green mind award

Summary of the Proposal

Project:

BernoulliBorg - The building of SUSTAINABILITY

BernoulliBorg – The building of SUSTAINABILITY

Nijenborgh 9
Zernike Complex,
The University of Groningen

Integrated design and a commitment to sustainability made this building an enjoyable and healthy place to learn, work and lowered the impact on the local and global environment.

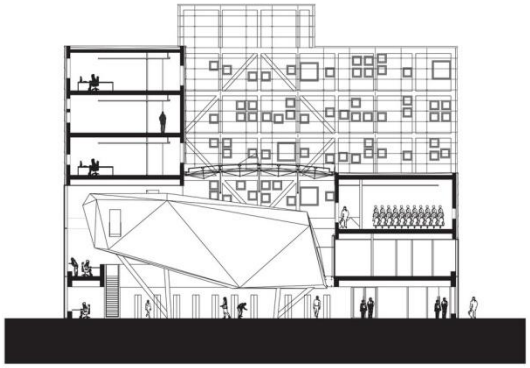
Green Building Highlights

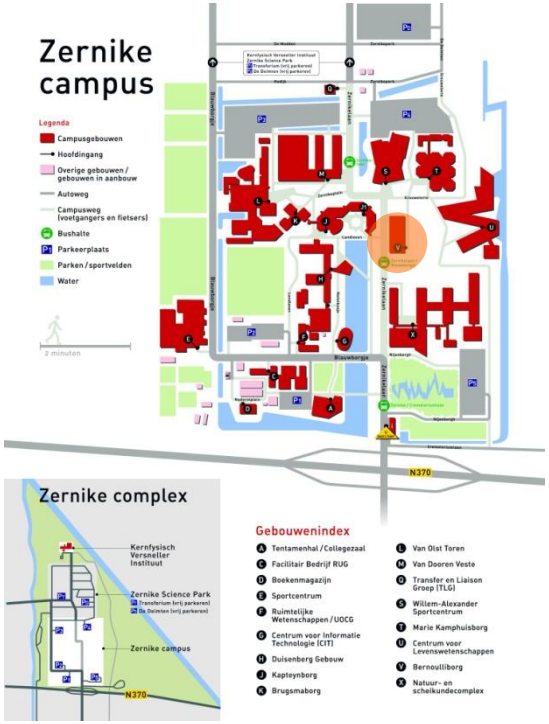
- **45%** of water saving
- **7.7%** of energy saving
- **20%** of waste reduction
- **€ 100, 000** investment
- **7 years** payback time

- More efficient lighting: Daylight harvesting and smarter occupancy detecting.
- Energy saving plug loads control: "Home grown" intelligent system to control plug loads, e.g. fridges, microwaves, coffee machines, etc.
- Water Consumption: Efficient faucets, toilets, and urinals reduce water use.
- Waste reduction: more effective categorizing results in drinks containers , cardboard, and from paper will be recycled.
- Real Time Utility Display: A monitor in the lobby shows tenants how much energy and water they are using, in real-time!

Location

The **Bernoulliborg**, located on the Zernike Complex (Nijenborgh 9), is a new building of the University of Groningen. It can accommodate 350 staff members and 500 students. With its size of 33 by 83 meters and a height of 27 meters the building has plenty of room for the central departments of the Faculty of Mathematics and Natural Sciences and the departments of mathematics, computing science and artificial intelligence.





Project scopes

In keeping with RuG's commitment to sustainability, the Bernoulliborg project implemented numerous energy and water conservation measures and try to pursue certification by Dutch Green Building Council's BREEM-NL program, aiming at achieving a BREEAM-NL Excellent rating.

- Project costs: **€ 100,000**
- Funded by: **Rijksuniversiteit Groningen**
- Implementaition duration: **Nov. 2012 to Nov. 2013**
- Payback period: **5 years**

Sustainable strategies

Bernoulliborg has already achieved 5 out of 9 Sustainable Sites credits in the BREEAM-NL program*:

1. Transport
2. Materials
3. Land Use and Ecology
4. Health and Wellbeing
5. Pollution

Now, this project will help Bernoulliborg to achieve the remaining 4 credits in the BREEAM-NL program, including:

6. Water
7. Energy
8. Waste

and

9. Management

Energy

Water

Waste

Management

*: The Dutch Green Building Council (DGBC) http://www.dgbc.nl/

Bernoulliborg will save

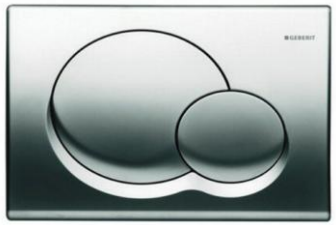
45% of water consumption, or

1,350 m^3 of water annually.

Bernoulliborg intelligently uses water and recycles as much as possible.

Bernoulliborg installs water-saving devices

Item	Current flow rate	Improved flow rate	Water saved
Water-saving Faucet	1.5 GPM/ 5.7 LPM	0.5 GPM/ 2 LPM	**67%**
Toilet	2.6 GPF/ 11 LPF	1.6-0.8 GPF/ 6-3 LPF	**45%**
Urinal	0.7 GPF/ 2.8 LPF	0.3 GPF/ 1.1 LPF	**61%**



Bernoulliborg will save

7.7% of overall electricity consumption, or

107,513 KWH annually

Bernoulliborg not only adopts various energy-efficient lighting controls, but also optimally controls plug loads.

Lighting controls: A "home-grown" system allows for smarter occupancy sensors and off hours zone control, time of day control, as well as daylight harvesting. All of these result in **25% of energy saving** in lighting.

Plug loads: Another "home-made" system that (1) monitors the energy consumption at the device level, (2) associates policies for the devices which conform with user requirements for comfort and productivity, (3) controls in an optimal way the energy consumption patterns of devices following the usage policies. All of these result in **10% of energy saving.**

HVAC: A "home-spun" decision-support system helps managers to control HVAC system based on weather information and real-time and predicted occupancy information which includes the number of occupants in each space/room. **Expected energy saving potential is 10%.**

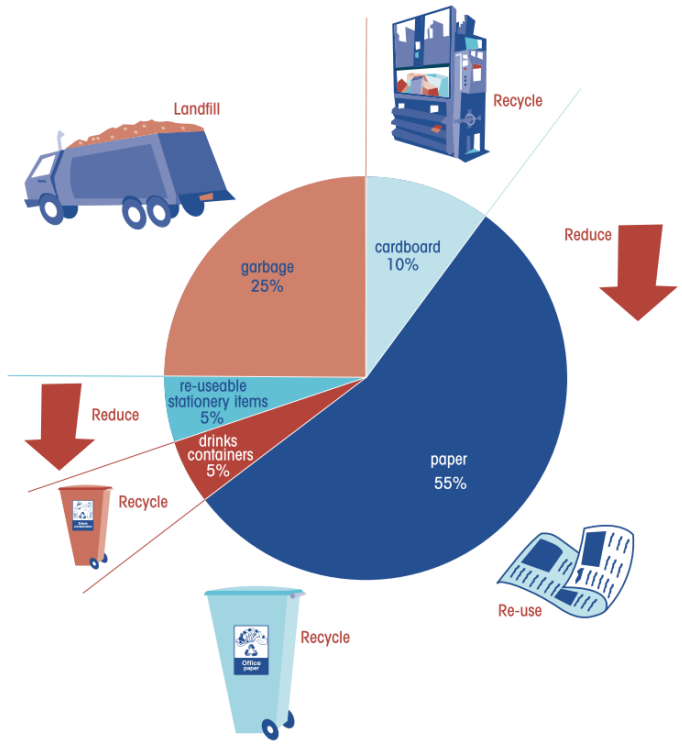
Waste Management

Bernoulliborg will recycle

20% more

Bernoulliborg strictly imposes category and recycling wastes. Effective waste categorizing increases the volume of recycled resources, reduce the load on existing waste handling facilities, saving cost and environment.

More effective categorizing: 5% from drinks containers , 10% from cardboard, and 5% from paper will be recycled.



Composition of “typical” office building waste

Better sustainability management and education

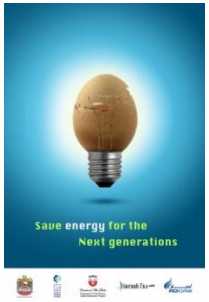
Screenshot of Real-time utility display

Real-Time Utility Display:

Occupants of Bernoulliborg can see their electricity, and water consumption in real-time on a touch screen in the lobby just inside the front doors. These systems are expect to reduce consumption, because occupants are constantly reminded of how much resources are being consumed and they can see the results when they push to conserve.

Greener Bernoulliborg posters and stickers:

Green posters and stickers are used to encourage occupants, including students how much resources are being consumed and how they can do to make Bernoulliborg a greener building.



Social media for sustainability lifestyle :

Motivation, empowered by platforms offered by social networks can bring unexpectedly good results. Hence, Facebook and Twitter pages are used to keep encouraging Bernoulliborg's citizens.

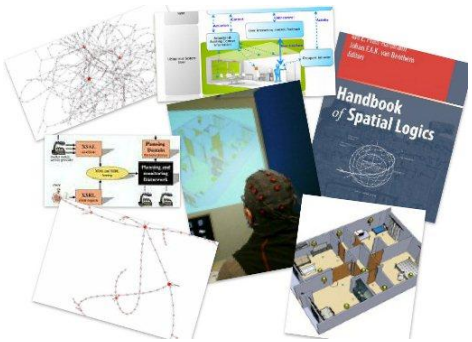
Innovations

- ✓ **“RuG-made” light control solution**
- ✓ **“RuG-grown” plug loads control solution**
- ✓ **“RuG-spun” real-time utility display**
- ✓ **“RuG-native” HVAC decision-support system**

All systems are designed and implemented by staff and students at DS group – JBI – FWN

- ✓ **Five Master Theses in Computer Science will be done**
- ✓ **Ten Bachelor Theses in Computer Science will be done**

Master and Bachelor Students of our University will be involved naturally.



BernoulliBorg Sustainability Missions

Have **Payback period** of **7 years**

Savings	year*1	year*2	year*3	year*4	year*5	year*6	year*7
Electricity 7.7%	12,697	25,394	38,091	50,788	63,485	76,182	88,879
Water 45%	2,970	5,940	8,910	11,880	14,850	17,820	20,790
Total money saved	15,667	31,334	47,001	62,668	78,335	94,002	**109,669**

Unit: €

Our commitment to the return on investment time: 7 years

Achieve **BREEAM-NL Excellent Certificate**

Bernoulliborg - The building of SUSTAINABILITY

Overview

Name of the project:

BernoulliBorg - The building of SUSTAINABILITY

Proposing group

Distributed Systems Group - JBI – FWN
University of Groningen
Nijenborgh 9
9747 AG Groningen
The Netherlands

Originators[1]:

Faris Nizamic and Tuan Anh Nguyen

Duration:

One year, from November 2012 to November 2013

Budget:

€100,000

Funding:

Green Mind Award - the University of Groningen

[1]The complete proposal was originally written by Faris Nizamic and then it was significantly improved by Tuan Anh Nguyen.

What's new?

1. Add section: Our commitment to the return on investment time: 7 years
2. Update water saving estimation
3. Update waste reduction information
4. Update energy saving estimation
5. Correct typos

Contents

1 Sustainability among the University

Sustainability is based on a simple principle: Everything that we need for our survival and well-being depends, either directly or indirectly, on our natural environment. Sustainability creates and maintains the conditions under which humans and nature can exist in productive harmony, that permit fulfilling the social, economic and other requirements of present and future generations [6]. Sustainability is important to making sure that we have and will continue to have, the water, materials, and resources to protect human health and our environment.

By far, sustainable projects are nothing new at the University of Groningen. The University, with its campuses that include many buildings spread the whole Groningen city, approximately 27,600 students, 1,400 PhD students, and 4,897 staff, has a significant environmental imprint. That fact alone would justify the university's developing a comprehensive strategy to minimize its environmental footprint. Moreover, the University has an additional responsibility to prepare its students to do their part to protect the planet's natural resources for future generations.

1.1 For Infinity

In 2014, our University will be 400 years old. The theme of the lustrum is "4∞", in other words: **For Infinity**. The term has been chosen because it is in line with the University's focus areas Energy, Healthy Ageing, and Sustainable Society. Just like in the past 400 years, the University wants to contribute to a sustainable society 4∞, and we would also like the lustrum programme to reflect that.

1.2 Green Mind Award

In line with the theme of the lustrum - "4∞", Green Mind Award competition asks all staff and students of our university for original ideas to boost sustainability in our business operations or buildings with a 'green' impact for years to come. Motivated by this, the premise of this project is that Bernoilliborg must ensure that its physical building and the experience it provides for its students, faculty, and staff reflect and respect sustainability principles.

1.3 Project goals

The project proposes aggressive but achievable goals in three priority areas: Energy and Water Savings; Waste Reduction; and Research and Education Engagement at the Bernoulliborg building, where our Faculty of Mathematics and Natural Sciences located. It outlines strong action in the Faculty operations, in complement with academic and research initiatives, in offices across the building. It takes a principled approach to reducing negative impacts selecting specific objectives in areas in which the building's community can achieve real and measurable progress. The strategies proposed in the plan are tailored to

the building, energy infrastructure, and academic and social environment that are particular to Bernoulliborg Building. By this away, **the Bernoulliborg building is going to achieve the BREEAM-NL[1] Excellent Certificate for Building of Sustainability.**

Bernoulliborg has already achieved five out of nine Sustainable Sites credits in the BREEAM-NL program, those are:

1. Transport
2. Materials
3. Land Use and Ecology
4. Health and Wellbeing
5. Pollution

Now, this project will help Bernoulliborg to achieve the remaining four credits in the BREEAM-NL program, namely:

6. Water
7. Energy
8. Waste, and
9. Management

By applying an integrated design and a commitment to sustainability made this building an enjoyable and healthy place to learn, work and lowered the impact on the local and global environment.

- Water Savings: Bernoulliborg intelligently uses water and recycles as much as possible. Bernoulliborg will **save 45% of water consumption, or 1350 m^3 of water annually.**

- Energy Savings: Bernoulliborg not only adopts various energy-efficient lighting controls but also optimally controls plug loads. Bernoulliborg will **save at least 7.7% and up to 18.2% of power consumption, or 107,513 KWH to 245,112 KHW annually.**

- Waste Reduction: Bernoulliborg strictly imposes category and recycling wastes. Effective waste categorizing increases the volume of recycled resources, reduce the load on existing waste handling facilities, saving cost and environment. Bernoulliborg will **recycle 20% more** or **6,300 kg annually** which comes from 5% of drinks containers , 10% of cardboard, and 5% more of paper will be recycled.

- **Commitment to the return on investment time: 7 years.** After carefully analysing the abilities of our proposed solutions, together with information provided from Bernoulliborg's managers, our commitments to the return on investment time is seven years.

[1]The Dutch Green Building Council (DGBC) `http://www.dgbc.nl/`

2 Strategies and Solutions for Sustainability Goals

2.1 Water Savings

The greatest impediment to achieving meaningful water savings in office building is the common disconnect between the person that pays the water bills, the building owner, the tenants, the building manager or engineer, and the various third party contractors that maintain the facility and equipment. However, office facilities are a great opportunity for water conservation and water use efficiency.

2.1.1 Goals

Our goals is to **save 45% of water consumption of Bernoulliborg** or **1350 m^3 annually**.
Actually, as listed in Table 1, the retrofitting of current devices with more water-saving ones may results in a higher amount of water saved. However, the water usage of each type may vary, for example the water flushed for toileting is more than water used for washing dishes or cooking and drinking from faucets. Therefore, in the worst case, we try to achieve water saving at 45%.

2.1.2 Strategies

Bernoulliborg intelligently uses water and recycles as much as possible. There are numerous retrofits available for the water-using equipment and fixtures within the office building. Developing a water use profile often leads to short payback periods for retrofits. Also, behavioural changes can improve water efficiency in Bernoulliborg.

1. **Installs water-saving devices**: Water savings can be achieved by retrofitting faucets, toilets, and urinals. The list of retrofitted devices is listed in Table 1. Some examples of water-saving measures are depicted in Figure 1.

    - Toilets: Current model toilets which use 2.6 Gpf (11 Lpf) can be replaced with new ULFTs (1.6 Gpf -6 Lpf), HETs (1.28 gpf - 4.8 Lpf), including dual-flush HETs using 1.6 gpf (6.1 LPF) for the full flush and no more than 1.1 gpf (4.0 Lpf) for the reduced flush (liquid waste). This replacement results in **45% water saving**.
    - Urinals: Current model urinals use 0.7 Gpf (2.8 Lpf). To assure water savings are sustained over time, the best strategy is to replace the entire urinal and flush valve with an HEU (e.g., 0.125 gpf or 0.25 gpf (0.5 Lpf or 0.95 Lpf) model. The replacement saves **61% of water use**.
    - Faucets: Current model faucets in Bernoulliborg already use NEOPERL water-saving flow regulators, that have flow range is 1.5 - 2.2 (max) Gpm or 5.7 Lpm. The proposal here is to replace faucets with greater flow regulator with flow range is 0.5 Gpm (2 Lpm), **resulting in 67% water saving**.

Table 1: Water-saving retrofit

Item	**Current flow rate**	**Improved flow rate**	**Water saved**
Water-saving faucets	1.5 GPM/ 5.7 LPM	0.5 GPM/ 2 LPM	**67%**
Dual-flush toilet kit	2.6 GPF/ 11 LPF	1.6-0.8 GPF/ 6-3 LPF	**45%**
Water-saving urinals	0.7 GPF/ 2.8 LPF	0.3 GPF/ 1.1 LPF	**61%**
Overall expected water saved:			**45%**

2. **Behavioural changes**: In multi-use or multi-tenant properties, water saving potential is frequently enormous, but successful implementation of changes always requires a cooperative effort from everyone involved.

   Behavioural change towards avoiding the use of toilet flush unnecessarily forms a sensible starting point for reducing water consumption in toilets. Users should be encouraged not to use the toilet as a garbage bin and not to dispose of, for example, tissues, dead insects, or similar waste. In private homes such changes can be relatively easy to implement. In institutional and commercial buildings, on the other hand, more formal training as well as the use of educational signs may be necessary to stimulate a change in user behaviour. Posters, as instanced in Figure 2, are also used to encourage and motivate Bernoulliborg's occupants to save water.

(a) A dual-flush system (b) Water-saving faucet aerator

Figure 1: Examples of water saving measures

2.1.3 People in charge

Building management department should be in charge of water saving program as well as waste reduction plan.

2.1.4 Financial Estimation

The money is mainly invested into retrofitting toilets, urinals, and faucets at Bernoulliborg. The estimated amount is represented in Table 2.

Table 2: Estimated investment for water saving program

Item	**Description**	**Price**	**QTY**	**Total**
Water-saving faucet aerators	Faucet aerators which have flow rate is 0.5 Gpm/2 Lpm	€30	35	€1,050
Dual-flush toilet kit	Dual-flush toilet kit which has flow rate is 1.6-0.8 Gpf/ 6-3 Lpf	€30	30	€900
Water-saving urinals	Urinal which has flow rate is 0.3 Gpf/ 1.1 Lpf	€400	5	€2,000
Posters	Posters to motivate people about water saving in Bernoulliborg	€5	50	€250
Labour	Worker who will install new devices (man-month)	€2,166	2	€4,333
Total:				**€8,533**

2.2 Waste Reduction

Reducing the amount of waste our office produces need not to be difficult or time consuming. Currently, the recycling system at the Bernoulliborg works very well, including paper and cartridge toner recycling. However, there are a few, key things all Bernoulliborg's occupants can do more that will dramatically reduce the waste from their office, and save money and the environment at the same time. As depicted in Figure 3, composition of "typical" office tower waste[2] also includes 10% of cardboard and 5% of drinks containers which are not recycled at this moment.

2.2.1 Goals

Bernoulliborg will **recycle 20% more** or **6,300 kg annually**.
Acording to EPI method developed by the Health, Safety and the Environment Service (AMD) of the University of Groningen to measure environmental performance, each squared meter is responsible for 3 kg waste, in 2011. Bernoulliborg which has gross floor area of

[2]Resource NSW `http://www.resource.nsw.gov.au/officebuildings`

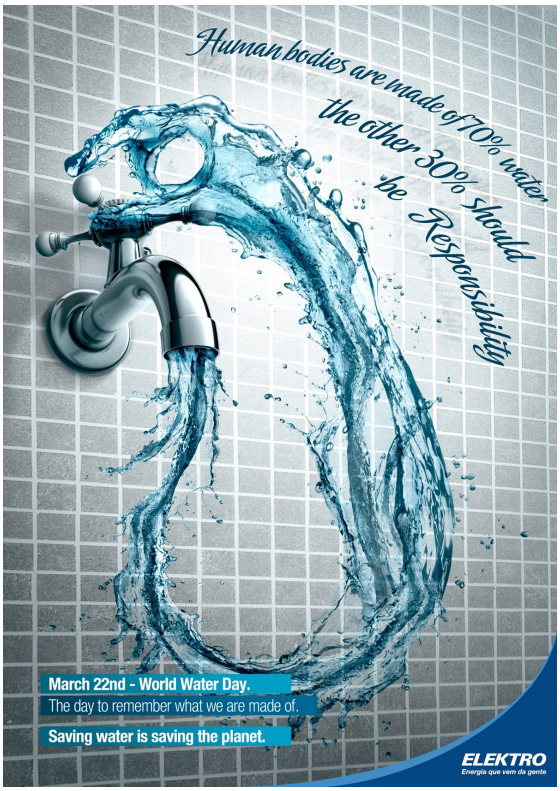


Figure 2: An example of water saving poster

$10{,}500m^2$ is responsible for 10,500*3 = 31,500 kg waste. Thus totally, the project could help Bernoulliborg to recycle up to 20% of 31,500 kg waste, equivalent to **6,300 kg of waste every year.**

2.2.2 Strategies

The following measures should be implemented in all office buildings where feasible:

- Better recycling of paper
- Recycling of drinks containers and cardboard, e.g. metal cans and glass bottles, rigid plastics, polystyrene and wooden pallets, etc., and
- Organic waste diversion.

While Bernoulliborg has implemented paper recycling programs, however, there are some simple things we can do to make the most of it. Also, some more things can be done to recycle drinks containers and cardboard.

1. **Proper recycling stations**: A central recycling station should be placed at convenient locations on each floor for the collection of glass and metal containers. Recycling stations can be placed by elevators, coffee stations, restaurant or any other high traffic area. One idea for placing new recycle containers at coffee corners is given in Figure 4

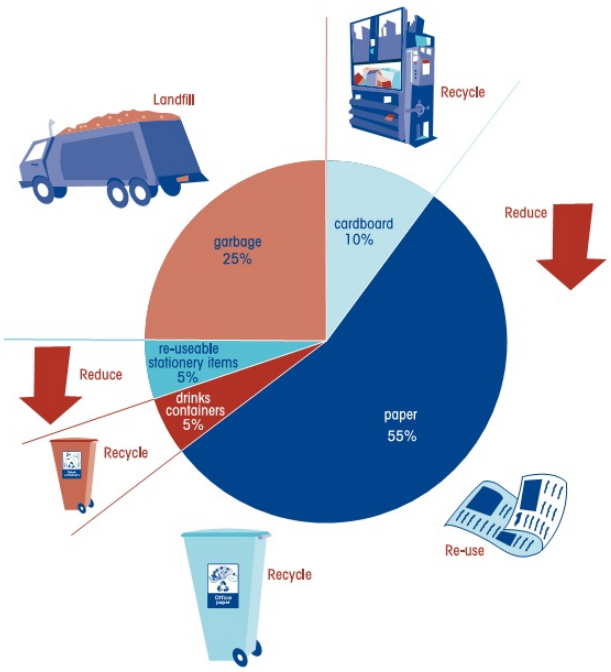


Figure 3: Composition of "typical" office tower waste

2. **Signs and bin labels**: Bin labels should be clear and be able to be read from five metres away.
3. **Posters**: Putting up posters near central recycling bins will let people know what can and can't be recycled. It will also remind people to use the recycling bin. Posters should be clear and eye catching. A sample poster is shown in Figure 5.
4. **Memos/email**: A quick memo or email from management asking everyone to recycle their waste paper and print/copy double-sided will help reinforce the Bernoulliborg's commitment to recycling and to the environment.
5. **Feedback and rewards**: Giving feedback is very important, as it acts as a reminder and keeps people on track. If the feedback can be linked with a reward, then it will greatly improve the chance of the recycling system working.

2.2.3 People in charge

Building management department should be in charge of waste reduction program and retrofitting the water system.

2.2.4 Financial estimation

The investment for the waste reduction program is not big, but this would be not only good for the environment and good for staff morale, but would save money. The following cost estimated are obtained and shown in Table 3.

Figure 4: New recycle containers at coffee corners

Table 3: Estimated investment for waste reduction program

Item	**Description**	**Price**	**QTY**	**Total**
Recycle Containers	Several types of container used fordrinks containers, cardboard, organic waste	€10	50	€500
Posters and bin labels	Several posters and bin labels used to hang at proper locations	€7	50	€350
Labour	Worker who will install new devices (man-month)	€2,166	0.5	€1,083
Total:				**€1,933**

2.3 Energy Savings

The Bernoulliborg has already been focusing on saving energy inside building. However, there are still lots of spaces for improvement of energy efficiency at Bernoulliborg.

This plan propose energy saving solutions to not only improve the efficiency of lighting system but also to save energy consumed by plug loads. Moreover, a decision-support system will be implemented to provide assistive information and advices on heating, ventilation, and air conditioning (HVAC) system.

2.3.1 Goals

Bernoulliborg will **save at least 7.7% and up to 18.2% of power consumption, or 107,513 KWH to 245,112 KHW annually.** This is achieved through following smaller goals:

1. **Up to 25% of energy saving from lighting**: 25% more of energy consumption for lighting in Bernoulliborg could be saved with smarter proposed lighting control solution.

Figure 5: Waste classification poster

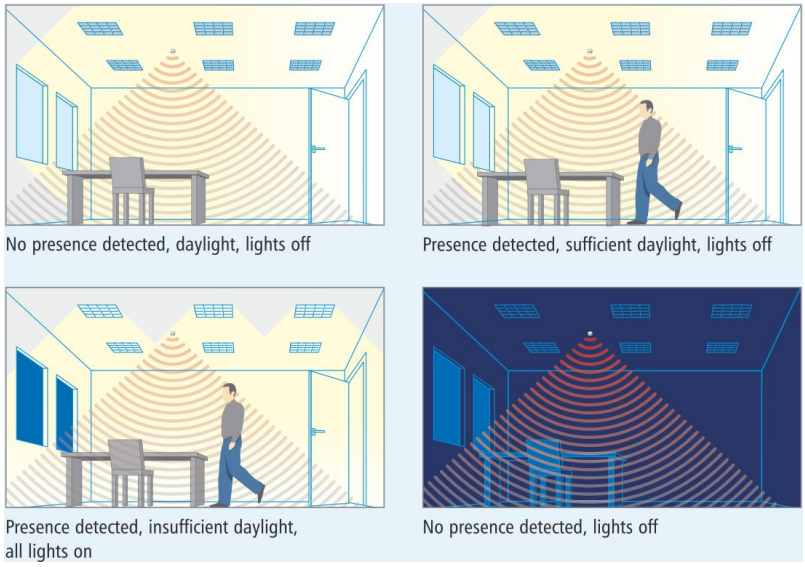
2. **10% energy saving from plug loads**: 10% of energy consumption for plug loads (e.g. coffee machines, fridges, microwaves, etc.) could be saved with our solution.
3. **HVAC control strategies based on occupancy monitoring and local weather information, possibly resulting in 10% of potential energy saving**: We propose a decision-support system that provides HVAC control strategies based on occupancy information and local weather conditions. The expected energy saving potential is 10% if the HVAC system is controlled accordingly.
4. **Real-time power consumption tracking**: Real-time power consumption of each subsystem, (i.e. HVAC, Light, Plug loads), each type of devices (e.g., PCs, Coffee machines, Microwave, etc.), or each area (e.g. each floor, restaurant, lecture rooms, etc.) is tracked and shown in a real-time utility display.

2.3.2 Lighting control

Strategies

Bernoulliborg, with its highly efficient light fixtures and bulbs, good lighting layout design, and Passive Infra-Red lighting controllers, already lowers the amount of electricity

consumed by the building, nevertheless there are still rooms for significant improvements. We propose a solution which not only enhances occupancy-based control but also realizes a daylight harvesting system, resulting in **25% energy saving for the lighting system of Bernoulliborg**. Our solution is generally represented in Figure 6.



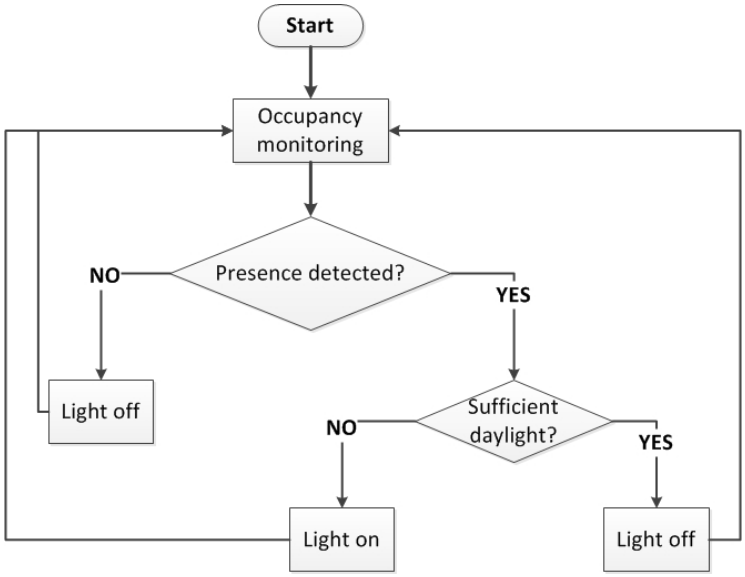


Figure 6: Proposed lighting control solution which not only enhances occupancy-based control but also realizes a daylight harvesting system.

- **Smarter occupancy-based control**: The sensors, which are currently being put to use, have a preset user adjustable time delay (TD) the time after which the lights or any other load will be switched "off" after the last motion is detected by the sensor.

The current preset TD is not sufficient enough, during the working hours (09:00 uur to 18:00 uur) the TD is long then, it has less energy savings, as the lights remain "on" during unoccupied period also. As an example, at 12:00, we usually go to the restaurant for lunch in one hour and when we come back at 13:00 the lights are still "on". At the same time, the TD is kept short after working hours (after 18:00 uur) and it results in unwanted switching "off" while we are still working in the office.

We propose design of smart occupancy sensors which can adapt to changing activity levels. Also, the system is able to detect "working with PC" as "human movement", thus increasing the accuracy of occupancy detection. Smart occupancy sensor can learn the variation in activity level of the occupants with respect to time of the day. With this information, it can change the TD with time of the day. Experiments conducted have shown that about 5% more energy can be saved by using smart occupancy sensor as compared to non-adapting fixed TD sensors [2].

- **Daylight harvesting**: Research indicates that daylight can improve user satisfaction/performance. Daylighting also enables daylight harvesting, an innovative control strategy that can generate 35-60+% energy savings[3]. A daylight harvesting system decreases electric light contribution as the daylight contribution increases. We also propose a daylight harvesting solution that can at least 25% more power consumed by lighting system inside Bernoulliborg.

Totally, our new lighting control system results in 25% energy saving from lighting.

Sensor used
In order to implement the above proposed solution Bernoulliborg needs to be equipped with programmable switching detectors with Lux level sensing.

People in charge
Our distributed systems group is responsible for design and implement the lighting control system. Building management department should be in charge of installing new sensors and devices.

Financial estimation
Money invested for lighting system is detailed in Table 4.

2.3.3 Strategies for plug loads control

Strategies
For plug load control, we also presented an approach to controlling offices to save energy. The approach is based on (1) monitoring the energy consumption at the device level, (2) monitoring energy production of small-scale generating units, (3) associating policies for the devices which conform with user requirements for comfort and productivity, (4) controlling in an optimal way the energy consumption patterns of devices following the usage policies.

[3] `http://lightingcontrolsassociation.org/`

Table 4: Estimated investment for lighting control system

Item	**Description**	**Price**	**QTY**	**Total**
Switching detectors	Programable wireless switching detectors with Lux level sensing	€125	150	€18,750*
Developer	Developer who will design and implement the control system (man-month)	€3,392	4	€13,568
Worker	Worker who will install new devices (man-month)	€2,167	3	€6,501
Total:				**€38,819**

**: Calculations are based on real offer from company with 30% discount*

Here, we present the main idea of our solution. Detailed system architecture and the implementation of our system are described in our paper [3].

The system consists of the several components (listed below) which provide the main functionality of cutting the unnecessary electricity dissipation by turning off the devices when they are not supposed to be used. To control the devices we use *Plugwise adapters*[4] consisting of plug-in adapters that fit between a device and the power socket. The adapters can turn the plugged mains device on and off, and can at the same time measure the power consumption of the device that is attached. The plugs are called 'Circles' and they form a wireless ZigBee mesh network around a coordinator (called 'Circle+'). The network communicates with the Controller through a link provided by a USB stick device (called 'Stick'). We have deployed the system in our own offices. The test site consists of three offices occupied by permanent and PhD staff, a coffee corner/social area and a printer area. The layout is illustrated together with the ZigBee network and the electrical appliances in Figure 7. The results shown that on average the savings in energy consumed between the situation without the scheduling policy and the situation considering it, is more than 15%. However, we set **the expected energy saving potential from plug loads control is 10%**.

Device used

In order to implement the above proposed solution plug loads need to be equipped with Plugwise system.

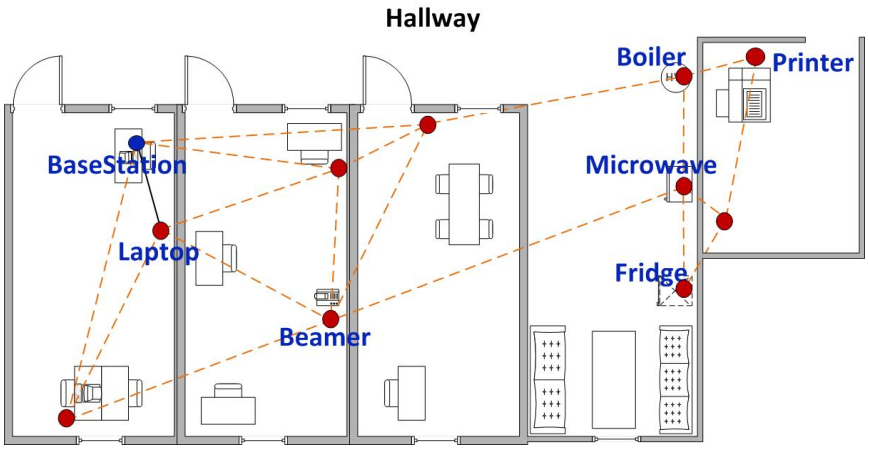
People in charge

Our distributed systems group is responsible for design and implement the lighting control system. Building management department should be in charge of installing new sensors and devices.

Financial estimation

[4] `http://www.plugwise.com`

(a) Plug loads are plugged into Plugwise adapters



(b) The layout together with the ZigBee network and the electrical appliances.

Figure 7: Real living lab is running in our offices at the 5th floor of Bernoulliborg

In order to come to exact price of hardware, first we need to know the number of controllable devices inside the Bernoulliborg. Regarding the base station, only two servers (main and backup) are sufficient to cover the plugwise network of whole building. Therefore, according to the information from Facility Manager Nijenborgh, Mr. Edwin van Burum, number of rooms and devices is represented in Table 5. Thus, money invested for plug loads control system is detailed in Table 6.

Table 5: Number of controllable devices

Type of rooms	**No. of rooms**	**Plugwise/room**	**Device/room type**
Office	180	2	360
Meeting room	8	1	8
Lecture room	16	2	32
Social corner	6	4	24
Facility corner(printers)	3	3	9
Total:			**349**

Table 6: Estimated investment for plug loads control system

Item	**Description**	**Price**	**QTY**	**Total**
Plugwise	Circles, Circle+s, and Sticks	€35	349	€12,215*
Servers	Servers on which the control system runs	€2,500	2	€5,000
Developers	Developer who will design and implement the control system (man-month)	€3,392	3	€10,176
Total:				**€27,319**

**: Calculations are based on real offer from company with 30% discount*

2.3.4 Strategies for HVAC decision support system

Strategies

In 2011, approximately 50% of the electricity in Bernoulliborg was used for HVAC systems. This significant number attracts our focus on proposing a solution to improve the efficiency of HVAC systems. We propose for monitoring and detecting the occupancy information of every area inside Bernoulliborg. Then this occupancy information, coupled with weather forecast information, works as the input of a decision support system that provides HVAC control strategies based on occupancy information and local weather conditions. Conclusion from our paper [4] indicates that it is possible to achieve 20% to 30% annual energy savings while still maintaining user's comfort.

- **Occupancy monitoring**: Currently, Bernoulliborg still conditions rooms assuming maximum occupancy rather than actual usage. As a result, rooms are often over-conditioned needlessly. Thus, in order to achieve efficient conditioning, HVAC control requires knowledge of occupancy. Fortunately, thank to the occupancy detection system that is used also for lighting control system we are able to provide occupancy information as input for HVAC control decision.

- **Local weather conditions**: Beside occupancy information, local weather conditions (e.g. outdoor temperature and wind speed) are also taken into account.

  Example scenario: Our decision support can provide precise occupancy information

from detection system coupled with the usage schedule of lecture halls which are heated independently from other block of BernoulliBorg. With this information, HVAC system can be controlled more customarily for lecture halls, satisfying usage needs and saving energy at once.

The expected energy saving potential is from 10% if the HVAC system of Bernoulliborg is controlled accordingly.

People in charge
Our distributed systems group is responsible for design and implementing the HVAC decision support system.

Financial estimation

The investment is mainly for developers to design and implement the system. Costs estimated are represented in Table 7.

Table 7: Estimated investment for HVAC decision support system

Item	**Description**	**Price**	**QTY**	**Total**
Developers	Developer who will design and implement the decision support system (man-month)	€3,392	2	€6,784
Total:				**€6,784**

2.3.5 Real-time power consumption tracking and utility display system

Strategies
Occupants of Bernoulliborg can see their electricity, and water consumption in real-time on a touch screen in the lobby just inside the front doors. These systems are expect to reduce consumption, because occupants are constantly reminded of how much resources are being consumed and they can see the results when they push to conserve.
Real-time power consumption of each subsystem, (i.e. HVAC, Light, Plug loads), each type of devices (e.g., PCs, Coffee machines, Microwave, etc.), or each area (e.g. each floor, restaurant, lecture rooms, etc.) is tracked and shown in a real-time utility display. It is very optimistic to realize the utility display system because we already have Plugwise adapters equipped for plug loads control system, and the power and water consumption information that is currently monitored by Bernoulliborg management system. An example screenshot is shown in Figure 8.

People in charge
Our distributed systems group is responsible for design and implement the utility display system.

Financial estimation
Money invested for real-time utility display system is detailed in Table 8.

Figure 8: Screenshot of Real-time Utility Display

Table 8: Estimated investment for real-time utility display system

Item	**Description**	**Price**	**QTY**	**Total**
Developers	Developer who will design and implement the real-time utility display system (man-month)	€3,392	2	€6,784
Total:				**€6,784**

3 Financial plan

3.1 Installation costs

From the financial estimations for each of the solutions above, the total investment for the project is summed up in Table 9.

Table 9: Estimated investment for real-time utility display system

Item	**Money**
Water Saving Program	€8,533
Waste Reduction Program	€2,083
Lighting Control System	€38,819
Plug loads control system	€27,319
HVAC decision support system	€6,784
Real-time utility display system	€6,784
Total	**€90,322**
Arising costs (≈10%)	€9,678
Total investment	**€100,000**

3.2 Payback periods

Before coming to the detail analysis of money saving as well as the return on investment time, we list here facts, assumptions, and expected goals.

3.2.1 Facts and Assumptions

Here are some facts about annually electricity and water consumption of BernoulliBorg
– **Facts**

- **Electricity consumption**
  1. Annually (2011) electricity consumption of BernoulliBorg: **1,396,276 KWH**.
  2. Current price for electricity is: **€0.1181 per kWh.**
  3. HVAC system accounts for 56% of total electricity consumption.
  4. The other 44% equally goes to lighting system and plug loads, 22% each.
- **Water consumption**
  1. Annually (2011) water consumption of BernoulliBorg: **3000** m^3
  2. Current price for water is: **€2.2 per** m^3**.**

– **Assumptions**
Besides, We calculate the money savings, assuming that

- Electricity and water price will not change/increase in the next 7 years.
- Electricity and water demand will not change/increase in the next 7 years.

3.2.2 Our commitment to the return on investment time: 7 years

After carefully analysing the abilities of our proposed solutions, together with information provided from Bernoulliborg's managers, our commitments in savings are

- **Electricity savings**
  1. **25% of electricity for lighting**, equivalent to 25%*22% = **5.5% of total building consumption.**
  2. **10% of electricity for plug loads**, equivalent to 10%*22% = **2.2% of total building consumption.**

  These savings result in **7.7% of total BernoulliBorg electricity saved**, equivalent to 7.7%*1,396,276 KWH = **107,513 KHW** per year, or 107,513KHW*0.1181€/KWH = **€12,697 saved annually.**
- **Water savings**
  – **45% of total BernoulliBorg water consumption**, equivalent to 45%*3,000m^3 = **1,350**m^3 **water saved** per year.

  This saving results in 1,350m^3*2.2€/m^3 = **€2,970 saved annually.**

Table 10: Our commitment to the payback period

Savings	**year*1**	**year*2**	**year*3**	**year*4**	**year*5**	**year*6**	**year*7**
Electricity 7.7%	12,697	25,394	38,091	50,788	63,485	76,182	88,879
Water 45%	2,970	5,940	8,910	11,880	14,850	17,820	20,790
Total money saved	15,667	31,334	47,001	62,668	78,335	94,002	**109,669**

Unit: €

From the above commitments to energy and water savings, we summarize the return on investment time in Table 10. **Evidently, our commitment to the return on investment time is 7 years.**

3.2.3 Further expected savings

More than what we commit, we foreseen positive results that are likely to be achieved.

1. **Further saving expectations from HVAC system**
   - **Save 10% of electricity for HVAC system**, equivalent to 10%*56% = **5.6% of total building consumption.**

     With the use of the proposed decision support system for HVAC control that we described in Section 2.3.4, it is likely to achieve 10% more of electricity consumption spent for heating, ventilation, and air conditioning. Please refer to the **Example scenario** we presented in Section 2.3.4 for a positive result that is likely to be achieved.

   This 5.6% further expected savings, together with **7.7% from our commitments** gives us **13.2% saving of overall electricity consumption**, equivalent to 13.2%*1,396,276 KWH = **184,308 KHW** per year, or 184,208KHW * 0.1181 €/KWH = **€21,767 saved annually.** Expected money saved in seven years is calculated in Table 11.
2. **Further saving expectations from changes in occupants' behaviours**
   - **5% of overall electricity saving could be expected from the changes in occupants' behaviours**.

     Occupant behaviour in buildings have been shown to have large impacts on space heating, cooling and ventilation demand, energy consumption of lighting and space appliances, and building controls. Careless behaviour can add one-third to a building's designed energy performance, while conservation behaviour can save a third [4]. Thus we expect that the campaign for a sustainable Bernoulli-Borg will positively change our colleagues' behaviours and attitude, saving more energy and water used and reducing waste.

   This **5% further expected savings** plus **5.6% from HVAC control** plus **7.7% from our commitments** equals to a great **18.2% saving of overall electricity**

Table 11: Our further expectations to the payback period

Savings (%)	**year*1**	**year*2**	**year*3**	**year*4**	**year*5**	**year*6**	**year*7**
Commitment (see Table 10)	15,667	31,334	47,001	62,668	78,335	94,002	109,669
From behaviour changes: 5%	8,245	16,490	24,735	32,980	41,225	49,470	57,715
Subtotal	*23,912*	*47,824*	*71,736*	*95,648*	*119,560*	*143,427*	***167,834***
From HVAC control: 5.6%	9,234	18,468	27,702	36,936	46,170	55,404	64,638
Total	33,146	66,292	99,483	**132,584**	165,730	198,876	**232,022**

Unit: €

consumption, equivalent to 18.2%*1,396,276 KWH = **245,122 KHW** per year, or 107,513 KHW * 0.1181 €/KWH = **€30,012 saved annually.** Positive expected 7-year money saved is also clarified in Table 11.

3.2.4 Discussions

First and foremost, **our commitments is that our solutions will result in at least 7.7% of electricity saving and 45% in water saving**, guaranteeing **the return on investment time within 7 years.**

The commitments are proposed with assumptions that the demand and price of electricity and water will not change in the next seven years. In fact, the number of staff and students at BernoulliBorg will likely to grow with the development of University of Groningen, leading to an increase in electricity and water demand. Moreover, the price will increase without much doubt. These may even shorter the return on investment time.

Thirdly, while impacting the current HVAC system of BernoulliBorg is not easy because of its pre-installed infrastructure and its effect to the thermal comfort of staff and students, however, our proposed decision support system for HVAC control bring supportive information (e.g. real time and scheduled occupancy information of each room and lecture hall) to building managers, makes it possible to achieve 3% to 5% or even more of electricity saved. A looked-small percentage results in a fairly large money saving at the end.

Last but not least, we strongly believe that changing behaviour of our colleagues is more optimistic and likely to be achieved once we motivate and encourage building occupants. This project - **"BernoulliBorg - The building of SUSTAINABILITY"** - will work as a perfect campaign to promote all BernoulliBorg's citizens to make a very small change in their behaviour, leading to one significant step ahead of sustainability.

3.2.5 Maintenance costs

Certainly, it goes without considering the maintenance costs for the systems. Thus we suggest that a certain amount of saved money should be used cover the maintenance or adaptation costs that might arise once the systems are deployed. For example, consider the case of expected saving with behaviour changes shown in Table 11, if we determine the payback time in 7 years we are going to have **€67,834** to cover maintenance costs in seven years.

4 Innovations

As the University dedicates in the call for Green Mind Awards,

> *"Sustainable projects are nothing new at the University of Groningen most notably at the Zernike campus...*
> *...The idea is not to have measures imposed by some outside consultancy but to go for 'home-grown' ideas. Given that the few square kilometres that the University covers contain the highest concentration of knowledge and in all Groningen, this of course should not be a problem."*

Our project provides plenty changes for our staff and students to innovate for our University Sustainability, **for Infinity**. All systems are designed and implemented by staff and students at Distributed systems group - JBI - FWN:

- ✓ **"RuG-made" light control solution**
- ✓ **"RuG-grown" plug loads control solution**
- ✓ **"RuG-spun" real-time utility display**
- ✓ **"RuG-native" HVAC decision-support system**

Students of our University will be involved naturally.

- ✓ **Five Master Theses in Computer Science will be done**
- ✓ **10 Bachelor Theses in Computer Science will be done**

5 BernoulliBorg Sustainability Missions

If the project is financed it can support the University to be one step ahead of sustainability.

- The proposed solutions help Bernoulliborg to fulfil all credits in the BREEAM-NL program, **achieving BREEAM-NL excellent certificate**.

- Furthermore, the integrated design and a commitment to sustainability made **Bernoulliborg an enjoyable and healthy place to learn, work and lowered the impact on the local and global environment.**

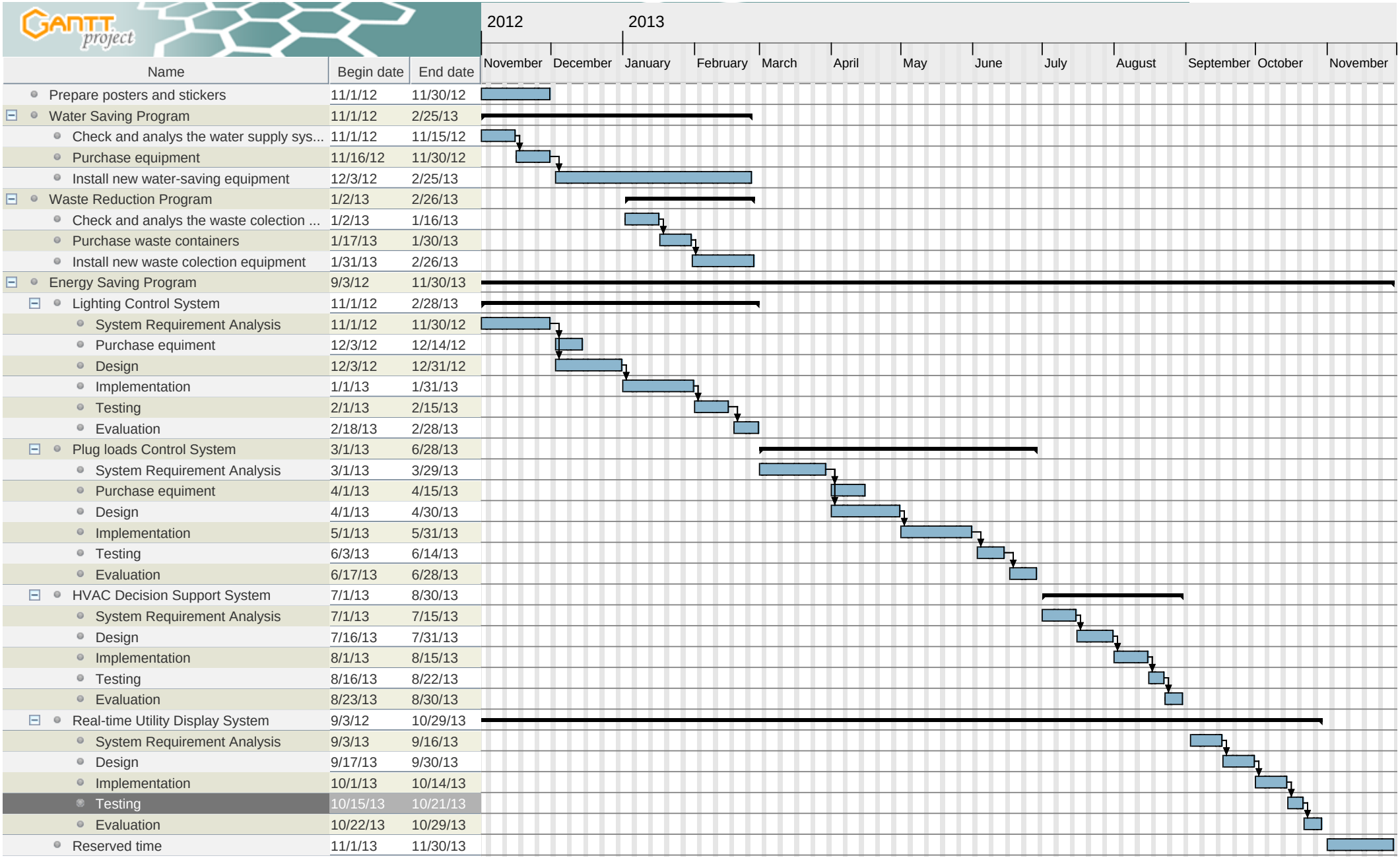
6 Realization

The project will be hosted by Distributed Systems Group, lead by Marco Aiello, that has two permanent staff members, 8 PhD students, plus supporting staff. The group is active on research on middleware, service oriente computing, and pervasive systems. It has a strong publication record and experience in projects at the national, EU and Asiatic level. Particularly in the area of Green Buildings, the group is currently running Energy Smart Offices - EnSO[5], funded by The Netherlands Organisation for Scientific Research (NWO)[6], and GreenerBuildings project[7], funded by the European Seventh Framework Programme (FP7)[8]. Our strong record gives a high guarantee of the success of the project.

Gantt Chart
Realization of the project will begin by the in November 2012, as soon as the price winners are announced, and it will finish within one year, before 1 November 2013. Gantt chart representing all tasks and their duration is shown below.

[5] `http://www.ensoffices.nl/`
[6] `http://www.nwo.nl/`
[7] `http://www.greenerbuildings.eu/`
[8] `http://cordis.europa.eu/fp7/home_en.html`

Gantt Chart



Name	Begin date	End date
Prepare posters and stickers	11/1/12	11/30/12
Water Saving Program	11/1/12	2/25/13
Check and analys the water supply sys...	11/1/12	11/15/12
Purchase equipment	11/16/12	11/30/12
Install new water-saving equipment	12/3/12	2/25/13
Waste Reduction Program	1/2/13	2/26/13
Check and analys the waste colection ...	1/2/13	1/16/13
Purchase waste containers	1/17/13	1/30/13
Install new waste colection equipment	1/31/13	2/26/13
Energy Saving Program	9/3/12	11/30/13
Lighting Control System	11/1/12	2/28/13
System Requirement Analysis	11/1/12	11/30/12
Purchase equiment	12/3/12	12/14/12
Design	12/3/12	12/31/12
Implementation	1/1/13	1/31/13
Testing	2/1/13	2/15/13
Evaluation	2/18/13	2/28/13
Plug loads Control System	3/1/13	6/28/13
System Requirement Analysis	3/1/13	3/29/13
Purchase equiment	4/1/13	4/15/13
Design	4/1/13	4/30/13
Implementation	5/1/13	5/31/13
Testing	6/3/13	6/14/13
Evaluation	6/17/13	6/28/13
HVAC Decision Support System	7/1/13	8/30/13
System Requirement Analysis	7/1/13	7/15/13
Design	7/16/13	7/31/13
Implementation	8/1/13	8/15/13
Testing	8/16/13	8/22/13
Evaluation	8/23/13	8/30/13
Real-time Utility Display System	9/3/12	10/29/13
System Requirement Analysis	9/3/13	9/16/13
Design	9/17/13	9/30/13
Implementation	10/1/13	10/14/13
Testing	10/15/13	10/21/13
Evaluation	10/22/13	10/29/13
Reserved time	11/1/13	11/30/13

7 Acknowledgement

The authors would like to thank to Dick Jager (Health, Safety and Environment Department), Edwin van Burum (Facility Manager Nijenborgh), Kor Smit (Energy and Water Manager from Facility Service of University of Groningen), Maya Koekoek (Buildings Manager Nijenborgh 4 and Bernoulliborg) and Helga Emmens (Project officer, Faculty of Mathematics and Natural Sciences) for providing the necessary information for preparation of this document.

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