

Education to sustainable development: example of a vertical and transversal concrete academic project

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Abstract: Sustainable development is a complex concept, which concerns a wide range of social, scientific, economical and environmental issues. The necessity of Education to sustainable development is now admitted by a majority of politic personalities. However, evolution in daily life is still slow. This paper describes a personal initiative of a few teachers of Bordeaux academy: pupils from primary school, teenagers and their secondary school professors, students and researchers from ENSEIRB-MATMECA electronic engineer school, members of University of Craiova (Romania), were involved in this multi level and cross disciplinary thematic project: details are given on project goals, development and management as well as on the technical design. Future applications for ENSEIRB-MATMECA electronic engineer school are finally discussed.

Key words: Education to sustainable development, Cross disciplinary collaboration, Renewable energy

1. Introduction

1.1 Presentation of ENSEIRB MATMECA engineering school

The project described here 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, founded in 1920.

ENSEIRB offers a wide range of engineer formation in four different departments: Electronic, Informatics, telecommunications, mathematics and mechanics. In addition, there are two departments of training in alternation: embedded systems and communication networks. ENSEIRB-MATMECA is now member of IPB (Institut Polytechnique de Bordeaux), a set of 6 engineer schools, strongly linked to the Bordeaux 1, Science and Technology University.

2. Education to Sustainable Development

2.1 Generalities

Rio de Janeiro conference (1992) and Kyoto protocol were maybe the most important milestones for the future of our planet. Sustainable development is obviously a complex concept, which concerns a wide range of social, scientific, economical and environmental interlinked issues. But the necessity of a harmonious development is now admitted by a majority of scientific and political personalities. Adoption of “agenda 21” [1] at national as well as local levels demonstrates the political will of public institutions. And at the individual level, each of us is able to do something for humanity evolution [2].

Education is one of the key points of Sustainable and Responsible Development. Particularly, teachers and researchers are responsible of sustainable development introduction in engineering education whatever the level and the field of study. Indeed, a radical but progressive cultural change is needed to embrace broad skills, environmentally aware attitudes, scientific knowledge and fundamental values, human behaviour, as well as a sense of ethical responsibility [3]. 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.

This new behaviour should replace progressively the narrow focussed “technical excellence” concept which is traditionally accepted as good engineering education definition.

Such is the major stake for which the teachers and researchers should devote all their energies. “All the remainder is only pure petty and poor occupation of the human spirit.”[4]

As Nicolas Hulot [5] said: “If each of us do not raise its own level of conscience and level of responsibility, the Nature will force us, willy-nilly”.

Even if we need national and international political framework and collective organisations, an interesting approach could start by an individual self questioning: “how each of us, we can do something in our daily and/or professional life”. Identifying our basic needs, being conscious of our relation to the nature and of our impact on environment (called the ecological footprint), we became able to start a deep internal evolution and to initialize citizen action.

2.2 Short overview of Sustainable development in French and Romanian educational systems

French and Romanian current teaching regarding sciences for sustainable development is not yet very developed [6] even if great sensitizing efforts are done in many schools [7].

2.2.1 Primary and secondary schools

Because child’s of today are the adults of tomorrow, priority must be given to nursery and primary schools.

The notion of exemplarity in educational system has been introduced by the French government [8], [9]. Thus, at primary school, pupils are now sensitized to sustainable development: “good” daily behaviours are discussed (i.e. to avoid wasting, turn off the light when not used, be careful with the water, waste sorting, public transportation use, climate changes, power saving, and so on). At secondary school, sustainable development is now included in the syllabus: In particular, teenagers work on “Agenda 21” contents, local agenda 21 and local actions in their towns, schools and so on.

2.2.2 Scientific higher education

University should be also leaders in education to sustainable development to insure continuity with primary and secondary education [10]. However, there is not till now an official program and no well-structured global approach for sustainable development teaching.

Despite this lack of general framework, local initiatives are fortunately starting in many French and Romanian universities: For example, French technical university departments offer now specialisations with a reduced number of students: Thus, a few French IUT (Technological University Institute, 2 years of study after A-level) started formation in this field (St.Malo, Pau, Bordeaux cities etc.). BTS departments (quite similar to IUT) have engaged reform to include sustainable development in their syllabus. Some punctual actions are done in ENSEIRB-MATMECA such as conferences on green energies technologies and sensitizing courses.

In Romania, the Faculty of Engineering in Electromechanics, Environment and Industrial Informatics (Craiova University), aims in formation of specialists who could control the various knowledge needed for understanding the global vision of Sustainable Development. 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. The main purpose in creating Tehnoplat Oltenia research platform is related to ensuring necessary conditions for salvation of 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. Moreover an important research project is initialized: “Research on the development of an intelligent sustainable rail vehicle, in condition of transportation safe, comfort and efficiency”.

Looking at these present situations, it appears that permanent efforts must be done to promote sustainable development education [11].

2.3.3 What means exemplarity?

A brainstorming session with some colleagues lead to the following ideas: Introducing individual and collective behaviour exemplarity concept rather than speaking about the “Technical excellence” should be an interesting questioning. Indeed, whatever the

scientific field of study, each of us (teachers and researchers) can try to “reach exemplarity”.

In the same way, mentality evolution stimulation, by awarding ethical and responsible behaviours rather than the race to publications should be suggested. Exemplarity covers two aspects in the daily life: personal and professional. And an exemplary attitude includes some common sense basic and simple behaviours. Among others, we can quote for university workers:

- To go to the work place by public transportation or bicycle instead of personal vehicle,
- To not print a paper copy of e-mail if not required,
- To turn off the light each time we leave a class room,
- To switch off the PC computer when not used.
- To provide student’s project in relation with sustainable development (for example low cost, low power electronic systems, power saving systems...)
- At the end of students project, to save components and to recycle them for the next time,
- To inform students, each time it is possible, about impact of their work, on carbon and energy assessment, product end of life management, and so on.
- To not buy a new computer if the previous one is not totally “down”
- To reduce the number of yearly publications or to publish differently: for example, by including location and transportation aspects when a conference is chosen or publish twice in the same conference to avoid multiple plane journeys.
- To increase partnership with private companies working into “green business”.

2.3 Students and sustainable development at ENSEIRB-MATMECA

Two consecutive opinion polls among roughly 100 students were performed in 2010 and 2011. The same tendency was observed over the two years.

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

Around 40% are not aware or not deeply involved in sustainable development Cf. table 1).

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

More than 60% do not know job opportunity in sustainable development field (cf. table 2).

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

Though, the international and national statistics [12], predict for the next decades a strong progression of jobs creation (research, industry, consulting, and craft industry) in sustainable development field.

Thus, it appears that “job opportunities in green business are not yet well known in student’s mind. Thus, this questioning confirms that a big work of awareness, communication, and education is required in our electronic engineer school like probably in other academic institutions.

3. The project

After noting the lake of pedagogical tools for practical lessons and according to the previous paragraphs, the “pioneer” project described in this paper started thanks to 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 design» project was born.

3.1 Project partners

The project was managed with the help of “the House of the Nature and the Environment” (MNE) of Bordeaux, the national French agency ADEME (Agency of the Environment and the Control of Energy) France, the ENSEIRB-MATMECA (33400 Talence), the colleges Chambéry SEGPA department (33140 Villenave d' Ornon) and Henri Buisson (33400 Talence) (professors and pupils).

Faculty of electromechanical and environment engineering (Craiova university-Romania) was an active European partner to start up the project definition and to find some future common scientific and pedagogical goals.

3.2 Technical goals of the project

The first and major goal was to build a modular model of house with genuine 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) to illustrate new approach in building design [13], [14]
- pedagogical tool 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 as well as insulator material thermal characterization, solar cells ratio measurement etc.

3.3 Social and cultural aspects

One of the difficulties was to find project partners. Indeed, till now, local actors in sustainable development are often scattered and work alone. Thus, this project makes it possible to build a small local network with different motivated people in various academic places. Due to the cross disciplinary aspect, it was also the opportunity to merge various competencies and complementary scientific knowledge for a common goal.

3.4 Motivation of the work

Before starting the project, a quick state of art was done: Small scale model cartoon houses already exist in private architect offices and in the national agency ADEME [15]. They explain new available green technologies in individual and collective buildings for respecting new insulation standard RT 2005 [16].

Many secondary colleges design cartoon small scale model to sensitize pupils to sustainable development.

There exist also «green houses» full scale (1:1) demonstrator created by the French ENSAM engineer school for solar decathlon challenge [17] (which is obviously not easily transportable).

Theoretical works are still done on house behaviour modelling [18].

However, pedagogical, genuine building materials and fully functional (thermal and electronic aspects) intelligent small scale modular house do not exist till now (neither in France nor in Romania).

It is thus an innovative and cross disciplinary work which will give place to many transversal projects fully compatible with the ENSEIRB-MATMECA and Craiova university main historical and roots goals.

4. Technical specifications

4.1 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 is done according to the traditional building in south west France and give priority to passive insulation and classical materials. The use of miniature PCM (phase change materials) is not currently suitable because of the price and packing. The chosen scale (1/20) makes the model big enough for ergonomic uses and small enough to be carried or moved easily.

At least, only standard and cheap electronic parts and COTS (components out of the shelf) components will be used for the future electronic equipment design student's project.

4.2 Small scale house technical specifications

1° For easy design, the house will be squared: 50 cm x 50 cm at 1/20 scale)

2° The total base surface will be 80cm x 100cm, made of wood board, 18mm thick (compatible to be transported through doors and corridors)

The house will be located on one side of the mechanical base. Four 20cm high piles under the house will allow an easy access underneath where some electronic devices will be installed, with a free space under the garden for electrical wiring (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 (ACC) (scaled thickness: 2.5 cm), also known as Autoclaved Cellular Concrete (ACC) [19]. This material has excellent insulation properties thanks to the manufacturing process and the air micro bubbles contained. Surface aspect: rough coat or smoothed. (Small brick sawn and machined in a big ACC block).

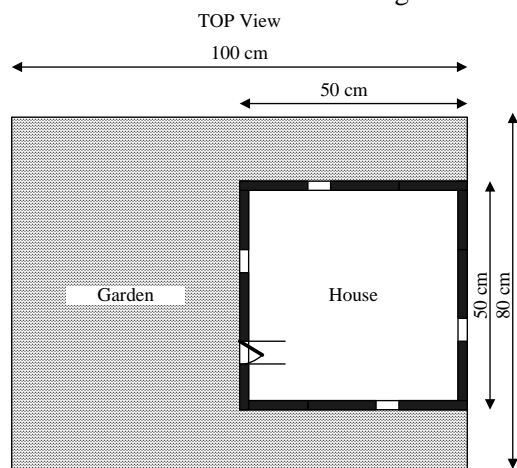


Figure 1: House implantation

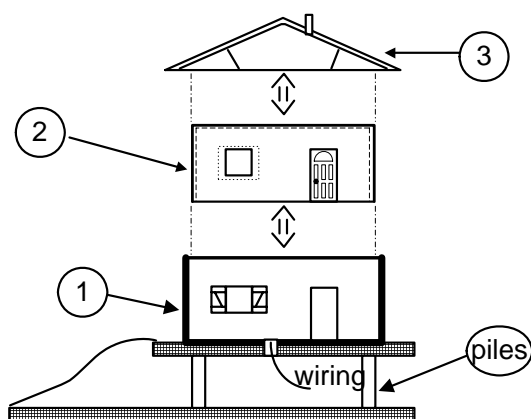


Figure 2: Modular house (side view)

Part 2: removable, interchangeable interior insulation double wall and ceiling, encasable by the top, inside the external walls.

A few types of insulators will be used to be able to make practical thermal performances comparison:

- Polyurethane (1cm thickness + aluminium coated). The thermal conductivity is between 0,023 and 0,028 W/m.K.
- 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 made of local pine tree wood covered with terra cotta scaled 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 (micro machined wood or PVC)
- 1 glazed normal size windows by main frontages total of four windows). Window frame in white extruded micro machined PVC, wood shutters, brass shutter's fastening.

One of the windows will be equipped with double glazing removable [20] assembled as indicated in figure 3. (Available glass surface 6cm x 5cm).

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

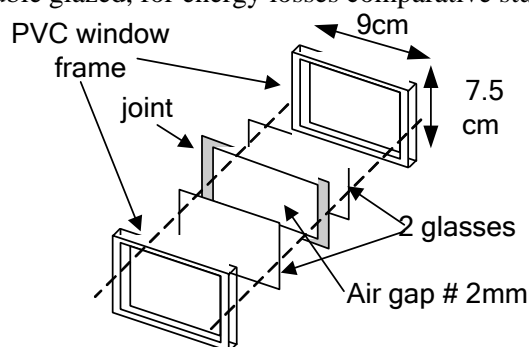


Figure 3: Double glazing window

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.
- Four stoppers to close these 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 rest room and living room will be installed to illustrate plumber, tiler and painter action.

- 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.
- Scaled terra cotta tiles on the other slope.

- Attic optionally filled with 1cm of mineral wool insulation,
- Two slot to fix the roof correctly on the wall's top.
- Rain water gathering by the roof gutters and water tank (esthetical but non functional).

8° House surroundings

- Soft slope till the border of the 80cm x 1m plateau, cardboard, 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

A second wood board with the same dimensions (cf. § 6.2.3) will received the different power energy generators: solar panels, hydrogen fuel stack, Stirling motor, wind generator, solar water pump etc.

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

5. Project management

The project has been scheduled over a full academic year 2010-2011 An average of 7 pupils supervised by 2 teachers worked on the house building at a rate of one weekly session of 4h. The main steps are indicated in the next paragraph.

5.1 Project main steps

- Preliminary feasibility study and specifications writing (one month at Enseirb-Matmeca and Craiova university, August 2010)
- Architectural drawings and detailed quotation, weight estimation, thermal and mechanical differential constraints estimation, (one month at college Chambéry, September 2010)
- Basic raw material needs evaluation and purchase (2 weeks)
- Student's team constitution, Tasks definition identification, repartition, and scheduling (one week)
- Checking and training with the required mechanical tools (stone saw, drilling machines, sander...)

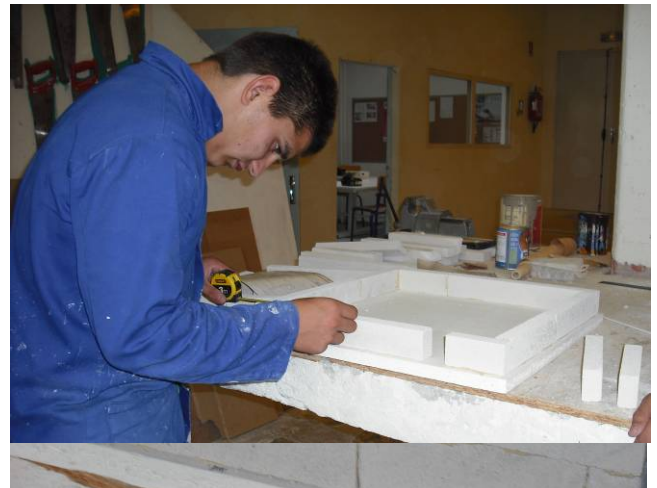
- Manufacturing: it was held in the Chambéry college mechanical workshop:

- Wall erection (one month),
 - Windows milling and micro machining (one month),
 - Internal Insulators construction and assembly (one month),
 - Roof wood frame (one month),
 - Roofing (#1500 scaled tiles) and roof solar panel insertion (one month),
 - Rendering, finishing, esthetical painting (one month).
 - Surroundings (one month)
- Final control: one week at Enseirb-Matmeca (June 2011)

5.2 Concrete realisation

5.2.1 Building the house

Figures 4 to 10 show the mains steps of the house's



building.

Figure 4: Starting the house's walls

Figure 5: ACC wall assembly

Living room internal installation has been removed from the house structure to take easy pictures (figure 8).



Figure 6: Wood parallel roof truss (pine wood), red tiles, chimney and roof solar panel place



Figure 9: Living room and rest room with accessories



Figure 7: Internal insulation preparation



Figure 10: Finished house

5.2.2 Surroundings realisation

80% of the surroundings on the second wood board base have been made of with reusable materials. (Cardboard, paper, wood, artificial green grass carpet, dry plants) (cf. figure 10). Unfortunately, some chemical glue was required for some robust assembly.



Figure 11: Surroundings

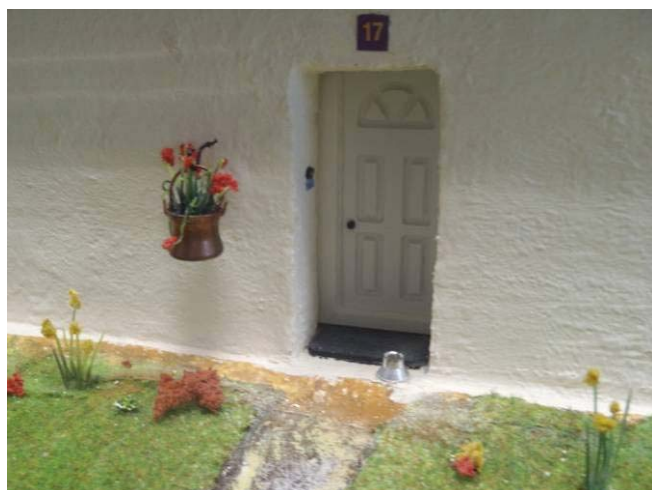


Figure 8: main entrance door

5.2.3 Power sources integration

In order to illustrate the different existing technologies to supply energy, some additional scaled power sources were installed, according to specifications given in § 4 (cf. figure 12).

We can mention:

- A modified hydrogen fuel stack kit, including solar panel, electrolyser, hydrogen and oxygen tanks, (based on H-tec company) [21]
- Wind generator (anemometer Vaisala company given by “Météo France” connected to a three phases brushless mini generator)
- Solar cells (panel integrated in the roof)
- Hand made motorised solar tracking system
- Solar water pump with coreless motor for cycling water in the pool (Opitec)
- Reversible Stirling motor [22], with mechanical transmission belt, dynamo and cement mixer assembled at Enseirb-Matmecca.



Figure 12: Global installation: Hydrogen cells, wind generator, mobile solar panel, Stirling engine, artificial river and pool.

5.2.4 Electrical heating of the house

In order to perform future thermal measurements like in a real house, a 10V DC power supply (equivalent to main for the small scale model) will be installed just under the house, to power the electrical heater. (Heaters will consist of floor heater, ceramic resistance for and/or halogen lamp depending of the measurements' goals). It should be done during student's projects (cf. § 7.1).

6. Project assessments

6.1 Pedagogical and human assessment

This project was mainly a strong individual and collective human experience with 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 federating project. Social origin diversity, mixing of the knowledge, was a source of personal enrichment for all the participants.

Four professors of College Chambéry used this project all over the year, as illustration for their courses and for supporting collective pupils work:

- Professor of mathematics in full classroom with 11/12 years old pupils for scale calculus, simple geometry and angle practical lesson, scaled drawings works...),
- Two Professors of building technology with around 14/15 years old pupils (hand work: walls, insulation and house manufacturing),
- Professor of art and technology in full classroom with 11/12 years old pupils (house surroundings creation, painting and design).

Two university teachers used this project as an opportunity to work on various sustainable development aspects with students:

- General philosophy of sustainable development, economical and financial impacts, with a hard bibliography work,
- Technical and electronic aspects of clean energy production.

Despite the lack of financial 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.

6.2 Work assessments

Up to now, the realization of the house model and surroundings took more than 1500 cumulated hours, of which 150h for the specifications definition and feasibility study. Around 1000h devoted to the practical work by the pupils and professors of the Chambéry 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.

Teacher and students exemplarity were of course required for this project. By respecting the sustainable development concept, the project was thus achieved with a minimum budget (labour costs obviously excluded). Raw materials and various basic devices represented a few hundred Euros. Syporex (ACC), insulators, wood pieces and other parts were salvaged materials.

6.3 Other impact

Communication and advertising around this project allowed to get in touch with other local University colleagues and private companies and to start collaborations. For example, four students from Enseirb-Matmeca electronic department found training period in Nobatek company, within Sumbiosi project (part of Solar Decathlon Challenge 2012) [23] with possible promise of job opportunities after that.

6.4 Awards

The 8 November 2011, the house model was prized during “Agenda 21” Trophy by “Council of Gironde department” [24], [25]. The house model has been awarded “heart price” in the Sustainable Development academic education thematic.

Figure 14 shows the opening ceremony with local politics representatives.

At last, the house model should be exhibited during the next international exhibition event of Bordeaux on MNE association stand.



Figure 13: CG33 awards ceremony

7. Future improvements

Due to the diversity of required competencies and availabilities, the global project is scheduled over a few academics years and is cut in three main phases. The first phase (design and building of the house) is now finished. The next phase will consist in the design and installation of various electronic equipments, to make the house model as realistic as possible as indicated in § 7.1.

The third phase will consist in the design of full monitoring system with a miniature home automation system (field bus, computer and data processing). It should be studied in the near future in collaboration with new local university partners.

7.1 Future student's projects

The green house model will support a lot of student's projects for the next two years. The main idea will be to design various robust COTS low power electronic equipments for energy saving and intelligent use of energy. Thus, the concept of Sustainable development will be introduced and included softly, while respecting the main scientific field of study of our school. The future projects are:

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 (H₂ level control and over heating safety control)

- Mobile solar panel and its solar tracking system (low voltage supply, servo motor, light sensors, analogue feed back loop)

3° Garden “lighting”:

- Low consumption LED switching circuits powered from solar battery (and/or from the main) 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”, timer and temperature criteria)

6° Canadian well and fresh air flow management. (Fan speed control by a circuit supplied from the hydrogen fuel stack).

7.2 Future extensions

Various extensions are already planned and new accessories will be added soon:

- A parabolic solar water heater (demonstration use only)
- A scaled parabolic solar cooking dish and its tracking system.
- A fully functional scaled (one meter high) modular solar tower kit with scaled fan inside (APRIT association collaboration) [26]. It will be included and installed to complete solar energy management aspects (cf. figure 14).



Figure 14: Solar tower kit

8. Scheduled small scale house uses

Once all the electronic equipment installed, the house model will be used for research and pedagogical purposes:

Firstly, all the technical aspects of the house model will be tested and characterised:

- Electronic circuits and systems. (Response curve, power consumption, and so on)
- Thermal behaviour (Comparative measurements double single glazed window, double wall insulation efficiency comparison, heat losses by thermal imaging.
- Monitoring and characterisation of power sources
- Project carbon assessment

Theoretical and practical results should be described and detailed in future publications.

Secondly a detailed report will be written in order to prepare a practical lesson support. Once fully operational and validated, we hope to transform this small scale green house model into a true pedagogical platform.

Thus, we should be able to prepare and to introduce integrated “electronic for sustainable development” practical lessons in first year study at ENSEIRB-MATMECA.

9. Conclusion

Sustainable development is the concern of all [27]. Education is a key part of this evolution process. Thanks to this motivating transversal, multi competence project, we merged sciences, technology, creative arts, social issues and hand craft work. Studies are now in progress to make our house model functional: Sensors, heating system and electronic control boards are going to be designed. A home automation for house energy management will be realized in collaboration with informatic department. Thus, the small scale house is an “always in evolution” project.

Finally, we hope with humility that this project helped to become conscious and convinced of education for sustainable development necessity [28], [29].

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