# Integrating sustainability concepts in IOT

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## 1. Introduction

The DTU B.Eng (IT and Electronics students) elective course **Sustainable Electronics and IT - SUSIE** applies sustainability in embedded wireless systems. As technical interested students it makes sense to apply the science in project work about building monitoring and control, and not just study the topic.

The B.Eng is a 3½ year programme, which includes a six-month internship in a Danish or international company.

**In Focus**

- **Gain knowledge about low power design and life cycle screening by prototyping embedded wireless systems**
- **Learning about building control/automation leads to less energy consumption**

## 2. Course learning outcome

**By end of the course the students should be able to**:

•Describe and use the different network protocols used in e.g. intelligent homes, smart homes and buildings(1) for monitoring and control

•**Use lifecycle screening method (MECO:** Materials, Energy, Chemicals and Others**) as part of the sensor-system**

•Analyze a given embedded system and suggest how to operate it in a low energy mode

•**Analyze, design and implement an Embedded System client-server system based on given libraries for monitoring physical data and control of actuators**

•Knowledge about energy-harvesting methods and storage to supply a wireless sensor node

•Use a sustainable energy source and storage for supplying a sensor-node

•Use a REST-web service in an embedded system for accessing a Cloud service

•Select components and solutions with focus on resources and energy consumption

•**Design and implement for low energy- and resource consumption**

•**Program Microprocessors using relevant programming languages in C and/or C++**

**As you can see in the learning outcome, the main scope is to work on real systems and implement a system which solves a problem**

(1) The reason for the building monitoring is chosen is that the building and its equipment are responsible for 30- 40% of the total Danish energy consumption (ref 1).

## 3. Active students

The 15 week course has been structured with weekly lectures in the first 10 – 11 weeks as well as related lab-work of 3.5 hours each. Students work in groups of 2 to 3 students.

By using the theories for solving questions in the labs, the students become active learners. That is the foundation for working on a team chosen project the last 4-5 weeks.

**Supervisor role:**

- The teacher supervises during the work.
- The Supervisor approves the project formulation.
- During the project work the teacher supervisor role changes from laissez-faire to controlling – with weekly meetings.

**Examples of lab exercises:**

•In building automation system and network addressing

•REST web-service-api –using a given service

•Embedded client-server

•Energy consumption in an embedded system

•Using digital sensors together with the Arduino board

•Setting up a network using Xbee modules

•LCA analysis on the Xbee module

## 4. Life cycle screening - MECO

Students are asked to do a Life Cycle Assessment (LCA) using the MECO screening method (ref 2)

An Xbee module is dismounted and its main parts identified.

1. **Production-Data for main parts are found** in SimaPro database (www.pre-sustainability.com)
    •resources
    •energy used pr kg unit.

2. **They use the MECO(1) method for:**
    •calculating the resource load in mPR(2)
    •the primary energy consumption for the production, transport, usage and disposal phase for the Xbee.

3. **The results are normally used by the students**:
    •comparing the found solution with alternatives for the service of the functional unit
    •discussing the environmental impacts of substituting materials with a high resource load in mPR

| Input ressources | XBee samlet mængde [kg] | mPR/kg | mPR |
|---|---|---|---|
| Aluminium | 0.000771 | 1.5 | **0.001157** |
| Chromium | 0.000150 | 2.3 | **0.000346** |
| Copper | 0.000593 | 16.5 | **0.009778** |
| Gold | 0.000006 | 90000 | **0.536146** |
| Iron | 0.003838 | 0.08 | **0.000307** |
| Lead | 0.000015 | 80 | **0.001163** |
| Nickel | 0.000373 | 106 | **0.039548** |
| Silver | 0.000009 | 19000 | **0.172077** |
| Tin | 0.000080 | 90 | **0.007190** |
| Zink | 0.000047 | 33 | **0.001558** |

Results for the Xbee separated in main parts (ref 3)

(1) MECO: Materials, Energy, Chemical and Others. (2 ) (milli Person Reserve)

## 5. Project work with embedded systems

**Open Project framework**

Team based project work is undertaken with the purpose of using all the topics from the classes in solving a self-chosen problem: At Campus Ballerup we are used to give open project frames, hence this part of the project proposal:

**"…Choose a problem domain for which it is relevant to monitor environmental data and controlling actuators, e.g. in a house, at Campus Ballerup, a green house, plant control, electrical vehicle, etc." …"One of the wireless nodes should be powered by a renewable energy source".**

**For prototyping and experiments each team is given a Box, a SUSIE kit, containing:**

IBoard – Atmel 328p with Ethernet incl. IP/TCP on board +Xbee socket

Olimexino – Atmel 328p with ethernet shield

4 pieces Xbee (IEEE802.15.4 + Zigbee protocol)

USB to serial adaptor and a USB to serial with Xbee connector for setting up Xbee and finally a bread board for fast prototyping incl. cables and wires

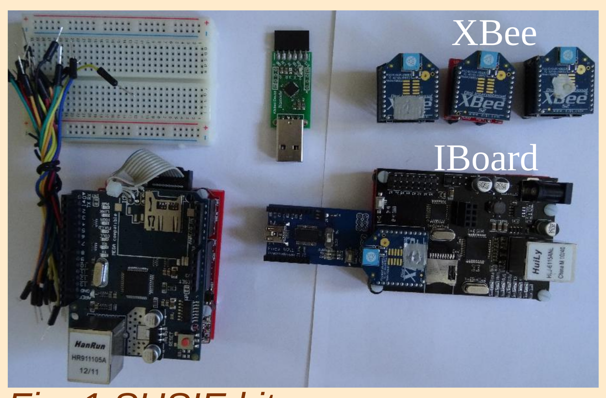

*Fig. 1 SUSIE kit*

## 5.1 Room monitoring

How is a class room used? That was monitored using the SUSIE kit and the knowledge gained in the first part of the course and using a free cloud service Xively.com (formerly cosm.com) for storage and visualization

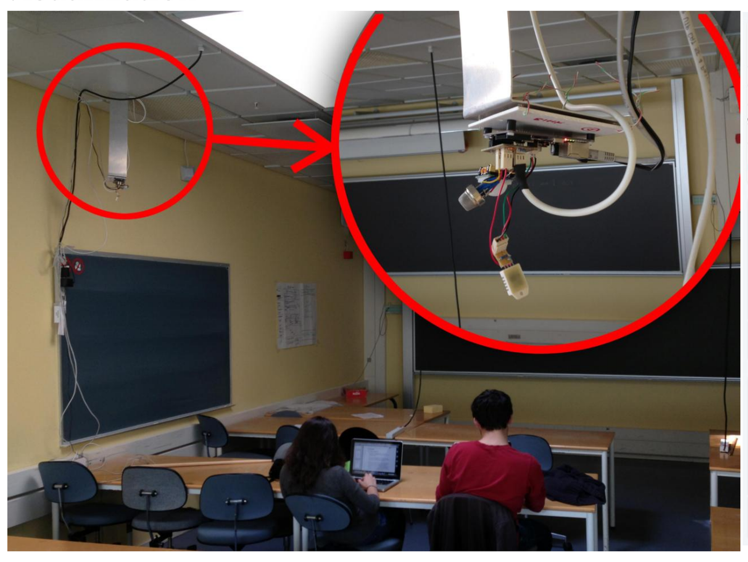
*Fig. 2 Test setup in a class-room(ref 4)*

*Fig. 3 Some measurements in the room(ref 5)*

## 5.2 One node – natural energy

**Solar cell powered Xbee end-device**

For getting a sensor working without battery or main power supply, The students must find out a Natural source for at least one node

Ex. The student made a test setup like this using a solar cell for charging a super capacitor of 35 F using a TI-charger evaluation Board (BQ25504EVM)

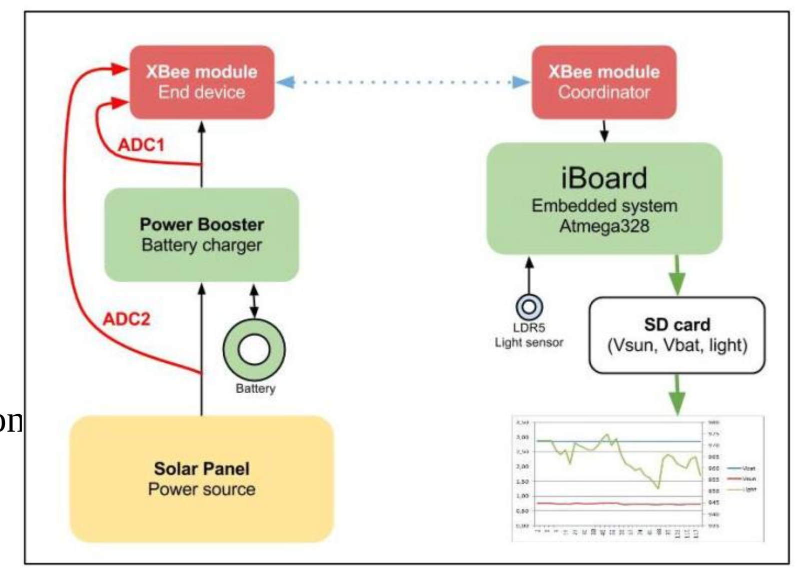

*Fig. 4 A project example – (ref 5)*

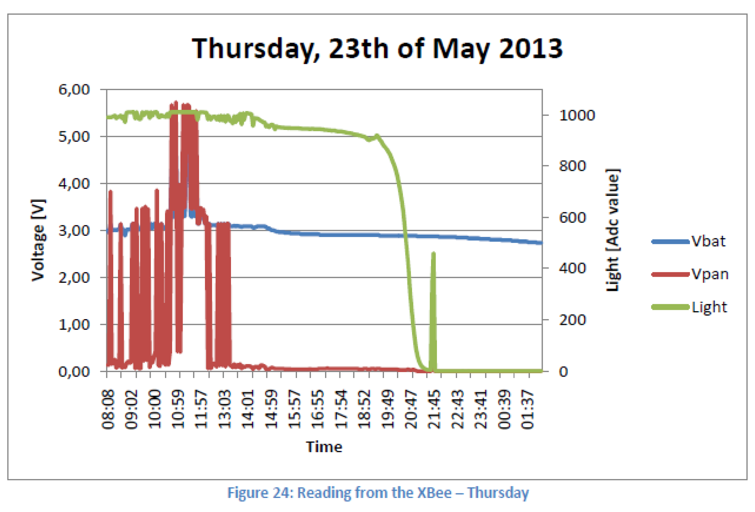

*Fig. 5 Measured voltages day (ref 5)*

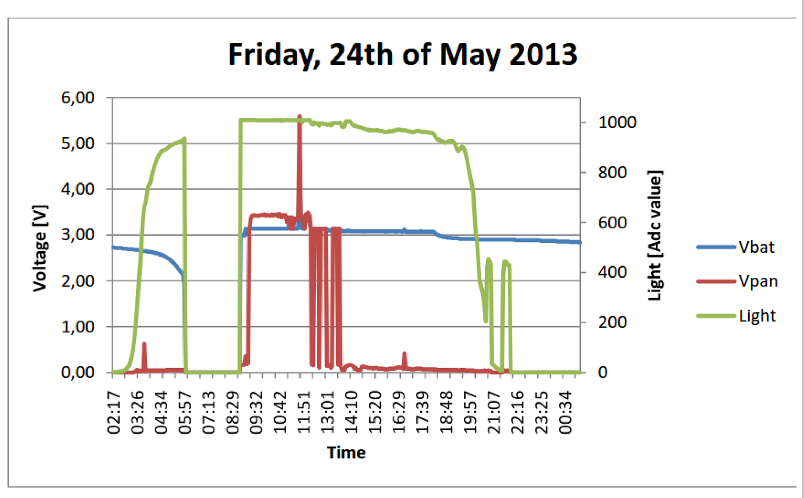

*Fig. 6 Measured voltages night – day (ref 5)*

Note in fig. 6 Xbee device stops working at 6 o'clock - when the voltage Vbat drops below 2.5V and at 8.30 it is again activated when capacitor is charged to 3 V – Power estimation problem?

## 6. Protocol and energy

Main focus is to teach the students how to design a low power system, using sensors for indoor climate monitoring, on low power Xbee wireless nodes. Students also learn how to use the internet protocol stack for transmitting data to a cloud service ex. www.thingspeak.com using an IBoard and Xbee. They are supposed to estimate power consumption and confirm by measurements.

An example showing a measurement on coordinator Xbee module while it's active

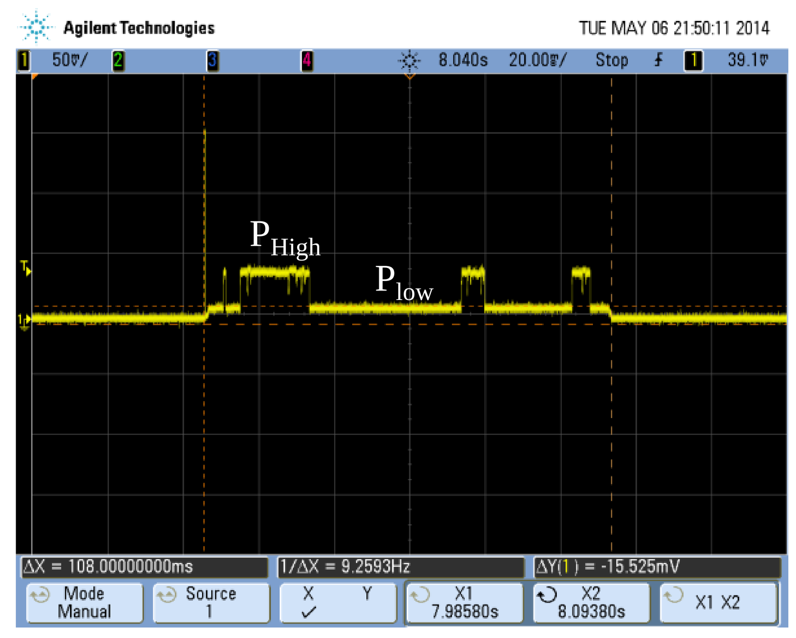

*Fig. 7 Measured voltages across 1 ohm (ref 6)*

$P_{High}$=94 mW and $P_{low}$= 27 mW at V supply 3.17 V

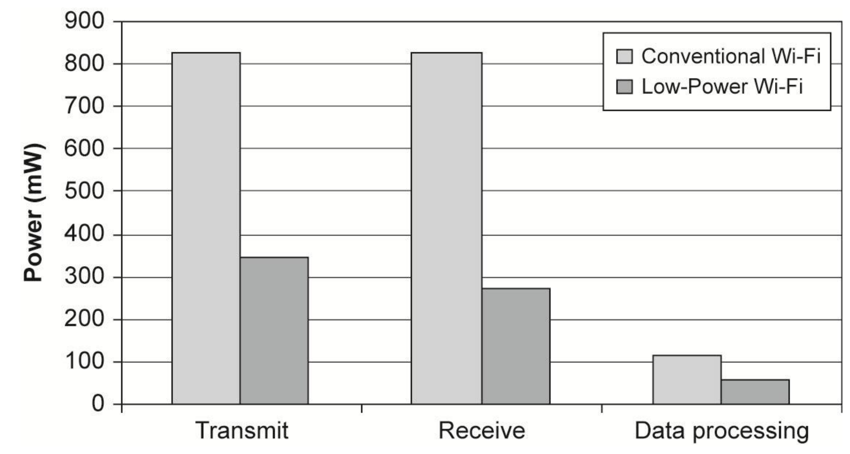

*Fig. 8 Comparison of power consumption in transmit, receive, and processing mode for conventional 802.11 and low-power 802.11.(ref 7)*

Compared to the conventional low power wireless the Xbee is using less power for transmitting.

## 7. Preliminary results

- Exams and practical prototypes proves the students obtain knowledge and can design for low power and get awareness about resources
- The course has been offered for the past 1½ years to Electronics and IT Bachelor of Engineering students. 24 students had had their exam. Five of these students have continued working with the subject as the topic for their final bachelor project.

**Relations to other courses**

- In parallel with the SUSIE course, a cross disciplinary optional course is given in Sustainable product development (SDTU) :
    - ➢ Energy and resource screening at Campus Ballerup plus proto typing. The students are able to apply their knowledge from the SUSIE course in SDTU, building prototypes for building monitoring and room control
- Can participate in DTU's "Green challenge" each year

## References

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