might be partially opened on one slope, to encase a solar panel.
- Terra cotta tiles on the other slope.
- Attic filled with 1cm of mineral wool insulation,
- Two pins of centering, to fix the roof correctly on the wall's top.
- Rain water gathering by the roof gutters and water tank.(esthetical but non functionnal)

8° House surroundings
-Soft slope till the border of the 80cm x 1m plateau, cardboard or equivalent, keeping free access under the piles.
- Surface decoration: green grass carpet, vegetable natural moss (from small scale train scenery).
- Artificial river

9° Compatibility for extension
Shape of surroundings must be compatible for joining a second and a third 80cmx100cm wood board (optional), which will be placed nearby.

10° Extension
The second board (cf. § 5.2.3) will received the different power energy generators: solar panels, hydrogen fuel stack, Stirling motor, wind generator and a solar waterpump and pool etc.

For demonstration uses, solar energy will be replaced by Halogen lamp and the wind, by a compressed air gun.

4. Project progress

The project has been scheduled over a full university year 2010-2011 as indicated in the next paragraph.

4.1 Project main stages

- Specifications writing (One month, August 2010)
- Architectural drawings and detailed quotation, weight estimation, thermal and mechanical differential constraints estimation, (One month, September 2010)
- Basic raw material needs evaluation and purchase (2 weeks)
- Student's teams constitution, Tasks identification, repartition, and scheduling (one week)
- Checking and training with the required mechanical tools (stone saw, drilling machines, sander…)
- Manufacturing: (in mechanical workshop). At rate of one weekly sessions of 4h, group of 7 pupils supervised by 2 teachers; Wall erection (one month), windows milling and micro machining (one month), insulator assembly construction and assembly (one month), roof wood frame (one month), roofing – #1500 scaled tiles and roof solar panel insertion- (one month), rendering, finishing (one month).
- Surroundings (one month)
- Final control: one week

4.2 Concrete realisation

4.2.1 Building the house

Figures 5 to 9 show the mains steps of the house's building.

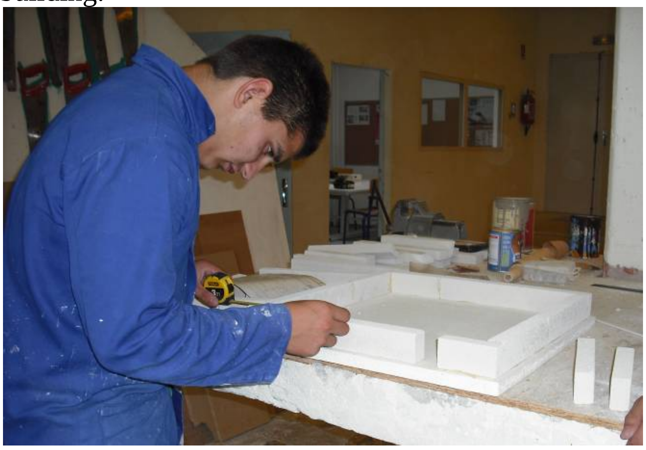

Figure 5: Starting the house's walls

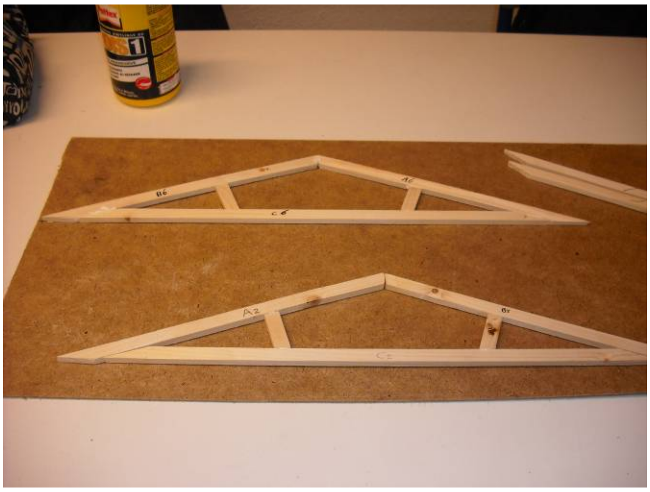

Figure 6: Roof structure preparation

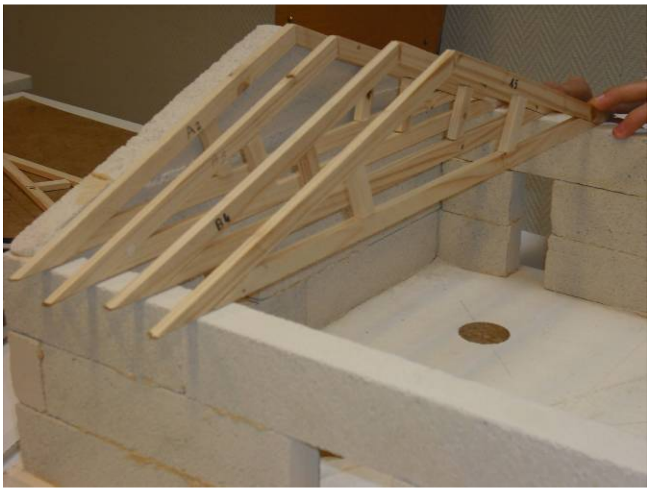

Figure 7: Wood parallel roof truss, (pine wood)

Figure 8: Internal encasable wall insulation

Interior installation has been removed from the house structure to take pictures (figure 9 and 10).

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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Final thanks to the local french warehouses for providing free samples of thermal insulators:
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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