European Project Semester 2010

Final Report

"Nanotechnology for Energy Saving. Nano-Product (System)-Concept Design"

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International Faculty of Engineering

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1. Team Building Part

1.1. Team

The name of our team, nano comes from our project description. Our team was formed to study nanotechnology for energy saving. The conception for the name and logo came up at an internal meeting during the forming stage of our project. It is grey green. Its colors resemble technology (grey) and care about the environment by saving energy (green). We also established the slogan:

"We may be small but we think big!"

It refers to our aim, and the aim of nanotechnology, to achieve impressive results in energy saving with the use of very small things. Another aspect is that our team is small but we want to plan excellent solutions for the future.

1.2. Team Profile

During a Team Building course we have made the Belbin test in order to estimate our strengths and skills which could be best used during our project. This helped us to organize the work. However we didn't follow much the guidelines suggested in this test. We divided the roles equally so that each of us was always occupied with work.

- Now we would like to focus on each team member separately.

Sean McManus. Scotland 

Sean is a 21 year old student from Scotland. He studies Chemical Engineering at Strathclyde University. Thanks to him we had help in the chemistry of nanomaterials. In our team his responsibilities were:

- Look for fresh ideas
- Do research on nanotechnology
- Write final report (solar cells & Fuel cells)
- Prepare of Midterm and Final Presentations
- Help us with his native English skills

Katarzyna Przybyt. Poland 

Kasia is 22 year old student at Politechnika Łódzka. She studies Biotechnology. Thanks to this project she could broaden her horizons. She knew little about nanotechnology however she learned quickly and was helpful. In our team her responsibilities were:

- Organize work within the team
- Do research
- Lead meetings
- Prepare and putting together Team Building, Midterm and Final Presentations
- To prepare graphic design of logo and presentation schemes
- Write final report (Batteries, Team Building Part)

Rosalía Ribela Rodríguez. Spain 

Rosalía, 27, from Spain is a Chemical Engineering student at the Technical University of Catalonia. Like Sean she helped us understand the chemistry of nanotechnology. At the beginning her language skills constrained her but later she became a very active member. In our team her responsibilities were:

- Write the Meeting Agendas
- Do research
- Write and putting together the final report (Wind generators, House description)
- Make midterm and final presentation
- Help us in building the proper content of report

Juan Riera Bauzá. Spain 

Joan is a 30 year old student who comes from Spain. He studies Electrical Engineering at the Technical University of Catalonia. Thanks to his knowledge we had a lot of help in the field of electricity and electronics. He was also very eager to both help and work within the team. In our team his responsibilities were:

- Secretarial duties
- Find new ideas
- Do research
- Write and putting together a final report (Conversion, Lightning System, Biogas)
- Make midterm and final presentation
- Help us in understanding the electrical part of our project

Piotr Skusiewicz. Poland

Piotrek, 22, comes from Poland. First, he studied Electrical Engineering but he changed it for Mechanical Engineering. Thanks to his former studies he was very helpful in the electrical and electronic part of the project. In our team his responsibilities were:

- Provide fresh ideas
- Do research
- Write the final reort (insulation, buckypaper)
- Prepare report from laboratories
- Make midterm and final presentation

Overall, our team cooperated very well even if the Belbin test showed us that we might have some problems with finishing the project and finding new ideas and information. We followed the indicated rules and values, avoided conflicts and we always reached a consensus during discussions. Our meetings were always productive (meeting Agendas from meetings with the supervisor and Internal ones can be found in Appendix) and helped us to organize work and move forward.

1.3. Methods of work

During our Team Building classes we established ground rules and values that will help us in the course of project.

TASKS

- Set small and big goals.
- Make decisions with discussions and compromising.
- Solve problems → discussion.
- Evaluate the project regularly → prizing, success but not necessary.
- Manage meetings with the supervisor, with ourselves. The meetings are obligatory on Wednesday.
- Determine roles and responsibilities. → roles are not necessary.
- Give and receive info → presentation (inside the group).
- Recognize and awarding accomplishments is not necessary.

INTERPERSONAL RELATIONSHIPS

- Encourage everyone’s participation by helping, good relationships.
- Better understanding group dynamic by discussion and evaluation of tasks and keeping good relationships.

- Give and solicit constructive feedback will be made by discussion, during meetings.
- Managing conflict by solving problems during discussion (problems, feelings) and compromising.
- Dealing with gossip by speaking out loud, discussing, speaking clearly and honestly, solve problems.
- Improve listening by helping each other, be patient.
- Acknowledge and respect individual differences by keeping rules of good relationships. Respecting each other.
- Present ourselves to others outside the team.
- Build trust by following the rules. Solving problems and understanding that we are a TEAM not INDIVIDUALS.

THE RULES OF THE TEAM

- We set small and big goals by discussion, our biggest success will be accomplishing them on time.
- At our regular meetings we:
  - evaluated process
  - solved problems
  - shared knowledge
  - shared responsibilities
- To have a good team, all members participate, are honest, ask and answer questions, give and receive constructive feedback.
- We have to remember that to build trust we need to follow the rules and understand that we are a TEAM not single beings.

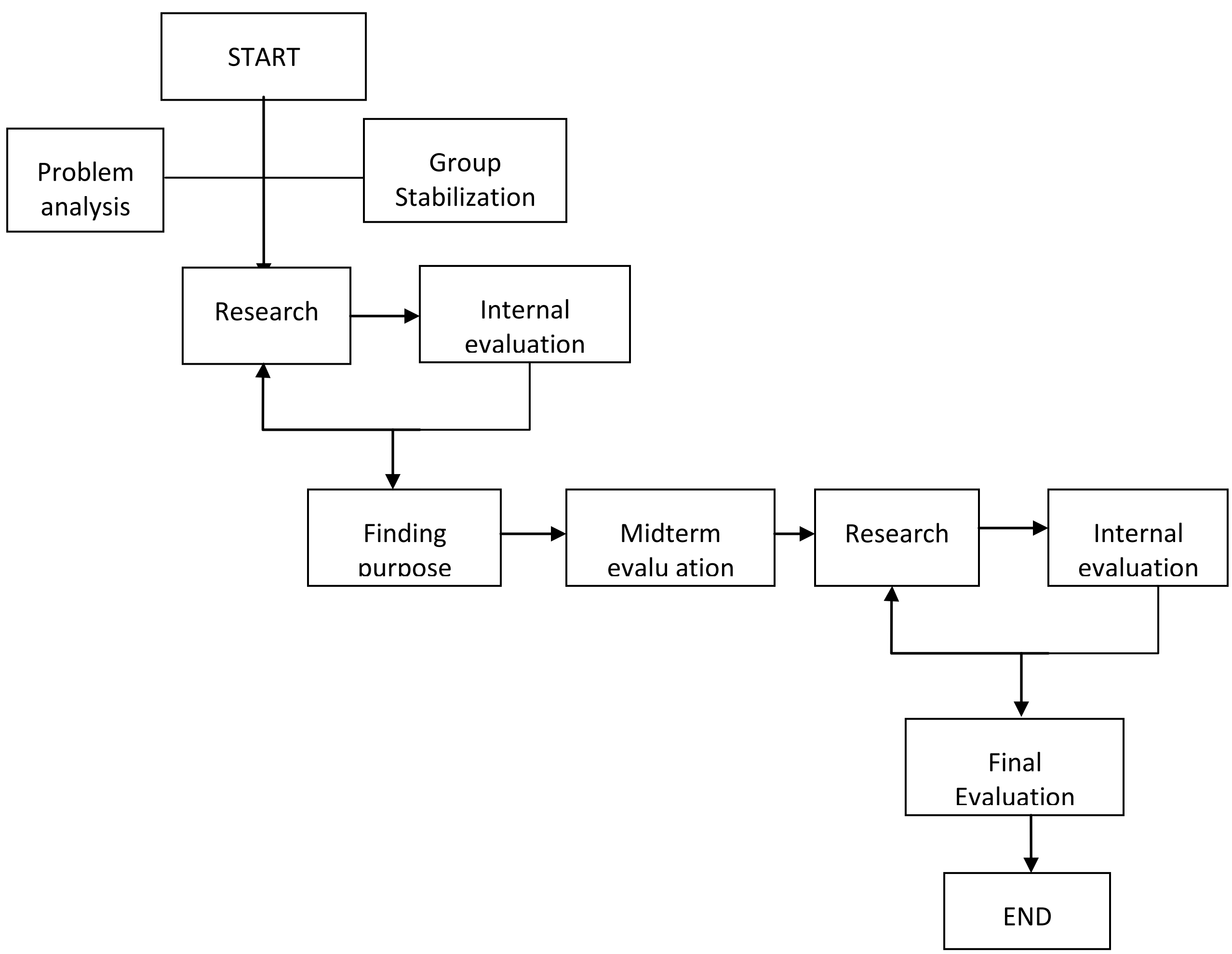
1.4. Project Progress

At the beginning we divided our project into 15 weeks and designed a rough system of work that was later upgraded.

STAGE	Introduction & Storming			Norming			Performing						Finishing		
WEEK	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

In first three weeks we established fundamental rules for our team and performed team building exercises in order to help our team integrate. In the Norming stage we held a major presentation on Team Building. The Performing Stage began with a Midterm presentation that showed our progress on building the team, we also presented our objectives for this project (Designing and feasibility study of a house powered by nanotechnology, and building and testing a nanocapacitor). At this stage we had a lot of internal presentations that helped us understand new ideas and gather information. In 13th week of the project we gathered all the information and ideas and formulated the content of report. Then we shared the responsibilities and started writing the report. When we were at the end of writing the final report we started working on the final presentation, which will be held in 15th week of our project.

To organize our work system we designed the action plan shown in the picture below.



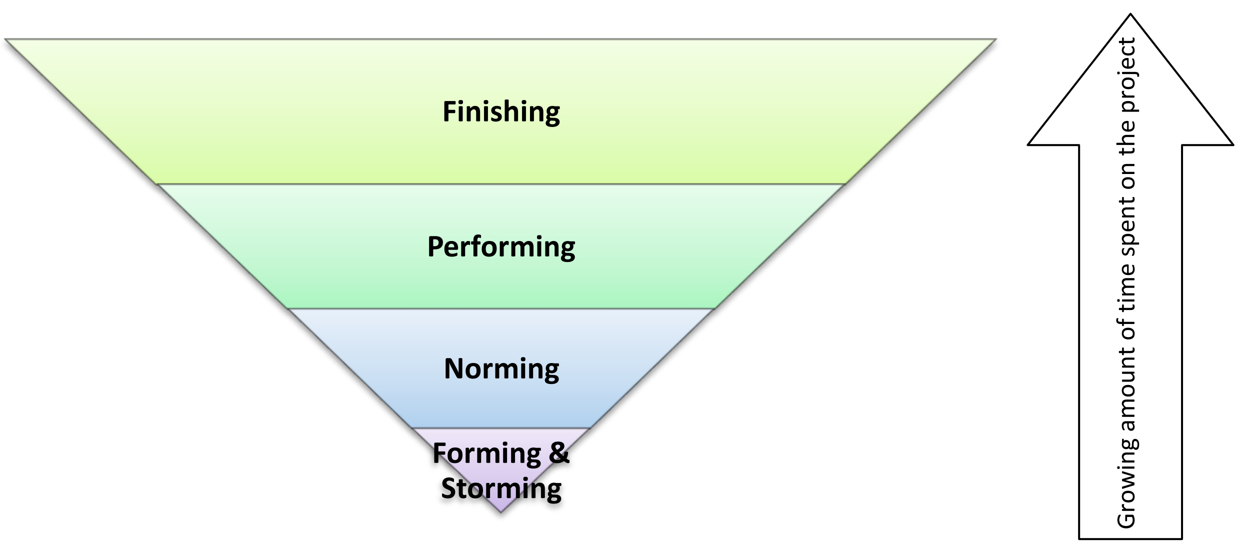
Our project began with group stabilization and problem analysis, then we started looking for information regarding our project. We had done internal evaluation to discuss the ideas and decide on further research. After this loophole we found the purpose and objectives of the project that were presented at the midterm evaluation. After this, in the performing stage we again looked for ideas and information and made an internal evaluation to see our progress. Thanks to this we gathered enough information to start writing the final report and making the final presentation, which will be presented at final evaluation, and after the approval of our work we will finish our project.

1.5. Record of Work

It was assumed during this one semester project that we will spend around 90 class hours on learning. We did not spend this amount on time only at IFE and in meetings with the supervisor. Additionally, we spent even more hours on doing research, finding new ideas and developing knowledge both on our own and together.

In the course of the project we held 15 meetings with the supervisor, which amounts to one meeting per weekend, however it was not like that. The exact schedule of meetings can be found in the calendars in the appendix. We also held 12 internal meetings that supplemented meetings with the supervisor and helped us to organize our work. The schedule as well as agendas (both internal meetings and meetings with the supervisor) can be found in the appendix.

As mentioned, our project took us more than 90 hours but we did not take the record of time spent on work. We can represent our workload by an inverted pyramid that can be seen below.



One can see that the amount of time we spent on the project was constantly growing. During the Forming and Storming stage we did little work, only team building exercises, as well as were introduced to our project by the supervisor. In the norming stage, apart from team building exercises, we started looking for information about nanotechnology, we had one major internal evaluation and we found the objectives. The time input slightly increased. Then we entered the Performing stage and started hard work on the project. The last stage, Finishing, lasted for only 2 weeks but the amount of work was really large, we had to gather all the information and ideas, write the final report and make the final presentation.

In order to help organize work we used an internet based working platform called Achievo. Then, because of its very slow operation we changed for Google products (Gmail, Google Calendar, Google Docs) where we gathered all our documents and schedules as well as To Do lists. In the appendix one can see printouts from Google Calendar. We found it very helpful because all of our information and ideas are stored in one easily-accessible place.

2. Objectives of the Project

This project aims to investigate possible energy savings that nanotechnology can bring to a conventional house and build and test a capacitor constructed with bucky paper in the laboratory.

2.1. Study energy saving house by applying nanotechnology.

To accomplish the first objective, we will focus on four main areas:

- Generation: How to improve solar panels, fuel cells and wind turbines. These devices allow us to generate energy through natural sources, like the sun and wind and reduce the use of energy sources, traditional finite and polluting, such as crude oil.
- Conversion: How to improve lighting and appliances to avoid a significant loss of energy when converting electricity into light or running appliances. Also to use the organic matter and convert waste into biogas.
- Insulation: How to increase the isolation of a house using nanomaterials to help keep the house warm in winter and cool in summer, therefore saving on heating and air conditioning expenses.
- Storage: How to improve batteries and capacitors to increase energy storage capacity so that it can be accessed when needed.

2.2. Construct a Capacitor with the use of bucky paper

To complete the second goal, in the laboratory we will build a bucky paper capacitor and also compare it with standard and super capacitors.

3. Analysis of location and size of a house

3.1. Analysis of location of a house

The house is located in Dziwnow, Poland.

Illustration 1 Location Dziwnów in the map
Picture taken from http://en.wikipedia.org/wiki/Dziwn%C3%B3w

Dziwnow is a town in north-western Poland situated on the Baltic Sea at the mouth of the river Dziwna.

Illustration 3 Dziwnów **Picture taken from www.skyscrapercity.com**

Illustration 2 Dziwnów **Picture taken from www.digitalphoto.pl/foto3/8885_b.jpg**

It is interesting to develop our project by locating a house in Poland, which is the country where we are.

To choose the place where we have located the house in Poland, we have analyzed the annual average wind speed, the impact of solar radiation and the mean annual temperatures in the country.

- **Mean wind speed** [1][2]

For the good production of electricity through wind power, the best location to install a wind turbine is open access so that it can catch the full force of the wind. The locations near the coast have the highest wind speeds and the region is more wind.

The most important thing is not the greatest speed but the number of hours that the wind speed is above 4 m/s. So for both reasons it is useful to estimate the average wind speed of the desired location.

To estimate the annual average wind speed wind maps, like the one shown below, of the last five years in Poland were analyzed.

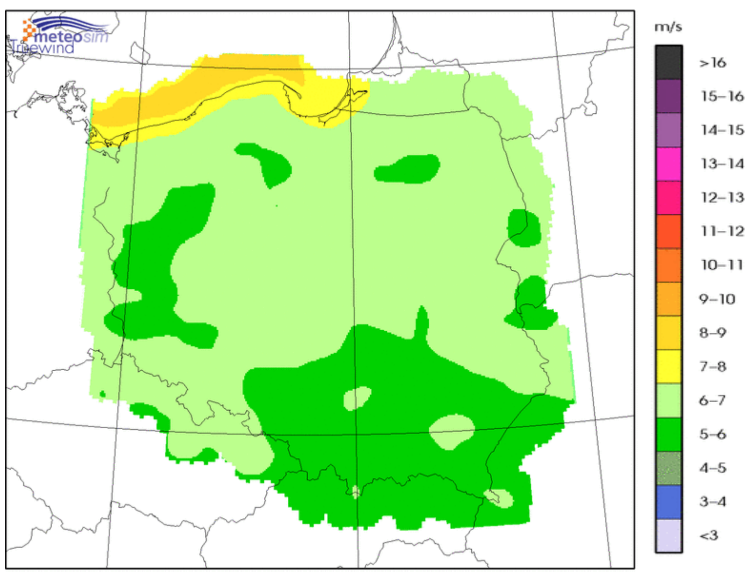


Illustration 4 Map of wind speed

Map taken from http://windtrends.meteosimtruewind.com/es/

The map shows that the area with the mean annual wind speed higher than 4m/s is the country's northern coast in the Pomeranian and West Pomeranian regions.

- **Solar radiation**

To determinie whether the location is also convenient for installing photovoltaic solar panels to produce electricity from light, we analyzed solar radiation maps and the presence of shadows coming from high buildings or plants.

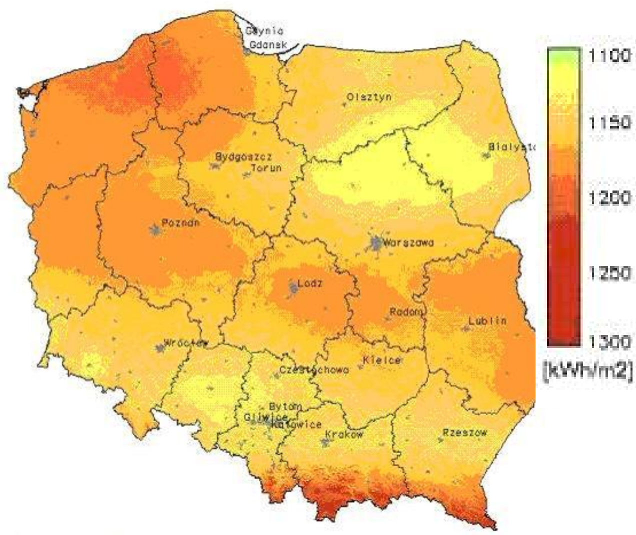


Illustration 5 Map of solar radiation
Map taken from www.wikipedia.com

As shown in the map the areas with higher solar radiation are in the south in Karpaty and the north coast of the Pomeranian and West Pomeranian regions, the latter coinciding with the area with a good mean wind speed per year.

- **Mean temperatures**

As in the two previous cases here the map of average annual temperature in Poland is analysed.

The areas with the highest average temperatures correspond to the country's west (Westpomeranian, Lubuskie, Lower Silesia and Opole regions) while the colder temperatures to the south of the country, in Karpaty.

Illustration 6 Map of average temperatures

Map taken from www.wikipedia.com

Analyzing the three previous studies, there are two possible locations, one in the south with, good solar radiation and the other in the west, due to a good average wind speed and average annual temperatures.

Pooling the data shows that the best area to locate the house is in the northwest, because the south has cold temperatures and the average wind speed does not reach values high enough to produce energy with windmills.

For these reasons, we place the house in Dziwnow, an excellent location for a modern house in which to implement renewable energy and other technologies, such as isolation, that save electricity and increase the savings with the implementation of nanotechnology.

3.2. Orientation of the house

The facade of the house will look to the South, since more surface area is exposed to the sun.

A well located house allows sunlight to penetrate laterally in the winter to reduce heating bills and prevent the direct entry of sunshine in the summer to reduce air conditioning bills.

3.3. Analysis of size of the house

It is a house for a typical family of four members, two parents with two children.

The housing design is classic and simple. The house has one floor and a cellar for the control center and also an extensive garden.

The area is 120m^2 and is distributed as follows:

Table 1 Distribution of the house

ROOM	QUANTITY	AREA (m^2)
Living room	1	42
Kitchen	1	24
Hall	1	8
Bathrooms	2	5 each one
Kids room	1	25
Parents room	1	11

The control center is 10 m^2 and it will place the batteries, regulators and converters to store energy produced by solar panels and wind turbines and provide electricity to the house. There will also be an exhaust for gas produced when everything is working.

The windmill will be located at one end of the garden and solar panels on the roof of the house.

In addition there will be a water tank in the garden. The water may be used, for example, to irrigate or for the toilet and if needed can be heated with the energy produced by the windmill through a resistance.

For details of the distribution of rooms, see the plan of the floor in the section of the plan of the house.

4. Nanotechnology

Nanotechnology is a new science which is based on the discovery of fullerenes, manometric scale particles formed by carbon atoms, to innovative machines that can be implanted into our bodies without any difficulty.

4.1. Concept

Nanotechnology is the study, design, creation, synthesis, manipulation and application of materials, devices and functional systems through the control of matter at the nanoscale, and the exploitation of phenomena and properties of matter at the nanoscale.

When handling the matter on such a minuscule scale of atoms and molecules, entirely new phenomena and properties are revealed. Therefore, scientists use nanotechnology to create materials, devices and innovative and inexpensive systems with unique properties.

The interest of the nano is mostly in the properties of the materials at these scales and how they differ from macro dimensions.

Nanotechnology has three key objectives, which are:

1. Place each atom in the right place.

2. Make almost any structure consistent with the laws of physics and chemistry that we can specify and describe at the atomic level.

3. Make sure manufacturing costs do not exceed considerably, the cost of raw materials and energy used in the process.

The technology is still at a very early stage, but every day truly amazing steps that could lead to a qualitative leap in practical applications, are happening with some incipient nanoparticles or with nanotubes.

Because Nanotechnology is at an early stage of development, there is little demand and prices for the customer are still very high. It is expected that in 5-10 years the demand for these products will increase and prices will drop in order to offer customers a quality product at competitive and affordable prices. [3]

4.2. How safe is nanotechnology?

As with all new products, no records are available regarding side effects, so it is very important to control quality and safety.

The United Nations reports, the Royal Society of British or EU admit that their understanding of these effects is still scarce.

The conclusions of a conference on nanosafety organized in Helsinki in October 2006 by the Commission were as such: "Nanomaterials are small compared with the body's natural barriers to foreign objects. They can have novel properties compared with those of the same substance in macro form. Scientists are still unable to predict these new properties. We must accelerate the characterization [of NanoMed-terials] and search for safe design to prevent unknown risks hamper the development of nanotechnology. "

It is known that nanoparticles, once in the body, after being inhaled, ingested, injected or absorbed through the skin, can cross the blood-brain barrier that prevents potentially toxic substances in the bloodstream enter the brain. [4]

An interview with Dr. Uwe Vohrer, an expert in CNT characterization and safety research at the Fraunhofer Institute for Interfacial Engineering and Biotechnology (IGB) in Stuttgart:

“How safe are CNTs?

Can carbon nanotubes be harmful to health?

Unfortunately there is no universal answer to that question, because not all nanotubes are the same. Manufactured products simply differ too greatly, for example in terms of the length and diameter of the tubes, or the catalysts used in production. For Baytubes®, however, current research shows that a risk to man and the environment from CNT agglomerates can be ruled out almost entirely. A toxicologist would never say the risk is zero, because even table salt can be toxic if you swallow large amounts of it.

How safe are products containing nanotubes?

Nanotubes are very firmly bound in plastic composites. We have not found any free nanotube particles at all from such products.” [5]

Nanoecotoxicología and nanotoxicology are responsible for investigating the side effects of this new science; nanotechnology will become increasingly present in our everyday life. But both nanoecotoxicología and nanotoxicology sciences are also new so we do not know what influence possible effects will have.

There have been some studies on how nanoparticles affect our health and according to the expert who conducted the study the majority of nanoparticles are likely to be harmless, but you have to consider "case by case." Do not rule out "acute adverse effects and long-term consequences," and stresses that a material is safe to normal size so does not mean that your nano version is safe.

Surely we need a more systematic research, and public control policies specific to the industry. "United States and Europe spend 7,700 million euros to investigate potential benefits of nanotechnology, but only 30 million euros to assess their risks. [4]

4.3. Applications

Manipulating matter at the scale of atoms and molecules get multiple properties, that’s why nanotechnology has many various applications.

The most important applications that will provide a breakthrough in human life are: medicine, the energy sector, electronics and materials, but other sectors, also being studied such as food or cosmetics.

Examples of specific applications of nanotechnology in various sectors: [6]

- Medicine

Researchers have synthesized "nanoparticles” capable of being incorporated into drugs where they are needed or new materials able to communicate with cells and induce tissue regeneration.

- Food

Nanotechnology applications in food will improve the chances of detecting small amounts of harmful substances, to create optical sensors for industrial fryers online for gaining control of production.

- Electronics

Advances in nanotechnology mean that computers will stop using the system to integrate silicon as the transistors that compose it and begin to cope with what is called quantum mechanics, which will make use of atomic-scale transistor possible.

- Nano-cables are capable of detecting gases

Researchers at Cornell University have achieved a technological breakthrough with the discovery of a simple way of placing nanowires on an electrode, and have built a prototype high-speed detector capable for detecting chemicals in nano quantities for example ammonia gas - the device can detect these gases at an extremely low concentration - 500 parts per trillion.

Currently, the Cornell team of scientists are investigating the development of detectors for other types of gases and hope to create a detector with a variety of cables sensitive to various chemical materials. A device with this capability could quickly detect and analyze the composition of gases in the atmosphere, the researchers said.

The advantage of this method is that it accomplished, with relative ease, the integration of nanowires with conventional electronics. According to the researchers, devices made from nanowire detectors could be available within three or four years. [7]

- Intelligent textiles

Since technological advances allow to implement electronic microchips into tissues in order to develop fabrics capable of changing color, sending and receiving radio waves, or act as a keyboard.

There are many who believe that the integration of technology with the tissues has enormous potential and now clothes, curtains, chairs, blinds, wall paper are slowly starting to emerge on the market. For example, a pioneer of this technique, Maggie Orth, founder, president and sole employee of International Fashion Machines, has just created a fabric that changes color. The fabrics containing fibers with moving electronic controls change its color when heated. He has also invented a "musical jacket, a garment that has an electronic musical keyboard that can be played by pressing a hand on the embroidery, and an evening dress with lights that shine.

According to Orth, one day our clothes may not only change according to the external temperature but could also contain a whole complex system of communication that allows people to call others as we do now with a phone. [8]

Among all the applications that has nanotechnology, our project will focus on the implementation in the energy sector.

5. Study of an energy saving house by applying nanotechnology in 4 main areas comparing it with a modern house

In the course of our project we decided to design a house that will use nanotechnology for energy saving. We will focus on 4 main areas where nanotechnology can be implemented: these are generation, conversion, insulation and storage.

5.1. Generation

5.1.1. Fuel Cells

A fuel cell is a device based on a very simple of science. Essentially, a fuel cell brings hydrogen and oxygen together (usually in the presence of a catalyst) in order to produce electricity. A fuel cell generally consists of two porous electrodes (anode and cathode) with an electrolyte between the two. A fuel is passed onto the anode and the cathode receives an oxidant; in most cases, these substances are hydrogen and oxygen respectively. The electrolyte separates the two substances so as there is no physical contact. The fuel is oxidized (and electrons released) at the anode; at the cathode the oxidant is reduced (and electrons absorbed). It will also be possible to use methanol as the fuel for the appliance but is proposed to be a future application which could be used to power small electronic devices such as mobile phones and mp3 players, so this report will focus on the hydrogen fuel cell technology.

The anode and the cathode must be connected by an electrical conductor for the process to work correctly. The charge transfer of the fuel cell is affected by the flow of ions through the electrolyte, this is very useful for the engineers using the device since the overall energy production rate can be controlled and worked out using the mass flow rate of the reactants.

On the next page there is a picture which clearly shows how the fuel cell functions:

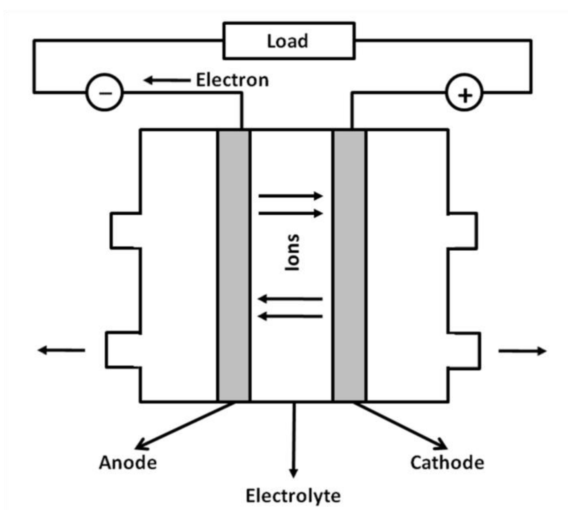


Illustration 7 Reaction on the electrodes

Picture taken from http://www.fuelcells.org/info/library/fchandbook.pdf

Here is another diagram which clearly shows the flow of electrons at the fuel cell electrodes:

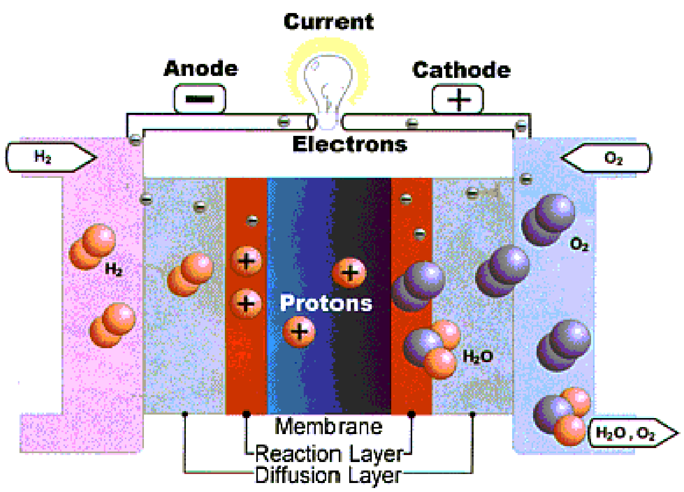


Illustration 8 Diagram fuel cells. Reactions on the electrodes

Picture taken from http://www.fuelcells.org/info/library/fchandbook.pdf

The electrodes of the fuel cell are not converted, which means they cannot be discharged the way as capacitor or a battery can. The reaction is essentially a combustion reaction, but it is termed cold combustion as the reaction is controlled and has a catalyst present. The working temperature of the electrolyte is around 40-80 degrees Celsius.

Here are the reactions that occur on the electrodes; the overall energy of the reaction is shown as well:

Anode: (oxidation)

Cathode: (reduction)

Overall reaction: $\Delta G = -237.3$ kJ/mol

At the anode, hydrogen molecules are oxidized to positively charged hydrogen ions (protons), releasing electrons. The protons can be conducted through the polymer membrane to the cathode. If the anode and cathode are connected by any electric conductor, electrons and hydrogen ions flow to the cathode and react there with oxygen, forming water. The electrons can perform work in the process. [9]

5.1.1.1. *The Market and Cost Analysis*

Fuel cells are quickly becoming highly sought after appliances. As we move away from fossil fuels, more and more companies are reaching out to hydrogen technology as a new way to produce energy.

Here is a graph of the recent and expected trend of the value of the fuel cell industry:

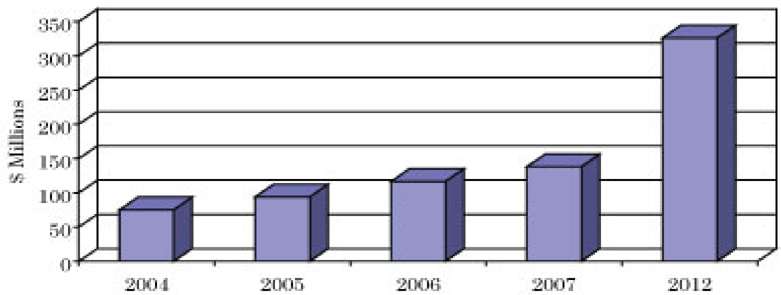


Illustration 9 Graph of the recent and expected trend of the value of the fuel cell industry

Map taken from BCC Research

5.1.1.2. *Energy Calculations*

First, we must calculate the flow rate of hydrogen needed to enter the fuel cell so that we receive the desired amount of current at the output end. [9]

So we first work out the flow rate needed to produce one Amp of current.

For every molecule of hydrogen (H2) that reacts within a fuel cell, two electrons are liberated at the fuel cell anode. This is most easily seen in the PAFC and PEFC because of the simplicity of the anode (fuel) reaction, although the rule of two electrons per diatomic hydrogen molecule (H2) holds true for all fuel cell types. The solution also requires knowledge of the definition of an Ampere (A) and an equivalence of electrons

Here is the reaction that is taking place at the anode: H2 >>> 2H+ + 2e-

This is equal to 0.037605g per Amp of electricity produced.

Thus for a 1.5A circuit which is the same as the one is our house we need 0.037604 x 1.5 = 0.056406 g per hour. [10]

For our conventional energy saving house we will use a Reformed Methanol Fuel Cell because it works within our power range (5W – 100kW). It is for commercial use as well as research and it has a relatively high efficiency (25 – 40%) it is not one of the most expensive fuel cells to buy. This is a type of proton exchange fuel cell and it has some advantages over the similar “Direct Methanol Fuel Cell”, these being it is more efficient, smaller cell stacks, no water management and operation at lower temperature. These types of fuel cells produce carbon dioxide and water as waste products.

Methanol might be a good substance to use as a fuel as it is naturally occurring, biodegradable and a good hydrogen carrier.

These fuel cells cost $5000 for a 25W cell, so in our house it makes sense that we use them to power appliances such as the fridge, TV and laptop. If we buy 4 of these that gives us a total cost of $20,000. [11]

5.1.1.3. Nanotechnology within Fuel Cells

The future of fuel cells lies within the realm of nanotechnology. A professor at a university is Pittsburgh, USA said ”For laptops, cell phones and other portable electronics"we envision a fuel cell system about the size of a cigarette lighter that could be re-fuelled by inserting a small cartridge of methanol,". It is also expected that nano-fuel cells will come into use in the automobile industry, with tanks of methanol being used to power the whole car.

The difference with nano fuel cells as compared to regular ones is that the catalyst substance is made to the nanoscale (width of 3nm and a length of 10nm). The catalysts properties then increase greatly. For instance, because of the huge rise in surface area, there are lots more active sites available for methanol to react and break down. This means the fuel cells are far more efficient and less methanol has to be used to produce the same amount of power compared to conventional fuel cells.

The improvement goes further when we think about constructing the electrodes using carbon nanotubes. The nanotubes have a much better rate of electrical conduction than the original metal electrodes. This in turn increases the efficiency of the fuel cell as not so much hydrogen is needed to create the electrical current needed.

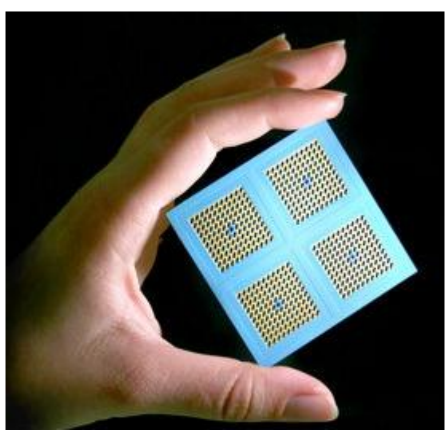


Illustration 10 Nano fuel cell
Picture taken from www.wikipedia.org

With the use of carbon nanotubes for the electrodes and a nanoscale catalyst, the performance rises by a factor of 3 with one fourth the catalyst loadings compared with previous generations. This, alongside the optimization of the fuel, air and water mixtures 15lb of units can deliver 600 to 1200 W of power per day.

The US military has been given fuel cell prototypes which have been safety and productivity tested up to military standard with resistance to rain, wind and sand. The large Californian corporation UltraCell opened a massive fuel cell manufacturing plant worth $74 million in 2007 and expects to begin production of commercial nano fuel cells by the end of this year. They also gave prototypes to the US army for testing. [12]

Here is a picture putting into context the size of these nano fuel cells:

Illustration 11 Size of the nano fuel cell

Picture taken from www.wikipedia.org

Carbon nanotubes can also be used as a material for hydrogen storage. Their ability to bond with the hydrogen molecules allows them to do this. At the same time though, they are not the best hydrogen carriers as the bond is not so strong. This is something that will be looked at in the coming years for improvement. Some advantages of using carbon nano tunes for hydrogen storage are; they can control the reactivity which means the correct rate of hydrogen release can be selected, selectivity can also be controlled which prevents the formation of borazine, work is also being done to prevent the fusion of nano particles as the reaction proceeds so that the nano tunes can be retrieved at the end and then re-used. [12]

5.1.1.4. Market Analysis

It is impossible to find information on the cost of nano fuel cells at the moment because it is only a proposed future technology, set to develop in the next ten years.

One company, Kia, have said they will be the leaders in fuel cell technology in the coming years. They plan to begin production in 2011 and sales should commence as early as 2012. They will be selling cars that run on nano fuel cells; this is expected to take the automotive market by storm. They are expecting to sell around 1000 or 2000 vehicles per year for the first 2 years of production, and then they are confident that the technology will catch on quickly so sales will rise to 20,000 after 4 or 5 years on the market. They have been working on these fuel cell products since the year 2000 along with rival company Hyundai. They will initially offer their product to government bodies and researchers to try and spread the cars credibility. The company's Borrego FCEV prototype reaches 100 km/h in 12 seconds and has a top speed of 170 km/h. The SUV is capable of covering 600 km before needing to refuel. The electrical energy is delivered to the car's engine via a super capacitor, which allows a much quicker response time then with a battery like other models use. [13]

5.1.1.5. Conclusions

In conclusion, it has been found from detailed study into the area of fuel cells that we can power household appliances such as the T.V and computer through use of solar cells. The total cost is $20,000 for our conventional energy saving house.

Prices and models of nano solar cells were unable to be found because it is such a new technology. It can be expected that nano fuel cell products will be seen in the next 5 years, these will be cars and devices used to power laptops , phones and other such electrical appliances.

A lot of time and money is being spent world-wide on research into the nano fuel cell market especially in USA and in large automotive countries. In the not so distant future we can expect to see a range of small electrical appliances such as lap tops and cell phones powered completely with nano fuel cells. Nano fuel cell technology may boost the energy sector closer to where it should be in the next few years as we move further away from non-renewable fossil fuels.

5.1.2. Solar Cells

The photovololtaic cell (solar cell) is a device that uses the difference in materials to create an electric current when the surface of a certain material is exposed to photons of light of a specific energy. The flow of electricity occurs due to the materials being doped; this is the process whereby the conductor has another chemical added to it to create holes within the metallic bonding structure. The material is now called a semi conductor. When incident light strikes the surface of the material, the energy excites one electron (or more depending on the material) making it move, the only place it can go is into the nearest hole. This process repeats itself until there is a constant flow of electricity. In most cases, the electricity flows to a storage facility such as a battery or a capacitor so it can be used at a later time.

Photovoltaic is the field of technology and research related to the devices which directly convert sunlight into electricity.

Due to the growing demand for renewable energy sources, the manufacture of solar cells and photovoltaic arrays has advanced rapidly in recent years.

Photovoltaic production has been doubling every 2 years, increasing by an average of 48 percent each year since 2002, making it the world's fastest-growing energy technology.

The solar cell is the elementary building block of the photovoltaic technology. Solar cells are made of semiconductor materials, such as silicon. One of the properties of semiconductors that makes them most useful is that their conductivity may easily be modified by introducing impurities into their crystal lattice.

There are several types of solar cells. However, more than 90% of the solar cells currently made worldwide consist of wafer-based silicon cells. They are either cut from a single crystal rod or from a block composed of many crystals and are correspondingly called mono-crystalline or multi-crystalline silicon solar cells. [10]

A number of solar cells electrically connected to each other and mounted in a single support structure or frame is called a 'photovoltaic module'. Modules are designed to supply electricity at a certain voltage, such as a common 12 volt system which works with 36 solar cells. The current produced is directly dependent on the intensity of light reaching the module.

Several modules can be wired together to form an array. Photovoltaic modules and arrays produce direct-current electricity. They can be connected in both series and parallel electrical arrangements to produce any required voltage and current combination.

The picture below shows a single photovoltaic solar cell:

Illustration 12 Single photovoltaic solar cell

Picture taken from http://www.goldbulletin.org/

Solar power is a very attractive form of renewable energy as it is free to harness, completely harm free to the environment. It is a fairly developed technology as it has been around for around 50 years but it was never heavily invested in due to the abundance of fossil fuels and peoples lack of thought about the future. Now and in the next 5 or ten years though, solar power is expected to play a massive part in the reshaping of our energy production methods as almost every government in the world has set hard targets in terms of renewable energy used as a percentage of total energy.

One of the main problems with solar power is that not everywhere in the world is the abundance of light energy from the sun needed to convert a sufficient amount of energy. For example, 20 German firms have come together and are about to embark on a $400 billion project to gather solar energy from the sun in the deserts of north Africa and send it to Europe. Although the major technology is not solar cells (they will use an array of mirrors to reflect sunlight to a river and use the heat energy to power a turbine) the scope of this project shows the importance of the solar power industry, especially in the next 5 years. [14]

With the better transportation methods for electricity, energy can easily be generated in hot places and used elsewhere in the world.

Here is a map of Europe and Africa showing the best areas for solar power:

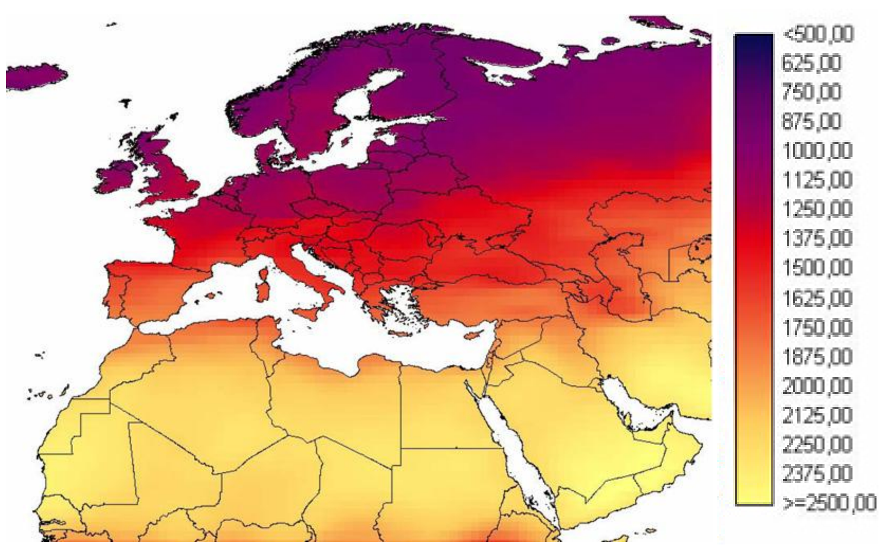


Illustration 13 Map of Europe and Africa showing the best areas for solar power

Map taken from www.nanopedia.org

The main applications of solar photovoltaic are:

- Power stations: The largest one in the world is the Olmedilla Photovoltaic Park in Spain, with 60MW;
- Buildings: Generally, an array is incorporated into the roof or walls of a building to supply it electricity;
- Transport: Photovoltaic is rarely used to provide power in transport applications, but is being increasingly used to provide auxiliary power in boats and cars;
- Standalone devices: Photovoltaic is used as well to power calculators, parking meters, emergency telephones, temporary traffic signs, and remote guard posts and signals;
- Rural electrification: In some rural locations the solar power is used to replace kerosene lamps;
- Solar roadways: In Idaho is testing the possibility of installing solar panels into the road surface.[15]

5.1.2.1. Solar Cell Materials

There are 3 main types of solar cells that are commonly used.

1. **Silicon Solar Cell**

This is quite an efficient cell made from monocrystaline silicon which is the same raw material used in the semiconductor industry. The efficiency of production models comes in at around 14% with results up to 25% in the laboratory. This can convert photons up to 1.15um in wavelength. These solar cells are usually around 3mm thick with a diameter of 10-15cm. They generate 35mA of electricity per square cm at a voltage of 550mV.each photon of light can only stimulate 1 electron hole pair, this is part of the efficiency problem.

The cost of these panels to be installed in our house amounted to:

- £659.99 for one panel of 120W
- We need 12 panels for our roof, so 12x659.99= £7919.88
- The installation cost is between £3000 and £20000, we will assume £11000 for our study =£18919
- A voltage regulator also has to be purchased to accompany the solar cells. This costs £80

Total cost =£18999 [15]

The following illustration shows how current output changes with ambient temperature, it can be seen that a drop in temperature is an inconvenience to the silicon solar cell:

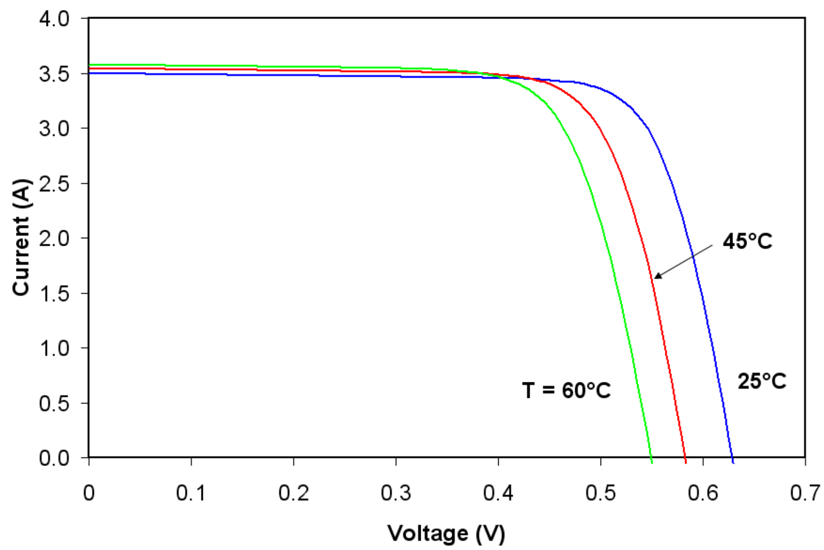


Illustration 14 Graph shows how current output changes with ambient temperature
Graph taken from http://www.sciencedirect.com

2. Amorphous/thin films

They are very cost effective and flexible, as it can be applied as a thin coating, this is useful as it is easier to achieve the desired position of the solar panel so as to obtain optimum solar energy. These cells have a very low efficiency though, around 8%. This is a high energy waste which means we will not consider these for our conventional energy saving house. There is a possibility that these could be used along with silicon panels however.

The cheapest available thin film solar cell was £269 for 120W with an installation cost of £4000. This gives a total cost of £4349.

One disadvantage is the range of light they can take in. They take in all visible light up to blue light wavelength. This is one of the efficiency setbacks.

3. Multi junction semiconductor

These cells consist of 2 or 3 layers of semi conductor material. They can achieve high efficiencies of up to 34%. They are massively expensive so cannot be considered for our house, they are mainly used for specialist applications such as feed satellites in space. The cost per unit energy for these is higher than that of fossil fuels, so not practical at all for residential use. [15]

5.1.2.2. Solar Panel Maintenance

Very little maintenance is needed for solar applications due to there being no moving parts. Only the circulation pump is subject to physical wear. The panels need to be regularly checked for damage caused by external elements such as the weather. This can be done by the homeowner with use of simple instructions so there is no additional cost for this. [15]

5.1.2.3. Nano-solar cells

Nanotechnology, due to the material high surface area and high level of electrical conductivity, can be used to improve the efficiency of solar panels/cells.

Here will be given a description of each of the nano solar cells available at the moment:

1. **Organic dye sensitized solar cells**

These devices work by absorbing a photon of light which forces an electron to move to the TiO2 nano particle layer. They are 60% less expensive than silicon solar cells and have a very low efficiency of around 10% in laboratory tests.

2. **Quantum Dots**

Quantum dots, also known as nanocrystals, are a special class of materials known as semiconductors, which are crystals composed of periodic groups of II-VI, III-V, or IV-VI materials. Semiconductors are a cornerstone of the modern electronics industry and make possible applications such as the Light Emitting Diode and personal computer. Semiconductors derive their great importance from the fact that their electrical conductivity can be dramatically altered via an external stimulus (voltage, photon flux, etc), making semiconductors critical parts of many different kinds of electrical circuits and optical applications. Quantum dots are unique class of semiconductor because they are so small, ranging from 2-10 nanometers (10-50 atoms) in diameter. At these small sizes materials behave differently, giving quantum dots unprecedented tunability and enabling never before seen applications to science and technology.

These may be used for decreasing the cost and increasing the efficiency of current silicon solar cells. For every one photon of light that hits the cell, 3 electrons are excited and taken away to be used as energy. This tells us that it is a very efficient device. A large amount of the spectrum of light can be harnessed for energy use from these quantum dots when different sized particles are placed in stacked layers, so less light is wasted compared to all other solar cells. The efficiency of quantum dot solar cells is 86.5%. This is a very exciting and new technology and will receive a lot of research attention in the coming years to try and push for its use commercially so as governments can work to achieve their energy goals. [14]

Here is a graph comparing most types of solar cell materials in terms of efficiency:

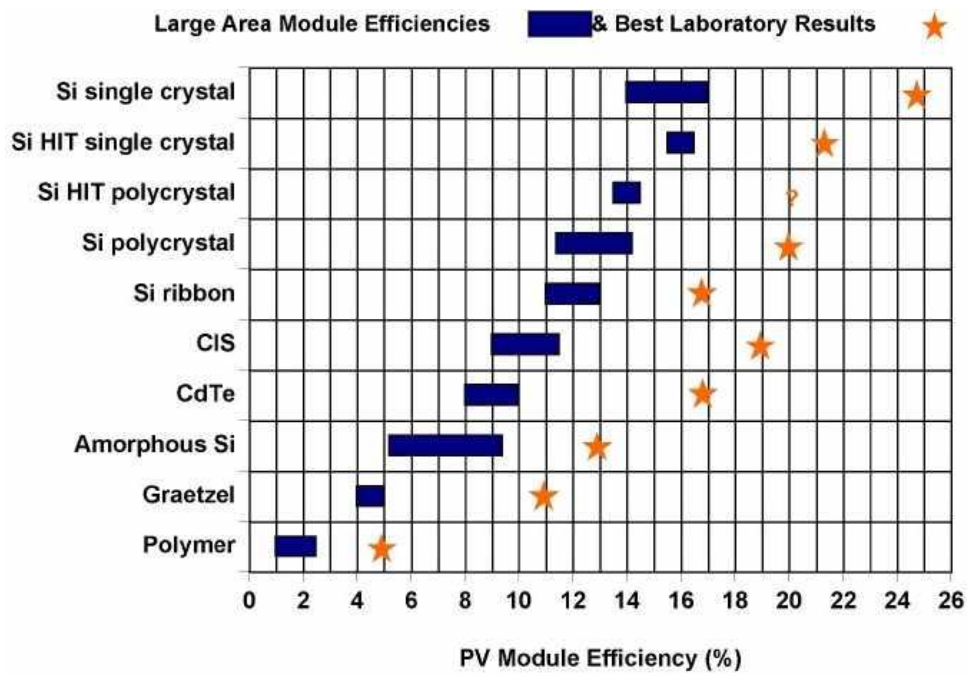


Illustration 15 Graph comparing most types of solar cell materials in terms of efficiency
Graph taken from http://www.sciencedirect.com

5.1.2.4. Calculations for Nano Solar Panels

The target of these calculations is torun our house with solar power photovoltaic. So, the first study was done to reduce, as much as possible, the electricity consumption, maintaining the maximum possible comfort.

First of all, we alculated the daily energy consumption:

Instantaneous power installed: 3611 W

Daily energy used: 2013.58 Wh/day

The power output of the converter should be 3611 W and the chosen converter has an efficiency of 95% so, the power input should be:

Power input = Power output / converter efficiency = 3611 W / 0.95 = 3801.05 W

We have to take in account that the converter has energy consumption; this consumption will be the difference between:

(Power input – Power output) x (nº of hours working daily) =

(3801.05 W – 3611 W) x 8 hours = 1520.4 Wh

We will add up to the house energy consumption the converter energy consumption in order to obtain the real daily consumption.

2013.5 W h / day + 1520.4 W h / day =3533.9 W h / day

Then, the electric current intensity each hour daily was calculated.

2013.5 W h / day + 1520.4 W h / day =3533.9 W h / day

I = 3533.9 W h /day / 24 V = 147.24 A h / day

To be certain that we have more than enough energy available we add up a 10% more.

147.24 A h/day + 14.72 = 161.95 A h / day

The solar energy level by Joules/squared meter in North West Poland is 11.5 Joules/m^2.

So we can calculate with the peak solar hours with the next formula:

11.5 Kj / m2x 0.024x 0.0116 = 4.131 H.P.S.

We apply the gain tilt factor of the solar panels:

4.131 H.P.S. x 1.06 = 4.38 H.P.S

Intensity per panel = 175 W / 24 V = 7.29 A

Intensity of panel= I (each panel) x H.S.P. =7.29 A x 4.38 H.P. = 31.9 A h/ day.

Nº of panels necessaries: 161.95 A h/day / 31.9 A h / day = 5.08......6 panels

Intensity of batteries:

I (A) / depth of going flat x days of autonomy=

161.95 Ah / days/ 0.7= 231.35A x 3 days = 694.05 A h

Nº of batteries: 694.05 A h/ 350 A h =1.98.........2 batteries

Calculation of the intensity of regulatory:

I panel x nº of panels= 7.29 x 6 panels= 43.74 A..........50 A

The solar energy level per day was taken from this graph of peak solar energy per day in Poland:

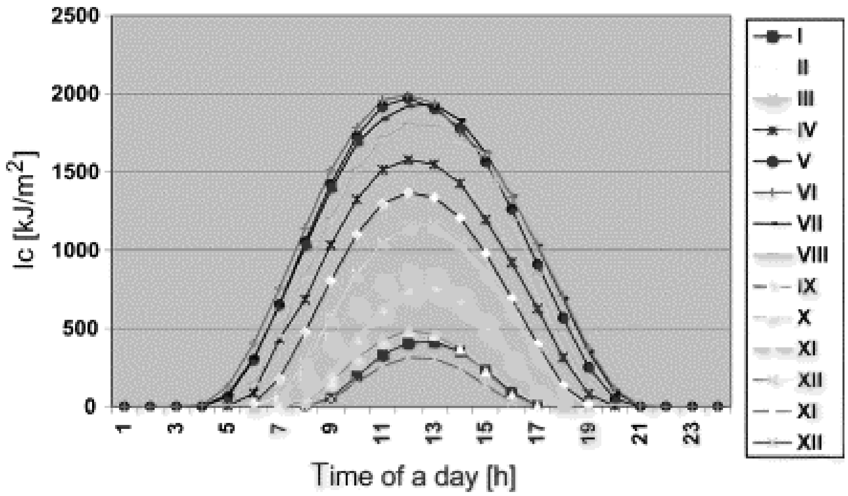


Illustration 16 Graph of peak solar energy per day in Poland

Graph taken from www.strath.ac.uk

This graph, also from the same website was used to work out the best inclination levels for the maximum energy:

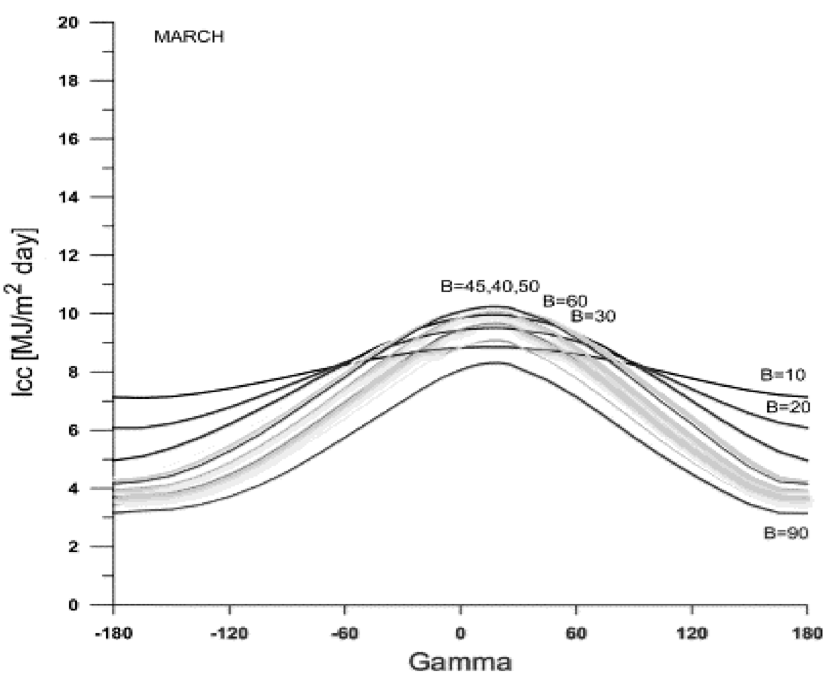


Illustration 17 Graph was used to work out the best inclination levels for maximum energy

Graph taken from www.strath.ac.uk

5.1.2.5. Cost Estimation for Solar Panels on House

As they are the most efficient nano product on the market at the moment, we ecided to use **Quantum Dots** for our solar panels.

It was very difficult to find cost information on solar nanotechnology as it is only just coming on to the market, but some websites gave us some information on its cost. The expected market price for quantum dot solar panels will be $1 per Watt, so for our 3801.05 W total power needs, the total cost of our panels will be $3801.5.

Plus an installation cost of $2000, which is typical for nano solar panels, we have a total cost of $5801 for our panels.

5.1.2.6. Future Nano Solar Technology

All around the world scientists and engineers are working to explore the possibilities for nanotechnology. The value of the nano market is expected to rise exponentially over the next 5 to 10 years such is our need for new sources of highly efficient green energy. Researchers at the University of Singapore have recently discovered some interesting properties of nano size gold when applied to photovoltaic solar panels. For example, then a thin layer of nano gold is inserted between the anode and the photovoltaic efficiency of the solar cells is seen to increase exponentially. These gold layers increase photocurrent efficiency by 16% and power conversion efficiency by 7%. [15]

5.1.2.7. Conclusions

Finally, we can construct solar panels for our conventional energy saving house for £18999 which will see to our energy needs. However, when we use Quantum dots to construct our nano solar panels, the cost amounts to $5801. It is therefore much cheaper and more environmentally friendly to use nano materials to construct solar panels.

5.1.3. Wind Energy

One way of saving electricity is to produce this energy from renewable energy, like wind energy.

Today, wind energy makes up 1% of global consumption of electricity (coming to represent 20% in Denmark and 10% in Spain).

Wind energy can be harnessed by changing its kinetic energy into a rotary force, thence to electricity in a wind turbine generator.

As the wind turbine does not produce emissions to the air, land, or water, the wind power does not harm the environment.

There has been a lot of talk about 'noise pollution' associated with running wind turbines. Mechanical sound comes from the movement of the turbine's components and aerodynamic noise is discernible from the whirling blades. With a wind speed of 8 m/s, the sound emitted by a single small wind turbine is equivalent to that of a domestic refrigerator.

The payback time for wind power depends on the wind conditions, the amount of electricity generated, and the total cost of electricity, taking into account taxation, the power transmission charge, and the price per kilowatt.

Today when the people listening talk about the wind power, generally associate it with large wind turbines located along sea coasts, but with small turbines is possible to produce electricity locally for private use by industry, farms, leisure homes and households. [16]

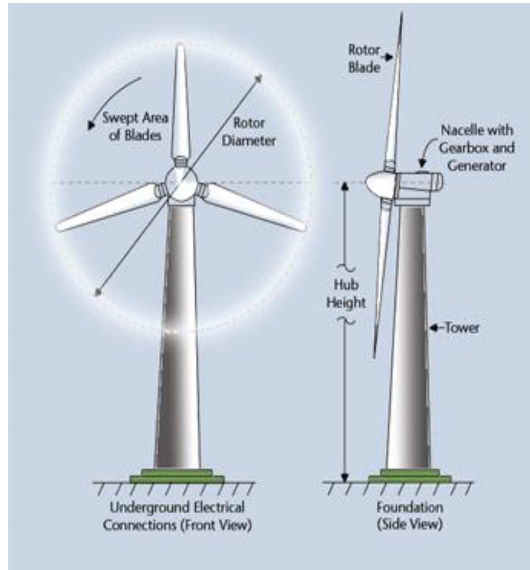


Illustration 18 Drawing of the rotor and blades of a wind turbine.
Picture taken from
http://www.cecu.es/campanas/medio%20ambiente/res&rue/htm/guia/eolica.htm

In the next figure we can see that in the year 2020 in Poland, the total number domestic of thewind turbines installed will be approximately 600.

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Onshore Wind	920	1404	2303	3202	4101	5000	6561	8098	9060	10008	10893
Offshore Wind	0	0	0	0	0	0	0	0	500	1000	1500
Domestic Wind Turbines	1	5	10	70	130	190	250	310	369	429	600

Illustration 19 Graph with the number of the wind turbines installed in 2020
Graph taken of "The wind power development in Poland by 2020- a visión"

The best possible siting for a wind turbine is an open area. This may or may not also be higher than its surroundings. An ideal installation places include the sea coast, the banks of inland lakes, large fields or meadows, and hill summits. The essential factor from the operating standpoint is for there to be as much empty space as possible towards the prevailing wind.

5.1.3.1. *Study of wind turbines for a modern house*

For small facilities or agricultural household wind turbines more useful and accessible are those with a diameter of 1-5 sweep m, capable of generating 400 W to 3.2 kW.

They have the advantage, moreover, that can boot to a wind speed lower than the larger, slower winds may take (such as sea breezes and mountain winds) and produce more energy.

They need a minimum wind speed of 3 m/s to boot (compared to 5.30 m/s of the largest), get maximum performance at 12.5 m/s and stand with winds of over 28 m/s in order to avoid damage, wear or overheating in its mechanism. The cost of residential turbine installations between 1.5 and 10 kW can vary between 13,000 and 40,000 €.

The energy produced by a wind turbine varies according to the diameter of the turbine blades and the height of the tower, but also influences the wind strength, the time to work and the orographic characteristics in the field, is for these reasons that we can only make an estimate of the energy produced by wind turbines installed. For more accuracy would require the study of maps of wind and a record of wind resource data the exact location of the wind turbine (frequency, velocity, duration and wind direction) for several months.

The wind turbine must be minimum 6m taller that the interferences such as house, trees or any objects. It also has to be placed in distance about 76m from them.

The cost of installation may vary due to transport costs, different tower heights, different rotor diameters, the rating of the turbine, type of charge controller, battery type and the type of inverter.

To estimate the cost of installation and the energy produced by the turbine, we have based on the parameters described above, and we choose the system best suited to our conditions and needs. [17]

5.1.3.2. *Wind system has installed:*

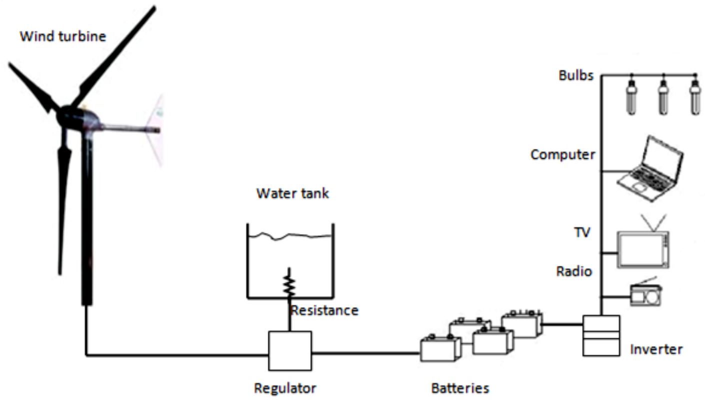


Illustration 20 Wind system installed

The following figures show the mean wind velocities in Poland at a height of 80 m in the last 5 years. The maps shows that in Dziwnow, where our modern house is located, the mean wind speed varies between 7 m/s and 9 m/s. [2]

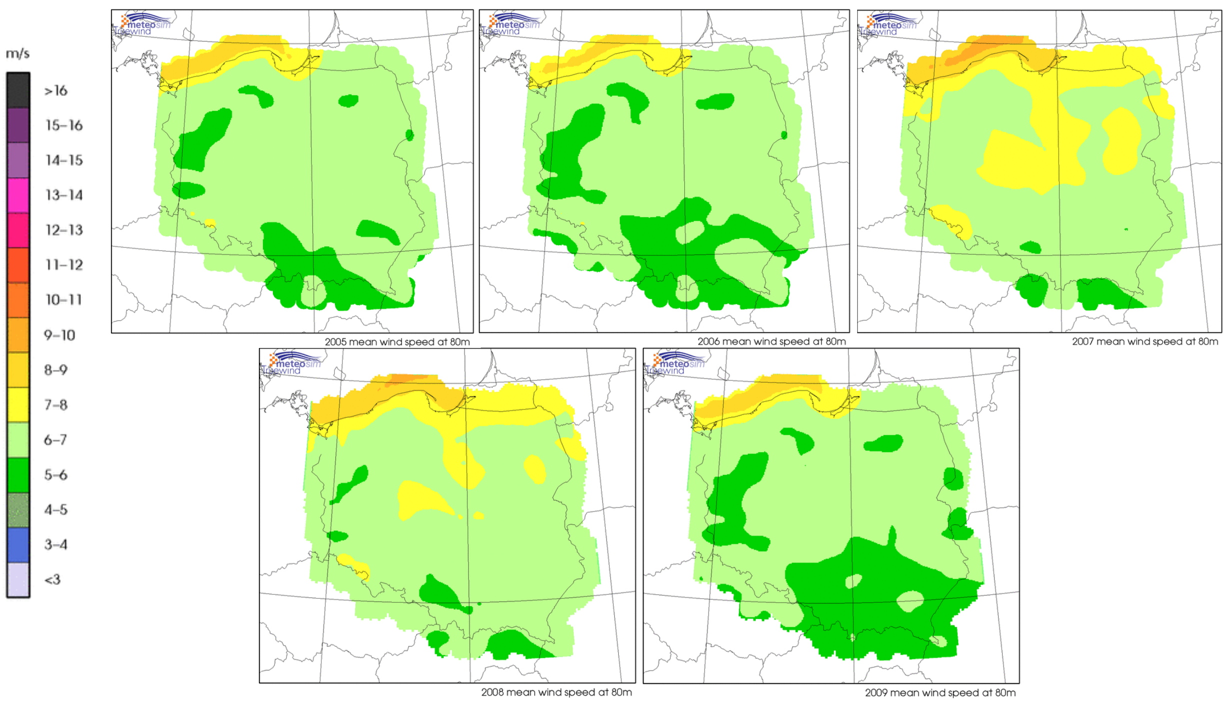


Illustration 21 Mean wind speed at 80 m since year 2005 to year 2009
Maps taken of http://windtrends.meteosimtruewind.com/es/mapas

There are several possible wind turbine of different companies, is necessary chose the best for our conditions. [18] [19]

We choose the Skytream 3.7 of the company Skytream.

Table 2 Technical characteristics of the selected wind turbine

WIND TURBINE Installation company Skystream	
Skystream 3.7	2,4 kW
Rated speed	50-330 rpm
Blade material	Fiberglass reinforced composite
Blade quantity	3
Rotor blade diameter	3.72 m
Minimum start-up wind speed	3.5 m/s
Weight	77 kg
Yaw control	passive
Survival wind	63.0 m/s (max.)
Alternator	Slotless permanent magnet brushless

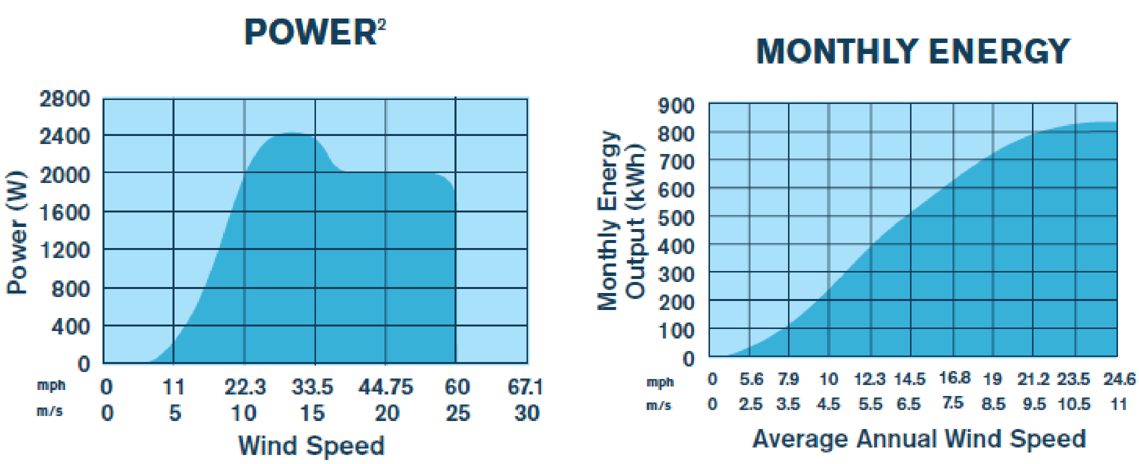


Illustration 22 Power of wind speed

Graphs taken of http://www.windenergy.com

The wind turbine will be located in a corner of the garden. In this place there will be no interference of the house, of trees or of objects more tall that the height recommended.

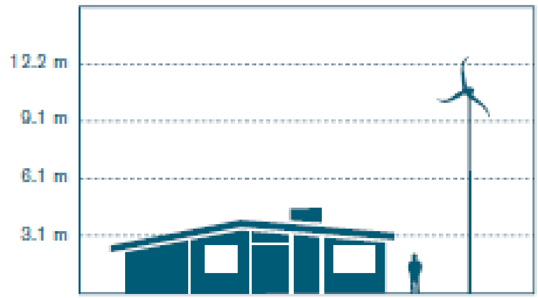


Illustration 23 Comparison of the scale

Picture taken of http://www.windenergy.com/index_wind.htm

The estimate of electrical power production facility with a 2.4kW wind turbine rated power and a tower of 10m of height; with the reference mean wind speed of about 8m/s.

Table 3 Cost and energy generated with convencional wind turbine

ECONOMIC VIABILITY	
Installation cost	€ 15,000
Energy generated in a year by the installation	7,560 kWh
Total consumption of electricity in a year	11,237 kWh

The turbines can be amortized in 10 years and last for 30 years (the average of industrial turbines is 20 years). Energy efficiency is about 45%.

The design of wind turbine able to reduce noise to stop bothering people who live or develop their activity near the facility produces a background noise of between 42 and 50 decibels at a radius of ten meters. Also it is possible to program the turbine to be less noisy during the night.

The 5 year warranty covers materials and raw materials.

Wind power is of course to be competitive on the liberalized market. Production cost per kWh has been reduced by more than 80% within the last 20 years and this trend is expected to continue resulting in a fully competitive technology in 7-10 years. Today wind turbines on good wind sites can already compete with new combined heat and power plants (CHP), but wind cannot yet compete on the present market terms.

5.1.3.3. Improvements with nanotechnology for wind turbines

The main problems are the **low efficiency** associated with the turbines based on the windmills, and **the intermittent** nature of wind needed to generate energy. Hence the need for large facilities with windmills blades formed by large size (which limits their use and greatly increases the cost of production and installation).

Nanotechnology applications:

- The implementation of carbon nanotubes in the manufacture of the blades of modern windmills. [20]

In combination with special epoxy resins, the use of carbon nanotubes can reduce the weight of the blades, and increase their resistance, since carbon nanotubes are about 100 times stronger than steel and much lighter.

This compound can be produced by windmills stations with larger blades, but stable and light, thus increasing the efficiency of these stations up to 30% (since the energy provided by each turbine is proportional to the square of the length of blades). The fact that the blades are lighter, also allows them to be operating with much lower wind speeds (2 m/s) than required by conventional mills.

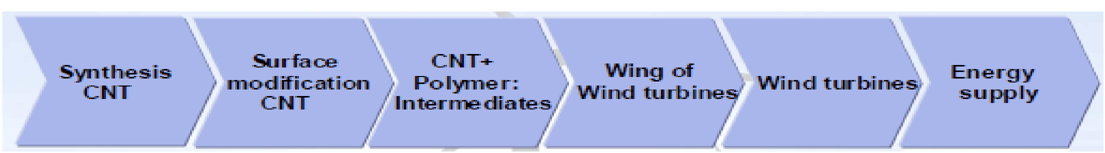


Illustration 24 Schematic process since it is synthesized nanomaterial until applied to the turbine
Picture taken of http://www.baytubes.com/downloads/bms_cnt_baytubes_en.pdf

- To Develop batteries and supercapacitors for storage of the electricity produced.

Both solar and wind energy sources of supply which is very intermittent and varies in unpredictable ways, this requires a storage system not too expensive and efficient, something that neither the current batteries or capacitors are able to do today.

The idea is to store electrical energy in such a way as to have both high power and high energy density in order to have a storage system that provides power, which in turn loads quickly.

The improvements in batteries and supercapacitors with nanotechnology are explained in detail late in 6.4 chapter about storage.

5.1.3.4. Market

Every year the number of installations of the residential wind turbines in the world increases. For the year 2020 the expected is increased about 600% of domestic wind turbines installed in Poland. Due to this fact and reduced price of the carbon nanotubes, expected a significant increase in the manufacturing wind turbines using the nanoparticles for make it.

In the following graph can see that the global nanomaterial demand will grow annually by 33% per year between 2003 and 2020.

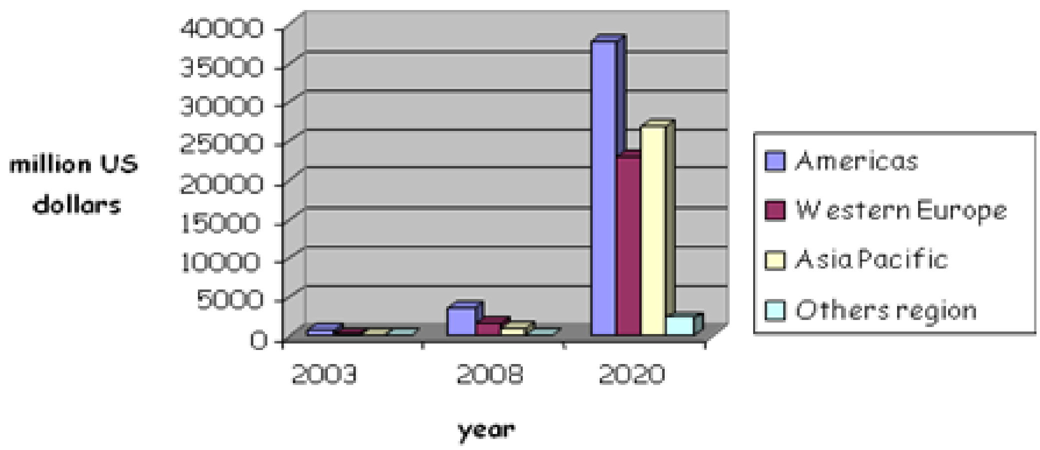


Illustration 25 Graph World nanomaterials demand
Graph taken of NRM_Energy

Nowadays there is one company working with carbon nanotubes for the production of blades. Is a Finnish company, whose name is *Eagle Tuulivoima* that uses nanomaterials from Bayer MaterialScience (carbon nanotubes manufactured for the company Bayer).

The company started manufacturing two models, one with 2 kilowatts and another with 5 kilowatts of rated output and after the expansion of another to models more with 10 and 20 kilowatts.

Eagle Tuulivoima expected that the cost decrease to the €10,000 of installation for a wind turbine of two kilowatts. The electric power produced in a year for this kind of turbines is estimate in 4,000 to 8,000 kilowatts hours depending of the location of the windmills. [21]

A wind turbine of this size could provide the electric power that need a single-family home with average consumption.

Table 4 Technical characteristics of one wind turbine with nanotubes

WIND TURBINE	Installation company Eagle power
Eaglepower 2 Rated Power	2000 W
Output voltage	AC230 V
Blade material	Hybtonite
Blade quantity	3 typical HAWT
Rotor blade diameter	4.5 m
Minimum start-up wind speed	2.5 m/s
Rated wind speed	9 m/s
Rated rotating rate	250 r/min
Generator output	3-phase
Output AC frequency	50/60 Hz
Tower height	6-30 m
Weight of generator	182 kg
Protection against strong winds	mechanical
Survival wind	50.0 m/s (max.)

5.1.3.5. *Carbon Nanotubes* [3] [22] [23] [24]

Carbon nanotubes which are long thin cylinders of carbon, were discovered in 1991 by S. Iijima. These are large macromolecules that are unique for their size, shape and extraordinary physical properties. Can be considered as a sheet of graphite (a hexagonal netting carbon) rolled into a cylinder. These intriguing structures have generated much enthusiasm in recent years and a great deal of research has been devoted to its understanding.

- ***Carbon structure:***

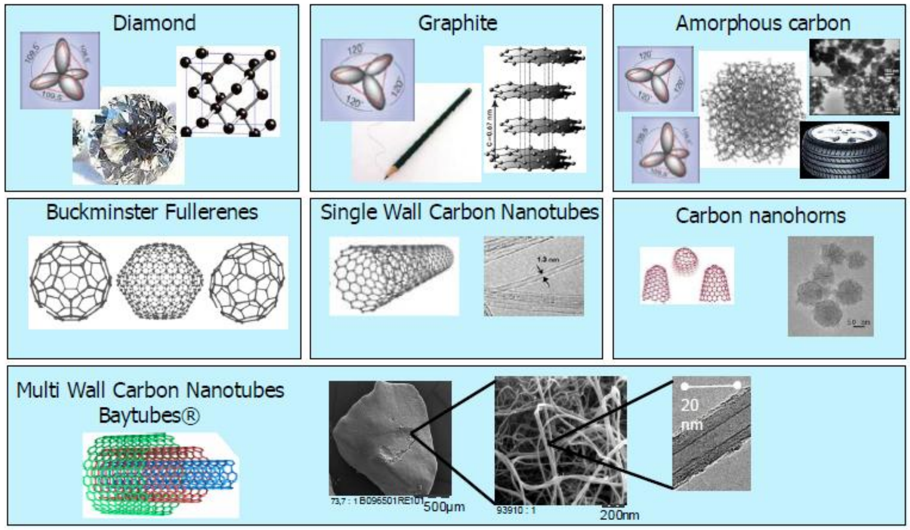


Illustration 26 Carbon structure
Picture taken of www.Baytubes.com

Currently, the physical properties of carbon nanotubes are still not known and discussed. What makes it so difficult is that nanotubes have a very wide range of electronic properties, thermal and structural which may change depending on the different kinds of nanotube (defined by its diameter, length, and "chiral" or spin). To make things more interesting, besides having a single cylindrical wall (SWNTs), nanotubes can have multiple walls (MWNTs) cylinders inside other cylinders.

The nanotubes can be up to one hundred times stronger than steel and are almost two millimeters long. These nanotubes have a "cap" on both corners of the hemispherical cylinder. These are lightweight, flexible, thermally stable and chemically inert. They have the ability to be metallic or semiconducting depending on the "twist" the tube.

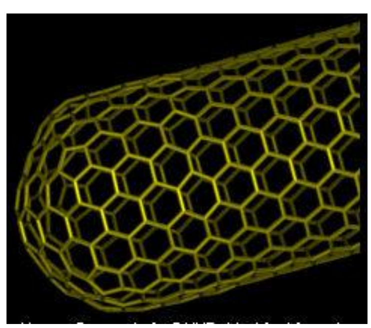


Illustration 27 End of a SWNT
Picture taken of http://html.rincondelvago.com/nanotubos-del-carbono.html

- ***Detailed structure.***

The average diameter of a SWNT is 1.2 nm. However, the nanotubes can vary in size, and are not always perfectly cylindrical. Nanotubes, such as the tube (20,20), tend to bend its own weight. The diagram below shows the average length of link and the separation of carbon values for a hexagonal grid.

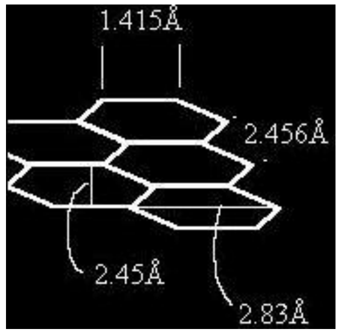


Illustration 28 Bond lengths of carbon and atomic spacing of the hexagonal grid.
Picture taken of http://html.rincondelvago.com/nanotubos-del-carbono.html

- ***Carbon nanotube ropes.***

In 1996, Thess measured properties of the "strings" of carbon nanotubes. As shown in the diagram below, the strings are condensed bundles of tubes in an orderly manner. It was found that a SWNT is packaged in a triangular grid with grid constant of about 17 Å. This was confirmed later by Gao, CAGIN, and Goddard in 1997. In addition, it was concluded that the density, the parameter grid, and the spacing between layers of the strings depend on the chiral tubes in the structure. Armchair tubes (10,10) have a grid parameter 16.78 Å and have a density of 1.44 g/cm3. The nanotubes of zigzag chiral (17.0) have a grid parameter from 16.52 Å and a density of 1.34 gm/cm3. Structures made of (12.6) and chiral SWNTs have a grid parameter 16.52 Å and a density of 1.40 g/cm3. The space between the tubes is also dependent on the chiral. Armchair tubes have a spacing of 3.38 Å, zigzag tubes have a spacing of 3.41 Å, and the tubes chiral (2n, m) are worth spacing between layers of 3.39 Å.

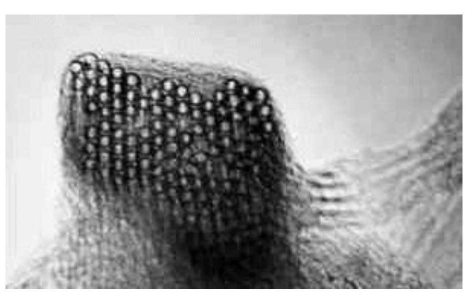


Illustration 29 A cord of nanotubes, made with about 100 of uniform diameter SWNT.
Picture taken of http://html.rincondelvago.com/nanotubos-del-carbono.html

- ***Properties***

In general the properties of nanotubes depend mainly on the following factors: the number of concentric layers it has, how they are rolled and the diameter of the nanotube.

Electronic Properties

- They conduct electrical current.

- They can act similar to metals (they act as semiconductors or even superconductors).

Mechanical Properties.

- Using nano materials we can get materials as hard as dimond

- It has a high "mechanical strength".

- It has a high flexibility.

Elastic Properties

- Because of its geometry, the nanotubes could be expected to be extremely hard in the direction of the shaft, but instead are flexible to deformation perpendicular to the axis.

- The curvature causes increased energy: carbon nanotubes are less stable than graphite, and the smaller the diameter the lower stability.

- For large radial deformations, nanotubes may be unstable. This occurs mainly for large diameter nanotubes.

- The mechanical properties of nanotubes are superior to carbon fiber, partial resistance to deformation, flexibility, etc. Which make them suitable for many applications.

Thermal Properties

- It features high thermal conductivity in the direction of the axis of the nanotube.

Table 5 Table of comparative properties of a Single Wall Carbon Nanotubes (SWNT).

PROPERTIES	SWNT	BY COMPARISON
Size	0.6 TO 1.8 nanometers in diameter	Electron beam lithography can create lines of 50nm wide.
Density	1.33 to 1.40 g/cm^3	Aluminum has a density of 2.7 g/cm3.
Tensile strength	45,000 million pascals	Alloys of high strength steel to break about 2,000 million pascals.
Elasticity	They can be bent to large angles and return to their original state without damage.	The metals and carbon fibers fracture at similar efforts.
Current carrying capacity	Estimated in billions of amperes per square centimeter.	The copper wires are fused to one million amperes for approximately 2cm.
Field emission	They can turn matches with 1-3 volts if electrodes are spaced one micrón.	Molybdenum tips require fields of 50 to 100 volts / m and have very limited lifetimes.
Heat transfer	It is predicted that as high as 6,000 watts per meter per kelvin at room temperature.	The nearly pure diamond transmits 3.320 W / mK
Thermal stability	Stable even at 2,800 degrees Celsius in vacuum and 750 ° C in air.	The metal wires in microchips melt between 600 and 1000 º C

- ***Applications***

Carbon nanotubes are unique materials as far as their structure and properties are concerned and this makes them an important raw material for the development of large number of applications that can provide unique characteristics.

Applications of carbon nanotubes:

- Energy

In the energy area, multiple technologies can benefit from the use of carbon nanotubes, both for storage (of hydrogen and other gases, supercapacitors) and for conversion (fuel cells, lithium ion batteries, solar cells, wind turbines). Especially outstanding is the interest that exists at present, fuel cells. The scientific and industrial interest in these technologies is important.

- Electronics

In the electronics area there are numerous applications for carbon nanotubes: nanocircuits (interconnects, diodes, transistors, switches), field emitters (flat panel displays, lamps, luminescent tubes, cathode ray tubes, electron beam lithography, sources of X-ray, microwave amplifiers, gas discharge tubes in telecom networks, electron microscopes, nanotriodos, betatrons), RF filters, memory, optoelectronics, recorded and spintronics. Foremost among all field emission, in particular, flat panel displays. There are now prototypes of memories, field emission lamps, X-ray sources, oscillators, diodes and field emission displays.

Although not yet commercialized electronic products incorporating carbon nanotubes, is expected to happen in the not too distant future and at that time will revolutionize the market by offering speed, miniaturization and long life.

- Sensors

Carbon nanotubes can be used to develop chemical sensors / biological, mechanical, thermal, electromagnetic field emission. Which aroused the most interest are the biological and chemical for its potential use in the detection of pollutants and for use in biological environments. There are now prototypes of sensors for heavy metals in water and debuggers for fluids.

- Scientific Instrumentation

Carbon nanotubes can be used for the manufacture of probe tips of scanning probe microscopes, as well as coulter counter membranes. Volume results highlight the scanning probe microscopes and, within them, the AFM (Atomic Force Microscope). A prototype of the AFM probe tip.

- Photonics

In the area of photonics, carbon nanotubes will improve existing devices and also be the basis for the emergence of new ones that will increase the independence of the photon with respect to electronics. The main applications identified are high-pass filters for light, saturable absorber mirrors for passive mode blocker emitting laser pulses, noise suppressors and switches.

- Materials

Nanorreforzados materials with carbon nanotubes are obtained by dispersing them in a matrix of another material. In this manner, new materials with interesting mechanical, electrical, electrorreológicas, hydrophobic, flame retardants, optical, chemical and thermal. Among the materials reinforced with carbon nanotubes for structural highlights, which exploit the mechanical properties of carbon nanotubes resulting composite lightweight and high mechanical strength.

There is a high degree of overlap of this application with others so, for example, for the development of some electronic products using composite materials containing carbon nanotubes, - while in other cases individual nanotubes are used and the same applies in other areas.

They are marketed as sports equipment made from composite materials incorporating carbon nanotubes, such as baseball bats, bicycles, tennis rackets, badminton rackets or hockey sticks.

The market for materials is presented and the most advanced of all the potential applications of carbon nanotubes.

- Biotechnology and Chemistry

There are a number of potential biotechnological and chemical applications for carbon nanotubes: adsorption and absorption, catalysis, electrosynthesis and medicine. Stresses in a special way medicine where carbon nanotubes pose an extraordinary revolution in different aspects such as administration of drugs

- Mechanics

Have been identified in this area the use of carbon nanotubes for the development of actuators, dampers, fluid devices, tribology, NEMS and MEMS.

Table 6 Examples of some applications

APPLICATIONS	THE IDEA
Chemical and genetic probes "DNA Strands"	A microscope with a nanotube tip can locate a strand of DNA and identify the chemical markers that reveal which of the possible variables of a gene with the thread
Mechanical memory "RAM nonvolatile"	It has tested a screen of nanotubes deposited on a support block as a function of binary memory devices, voltages forcing contact between tubes ("on" state) or separation ("off" state)
Nano-tweezers	Two nanotubes attached to electrodes on a glass rod, open and close via a voltage change. These clamps are used to imprison and move objects 500 nanometers in size.
Supersensitive sensors	Semiconductor nanotubes a resistance change drastically when exposed to alkalis, halogens and other gases at room temperature. Hence the hope of achieving better chemical sensors.
Hydrogen and ion storage	The nanotubes could store hydrogen in its interior cavity and gradually release it in fuel cells cheaper and more efficient. Also home to lithium ion batteries that could lead to longer term.
Maximum strength materials	Embedded in a composite material, the nanotubes enjoy enormous elasticity and tensile strength. Could be used in cars that bounce off buildings in an accident or an earthquake hover instead of cracking.
Scanning microscope higher resolution "This application is ready for market"	Attached to the tip of a scanning probe microscope, the nanotubes can amplify the lateral resolution of the instrument factor of ten or more, allowing clear representations of proteins and other molecules.
Mechanical oscillator "theoretical versions"	An internal nanotube could range at frequencies of the order of giga-hertz in a nanotube higher under the influence of Van der Waals forces.

- ***Price of carbon nanotubes***

The price of carbon nanotubes is very varied, ranging from € 8.15 per gram to € 1631 per gram, depending on nanotube type, purity and quality.

In 2020, the price of the carbon nanotubes might be from 10 to 100 times lower.

- ***Market of carbon nanotubes***

The world market is dominated by the MWCNT because they are cheaper to produce the SWCNT. The MWCNT used in applications where the price is important that the structure of the nanotube, as the reinforcement of composites, while SWCNT that are preferred in applications such as electronics where need nanotubes with great perfection in structure but are more expensive.

The largest potential market applications and further development are the materials, electronics and sensors, especially chemical and biological.

The high potential market for applications in **biotechnology and chemistry** is because of medical applications, especially for drug delivery, have a promising future, but it is a very immature technology.

The **energy** is also expected to be an application with a large potential market, but has yet to evolve hard to achieve adequate maturity.

57 patents of applications of carbon nanotubes in the energy field have been identified. Of these, 31.5% deal with fuel cells, followed by 27.4% for the storage of hydrogen and other gases.

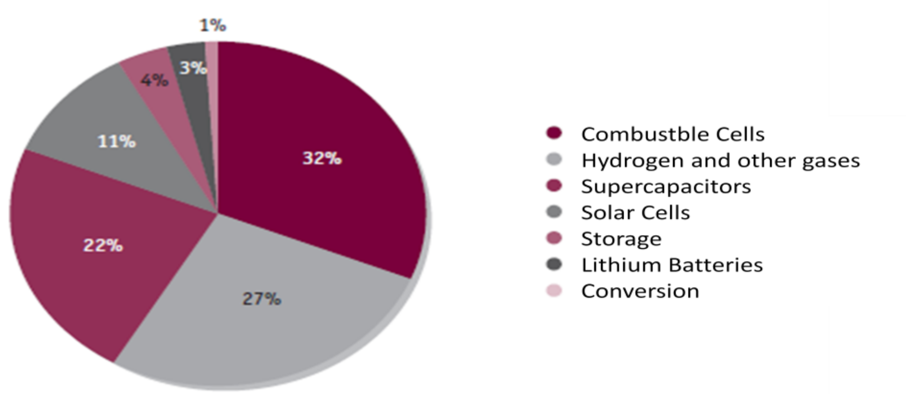


Illustration 30 Distribution of patents according to the energy fields.
Graph taken of www.madrimasd.org/informacionidi/biblioteca/publicacion/doc/vt/vt11_nanotubos.pdf

The search for solutions based on carbon nanotubes for the development of fuel cells is the most frequent subject.

The **mechanics, photonics and scientific instruments** are some mature technologies as well, with less market potential that all the applications mentioned earlier.

The main countries that publish scientific references are U.S., China, Japan and Korea, so that, although U.S. the leading country, the total Asian publications exceed the U.S. Europe lags behind U.S. and Asia in terms of number of scientific references.

In patents there is a clear American leadership over the other regions, followed by Asia and Europe. These data are a clear reflection of the strong interest of U.S. industrial firms in the applications of carbon nanotubes as they have a very diverse market in which output can have a multitude of products.

In the field of Energy United States is again the leader in number of patents, followed by two Asian countries: Japan and Taiwan.

In general the market for applications of carbon nanotubes is very new. Except for some composite materials, the remaining applications are not yet marketed, some already exist as prototypes and other opportunities only arise as a result of future scientific research.

For applications of carbon nanotubes from breaking permanently to the market needs to move forward on many fronts. Nanotube suppliers must improve the quantity, quality and price of producing nanotubes, and their ability to adapt to the requirements of its customers and application vendors must find new ways to manipulate the nanotubes to develop their products by industrial processes.

Thus, it is observed that carbon nanotubes have enormous scientific and industrial interest. Their use in the development of numerous applications can bring to these important improvements to make a significant commercial impact and will result therefore in great benefits for companies that produce them.

5.2. Conversion

5.2.1. Illumination.

1. **LED technology.**

LED acronym means “Light Emitting Diode”.The diode is a semiconductor light source. It is a device that emits incoherent narrow-spectrum light when polarized directly the PN junction of it. This phenomenon is a form of electroluminescence

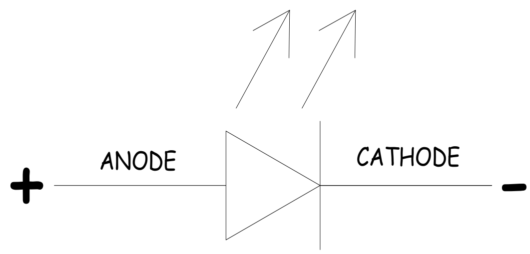


Illustration 31 *LED diode symbolic representation.*

The first LED was developed in 1927 by Oleg Vladimirovich Losev, however not used in the industry until the 1960s. It could be built only red, green and yellow in low light intensity and limited their use for remote controls and appliances to mark the on and off. At the end of the twentieth century were invented ultraviolet and blue LEDs, which gave way to the development of white LED, a blue light LED with phosphor coating that produces a yellow light, the mixture of blue and yellow produces a white light called “Moonlight” getting high luminosity (7 lumens each) thus has expanded its use in lighting systems

Today, are developing and beginning to market LEDs with performance than those of recent years and with a promising future in various fields, including general lighting applications. As an example, we can emphasize that Nichia Corporation has developed a white light LEDs with a luminous efficiency is even higher than the vapor lamp, high pressure sodium (132 lm/W), which is considered one of the most efficient light sources.

Spontaneous emission therefore does not occur significantly in all the diodes is only visible as visible light LEDs, which have a particularly constructive approach in order to avoid radiation is absorbed by the surrounding material and a band gap energy corresponding to coincide with the visible spectrum. In other diodes, the energy is released mainly as a heat, infrared radiation or ultraviolet radiation. In the case of the diode released in the form of ultraviolet, you can get to take this radiation to produce visible radiation, using fluorescent or phosphorescent substances that absorb ultraviolet radiation emitted by the diode and then emit visible light.

2. LED illumination, advantages and disadvantages.

The future bulbs for illuminating a house seem to be the LED bulbs; actually is impossible to compare in terms of efficiency the incandescent conventional bulbs with LED bulbs.

Advantages of LED illumination:

- **Lower power consumption:** LED lamp is powered at low voltage and low power consumption.

For example: A 50 W halogen lamp light power 25 lumens/ W by getting a total of 1250 lumens. To achieve the same illumination LED lamp we will need 179 LEDs (using high brightness LEDs that illuminate 7 lumens/ unit), thus we have the same lighting with lamps and yet both our consumption with the LED lamp will be four times smaller and consumes only 13 W approximately.

- **Low voltage:** All our products are fed to 24 V DC, perfectly adapted to most of the power supplies of equipment, and minimizing the risks of electrocution. The range of voltages is between 12 and 250 V. In our house the voltage will be 230V.
- **Faster response:** The LED has an answer much faster performance than halogen and fluorescent, the order of few microseconds, this makes it ideal for use with a strobe (strobe systems), thereby increasing the benefits of the latter.
- **Low temperature:** LED is powered by low voltage and consumes little energy and therefore emits little heat. This is because LED is a device that operates at a low temperature relative to the light that it provides. Other lighting systems equal brightness LED emits much more heat.
- **Small spectral width:** The LEDs have a small spectral width, thus making them the perfect system of lighting for machine vision, because this way the camera captures much more detail subject and can better appreciate the potential weaknesses therein.
- **Wide spectral band:** The LED is a fixed wavelength device but can work in a wide band of the spectrum. To cover all the bandwidth available on the market a wide range of LED that will allow us to light with a wavelength specifies, or which is the same in particular color (red, green, amber, white and even ultraviolet).
- **Brighter light:** In the same conditions of luminosity as their rivals, the light emitted from the LED is much shaper and brighter.
- **Durability and reliability:** The life of a LED is very long compared to other lighting systems.

Table 7 Life of a LED

AVERAGE LIFE EXPECTANCY	HOURS
LED	100,000
Fluorescent	20,000
Halogen	4,000

And their reliability is much higher, due to the degradation of the light is minimal in relation to halogens and phosphorescent lights.

The comparison of reliability can be seen in the table below:

Table 8 Comparison of reliability

Datas of the table obtained from the Philips brand in lighting market

LUMINOSITY LOSS	-20%	-30%
LED	45,000 h	100,000 h
Fluorescent	5,000 h	20,000 h
Halogen	1,500 h	4,000 h

Disadvantages of LED illumination:

- **Price:** The biggest drawback of LED is the price, but if we evaluate its multiple and unbeatable operating conditions, and above all its long life in comparison to other lighting systems, we can say that investment is the most sensible, cost-effective we can do.

5.2.1.1. Illumination of the house with LED.

Illumination design of the house was done using specific software called Dialux, all the data and features can be seen in the document annexed of the report.

In such a document among other things are explained:

- The power installed is less than 350 W which is a really low consumption, the reason is that our LED bulbs are 7 Watts but light as a conventional incandescent bulb of 40 Watts, in the house there are installed 38 LED bulbs so the total power installed equivalent to over 1500Watts if they were conventional bulbs, it shows the energy saving compared with other lighting system on the market, in order to save as much as energy as possible.

- We have chosen Philips lamps due to is a brand with a wide range of possibilities in LED lighting concerns, and their catalogues has a very good data specifications to make calculations on efficiency and energy saving.
- Is one of the most popular illumination brands and very compromised with the environment.
- Is a brand with a lot of experience and the reliability is guaranteed.
- Offers plug inns compatibles with Dialux to compare results and even to check the results in 3D.
- The chosen lamps are the model *PHILIPS Leuchten Lux Space MiniBBS481 1xDLED-3000 PSU-E WH,* all features are fully explained in Annex III.

Technical specifications of the chosen LED bulbs by Philips:

Philips - Econic Bulb 7 W (40 W) Bayonet cap Warm white - G08727900871739 -

- EEL: A
- Shape: Bulb
- Light effect: Warm white
- Wattage: 7 W
- Wattage standard bulb: 40 W
- Fitting/Cap: B22
- Voltage: 230–240 V
- Dimmable: yes
- Lifetime of lamps: 25 year(s)
- Lifetime of lamps: 25,000 hour(s)

Illustration 32 Bulb
Picture taken from www.philips .com

5.2.1.2. *How to improve LED illumination with nanotechnology.*

Everybody knows that the LED bulbs are much more expensive than incandescent bulbs, maybe 3 or 4 times more, but they produce about twice as much light per watt; they last up to 50,000 hours or 50 times as long as a 60-watt bulb; and they are very tough and hard to break. Because they are made in a fashion similar to computer chips, the cost of LEDs has been dropping steadily. The Department of Energy of the US has estimated that LED lighting could reduce energy consumption of the country for lighting by 29 percent by 2025, saving the nation's households about $125 billion in the process. We are without any doubt to the future of lighting technology.

But, how does it exactly work? , we will see in the next point that the quantum dots are a nanotechnology application used to improve the LED illumination. [25]

5.2.1.3. Quantum dots

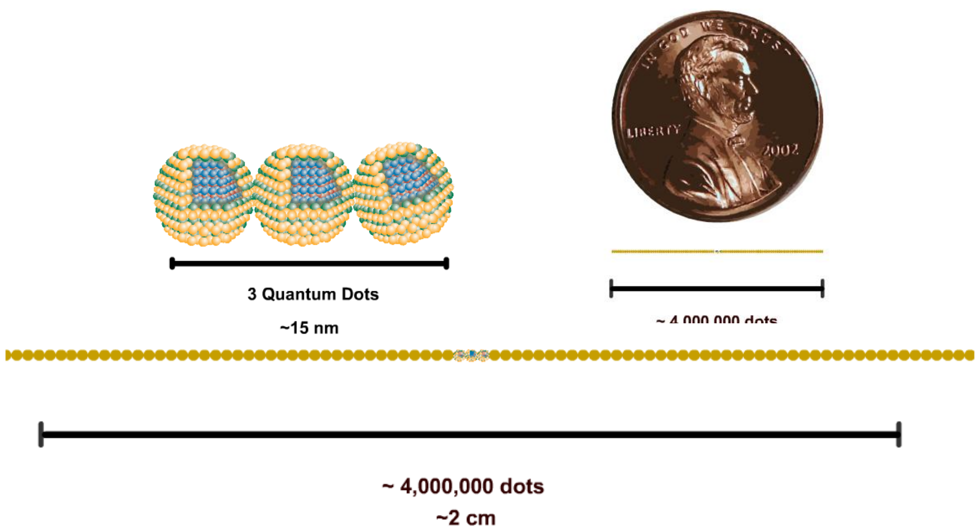


Illustration 33 Size of the quantum dots.
Pictures taken from *http://www.nanomaterialstore.com*

5.2.1.4. *Applications of quantum dots*

The main applications that the researchers are studying nowadays are basically in the following four areas:

Optoelectronics, Biomedicine, Experimental Solar Panels, **Illumination Systems**.

We are going to explain a little bit of each application in order to know what could be achieved exactly in the near future with quantum nanodots technology. However in this project we only focus our research of quantum dots in the areas such as experimental solar panels (in the section of generation), and Illumination systems (in this section).

- **Optoelectronics:** Light-emitting diode lasers are being improved using quantum dots made of indium arsenide and indium phosphide. It seems will be used to make the futures new CD players, barcode machines and things like that to medium term.

- **Biomedicine:** In this area the application of the quantum dots are very revolutionary, due their good illumination properties is possible to insert it in the human body in order to illuminate areas that could be impossible to see without this technology, such tumors, and other cells. It allows do very exacting diagnosis and detecting diseases that before were imperceptibles. Quantum dots emit bright and very stable and there is no fear of being shut down.
- **Experimental Solar Panels:** The third generation of photovoltaic cells used, among other possibilities, surfaces with quantum dots. The yeld is higer than the cells of first and second generation and manufacturing is cheaper. Quantum dots are manufacturing cheap, and can do their work also cheap production. A working quantum point polymer could place, eventually, solar electricity equal to one-off electricity from coal. If this could be done, would be revolutionary. A cell quantum dot solar business is still years away assuming it is possible. But so, would help overcome this fossil fuel.
- **Illumination Systems:** As we have seen previously, with quantum dots it is possible to achieve new lighting systems with more efficient performance.[31]

Some data and publications: [30]

"In lighting, quantum dots allow the colour of the light from a light source to be precisely controlled, says Jason Hartlove, the chief executive of Nanosys, based in Palo Alto, California—one of a handful of companies making quantum dots and selling lighting components based on them." The Economist, March 4th, 2010.Quantum Dots: A quantum leap for lighting. [30]

Report of global market of Quantum Dots:

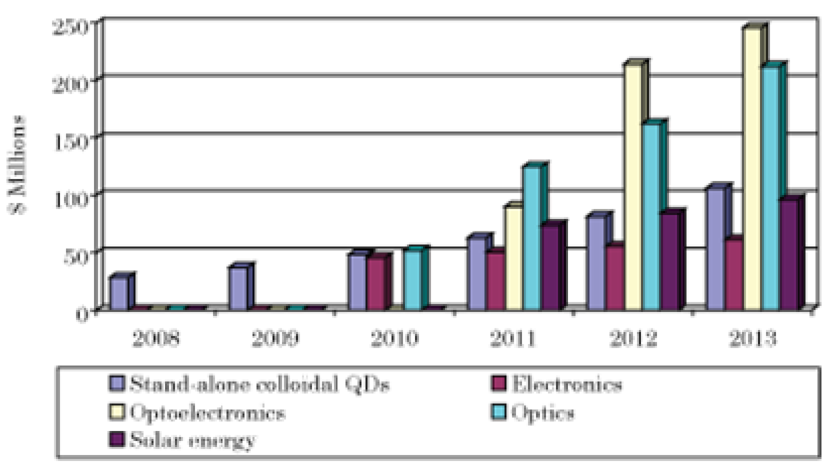


Illustration 34 Global market growth for quantum dots in promising commercial market sectors, 2008-2013 ($ Millions)

Graph taken from BBC research Report code : NANO27B, Published: September 2008, Analyst: John Oliver

Phosphor dots shown under UV excitation. [29]

Illustration 35 Phosphor dots shown under UV excitation.
Picture taken from *http://www.nanomaterialstore.com/nano-phosphor.php*

We know too well that LED technology is the lighting system is more efficient and has better future. However it has some points that could be even better. For example, the color quality, but that is comes to solving a new breakthrough developed by nanotechnology. Current methods for increasing this visual performance are too expensive, too power hungry, and compromise on brightness.

A phosphor material created from nanomaterials was developed, that increases the brightness of the colors of LED lights which can be incorporated into any lamp or device that uses LEDs as a layer. The best thing about this system , apart from that can generate a spectrum of vivid colors, is that it does so without increasing power consumption and also makes it can easily incorporate the devices without having to significantly modify their production systems.

Now, unlike organic LEDs are polymeric LEDs (PLEDs), where the latter presented a dissolution process, which is much easier and cheaper costs. Currently, improve their performance has been the focused target of much research and developments within the last two decades.

One application would be the integration of nanostructures in the PLED, incorporating self-assembled organic nanowires to these duplicate the performance.

The system is quite simple; the best thing is that, unlike others, it is not to reinvent the technology from the beginning. The manufacturers would only have to implement this layer in the manufacturing chain and to use. In addition, the system could also improve the laptop displays or HD TV, and without increasing power consumption.

Nanosys: Is a Company founded in 2001 to drive materials revolution, located in Palo Alto, California. Nanosys (Palo Alto) designs products based on a technology platform that incorporates high performance inorganic nanostructures. This technology is currently being applied to address opportunities in LED general lighting among other things.

The Nanosys QuantumRai device helps makers of LED displays deliver a better visual experience, using their existing manufacturing processes, at a fraction of the cost of alternatives. Architected from **quantum dots**, the Nanosys QuantumRail improves color gamut, saturation and brightness from blue LED sources while delivering higher efficiency at lower cost than alternatives like OLED. [35]

Get better picture quality for the same low energy input.

Illustration 36 Quantum dots

Picture taken from http://www.treehugger.com/files/2010/01/ces-2010-nanosys-using-nanotechnology-to-make-led-lighting-more-beautiful.php

Article .CES 2010 - Nanosys Using Nanotechnology to Make LED Lighting More Beautiful by Jaymi Heimbuch, San Francisco, California on 01.11.2010 [32]

According to Nanosys Company sources LED lights can increase up to 10 % efficiency, that means substantial energy savings when incorporated into our house this application. [27] [28]

Light creates a warm white light with LEDs that have Nanosys' material layered over them:

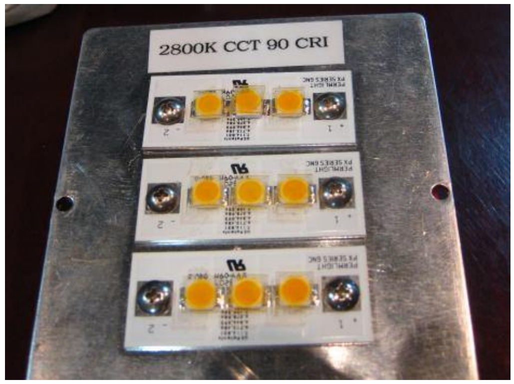


Illustration 37 Light creates a warm white light with LEDs that have Nanosys' material layered over them
Picture taken from http://www.treehugger.com/files/2010/01/ces-2010-nanosys-using-nanotechnology-to-make-led-lighting-more-beautiful.php

5.2.2. Appliances.

5.2.2.1. High efficiency appliances.

"The European Union (EU) to harmonize national measures concerning the publication of data on the consumption of energy and other essential resources by household appliances, so that consumers can choose devices that superior energy efficiency.

***On 30 and 31 March 2009**, the Commission submitted for endorsement by the Committee of Member States, draft Directives for the energy labeling of household refrigerating appliances, televisions, washing machines and dishwashers.*

In the annex there is the document agreed by the European Committee where explain the rules concerned with the actual and future regulations.

Brussels, 31 March 2009"

Text taken from

http://europa.eu/rapid/pressReleasesAction.do?reference=MEMO/09/144&format=HTML&aged=0&language=EN&guiLanguage=en [34]

The information provided by the manufacturer:

In this part of the label is where the manufacturer states the characteristics of the instrument brand, model, effectiveness, efficiency, consumption, etc.

5.2.2.2. European Energy Labels.

The energy label reports the values of energy and water consumption of the device (efficiency) and the benefits thereof. That is, how well an appliance is capable of performing their tasks (efficiency). It is mandatory in refrigerators, freezers, washers, dryers, dishwashers, ovens and air conditioners.

The color and wording of the efficiency:

There are seven levels of efficiency represented by colors and letters. They range from the green and letter A for the most efficient equipment, even the color red and the letter G the least efficient. For refrigerators have created two levels: A + and A ++, the lowest power class A.

Illustration 38 European Energy Labels
Pictures taken from www.philyps.com

5.2.2.3. Our appliances.

After having conducted a market study of the major brands of electrical manufacturers we agreed Siemens, due to the level of efficiency and energy saving in their appliances.

Why Siemens?

Siemens has created the ecoPLUS label that as can see above that distinguishes one consumer appliances with less than Class A, within each of the ranges.

Therefore, Siemens appliances to choose ecoPLUS seal to ensure maximum performance, lower consumption and minimal environmental impact.

- Dishwasher with zeolites filter to save water, only seven liters of water are necessaries with ECOplus label.
- IQdrive wash machines have unique qualities that are at the forefront of the market, with ECOplus label.
- Fridge A+ with ECOplus label.
- TVs with LED screen seems to be the best option to save energy while maintaining the best image quality. [39]

5.2.2.4. How to improve appliances with nanotechnology

- **Thermoelectricity**

Thermoelectricity is the conversion of heat to electricity or vice versa.

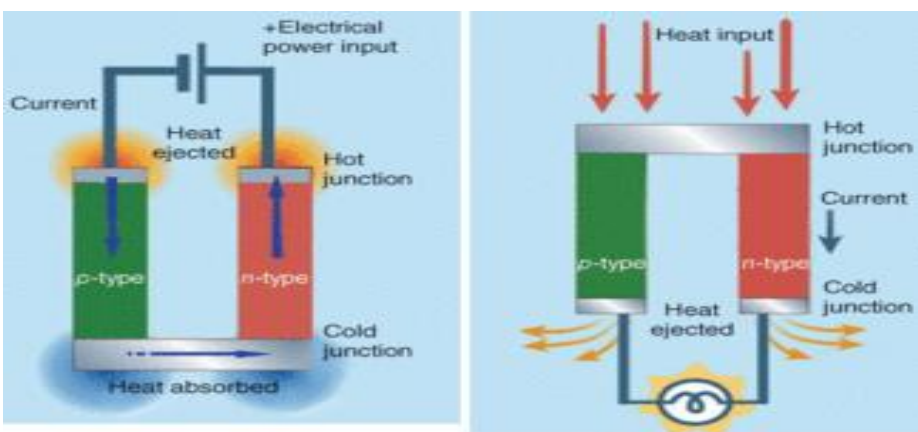


Illustration 39 Scheme of the process of the thermoelectricity
Picture taken from http://images.pennnet.com/articles/lfw/thm/th_0708lfw04f1.gif

The most efficient materials are those which have a relatively high electrical conductivity and low thermal conductivity.

The target of the Thermoelectricity is to increase the efficiency of the electric and electronic devices, making useful energy from the waste of heat produced by such appliances.

The key to the development will be controlling the dimensionality of new materials to ensure that thermal conductivity is decreased while at the same time maintaining or increasing electrical conductivity.

Nanotechnology applied to thermoelectricity:

- **Nanocrystalline materials:** It can aid in decreasing thermal conduction.
- **Quantum well materials:** These effectively confine electric charge to two dimensions.
- **Superlattices:** These have the effect of reducing thermal conduction without affecting electrical conduction.
- **Nanowires and Nanoparticles**: Could be increased the efficiency and have potential applications in micro-coolers and micro-generators. [33]

5.2.3. Biogas.

5.2.3.1. Biogas technology.

Biogas is a mixture whose main components are methane and carbon dioxide, which produces cone result of fermentation of organic matter in the absence of air, by the action of a group of microorganisms.

In nature there is a wide variety of organic waste from biogas which can be obtained, among them are: wastes from domestic animals such as cows, pigs and poultry, vegetable waste such as straw, grass, leaves and household waste.

Biogas is the result of digestion of biomass in anaerobic conditions has a caloric value of about 5,500 kcal/m^3.

Biogas in Europe: The European Union countries are becoming more and more interested in the characteristics of biogas in terms of environment and energy production, developing its recovery appropriate channels according to their potential. Thus biogas production reached almost 5.3 million tons of oil equivalent in 2006, which represents a 13.6% increase over 2005.

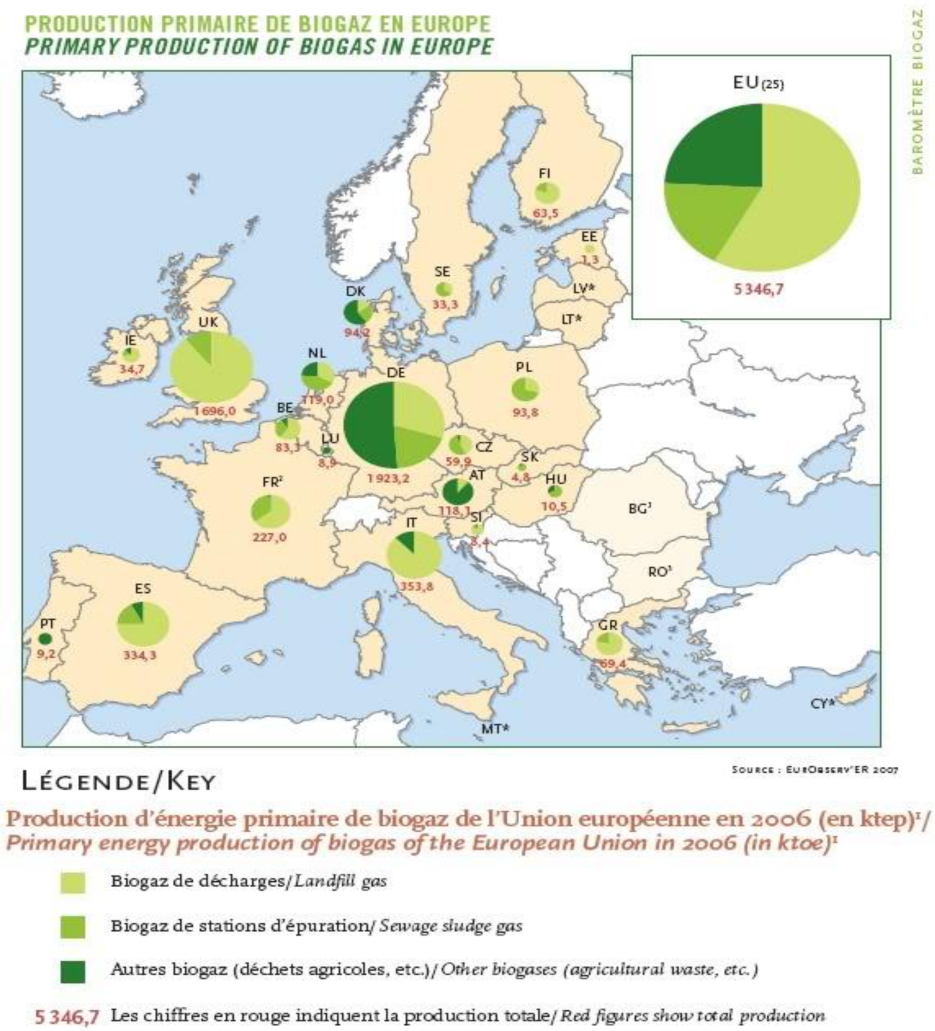


Illustration 40 Primary production of biogas in Europe

Map taken from *Biopact Toward a green energy pact between Europe and Africa.*

5.2.3.2. Biogas installation in a familiar house.

- Daily load: 20 Kg of manure (cow) and 60 liters of water mixed.
- Biogas production diary: 700-750 liters (4 to 5 hours of cooking)
- Fertilizer production diary: 80 liters
- Retention time: 75 days
- Average time delay to start working: 2 months
- Temperature: 10 ^{o} C
- Ambient temperature: -12 to 20 ^{o} C.

To define our possible installation of biogas was used as a reference a reference a study to supply with biogas flat regions of Bolivia the project is called *"Biodigestores familiares, guía de disenyo y manual de instalación",* collaborative project between Germany and Bolivia and directed by engineer Jaime Martí Herrero in 2008.

A scheme of a complete digester system for a single house, along with the transportation of biogas to the kitchen, considering the safety valve and the reservoir of biogas.

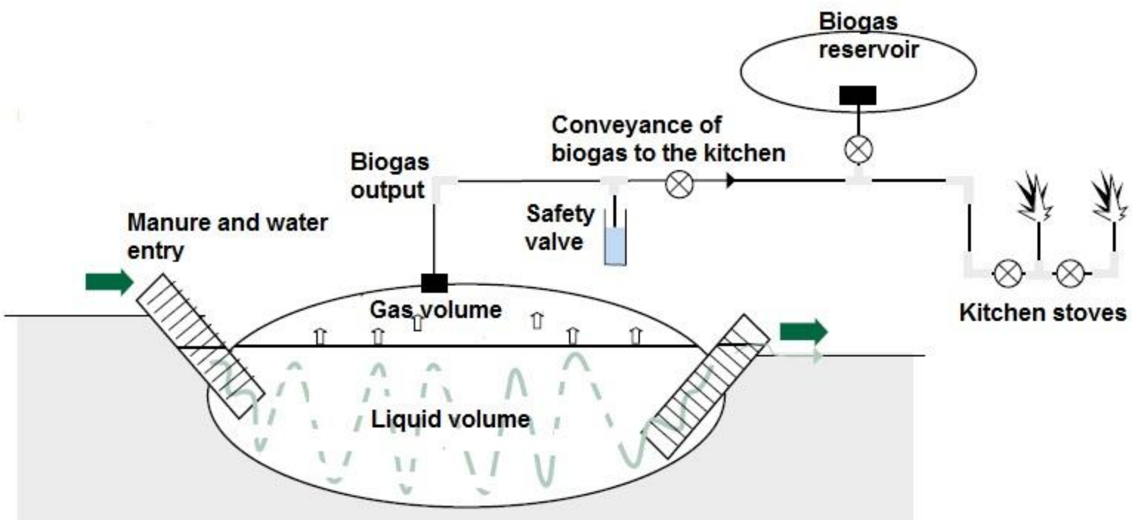


Illustration 41 Scheme of the transportation of biogas to the kitchen

Picture taken from http://www.upc.edu/grecdh/pdf/2008_JMH_Guia_biodigestores.pdf

It can be used for natural insulation gases, such as straw (reeds, for example).

The placement of the insulation must be in natural exterior walls of rammed earth to win the heat from inside the greenhouse and putting the insulation in the greenhouse.

How to improve biogas with nanotechnology?

The optimal conditions to produce biogas inside the digester of the installation are between 6ºC and 40ºC, and that below these temperatures, microorganisms that cause fermentation do not develop, we also have to bear in mind that from 40 degrees is detrimental to the proper growth of bacteria, even to completely destroy the process if it reaches temperature of 75 degrees.

Then the temperature plays an important role in the biogas production process, for example, gas production per day is half if we work at a temperature of 20 degrees to 25 by working to achieve the same amount of biogas would have to double the amount of organic waste.

We must take into account that the winter in Poland is very cold, and it is a drawback to achieve production of biogas, so we need an extra quantity of heat. We will achieve this by using part of the gas produced to heat water and driven by a small pump through a coil installed inside the digester. [36], [37], [38]

Here is where nanotechnology could have a very important role:

Illustration 42 Nanomaterials for the construction of a digester

Picture taken from J. Herrero. 2008. Biodigestores : Guía de diseño y de instalación.GTZ-Energía. Bolivia.

In the previous picture you can see the preparation of insulating materials for the construction of a digester in the Bolivian highlands, where the variation in temperature can be 30 ° C on the same day, -5 ° C at night and 25 ° C at noon.

We can see in this picture Biodigestor already installed, and beginning to be and manure -laden water until their mouths are plugged
tubes inside and out. The digester house would have a similar size to the picture; this is a design for a biogas provides townhouse in Bolivian highlands.

Illustration 43 Digester installed

Picture taken from J. Herrero. 2008. Biodigestores : Guía de diseño y de instalación.GTZ-Energía. Bolivia.

With nanotechnology we can get insulation materials that would be unthinkable a few years ago.

Thanks to that we can maintain the ideal temperature inside the digester and thereby achieve high efficiency in biogas production.

Insulating nanomaterials are used to keep the temperature constant in an enclosed space such as a house or a vessel, either warmer or colder than the surroundings

The basic requirement for thermal insulation is to provide a significant resistance path to the flow of heat through the insulation material.

To accomplish this, the insulation material must reduce the rate of heat transfer by conduction, convection, radiation, or any combination of these mechanisms. [34], [35], [36]

Insulating materials can be adapted to any size, shape or surface.

Different materials could be used by this target such as:

1. **Aerogels and nanofoams**. Low density, highly porous materials and high dielectric constant , with pores in nanoscale dimensions.
2. **Thin films.** Photochromic, thermochromic and electrochromic thin films are being developed.
3. **Nanocomposites.** Materials containing nanoparticles are being developed.

But in the next point we will explain better the insulation possibilities of the nanomaterials. [33]

5.3. Insulation

Thermal insulation is the technology that deals with the trapping of heat inside a structure through the use of materials with a favorably low rate of heat transfer. Insulation is one of the most important areas of a house in terms of energy conservation as no matter how much energy you convert, and how efficiently you do it, it can be a wasted effort if the insulation is not carefully fitted and designed. Because of this, insulation was a major focus of our project, with the aim of:

1. Finding a way of insulating a house without nanotechnology which is an improvement on conventional insulation.

2. Finding a nano material suitable for insulating our nano house and work out a way of implementing it.

For both of these studies we will carry out an efficiency and energy saving calculation, and also a cost analysis. Firstly though, a brief overview of insulation in buildings will be given, beginning by looking at the technology from the customer's point of view. The simplest need of a homeowner is to be warm and comfortable. This can only be achieved with good insulation. The second need is to save money, as logic tells us, the more heat we can trap inside our house; the less money has to be spent producing heat energy as less is needed. Typical materials used for insulation of houses are, rock wool, polystyrene, urethane foam and vermiculite. These materials are often inefficient, non environmentally friendly and damaging to humans.

The next part of this report will look at a conventional energy saving house during which these insulation substances will be looked at in more detail. Then in the feasibility study nano materials will be looked at to see how they can help save energy through insulation. This is a relatively new and groundbreaking step for the science of insulation.

Generally insulation can be divided into two main parts. Insulation of walls and pipes is much different than the insulation of windows due to its transparency. At the beginning let's focus on the first type.

Nowadays there are numerous insulating materials available. We can choose from the variety of Styrofoam, polyurethane, fibreglass or phenolic rigid panel. Using combination of these materials can provide good insulating conditions. It is even possible to obtain the passive house – a house that is not using external heat sources. However that type of house usually has quite bad design (the shape has to be very simple) and enormously also thick walls. Another threat is the fact that in cold regions of earth building such a house is almost impossible. Nanotechnology is a great chance to improve that situation.

Using the Uponor OZC we have calculated the heat consumption of our house. We have assumed the 20 degrees Celsius in our house and standard Styrofoam and fibreglass insulation. It is situated in Pomaria, and we are using metrological data for Koszalin (metrological station in Kołobrzeg). The total heat that will be dissipated through our house is **18813** kWh for a whole year. That energy is needlessly wasted.

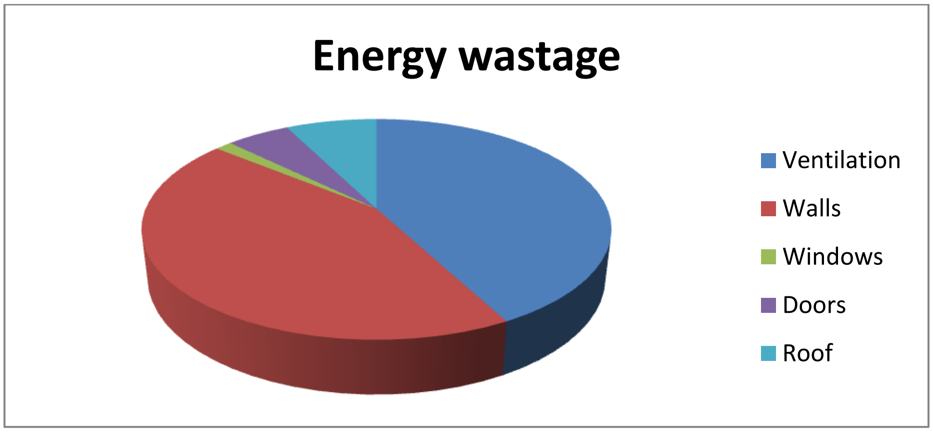


Illustration 44 Graph present percentage of energy wasted in a whole house

This graph present percentage of energy wasted in a whole house. As you can see around 43% of energy is wasted due to ventilation, 14% to windows and 43% through walls and doors.

5.3.1. How can we improve that situation?

5.3.1.1. Walls and doors.

Currently the most popular insulating materials are Styrofoam and glass wool, whose thermal resistance is 0,52 and 0,55 [m^2C/W] respectively. Styrofoam is a porous material obtained directly from polystyrene. It is highly flammable, so some sort of Styrofoam contains special additions. This type of Styrofoam is marked as self-extinguish. Styrofoam also provides some acoustic insulation. Glass wool is an insulating material composed of fibreglass. [42] [43]

Due to its wool-like structure it is also a good sound insulator.

Illustration 45 Insulating material – fiber glass

Picture taken from

http://upload.ecvv.com/upload/Product/20085/China_Fiber_Glass_Wool20085211742485.jpg

Illustration 46 Insulating material – styrofoam

Picture taken from http://rcreptiles.com/blog/media/styrofoam.jpg

The main advantage of this solution is of relatively low cost and sufficient insulating quality. However, in order to properly insulate a building you have to apply multiple layers of these materials which increase the cost of whole building. Another disadvantage is the fact that Styrofoam and fiberglass are flammable.

Aero gels are having the lowest density of any insulating material. The manufacturing process replaces the liquid component in gel with a gas. Due to that, we obtain a very light "frozen smoke" (as the 99.98% of is volume is simply air) In touch it is very similar to the Styrofoam, but it has better properties. In comparison nanotechnology-enhanced aero gels can reach the thermal resistance of 1.76 with a perspective of growth in a near future. The calculation shows that solution can reduce the energy losses on walls and doors by 69% (maintaining the same layer thickness).

Another important thing is that aero gels are very resistant to fire. Even when the fire starts in one room, they will keep the cool temperature in other rooms. It will not allow the fire to escape the room where it started. [44][45]

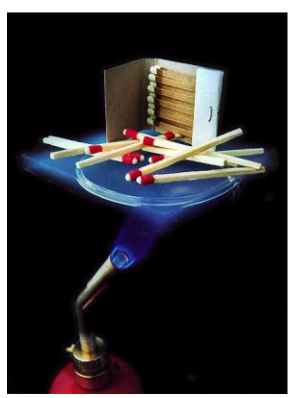


Illustration 47 Aerogels resistant to fire

Picture taken from http://www.optics.rochester.edu/workgroups/cml/opt307/spr08/matt/aerogel-matches.jpg

5.3.1.2. *Ventilation*

In order to save energy in a modern house we can install a heat recovery system. The energy naturally dissipated through the ventilation now can be recovered and used to heat the incoming air. Solutions available today, using a counter flow approach can reach efficiency up to 95%. However, these heat recovery systems are quite big and hard to install. The thin heat wires can be replaced by carbon nanotubes in order to reduce dimensions, and improve efficiency. [46]

Illustration 48 Ventilation – heat recovery system
Picture taken from http://www.isd.com.pl/obrazki/rekuperator1.jpg

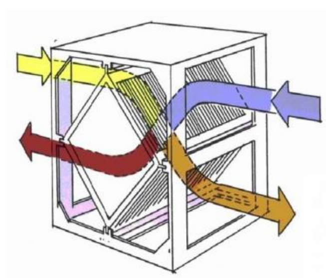


Illustration 49 Ventilation – counterflow heat recovery sytem
Picture taken from http://www.omega-bud.pl/img/klima/rekuperator2.jpg

5.3.1.3. *Windows*

In regions with a long heating season, windows are one of the biggest gaps in insulations of a house. Over the previous few years, windows have undergone a technological revolution. It is now possible to have lower heat loss, less air leakage, and warmer window surfaces that improve comfort of living. The energy efficient windows consist of many different parts – energy efficient frames, double or even triple glazing and special gas chambers. Those windows has also ability to let the heat in, but do not allow it to escape. It is a very efficient way to gain additional heat energy in a passive way. To make use of this technology, proper placement of windows is necessary. Also the whole shape of the house, and the orientation should be adjusted to the average sun elevation in the specific region. The most promising material in further window technology development is aero gel. Using special compounds make these aero gels almost one hundred percent transparent, and provide insulation properties better, than many non transparent materials. [47]

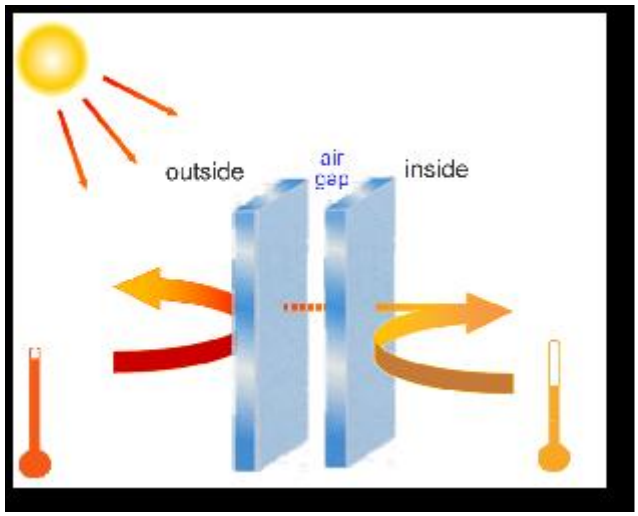


Illustration 50 Double glazing used in modern windows
Picture taken from http://www.jclwindows.com/img/

5.3.2. Summary

Finally we can see that a lot of energy can be saved due to modern technology. The use of carbon nanotubes can not only improve the insulation, but also will help to reduce dimensions and safety.

The graph on the next page presents the energy saved due to nanotechnology.

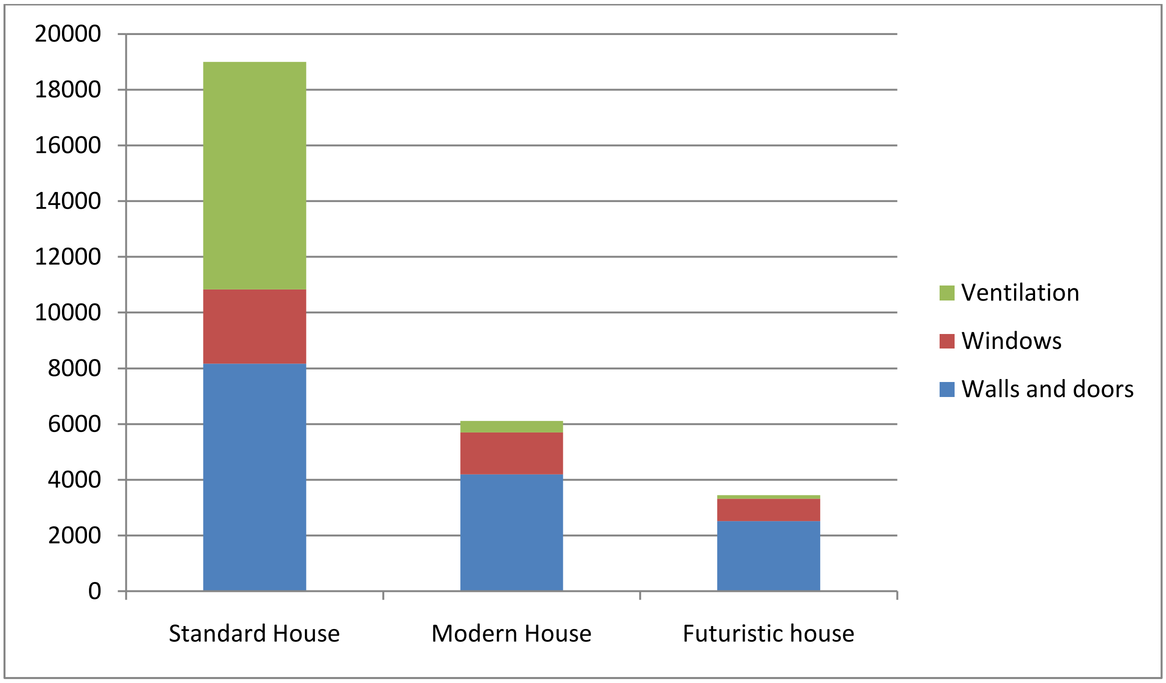


Illustration 51 Graph energy saved due to nanotechnology

As you can see the amount of energy wasted has dropped significantly. We can see that for a modern house around 69% of energy is saved. For a futuristic house (available approximately in 10 years) it is even better, and around 82% of energy will be saved. We should also keep in mind, that each year new appliances of nanotechnology are being found. It is very hard to predict all the possibilities, especially the detailed specification of future products.

Here are some pictures showing our energy consumption study in UPONOR OZC program. [41] [48] [49]

Table 9 Energy consumption study

Project name:	**Nano**
Localization:	**Dziwnów**
Date:	**Sunday 30.05.2010, 19:06**
Climate zone	**3**
Surface [m2]	**120**
Volume [m3]	**300**
Calculated energy consumption [W]	**7883**
Energy for ventilation	**1592**
Energy per square meter	**535**
Energy per cubic meter	**214**
Energy consumption per year [kWh/year]	**17837**

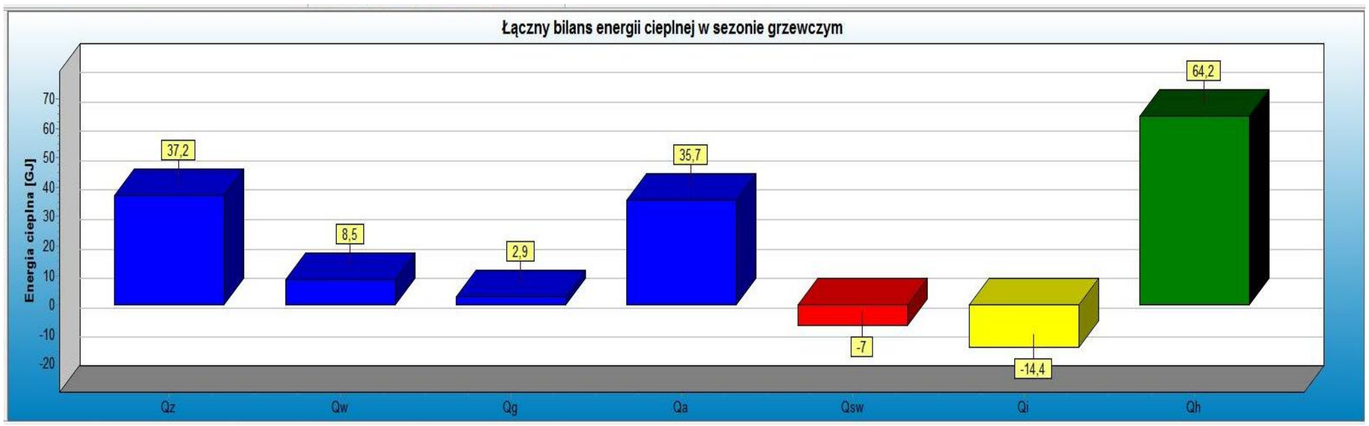


Illustration 52 – Yearly summary of energy consumption

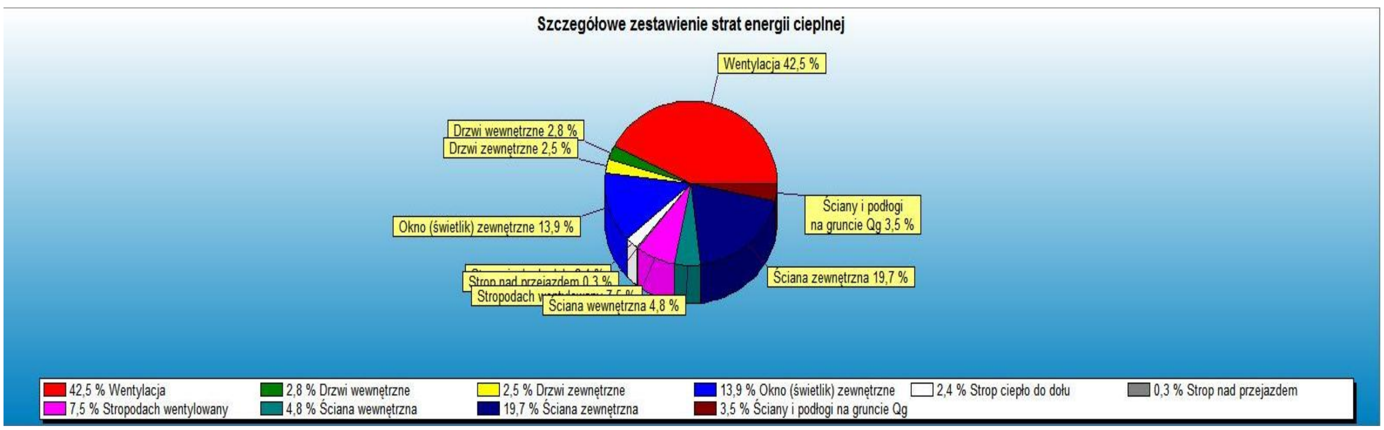


Illustration 53 – detailed analysis of energy consumption

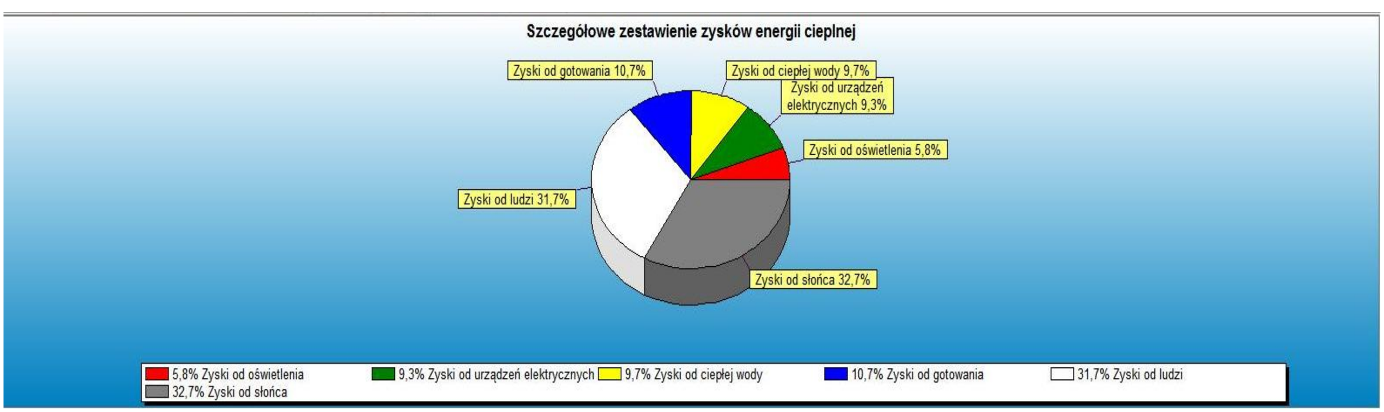


Illustration 54 – detailed analysis of energy gains

5.4. Storage

In a house we want to implement two types of storage devices: batteries and capacitors.

5.4.1. Batteries

Battery is an electrical energy storage device consisting of one or more electrochemical cells. It stores electricity in chemical energy and it can be converted into electricity. It is characterized by long charge and discharge time. Thanks to that we have long fairly uniform power supply; however the power generated by batteries is low in comparison to capacitors.

The first battery was invented in 1800 by Allessandro Volta. Since then batteries have become very popular and many types were invented. There are two types of batteries. Primary batteries that can be charge and discharged only once, and secondary batteries that can be charged and discharged many times. In course of our project we took into consideration only secondary batteries.

Nowadays, a single cell battery consists of two half cells connected with conductive electrolyte. One half cell consists of electrolyte and anode, the second one electrolyte and cathode. Anode is a negative electrode to which negatively charged ions migrate (anions). Cathode is an opposite to a anode. It is sometimes called a positive electrode. Toward the cathode positively charged ions (cations) migrate. What triggers the conversion of chemical energy into electrical energy is a redox reaction. The reduction (addition of electrons) of cations is present on the cathode, and oxidation (removal of electrons) of ions occurs on anode. The cathodes are not touching directly each other but are connected electrically by electrolyte. Two half cells are linked with salt bridge separator that permits the transport of charged molecules (ions) but not water molecules. The drawing on the other page shows a simple galvanic cell.

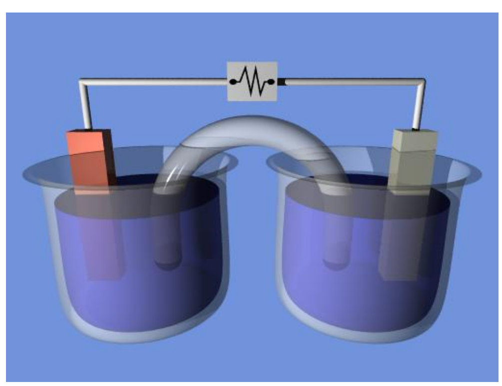


Illustration 55 Sample drawing showing the voltaic cell from a battery.

Picture taken from http://en.wikipedia.org/wiki/File:ElectrochemCell.png

Each half cell has a specific value of electromotive force (also called emf). It is determined by its ability to drive electric current from the inside to the outside of the half cell. To describe battery we use a term called net emf. It is a difference of each half cell emf. This can be shown by equation

$E_{net}=E_2 – E_1$

Where:

E_1 – Emf of the first electrode

E_2 – Emf of the second electrode

E_{net} can be also described as difference in reduction potentials of two half reactions.

When conversion from chemical energy into electrical one occurs we now deal with an electrical driving force of the battery also called a terminal voltage (ΔV_{bat}) which is represented in Volts. The terminal voltage equals to emf of the cell when the battery is neither charging nor discharging (open circuit cell).

Among secondary batteries we have many different types of batteries. Among the main types of secondary batteries belong: Nickel Cadmium batteries, Lead acid batteries, Nickel metal hydride batteries, Nickel Zink batteries, Lithium polymer batteries and Lithium Ion. Those are conventional types of batteries. Later in this document we will describe how to improve conventional batteries with nanotechnology. [50]

5.4.1.1. Conventional Batteries

- ***NiCd batteries***

Illustration 56 Different types of NiCd batteries.

Picture taken from http://en.wikipedia.org/wiki/File:NiCd_various.jpg

NiCd batteries are a common type of batteries. They consist of nickel oxide hydroxide and metallic cadmium electrodes. NiCd batteries are characterized by big electrical efficiency but have a big disadvantage of memory effect. Memory effect means that the battery when discharged only partially can be charged only to the point of last discharge. That means that after few cycles of not total discharge and charge, battery loses part of its capacity. That results in shorter work time of a device. To avoid memory effect NiCd batteries should be fully discharged before charging them again. Nowadays memory effect can be reversed by a special battery charger with refresh function. Another advantage of NiCd batteries is their low value of self discharge and thanks to this they can be stored for a longer time when charged.

NiCd batteries are nowadays one of the most durable batteries and if carefully charged and discharged can last more than 1000 cycles. They are also inexpensive. However their capacity versus weight is not satisfactory. Nowadays they are changed with NiMH and Li ion batteries. NiCd batteries are also withdrawn from the market because of environmental issues. It is because when NiCd battery is used it's dangerous for the environment, secondly they capacity versus weight is unsatisfactory and thirdly they are very durable and cheap and this is unprofitable for manufactures. [51]

The chemistry in NiCd batteries when discharged is as follows:

anode: $Cd + 2OH^- \rightarrow Cd(OH)_2 + 2e^-$

cathode: $NiO(OH) + H_2O + e^- \rightarrow Ni(OH)_2 + OH^-$

Sumary:

$$2NiO(OH) + Cd + 2H_2O \rightarrow 2Ni(OH)_2 + Cd(OH)_2.$$

- ***Lead acid batteries***

Illustration 57 Car Lead acid battery used in a car.
Picture taken from http://pl.wikipedia.org/wiki/Plik:Photo-CarBattery.jpg

This type of battery is composed of a galvanic cell consisting of lead electrode (anode) and lead dioxide electrode (cathode) both submerged in 37% sulphuric acid which act as an electrolyte. This kind of buttery was discovered in year 1859 and despite its many disadvantages is still one of the most popular big batteries in the world. It is widely used in car industry. It is also used as an element of backup power storage system in many industry buildings, hospitals, telephone centrals and in field lightning systems.

A typical Lead acid battery is built of 6 cells connected in series. Each cell generates an electromotive energy equal 2.1 V so the whole battery has SEM equal 12.6 V. Thanks to low internal resistance lead acid battery is able to generate high voltages and that's why it found use in car industry.

Among the main disadvantages of lead acid batteries is the fact that when a battery is fully discharged the $PbSO_4$ that is formed in the electrolyte starts to crystallize after some time. Crystallized $PbSO_4$ is an electrical insulator. That leads to a drop in capacitance of the battery. To prevent this manufacturers add sulfur to electrodes that lowers the adhesion of $PbSO_4$ crystals on electrodes. Another disadvantage of lead acid batteries is that they can lose easily water when not sealed properly. This leads to concentrating the electrolyte. There is also risk of acid leaking. Both problems can be solved with good sealing. [52]

The chemistry in lead acid battery when discharged is as follows:

anode: $Pb + SO_4^{2-} \rightleftharpoons PbSO_4 + 2e^-$

cathode: $PbO_2 + SO_4^{2-} + 4H^+ + 2e^- \rightleftharpoons PbSO_4 + 2H_2$

Sumary:

$$Pb + PbO_2 + 2H_2SO42^- \rightleftharpoons 2\ PbSO_4 + 2H_2.$$

- ***Nickel Metal Hydride batteries***

Illustration 58 Multi-cell nickel metal hydride battery.

Picture taken from http://en.wikipedia.org/wiki/File:Nickel-Metallhydrid-Batterie.jpg

This is the type of battery where the cathode is constructed from the metallic nickel and the anode is from metal, which reacts with hydrogen liberated during charging, to form a metal hydride compound. The electrolyte is alkali and the salt bridge in these batteries is from polyamide or polyethylene.

Among their main advantages is a high energy density around 0.36 MJ/kg. It also does not contain an environmentally toxic compound such as Cd, like in NiCd batteries. Besides, the anode construction NiMH batteries don not differ much from NiCd batteries. Another advantage of these batteries is that their cell voltage equals 1.2 V so they can be used in exchange for NiCd batteries. NiMH batteries have also around 3 times bigger capacitance in comparison to NiCd type. They also have low memory effect.

On the other hand, NiMH batteries are more expensive than the older type with cadmium. They are also characterized with shorter life (number of charge/discharge cycles). Also they have short time of self discharge.

It took a fairly long time to introduce NiMH batteries into the market. That was because the cell needs absolute sealing, a porous electrode and a high pressure. The only solution was to bind Hydrogen into chemical compound that will be formed during charging. This compound has to decay during discharging to release hydrogen molecules. Such compounds were discovered at the end o the 1960. In modern NiMH batteries anodes are constructed from metallic alloys. Those alloys consist of metals such as vanadium, titanium, zircon, nickel, chromium, cobalt and iron. Why such alloys have better efficiency (binging and releasing hydrogen) is still unknown, the proportions of alloys are established experimentally. [53]

The chemistry in NiMH battery when discharged is as follows:

anode: $H_2O + M + e^- \rightleftharpoons OH- + MH$

cathode: $Ni(OH)_2 + OH^- \rightleftharpoons NiO(OH) + H_2O + e^-$

Sumary:

$$M + Ni(OH)_2 \rightleftharpoons NiO(OH) + MH.$$

- ***Nickel- Zink battery***

Illustration 59 Picture of sample NiZn battery.

Picture taken from http://www.ces-show.com/0239/ritz-camera/accessories/nickel-zinc-batteries/

This type of batteries is fairly old. They are known from around 100 years but only recently some advancement have been made. Nowadays they can be used for cordless power tools, cordless telephone, digital cameras, battery operated lawn and garden tools, professional photography, electric bike and light electric vehicle sectors.

NiZn batteries are commercially available mainly in AA size for digital cameras use. They are similar to NiCd and NiMH batteries however they have higher nominal voltage that equals 1.6 V. NiZn batteries have potential to replace lead acid batteries because they offer higher energy to mass ratio and power to mass ratio as well. That means that they can be up to 75% lighter for the same power value. They are also cheaper in comparison to NiCd. Moreover nowadays in European Union there is a ban for NiCd batteries, which creates the opportunity for NiZn batteries. Another advantage is that nickel and zinc are no heavy toxic compounds they also commonly occur on Earth. They can be fully recycled also.

Among the disadvantages of this battery type is the problem of reforming the electrode. Zink that dissolves to the electrolyte during the discharge cycle does not easily go back to the electrode. It also forms dendrites or whiskers that lead to lowering the capacitance of the battery. Recently this problem was solved by applying electrode separators, zinc material stabilizers and electrolyte improvements. [54]

The chemistry in NiZn battery when discharged is as follows:

anode: $2OH^- + Zn \rightleftharpoons H_2O + ZnO + 2e^-$

cathode: $NiO(OH) + H_2O + e^- \rightleftharpoons Ni(OH)_2 + OH^-$

Sumary:

$$H_2O + Zn + 2NiO(OH) \rightleftharpoons ZnO + 2Ni(OH)_2$$

- ***Lithium Ion batteries***

Illustration 60 Picture of a Multi-cell Lithium Ion battery.
Picture taken from http://pl.wikipedia.org/w/index.php?title=Plik:Lithium-Ionen-Accumulator.jpg&filetimestamp=20080115024209

In this type of battery one electrode is composed of porous carbon and the other one from metal alloys. The electrolyte is made of complex lithium salts such as $LiPF_6$, $LiBF_4$ or $LiClO_4$ in an organic solvent, such as ethylene carbonate. This type of battery has nominal voltage equal to 3.6 V per cell. That means that two times bigger energy can be stored per the same weight in comparison to NiMH batteries. There is also no memory or lazy battery effect. This is a big advantage of these batteries.

Li ion batteries are very popular in consumer electronics, such as laptops, cell phones or digital cameras. They are also being applied in electrical vehicles and energy storage in backup systems. Their advantage is a slow loss of charge when stored properly.

Among the advantages of Li ion batteries are a wide variety of shapes and sizes old batteries that are efficiently fitting the consumers electronics. They are also lighter than other secondary type batteries. Li ion batteries are also characterized by low self discharge rate (around 5- 10% per month comparing with 30% of NiMH batteries)

But there are also disadvantages of Li ion batteries. Storing fully charged batteries at higher temperatures may lead to big irreversible energy losses (25 °C during a year may lead to 20% capacitance loss). These losses can be lowered up to 2% capacity loss by storing the batteries charged only in 40% – 60%. Li ion batteries are also characterized by bigger internal resistance in comparison to NiCd or NiMH batteries. This value increases with both cycling and age. Also Li ion batteries are not so durable as NiMH batteries and can be dangerous (explosive) when treated improperly. When overcharged and overheated they can be irreversibly damaged. Those problems are solved by installing small circuits that will cut off the battery when its capacitance reaches nominal value.

In Li ion batteries lithium ions are transported from and to cathode or anode. This is accompanied by the transition of metal, cobalt, in Li_xCoO_2 being oxidized from Co^{3+} to Co^{4+} during charging. [55]

There are different types of anodes and cathodes used in Li ion batteries. Below are the tables from Wikipedia (http://en.wikipedia.org/wiki/Lithium-ion_battery#Cathodes and http://en.wikipedia.org/wiki/Lithium-ion_battery#Anodes) presenting different composition of anodes and cathode.

Table 10 Different types of anodes and cathodes used in Li ion batteries.
Below are the tables from Wikipedia (http://en.wikipedia.org/wiki/Lithium-ion_battery#Cathodes and http://en.wikipedia.org/wiki/Lithium-ion_battery#Anodes)

ANODES	
Cathode Material	**Average Voltage**
LiCoO2	**3.7 V**
LiMn2O4	**4.0 V**
LiNiO2	**3.5 V**
LiFePO4	**3.3 V**
Li2FePO4F	**3.6 V**
LiCo1/3Ni1/3Mn1/3O2	**3.6 V**
Li(LiaNixMnyCoz)O2	**4.2 V**

CATHODES	
Anode Material	Average Voltage
Graphite (LiC6)	**0.1-0.2 V**
Hard Carbon (LiC6})	**? V**
Titanate (Li4Ti5O12})	**1-2 V**
Si (Li4.4Si)	**0.5-1 V**
Li|4.4|Ge)	**0.7-1.2 V**

The chemistry in Lion battery when discharged is as follows (x is a coefficient, in this equations unit moles are used):

anode: $x\text{Li}^+ + xe^- + 6\text{C} \rightleftharpoons \text{Li}_x\text{C}_6$

cathode: $\text{LiCoO}_2 \rightleftharpoons \text{Li}_{1-x}\text{CoO}_2 + x\text{Li}^+ + xe^-$

Sumary:

$$\text{Li}^+ + \text{LiCoO}_2 \rightleftharpoons \text{Li}_2\text{O} + \text{CoO}$$

- ***Lithium polymer batteries***

Illustration 61 Lithium polymer battery from a Nokia cell phone.
Picture taken from http://pl.wikipedia.org/wiki/Plik:Lipolyo1rp.jpg

In this type of batteries lithium alloys are used for electrode and different conducting polymers. It is similar to Li ion batteries. What differ Li poly battery fro Li ion battery is their construction. The electrolyte is stored not in a form of organic solvent but in the form of polymer composite such as polyethylene oxide or polyacrylonitrile. Secondly Li poly batteries are pouch cells and Li ion batteries use rigid cylindrical cell. Thanks to use of polymers a new technology enables production of very thin, even few mm, elastic batteries. However this cell type is very vulnerable to over discharge that can destroy it irreversibly. Complicated control circuits have to be applied in order to avoid break down. Thanks to no rigid case Li poly batteries are also around 20% lighter. In comparison to Li ion batteries they have longer life cycle degradation rate.

Li Poly batteries are widely used in customer electronics; they also gained popularity in RC flying or driving models. There is also conducted a big research in order to apply Li poly batteries in electrical vehicles or hybrid cars, there is a perspective that if Li poly batteries enter the mass production their prices will drop down. Nowadays they are very expensive.

The chemistry in Lion battery when discharged is the same as in the case of Li ion batteries. [56]

5.4.1.2. Summary

Below on this page is the table comparing all the described batteries. When designing a storage system for conventional house it is advisable to discard NiCd batteries as they contain environmentally hazardous compounds. The best way would be to use Li ion and Li Poly batteries however they are the most expensive one. In further feasibility study sample prices will be calculated for NiMH batteries as they are one of the most popular and moderately inexpensive ones. There will be also conducted a price study for Li ion and Li Polymer batteries.

Table 11 Comparison of popular battery types.
Table is based on data taken from
http://en.wikipedia.org/wiki/Battery_(electricity)#Rechargeable_battery_chemistries

BaATTERY TYPE	CELL VOLTAGE	ENERGY DENSITY [MJ/kg]	DESCRIPTION
NiCd	**1.2**	**0.14**	Inexpensive. High/low drain, moderate energy density. Can withstand very high discharge rates with virtually no loss of capacity. Moderate rate of self discharge. Reputed to suffer from memory effect . Environmental hazard due to Cadmium - use now virtually prohibited in Europe.
Lead acid	**2.1**	**0.14**	Moderately expensive. Moderate energy density. Moderate rate of self discharge. Higher discharge rates result in considerable loss of capacity. Does not suffer from memory effect. Environmental hazard due to Lead. Common use - Automobile batteries
NiMH	**1.2**	**0.36**	Inexpensive. Performs better than alkaline batteries in higher drain devices. Traditional chemistry has high energy density, but also a high rate of self-discharge. Newer chemistry has low self-discharge rate, but also a ~25% lower energy density. Very heavy. Used in some cars.
NiZn	**1.6**	**0.36**	Moderately inexpensive. High drain device suitable. Low self-discharge rate. Voltage closer to alkaline primary cells than other secondary cells. No toxic components. Newly introduced to the market (2009). Has not yet established a track record. Limited size availability.
Li Ion	**3.6**	**0.46**	Very expensive. Very high energy density. Not usually available in "common" battery sizes. Very common in laptop computers, moderate to high-end digital cameras and camcorders, and cell phones. Very low rate of self discharge. Volatile: Chance of explosion if short circuited, allowed to overheat, or not manufactured with rigorous quality standards.
Li Poly	**3.7 V**	**0.32 – 0.40**	Very expensive. Very high energy density. Very popular among small customer electronics (cell phones, palmtops etc.)

5.4.1.3. *Possible improvement of batteries with application of nanotechnology*

Taking into consideration the battery design there is not much to be changed and improved. We should focus on improvement of battery components. These are electrodes and electrolyte. The goal is to increase the power density of batteries, their nominal voltage as well as their durability and life cycle.

- ***Electrolyte Improvement***

Improving electrolyte is not a popular approach to make batteries better, however, there are some researches done in order to do this. Li poly batteries are taken into account mainly. Scientists are working on improving the composition of polymer electrolyte. According to the information found via The Electrochemical society there are prospects of improving the battery performance by dispersion of nano inorganic particles of TiO2, Al2O3, MgO. This leads to one, two or even three fold improvement of battery conductivity. In a short review "**Transport studies on nano-composite solid polymer electrolyte for lithiumbatteries"** by C.W. Lin, C L. Hung and B. J. Hwang we can read:

> *"The impedance results showed that the addition of 5%TiO2 nano-size particle to the polymer matrix improves the conductivity (1.34 x 0-4 S/cm) by an order of magnitude at room temperature."[57][63]*

Moreover, according to "**electrochemical properties of nano filler added PEO solid electrolyte"** by Kwang-Sun Ji, Hee-Soo Moon, Jong-Wook Kim, Jong-Wan Park, the addition of SiO_2 to PEO-LiClO4 based electrolyte increased conductivity by 2~3 orders of magnitude from 10-8S/cm to 2.4 x 10-6S/cm at room temperature.[58]

There is also an experiment carried out where instead of the addition of the earlier mentioned inorganic nano particles, Zirconium based Super-acid nano particles will be added. Scientists report that this results in an increase of the value of the lithium transference number together with overall good transport and stability properties. [59][62]

- ***Electrode improvement***

In this area there are many possibilities of improvement. Starting from carbon nanotubes, and even more effective new silicon nanotubes, to nanocomposite electrodes. All this things are now in development, on the internet there are many interesting ideas described. Here we will tell briefly about carbon and silicon nanotubes and few examples of nanocomposite electrodes.

- ***Nanowire battery***

A nanowire battery is a lithium ion battery type. However the graphite anode is changed for a stainless steel anode covered in silicon nanotubes. These are really similar to carbon nanotubes but yielded better results. Team led by Dr. Yi Cui at Stanford University found that their new battery had even a 10 fold boost of capacitance (in comparison with conventional Li ion battery) during the first charge/discharge cycle, and then leveled out around 8x . This is because silicon nanotubes have a much great lithium ions uptake than graphite. Earlier scientist tried to make anodes from silica but it cracked after few uses as it swelled with lithium. But fortunately nanowires are not prone to such things. Nanowires battery discovered in 2007 are now waiting for commercialization. They are expected to arrive into the market in five years so in 2012 we should look for them. [60][61][64]

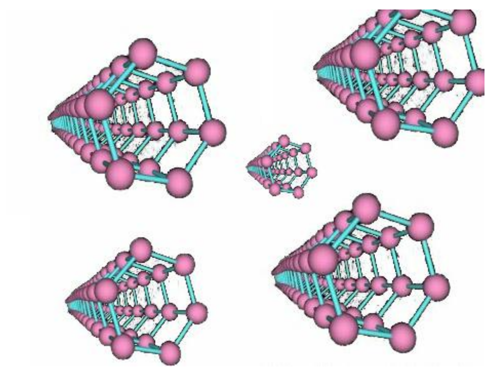


Illustration 62 Picture of single walled silicon nanotubes.
Taken from http://www.treehugger.com/files/2009/09/silicon-nanotubes-anodes-boost-lithium-ion-battery-capacity-10x.php

- ***Nanocomposite electrodes***

There is a trend in improving the electrodes by either adding some nano particles into a graphite traditional anode or making new nano electrodes. Former method decribed in "**Nanostructured molybdenum oxides as negative-electrode materials for Lithium-ion batteries**" by Se-Hee Lee, Rohit Deshpande, Phil A. Parilla, Kim M. Jones, Bobby To, A. Harv Mahan, and Anne C. Dillon from National Renewable Energy Laboratory 1617 Cole Boulevard, Golden, CO 80401-3393 USA, tells us that addition of crystalline transition metal oxide particles, with an average diameter of ~ 70-200 nm, can boost the capacity from ~ 350 mAh/g (graphite anode) up to ~ 800 mAh/g(graphite anode with addition of Co3O4 nanoparticles) or even ~1300 mAh/g (graphite anode with addition of MoOx nanoparticles). This is around 3.7 times more capacitance per battery. This is very positive trend in constructing new batteries as we gaine more capacitance per same weight. [65]

- ***Paper battery***

A paper battery is an interesting concept presented by a group of students from Rensselaer Polytechnic Institute. The battery is made from thin layer of paper and imprinted into it aligned carbon nanotubes. As an electrolyte the best is just kitchen salt solution, but to activate the battery any electrolyte such as blood or even human sweat can be used. Thanks to the use of paper the battery is very thin and flexible, can be cut into smaller pieces and aligned, stacked as we want. The paper battery can also become a capacitor it only depends on right folding of the imprinted paper. It is a very promising new technology, which when tested, improved and made easy and cheap to product may become a future of batteries. [66]

5.4.2. Capacitors

Capacitors, also called condensers, are the second type of storage device we will consider while designing a house energy supply. Its construction is very simple, it consists of two conducting plates called conductors and the non-conducting layer between them called a separator or dielectric (insulator).

The energy is stored in a capacitor when a potential difference (voltage) exists on conductors. Voltage produces electric field in the dielectric and this is the energy of the capacitor. The energy stored is greater when the separation between conductors is smaller and when the conductor's area is greater.

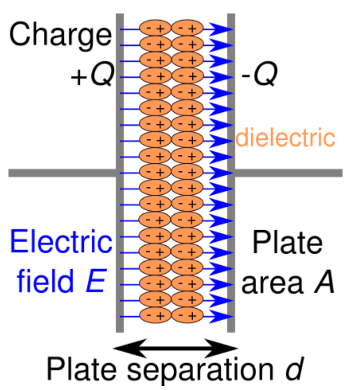


Illustration 63 Capacitor_schematic_with_dielectric.svg presenting the scheme of simple plate capacitor. Picture taken from http://en.wikipedia.org/wiki/File

The energy (capacitance) stored in a capacitor is measured in Farads and it is the ratio of the electric charge on each conductor to the potential difference between them. In reality there is so small leakage current between the plats that lower the capacitance.

Nowadays capacitors are used widely in electronic circuits to block direct current (DC) while allowing the alternative current (AC) to pass. They are also used to smoothen the circuit a filter the interferences.

What differentiates capacitors from batteries, as we consider them energy storage devices, is that capacitors are able to supply a large amount of voltage however in short time. That is why it is hard to use them as a long term power supply, however there is a great use for them when the burst of energy is necessary. For example in a electric car engine, or in a house to open the garage door or to start the work of fridge compressor.

Among capacitors there are many different types of them differing in materials they are made from. Some of them are electrolytic capacitors, tantalum capacitors, ceramic capacitors, polystyrene capacitors, polyester and polypropylene capacitors, mica capacitors. The more modern ones are ultracapacitors also called electric double layer capacitors. Later in this document we will also propose how to improve capacitors with use of nanotechnology. [67]

- ***Electrolytic capacitors***

Illustration 64 Picture of different types of electrolytic capacitors

Picture taken from

http://pl.wikipedia.org/w/index.php?title=Plik:Electrolytic_capacitors.jpg&filetimestamp=20060610061608

These types of capacitors are constructed from two pieces of conducting aluminum foils, where one is coated with an insulating oxide layer, and a paper spacer soaked in electrolyte (The electrolyte is usually boric acid or sodium borate in aqueous solution). The layer which is insulated by the oxide layer is the anode while the liquid electrolyte and the second foil acts as the cathode. The whole construction is then rolled and put in an aluminum case. Thanks to the use of electrolyte there is an increase of capacitance per unit volume. These types of capacitors are characterized by large values of capacitance (up to 1000µF) in comparison with the size of the capacitor. It is so because a dielectric layer is very thin. The most important characteristic of electrolyte capacitors is that they are polarized. They have a positive and negative electrode. Electrolyte capacitors are mainly used as a ripple filter in a power supply circuit, or as a filter to bypass low frequency signals.

Another type of electrolytic capacitor is a tantalum capacitor. This one use a material called tantalum as electrodes. Tantalum capacitors are manufactured from a powder of relatively pure tantalum metal. The typical particle size is between 2 and 10 µm thus the surface area is increased. That leads to increase of capacitance. This type of capacitors is also characterized with big capacitance versus the small size. They are a little more expensive than aluminum electrolyte capacitors. [68][69]

- ***Polymer capacitors***

This is a big group of capacitors that uses different kind of polymers as a dielectric. Among them Polystyrene Film Capacitors, Polyester Film Capacitors, Polypropylene Capacitors, Metalized Polyester Film Capacitors can be found. All of them are used in case of low and medium frequency circuits. Their capacitance is in the range of pikofarads. They are also cheap. [69]

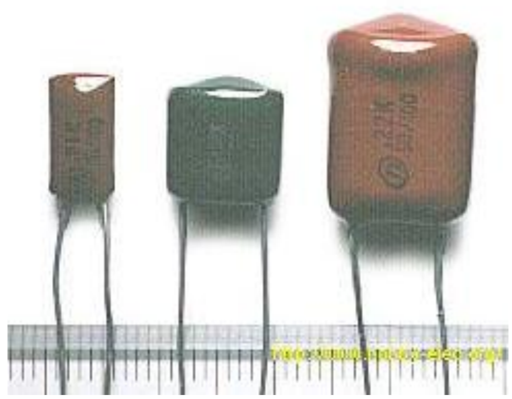


Illustration 65 Picture representing some of the Polyester Film Capacitors.
Picture taken from http://hobby_elec.piclist.com/e_capa.htm.

- ***Ceramic capacitors***

Illustration 66 Picture of ceramic capacitor
Picture taken from http://hobby_elec.piclist.com/e_capa.htm.

These types of capacitors are constructed with materials such as barium titanate or other titanium compounds used as the dielectric. Internally, these capacitors are not constructed as a coil, so they can be used in high frequency applications. Typically, they are used in circuits which transmit high frequency signals to ground. Their capacitance is very small in the range of pikofarads. [69]

- ***Ultra capacitors***

Illustration 67 Picture showing different types of ultracapacitors
Picture taken from http// en.wikipedia.org/wiki/File:Maxwell_MC_and_BC_ultracapacitor_cells_and_modules.jpg

Ultracapacitors, also called Electric double-layer capacitors, are the most promising however very expensive type of capacitors. They are characterized by very high capacitance in the range of few thousand of Farads. This type of capacitor is slightly different in construction than a traditional one. It consists of two conducting plates but it does not have a typical dielectric inside. It has two plates separated by intervening substance. This double layer is made from the same material and it is usually an activated charcoal. Despite the very thin separation between two plates and thanks to high porosity of activated charcoal the energy stored in each plate is very great. However the energy released by single cell is of rather low voltage. Multi cell capacitors have to be used to acquire higher voltage. Another advantage of this kind of capacitor is its long life- they can stand thousands of cycles, they are also of low toxicity. Ultracapacitors are also very quick to charge (almost instantly) there is also no fear of overcharge of the capacitor. All this advantages make them very suitable for future use in electric car vehicles (for burst of energy during starting the engine) or small consumer electronics (for example a flash light in cameras). [70]

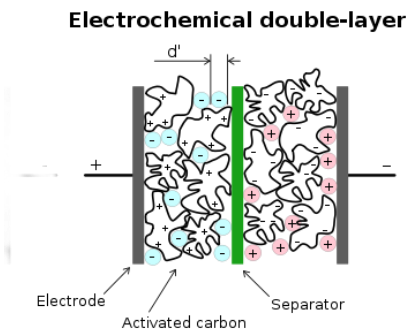


Illustration 68 Picture showing how energy is stored in the double layer capacitor.
Picture taken from http://en.wikipedia.org/wiki/File:Supercapacitor_diagram.svg

5.4.2.1. Possible improvement Capacitors with application of nanotechnology

The current and future improvements are made to the ultracapacitor type. Nowadays they use activated charcoal but scientists are already experimenting with replacing them with nanotubes because of their greater ability to store the energy thanks to high surface area and porosity.

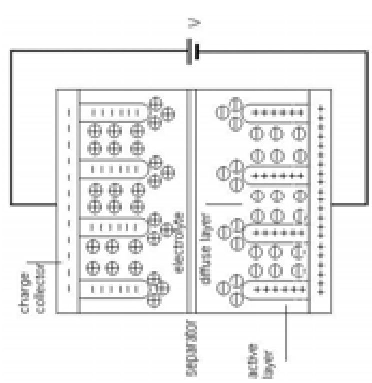


Illustration 69 Picture presenting how the energy is stored between carbon nanotubes in supercapacitor.
Picture taken from http://lees.mit.edu/lees/posters/RU13_Oct05.pdf

Scientists at the Massachusetts Institute of Technology (MIT) are currently developing a new technology awaiting commercialization. They claim that a new supercapacitor with carbon nanotubes has the strength of today's batteries with the longevity and speed of capacitors. This new technology is very promising for electric car vehicles as well for small electronics that need instant power, have to charge quickly and be very durable. The table below shows a comparison between a nanotube ultracapacitor, a conventional ultracapacitor and a typical Li ion battery. [71][72]

Table 12 Performance comparison of conventional and nanotube capacitors with Li ion battery.
Table taken from http://lees.mit.edu/lees/posters/RU13_Oct05.pdf.

	DOUBLE LAYER CAPACITOR (typical)	Li ion BATTERY (typical)	MIT NANOTUBE ULTRA CAPACITOR (expected performance)
Energy density (Wh/kg)	5.44	140	30 - 80
Power density (kW/kg)	5.61	0.2	40
Rated voltage	2.7	2.2	3.5 - 4
Longevity (cycles)	300 000	300 - 1000	300 000
Robustness and reliability	Excellent	Good	Exellent
Temperature dependency	Minimal	Moderate to high	Minimal

6. Feasibility Study for a nano energy saving house

6.1. Generation

6.1.1. Fuel cells:

For a 1.5A circuit which is the same as the one is our house we need 0.037604 x 1.5 = 0.056406 g per hour.

These fuel cells cost $5000 for a 25W cell, so in our house it makes sense that we use them to power appliances such as the fridge, TV and laptop. If we buy 4 of these that gives us a total cost of $20,000.

Because the technology is still developing, it is impossible to even estimate the cost of a nano fuel cell. This information will not be available for around 5 years although some production in the automotive industry has begun.

6.1.2. Solar cells

- Conventional House

Solar panels:

We need 12 panels for our roof so 12x794.53= €9,534.35

The installation fee is between €3,611.51 and €24,077, we will assume €13,242.35 for our study =€22,804.97

A voltage regulator also has to be purchased to accompany the solar cells. These cost €96.35

Total cost =€22,871.95

- Nano House

Solar Panels:

I panel x nº of panels= **7.29 x 6 panels= 43.74 A..........50 A**

It was very difficult to find cost information on solar nanotechnology as it is only just coming on to the market, but some websites gave us a little cost information. The expected market price for quantum dot solar panels will be $1 per Watt, so for our 3801.05 W total power needs, the total cost of our panels will be **$3801.5.**

Plus an installation fee of $2000 which is typical for nano solar panels, we have a total cost of $5801 for our panels.

6.1.3. Wind turbine

- ***Calculations***

The total daily consumption of electricity in a conventional house of a family of four members is:

Appliances: 22.2536 kWh daily

Illumination: 1.334 kWh daily

Control center consumption: 7.2 kWh daily

Total: 30.7876 kWh daily

Total consumption per year of electricity in a conventional house of a family of four members is:

30.7876 kWh daily x 365 days = **11,237 kWh per year**

Table 13 Feasibility study of the wind turbine

ESTIMATE SAVING IN ELECTRICITY WITH CARBON NANOTUBES IN WIND TURBINE	
Total consumption of electricity in a year	11,237 kWh
Energy generated in a year by the conventional installation	7,560 kWh
Increase the efficiency with nanotechnology	30 %
Energy generated in a year by a turbine with nanotechnology	9,797 kWh

As the previous table shows the total electricity consumption of a normal house of a family of four members is 11.237 kWh, of which 9.797 kWh can be obtained from a nanowind turbine compared to 7.560 kWh would get with a conventional wind turbine.

It is difficult to find out about exact prices on new wind turbines constructed with nanomaterials, but estimates that the cost decrease to the €10,000 of installation for a wind turbine of two kilowatts. The electric power produced in a year for this kind of turbines is estimate in 4,000 to 8,000 kilowatts hours depending of the location of the windmills.

In our case, the location of the house greatly favors usage of wind turbines. Even one nanowind turbine can almost fully satisfy all the energy needs.

6.2. Conversion

6.2.1. Feasibility study of LED illumination with nanotechnology

Although LED lamps are significantly more costly than conventional bulbs, this demonstrated that in addition to saving a lot of energy is amortized in a few years alone, due to their low energy consumption and durability. [26]

Table 14 Feasibility study of LED illumination

ESTIMATE SAVING IN ELECTRICITY WITH QUANTUM NANODOTS ON LEDS	
Energy consumption in a year by the conventional installation	632.98 kWh
Energy consumption in a year with LED	486.91 kWh (-30%)
Energy consumption in a year with LED improved with nanotechnology	438 kWh (-10%)
Increase the efficiency with nanotechnology	+ 10%
Savings in annual electricity	48.91 kWh
Electricity bill reduced in a	10%

6.2.2. Feasibility study of biogas installation

The production of biogas technology, besides being very profitable due to its high amount of energy transformed is very economical because the installation costs only €500, approximately.

Table 15 Feasibility study of biogas installation

Datas:http://www.energy.eu/,http://www.biogasmax.eu/media/biogas_production_poland.pdf

ENERGY SAVING WITH A BIOGAS INSTALLATION	
PRICE INITIAL INSTALLATION	~ 500 €
ENERGY PRODUCED	1.84 kWh/ day
MONEY SAVED	0.25 €/day, 7.78 €/ month
AMORTIZATION	5 years

In this application, nanotechnology not only improves the performance of production, ensuring the supply during all the year, even during the coldest months in Poland.

The amortization may seem very long term, but the good thing is you do not need any maintenance to produce biogas, simply put manure daily.

6.2.3. Feasibility study of thermoelectricity

After having studied the possible applications of thermoelectricity in our house, the conclusion is that this low efficiencies of only 1%, as against 26% efficiency for gasoline or diesel - powered electric generators.

6.3. Insulation

Nowadays it is quite hard to buy aerogel panels for insulation. The prices are also very high. From the data delivered by manufacturer, we know that it is possible to buy 60x70 inches panel for 595$. [40]

Extra Large Panel (up to 60″ x 70″), all polypropylene shell $ 595.00

2,7m^2 – 595$ = 486 euro

So the price is **180 euro** per square meter.

In comparison to Styrofoam - **4 euro** per square meter

Even, when we calculate, that aero panels are 3 times better than Styrofoam, we can clearly see that aerogel is 15 times more expensive than standard solution.

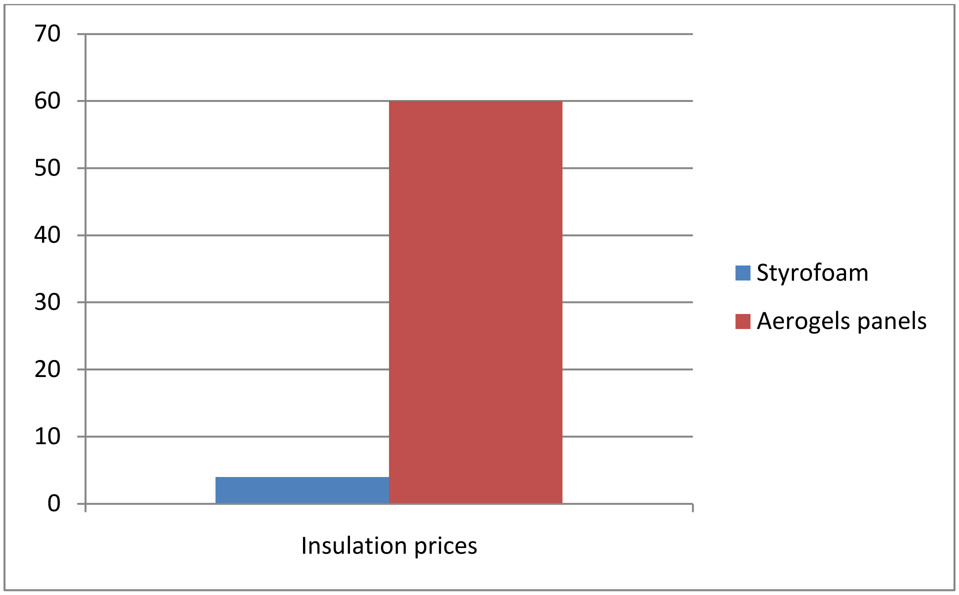


Illustration 70 Insulation prices

We should keep in mind, that insulation of the building requires a lot of resources. Nanotechnology nowadays is too expensive for that purpose. However, it is expected that the prices will drop significantly during next 10 years. It is crucial, because now it is chipper to place 3 layers of Styrofoam, and the effect will be almost the same. That makes us think, that aerogel insulation is still a technology of future, and nowadays it is only useful for advanced technologies such as space ships and aircrafts – where the mass and properties are much more important, than the cost of material.

6.4. Storage

6.4.1. Batteries and supercapacitors

During the course of the project we established the power consumption for our house. We designed the house and decided what appliances we need in a house. These are listed in the tables in the next page.

Table 16 Appliances in a house, their average time of use per day and daily power consumption

DEVICE	TIME OF USE (h)	kWh - DAILY
Refrigerator (average - cooling+compresor)	24	3,84
Dishwasher that heats water 3h	3	10,8
Big TV (50-56" DLP television) 6h	6	1,02
DVD + Sound System 3h	3	2,1
Small TV(19" CRT television) 3h	3	0,27
PC average (Desktop Computer & 17" CRT monitor) 6h	6	1,8
Laptop 6h	6	0,27
Microwave 15 min	0,25	0,36
Coffe maker 15 min	0,25	0,225
Toaster 10 min	0,17	0,1224
blender 5 min	0,08	0,048
Iron 30 min	0,5	0,6
Hair dryer 20 min	0,33	0,396
Kitchen ventilation 2h	2	0,3
small appliences (3 phones,4 tooth brushes)	0,8	0,0482
ALL		**22,2536**

Apart from this we also know that in our house the control station for powering devices (wind generators, solar panels) will be necessary. After some research (thanks to Politechnika Lodzka and their green energy power generators- solar and wind) we found that transformators used to convert DC/EC currents use around 15% of power they convert. Moreover we have to consider good ventilation in the cellar because it is a place where batteries and capacitors will be stored. We found that 24/day use of ventilation in this place will consume around 7.2 kWh.

We also designed and calculated LED illumination inside a house the calculations can be seen in the table on another page. After a research we found that LED lights improved with use of nanotechnology can save up to 10% of consumed power. This was also included in our calculations.

Table 17 Lightning over the house, their daily use and power consumption

LIGHTNING	kWh - DAILY
kitchen 3x2h 3x4h	0,3312
2x bathroom 2x 1h	0,0736
Bedroom 4 lights 2x1h 2x2h	0,1104
Living room 12 lights 3x3h 6x2h 3x1h	0,4416
Hall 1x0,5h	0,0092
Kids' room 6 lights 2x2h, 2x3h, 2x5	0,368
ALL	1,334
Lightning power consumption improved with nanotechnology is reduced by 10%	**1,2006**

Adding all the values together we obtain a little less than 31 kWh. However it would be more safe if Control center ventilation and controlling devices were supplied with external energy in case of bad weather (no sun and do wind). Extracting 7,2 kWh from 31 kWh leads us to the value of kWh that have to be produced by batteries we will have in a house. Our batteries and capacitors will have to supply around 24 kWh daily.

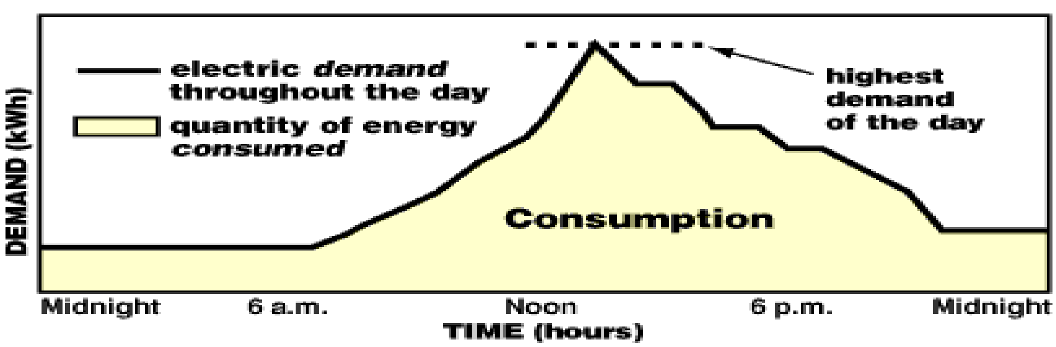


Illustration 71 A typical daily use of energy during 24 h period

The figure above presents a daily power distribution in a normal house, with its low consumption during the night and the high peak after noon. It is obvious that during day there is much more energy use than in the night. As we consider energy sources during day we can rely on solar cells, wind generators, gas cells and fuel cells. During night it's better to use batteries. However distribution of energy from batteries should be uniformed during the day, in case of lack of sun wind. Taking into consideration traditional batteries we made the price research and gathered all data in one table.

Table 18 Table presenting the calculations for traditional batteries. **All data taken from www.batteryspace.com**

Battery type	Voltage (V)	Amperhours (Ah)	Power (kWh)	How many of them?	How much space 2 m celling (m2)	Price per one (€)	total price (€)	price per W/h
NiCd Battery Pack: 12.0V 2600mAh (10x1/2D) for Solar Panel / Emergency Lighting	12	2,6	0,031	769	0,286	30	23.329	972
NiCd Battery Pack: 12V 3Ah (C x10) for Solar Panel / Emergency Lighting	12	3	0,036	667	0,290	23	15.546	648
NiMH Battery Pack: 48V 10Ah (480Wh 40xD) Battery with Discharging / Charger Terminals	48	10	0,48	50	0,137	318	15.900	662
NiMH Battery Pack: 25.2V 13 Ah with Tamiya Connector for Electric Bike and Scooter (3R777xF)	25,2	13	0,328	73	0,206	262	19.219	801
LiMnNi 26650 Battery: 14.8V 16Ah (236 Wh, 16A rate) in Aluminum-Box with CMB & Fuel guage display (19.2)	14,8	16	0,237	101	0,156	254	25.716	1071
LiMnNi 26650 Battery: 37V 8Ah (296 Wh, 40A rate) with PCM for E-Bike (24.0)	37	8	0,296	81	0,158	281	22.763	948

LiFePO4 26650 Battery: 38.4V 6.6Ah (253 Wh, 30A rate) with PCM (23.76)	38,4	6,6	0,253	95	0,205	308	29.181	1216
LiFePO4 26650 Battery : 12.8V 13.2Ah (168Wh, 16A rate) in Aluminum-Box with CMB & Fuel guage display (15.84)	12,8	13,2	0,169	142	0,546	242	34.405	1434
Powerizer Polymer Li-Ion Battery: 14.8v 3.6Ah (53.28Wh, 30C) w/o PCB for RC Flight--- CE listed / UN Approved (4.32)	14,8	3,6	0,053	450	0,093	71	32.104	1338
Powerizer Polymer Li-Ion Battery: 18.5v 3.6Ah (66.6Wh, 30C) w/o PCB for RC Flight--- CE listed / UN Approved (5.4)	18,5	3,6	0,067	360	0,097	82	29.523	1230
Li-Ion 14430 11.1 V 600 mah battery module (6.66Wh , 1.2A rate) with PCB&Polyswitch (0.54)	11,1	0,6	0,007	3604	0,107	16	58.367	2432
Li-ion 18650 Box Battery: 14.8V 5.2Ah (77Wh, Trail-Tech Female plug) with Fuel Guage & On/Off Switch (6.24)	14,8	5,2	0,077	312	0,123	106	33.117	1380

One can see that installing a backup system consisting from batteries is a really expensive investment. Prices are even up to € 33,636 and the cheapest solution is around € 15,583 (NiCd Battery Pack: 12V 3Ah (C x10)).

Our next step was to investigate the Newer technology, these are ultracapacitors. We chosen LS Ultracapacitors manufactured by LS Mtron Company. They are producing capacitors as single batteries and in modules. However we had a small problem with receiving the data considering the prices for single batteries.

Table 19 Table presenting calculations for single ultracapacitors

LS ULTRACAPACITOR TYPE	VOLTAGE (V)	CAPACITANCE (F)	DC ESR (mΩ)	kWh	HOW MANY?	HOW MUCH SPACE 1 m HIGH (m2)
LSUC 002R7R0003F EA	2,7	3	100	3,04E-06	7901235	2,48
LSUC 002R7R0005F EA	2,7	5	75	5,06E-06	4740741	1,49
LSUC 002R7R0010F EA	2,7	10	50	1,01E-05	2370370	1,15
LSUC 002R7R0025F EA	2,7	25	35	2,53E-05	948148	0,62
LSUC 002R7R0050F EA	2,7	50	25	5,06E-05	474074	0,56
LSUC 002R8S0100F EA	2,7	100	9	1,01E-04	237037	0,38
LSUC 002RS80120F EA	2,8	120	9	1,31E-04	183673	0,33
LSUC 002R8L0350F EA	2,8	350	3,2	3,81E-04	62974	0,21
LSUC 002R8L0400F EA	2,8	400	3	4,36E-04	55102	0,22
LSUC 002R8P1000F EA	2,8	1000	0,58	1,09E-03	22041	3,69
LSUC 002R8P1700F EA	2,8	1700	0,5	1,85E-03	12965	3,36
LSUC 002R8P3000F EA	2,8	3000	0,36	3,27E-03	7347	3,44
LSUC 002R8P3000F EA	2,8	3000	0,35	3,27E-03	7347	3,44
LSUC 002R5S0100F EP	2,5	100	14	8,68E-05	276480	0,50
LSUC 002R5L0300F EP	2,5	300	5	2,60E-04	92160	0,31
LSUC 002R5P2800F EP	2,5	2800	0,65	2,43E-03	9874	4,63
LSUC 002R5S0220F EA	2,5	220	18	1,91E-04	125673	0,23
LSUC 002R5L0650F EA	2,5	650	8	5,64E-04	42535	0,14
LSUC 002R5L0850F EA	2,5	850	7	7,38E-04	32527	0,13
LSUC 002R5P1800F EA	2,5	1800	0,9	1,56E-03	15360	2,57
LSUC 002R5P5400F EA	2,5	5400	0,5	4,69E-03	5120	2,40

One can see that using single ultracapacitors is ineffective because we will need a lot them, and connecting them together into a one system would be a really hard work. However we found a solution to use modules of ultracapacitors. Again we have made calculations for them similar to previous ones.

Table 20 Table presents calculations for the modules of capacitors

LS ULTRA-CAPACITOR TYPE	VOLTAGE (V)	CAPACITANCE (F)	DC ESR (mΩ)	kWh	HOW MANY?	HOW MUCH SPACE 1 m high (m2)	PRICE PER ONE €	TOTAL PRICE €	PRICE PER kwh
6 Series	16,8	500	3	1,96E-02	1 224	3,18	550	673 469	34 515
12 Series	33,6	250	6	3,92E-02	612	6,37	930	569 388	29 181
18 Series	50,4	166	9	5,86E-02	410	6,39	1450	594 214	30 453

One can see from these calculations that prices for ultracapacitors backup system are even 20 times higher! This is a great amount of money and there is no possibility to make such backup system, it is simply too pricy. However during our project we analyzed some data and found that prices of nanotechnology products can drop from 10 up to 100 fold down in next ten years. This is very promising because then it will be very easy to buy and apply this technology.

100 fold drop down For ultracapacitors	Conventional batteries prices
8 284	40 000
7 003	19 000

We also have to keep in mind that ultracapacitors are not real nanocapacitors. They only use activated carbon. If we consider a real nanocapacitors, for example the most promising ones with silicon nanotubes we can expect 10 times more capacitance per one battery. That lead us to 10 times less batteries used. Connecting this with low prices will lead us to a clean, safe and cheap source of energy.

- ***Calculations***

All sample calculations are done for LS ultracapacitor 6 series module with the need of 24 kWh daily.

$$Power\ (kWh) = \frac{Voltage\ \ (V)\times Capacitance\ \ (F)}{3600\ sec\times 1\ 000}$$

$$Power = \frac{16{,}8\ (V)\times 500\ (F)}{3600\ sec\times 1\ 000} = 1{,}96 \times \mathrm{E}^{-0{,}2}$$

$$How\ many\ ? = 24kWh/Power$$

$$How\ many? = \frac{24kWh}{1{,}96} \times E^{-0{,}2} = 1\ 224$$

$$Theoretical\ Space\ (m^2) = \frac{Dimensions\ (m^3) \times Number\ of\ batteries}{1m}$$

$$Theoretical\ Space(m^2) = \frac{0{,}0052\ (m^3) \times 1224}{1m} = 3{,}18$$

$$Total\ Price\ (\ €) = Number\ of\ batteries \times Price\ (\ €)$$

$$Total\ Price\ (\ €) = 1\ 224 \times 550\ (\ €) = 673\ 469\ (\ €)$$

7. Future applications

7.1.1. Saving water with nanotechnology

A possible future application of nanotechnology could be to purify dirty water through filters, Currently a Company from Florida called Dais Analytic is making great progress with nanotechnology, a solid film with interconnected nanostructures that can filter waste out of water down to a few parts per billion and provide safe, clean drinking water. The process requires only about half the energy of current treatment technologies. This technology opens up the possibility that you can take effluent water of any quality and return it as potable and close the loop.

Saving water is saving energy so we thought it should at least name this application

8. Bucky paper

Bucky paper is a thin paper like sheet made from carbon nanotubes. It has outstanding specification – the mass is ten times lower than the mass of steel, and it is also 500 times stronger.

It can be used to produce armors. It also has a great ability in conducting heat and electric current. Due to that facts there are mane researches concerning future use of buckypaper. Buckypaper can also illuminate, when it is exposed for a proper voltage. Some scientists suggest that it can be useful for electronic devices and displays. Also using it as a heatsink could be good idea. Other ways to use buckypaper are filters, or sensors. There are many ways to fabricate buckypaper, and still many new are being developed. The simplest way to manufacture buckypaper is to crush nanotubes together. Another method involves some chemical reactants.

Generally speaking, buckypaper due to its durability and low mass can revolutionize our life, starting form medicine, aircrafts and vehicles, and finishing on every-day electronics. To better understand the meaning of buckypaper in future electronics, we are going to build our own capacitor, basing on this material.

9. Laboratory work report

Our capacitor consisted of two thin layers of buckypaper and a layer of separator between them. The separator was simply a paper submerged in salted water. The construction of this capacitor is a standard SLC. It was a disc with a diameter of 50mm.

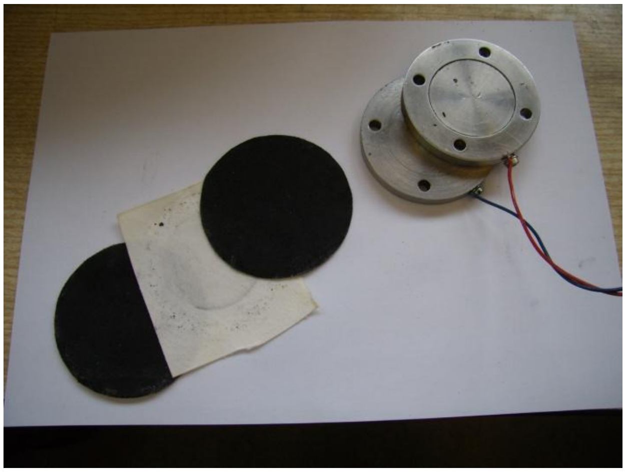


Illustration 72 Capacitor with bucky paper

In our laboratory room we had two measuring devices available. The first one was the oscilloscope, and the second one was the special device for measuring the capacitance. Using this equipment we were able to create a specification of our buckypaper capacitor and also compare it with standard and super capacitor.

Illustration 73 Measuring stand

At the beginning let us consider the buckypaper capacitor. Measuring stand consist of 1,5V battery, resistor 15kOhms and oscilloscope. The curve below shows the discharge curve of the capacitor. There is also attached a curve without a capacitor for comparison. Important thing to notice is fact, that we were using only 1,5V battery to charge the capacitor. Theoretically it should stand about 2,5-2,7V but we decided to lower the voltage to prevent the water from electrolysis and gasification.

Illustration 74 Oscilloscope

Another value to measure was the capacitance. For that purpose we have used a special machine. The first step was to set the approximated capacitance of capacitor. Then, the measurement was performed automatically. The results are as seen below.

We have reached the capacitance of 670uF, which was rather small for this nano capacitor. We have deiced to repeat the measurement, but the result was even worse (633uF). Obviously something was wrong. After short discussion, we came up with the idea that the separator layer

is simply too thick for this low voltage. We have repeated the measurement once again, but now with only one layer of buckypaper, and no separator. We were surprised, as the capacitance broke the limit of 1mF and reached the value of 1,03mF.
This is a good value for a capacitor with dimensions as ours.

Illustration 75 Device for measuring capacitance

In order to clearly understand the possibilities of nanotechnology, we have also tried to compare the standard and super capacitor. Those capacitors had almost the same dimensions. The first one has a capacitance of 100uF and operational voltage of 25V.

We calculate that energy stored in this capacitor is:

$$E = \frac{1}{2} C * V^2 = 3{,}12 * 10^{-2} J$$

The ultracapacitor has lower operation voltage (2,7V), but also has much greater capacitance (5F)

$$E = 1{,}82\ J$$

We can see that energy density in ultracapacitor is over 58 times higher than in traditional one.

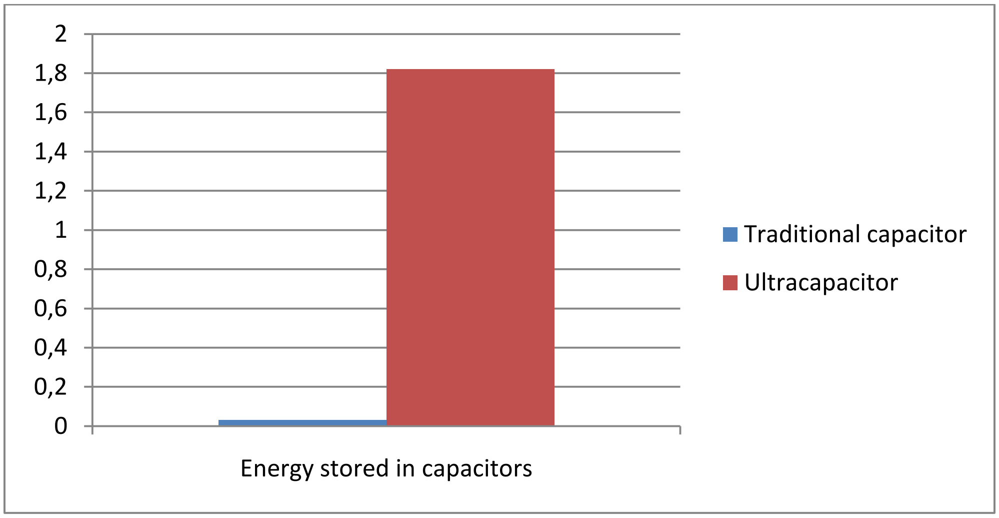


Illustration 76 Energy stored in cspscitors

The chart above clearly presents the difference between those two solutions.

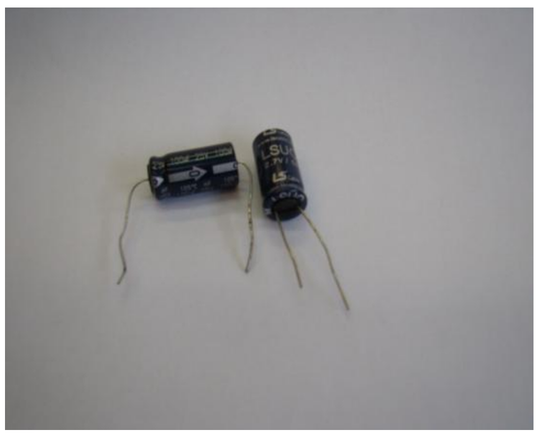


Illustration 77 The capacitor on the left is a traditional electrolytic capacitor

The capacitor seen on the right hand side is a supercapacitor. It consists of two layers of activated carbon that forms a porous structure, greatly improving the internal surface. As you can see, the capacitors have equal dimensions. However, energy stored in each capacitor greatly differs.

Summing all up, the nanotechnology can greatly improve the specification of capacitors. Using activated carbon has numerous advantages. Capacitors using that technology provide thousands of charge-discharge cycles, with a very low degradation factor. They have great power density and power output, and at the same time, they have extremely low internal resistance. Those types of capacitors are also much environmental friendly as they do not consist of any toxic electrolyte. There is also no danger of overcharging.

As every technology, this one also has some drawbacks. The main one that has to be considered is the low voltage per each capacitor - around 2,7V. This limitation is due to fact, that in higher voltages, water would undergo the process of electrolysis that could destroy the capacitor. Connecting those capacitors in series solves that process, but it also causes faster self-discharge of the capacitor.

10. Conclusions

As a group we were enthusiastic about our chosen topic from the very beginning for many reasons. The main thing that has to be said is that the issue of renewable energy is one of the biggest in the world at this moment in time. The fact is that fossil fuels are destroying our planet and changing the climate day by day, this cannot be denied. The greenhouse gas problem was known about by both politicians and scientists decades ago yet nothing has been done until recently. This delay in action makes it all the more important that we do all we can to rectify the situation as quickly as possible before it is too late. After the Kyoto convention, all the advanced countries of the world set themselves targets to meet by 2020 in terms of amount of energy created from renewable sources. Most countries have a target of 15-20% but at the moment only Germany and the UK are on track to meet this goal.

Our group focused on one new type of technology which can be used in the renewable energy sector, this is nanotechnology. As explained in the report, nanotechnology works by decreasing the size of molecules down to something under 100µm. When something is this small it gains some fascinating new characteristics such as a massive volume to mass ratio, high electrical conductivity and excellent insulation properties among other things. Not only this, nanotechnology can be used to make devices smaller and more reliable.

Nanotechnology can be used to improve almost every part of our lives. There are also medical uses for carbon nanotubes where they can be used to treat diseases but for our project we focused on their energy saving abilities as we constructed an energy saving house consisting of nano appliances. We used a conventional energy saving house as a comparison for our study and we looked at the differences in terms of efficiency and cost in relation to our nano house.

We found from our research that most nano appliances are still very much in the development stage with products not yet released even though the theory is ready. Within 5 years it can be expected that production and market entry will begin as most products are almost on the verge of coming out. At the present moment though, nano products can be used alongside conventional energy saving devices in what is called a hybrid method. This way conventional energy saving can be improved gradually more and more, and hopefully 5 or 10 years down the line it will be completely nano with extremely high efficiency levels.

The use of nanotechnology to generate, store, convert and insulate the energy needed for a regular house to operate was found to be much more efficient than when conventional energy saving techniques were used. After a detailed study of the current market and of the expected change in the market, it can be predicted that when the demand for nano materials rises, the cost of production and purpose will fall dramatically so that they will overtake all current forms of energy saving technology. This is a hugely positive step for the planet as this switch in energy consumption habits will slow down global warming greatly and help us to find a complete replacement for fossil fuels in time to save the environment. This being said, at the moment nano materials are too expensive, too early in development and have not been safety tested enough to be brought out for public use.

11. Sources

- http://www.hydrogencarsnow.com/blog2/index.php/fuel-cells/sub-nano-platinum-particles-power-fuel-cells/ [12]
- http://www.physorg.com/news11044.html [27]
- http://www.fuelcells.org/info/library/fchandbook.pdf [13]
- www.wikipedia.org [9]
- www.strath.ac.uk [10]
- http://www.sciencedirect.com [15]
- http://www.goldbulletin.org [14]
- http://efektywne-ogrzewanie.pl/koszty-ogrzewania-domu/ [43]
- http://www.ogrzewnictwo.pl/index.php?akt_cms=77&cms=183 [48]
- http://www.uponor.com.pl [41]
- http://www.lifetimeroofingltd.com/wp-content/ [42]
- http://www.ufh.biz/mediac/400_0/media/ [49]
- http://www.aerogel.org/ [44]
- http://www.brinkclimatesystems.nl/renovent-hr/1696 [46]
- http://www.aerogel.com/markets/building.html [45]
- http://www.efficientwindows.org/ [47]
- www.nanomercado.com/supercondensador-nanoestructurado-gracia/_C3VTDDatmVFzWaF4O1n_f6qQsNXbt8ra8Y2EXDTGqI_-_d7ZjjaBIbkta0CBqIzJ
- http://ecopowerchile.com/blog/?p=1567
- http://encuentronano.fan.org.ar/ponencias_resultados.htm [6]
- http://www.biodisol.com/medio-ambiente/generador-de-energia-eolica-domestica-energias-limpias-turbinas-domiciliarias/ [16]
- http://www.eagle.fi/index.asp?pn=1&kieli=2&aihe=68&avaa=Windpower [19]
- http://medioambienteok.blogspot.com/2008/08/austrowind-presenta-una-elica-domstica.html [18]
- http://www.windenergy.com/index_wind.htm [21]
- http://www.eaglepower.co.uk/Enquiry.html [17]
- http://www.ebrdrenewables.com/sites/renew/countries/Poland/profile.aspx#Wind [1]
- http://www.research.bayer.es/edicion-21/nanotubos.aspx [20]
- http://windtrends.meteosimtruewind.com/es/mapas_anomalia_viento.php?zone=POL [2]
- http://www.monografias.com/trabajos48/nanotecnologia/nanotecnologia.shtml [3]
- http://bibing.us.es/proyectos/abreproy/11175/fichero/vol1%252Frv_T1_Motivaciones_v04.pdf http://www.baytubes.com/downloads/bms_cnt_baytubes_en.pdf [5]

- http://www.euroresidentes.com/Blogs/avances_tecnologicos/2004/06/nano-cables-capaces-de-detectar-gases.htm [7]
- http://www.euroresidentes.com/Blogs/avances_tecnologicos/2004/06/los-tejidos-inteligentes-la-ropa-del.htm [8]
- http://www.pa.msu.edu/cmp/csc/nanotube.html [22]
- http://www.cecu.es/campanas/medio%20ambiente/res&rue/htm/guia/eolica.htm
- http://www.marketsandmarkets.com/nanomaterials-market-research-63.html
- Nano Road Map_ Energy [28]
- http://www.elpais.com/articulo/futuro/ [4]
- http://sisbib.unmsm.edu.pe/bibvirtualdata/tesis/basic/alcca_qf/cap5.PDF [23]
- http://www.madrimasd.org/informacionidi/biblioteca/publicacion/doc/vt/vt11_nanotubos.pdf [24]
- http://www.solartec.org/SVbioclimatica.htm
- http://en.wikipedia.org/wiki/Battery_(electricity) [50]
- http://pl.wikipedia.org/wiki/Akumulator_niklowo-kadmowy [51]
- http://pl.wikipedia.org/wiki/Akumulator_kwasowo-ołowiowy [52]
- http://pl.wikipedia.org/wiki/Akumulator_niklowo-metalowo-wodorkowy [53]
- http://en.wikipedia.org/wiki/Nickel-zinc_battery [54]
- http://pl.wikipedia.org/wiki/Akumulator_litowo-jonowy [55]
- http://pl.wikipedia.org/wiki/Akumulator_litowo-polimerowy [56]
- http://www.electrochem.org/dl/ma/203/pdfs/1685.pdf [57]
- http://www.electrochem.org/dl/ma/200/pdfs/0034.pdf[58]
- http://www.electrochem.org/meetings/scheduler/abstracts/210/0252.pdf[59]
- http://en.wikipedia.org/wiki/Nanowire_battery [60]
- http://www.treehugger.com/files/2009/09/silicon-nanotubes-anodes-boost-lithium-ion-battery-capacity-10x.php [61]
- http://www.electrochem.org/dl/ma/200/pdfs/0034.pdf[62]
- "Nanocomposite PEO-based polymer electrolyte using a highly porous, super acid zirconia filler"
  Gaelle Derrien b, Jusef Hassoun a, Simone Sacchetti a, Stefania Panero a
  Solid State Ionics 180 (2009) 1267–1271 [63]
- http://pubs.acs.org/doi/abs/10.1021/nl902058c?journalCode=nalefd [64]
- http://scitation.aip.org/getpdf/servlet/GetPDFServlet?filetype=pdf&id=MAECES000602000005000254000001&idtype=cvips&prog=normal [65]
- http://www.technewsworld.com/story/58833.html?wlc=1274911067 [66]
- http://en.wikipedia.org/wiki/Capacitor [67]
- http://en.wikipedia.org/wiki/Electrolytic_capacitor [68]

- http://hobby_elec.piclist.com/e_capa.htm [69]
- http://en.wikipedia.org/wiki/Supercapacitors [70]
- http://peswiki.com/index.php/Directory:MIT_Nanotube_Super_Capacitor[71]
- http://lees.mit.edu/lees/posters/RU13_Oct05.pdf [72]
- http://www.energiasrenovables.ciemat.es/suplementos/sit_actual_renovables/biogas.htm[36]
- http://europa.eu/rapid/pressReleasesAction.do?reference=MEMO/09/144&format=HTML&aged=0&language=EN&guiLanguage=en [35]
- http://www.upc.edu/grecdh/pdf/2008_JMH_Guia_biodigestores.pdf [37]
- http://news.mongabay.com/bioenergy/2007/07/study-eu-biogas-production-grew-136-in.html [33]
- http://europa.eu/rapid/pressReleasesAction.do?reference=MEMO/09/144&format=HTML&aged=0&language=EN&guiLanguage=en [34]
- http://www.nanomaterialstore.com/nano-phosphor.php [29]
- http://www.treehugger.com/files/2010/01/ces-2010-nanosys-using-nanotechnology-to-make-led-lighting-more-beautiful.php [32]
- http://www.vanderbilt.edu/exploration/stories/quantumdotled.html [31]
- http://www.energy.eu/ [26]
- http://www.biogasmax.eu/media/1t1_biogas_production_in_poland__050402600_0649_30092009.pdf [38]
- http://www.Philips.com/ [25]
- http://www.economist.com/ [30]
- http://www.siemens.com/ [39]
- http://www.glacierbaytechnology.com/category/insulation/ultra-r-thermal-insulation/ [40]

12. Plan of the house (A3 Page)

13. Annexes

13.1. Annex I European regulation for efficiency appliances

MEMO/09/144

Brussels, 31 March 2009

New format for the Energy Label and ecodesign requirements for household refrigerating appliances and TVs

On 30 and 31 March 2009, the Commission submitted for endorsement by the Committee of Member States, draft Directives for the energy labelling of household refrigerating appliances, televisions, washing machines and dishwashers.

Fridges and freezers, washing machines and dishwashers (as well as washer-dryers, tumble dryers, lamps, ovens, air-conditioners) are already labelled since the mid/end 90s. TVs are currently not yet labelled.

The energy Label requires the manufacturers to declare how energy efficient/inefficient their products are and to supply a label to retailers who have to display the label on the appliances shown in shops. The aim is to provide credible and comparable information on the performance of the products to consumers before they make their purchasing decision.

For all four product categories the Labelling directives are accompanied by Ecodesign regulations, which set out the minimum level of efficiency that the appliances have to meet in view of being placed on the market.

The new Label layout - Main characteristics:

Since it was introduced by the Commission in the mid 90s, the energy label was so successful that today most products are in the "A" class. There was a need to go "beyond A", to allow manufacturers to further compete by developing products that are more and more efficient and to show how much better they are for consumers who could then make well informed choices. By buying more energy efficient appliances, consumers might pay higher upfront prices but make a profit on the lifetime of the appliance by saving on the running costs.

The new label:

Is based on the A-G well known coloured scheme; Pre-defined additional classes e.g. "A-20%, A-40% …" are added to the label on top of class A with a frequency which depends on the product category and which is pre-defined in the Directives. The black arrow shall display how much better the product is compared with an A class product.

In principle, the energy efficiency class of a particular model already on the market remains unchanged (A is A). For fridges/freezers, there will be a transition with A+ fridges corresponding to A-20%, A++ will be equivalent to A-40%.

Manufacturers who can put a product on the market that is more efficient than the top class can show it on the label ahead of the date on which the display of a "higher" class becomes mandatory.

The design of the new label is clearly different from the current design, i.e. new labels can be clearly distinguished from existing labels during the transition period.

The label is "language-neutral" – using pictograms - so that suppliers will provide the label in one piece without having costs for adapting to local language versions. This will also ensure that the full label is shown in shops (and not just the strip).

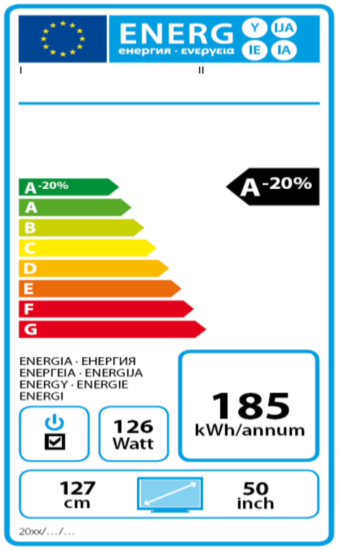
The top class arrow on the left side of the label shall always be shown in dark green (as for the current A class colour). That means that the colours will be uplifted each time a higher class is introduced. Classes at the bottom will be in dark red (same as G colour today). The message could be "buy green".

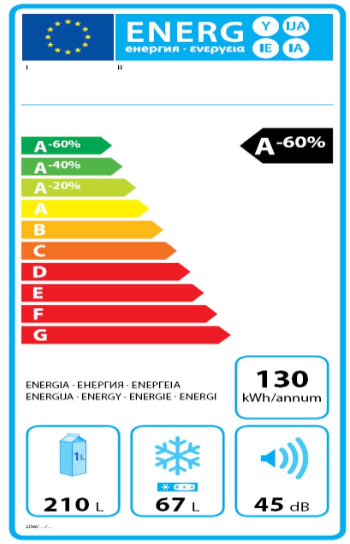
Advantages of the new label format:

consumers can judge at a glance how much "better than A" a product really is (20% more efficient, 40% more efficient …), which is not the case with the current "A+/A++" naming of top efficiency fridges and freezers; manufacturers can show in "real time" how much "better than A" a product really is, which is not the case with the current system, not allowing to show "better than A++" for fridges/freezers, and "better than A" for the other labelled products; there will be no confusion for consumers between new and old classes as would have been the case if products had been reclassified; retailers will have no additional burden for the transition from "old" to "new" format, and it will be easier for the manufacturers and the retailers to label in practise (full label is in the box, ready to be displayed in the show room).

Impact of the new label format: more **incentives for innovation**, resulting in an accelerated "race" for top efficient products; **boosting of market transformation** towards high efficiency products, and ultimately; **energy and CO2 savings.**

Examples of the new label format:





Refri 2012

Ecodesign requirements for household refrigerating appliances

Application date	Energy Efficiency Index (EEI)
1 July 2010	EEI < 55 i.e. equivalent to removing current classes B,C and below
1 July 2012	EEI < 44 i.e. equivalent to removing current class A (current classes A+ and above will remain)
1 July 2014	EEI < 42 i.e. only current classes A+ and above will remain

Ecodesign requirements for household washing machines

APPLICATION DATE	ENERGY EFFICIENCY INDEX (EEI)
1 July 2010	EEI < 68 i.e. equivalent to removing current classes B,C and below
1 July 2013	EEI < 59 with rated capacity c ≥ 4kg i.e. equivalent to removing current class A (=only current classes A+ and above will remain)

Ecodesign requirements for TVs

Stage 1: expected July 2010 (one year after entry into force of regulation)

On-mode power consumption of "full HD" resolution (1920 x 1080 pixels) TVs:	On-mode power consumption of TVs with all other resolutions:
20 Watts + A · 1.12 · 4.3224 Watts/dm2	**20 Watts + A · 4.3224 Watts/dm2**

This means: Only TVs with energy efficiency better than the current average can be placed on the market (A is the screen area of the television, expressed in dm^2).

Stage 2: 1 April 2012

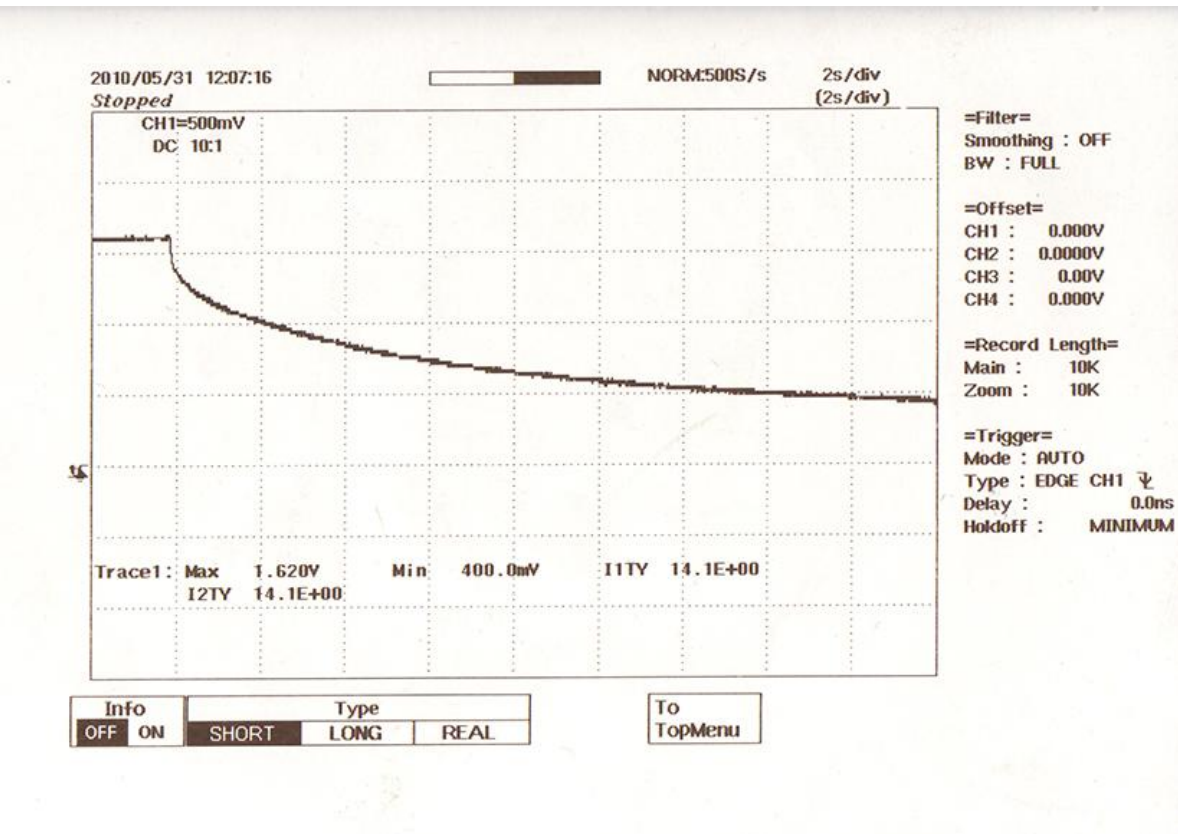
On-mode power consumption, all resolutions:
16 Watts + A · 3.4579 Watts/dm2

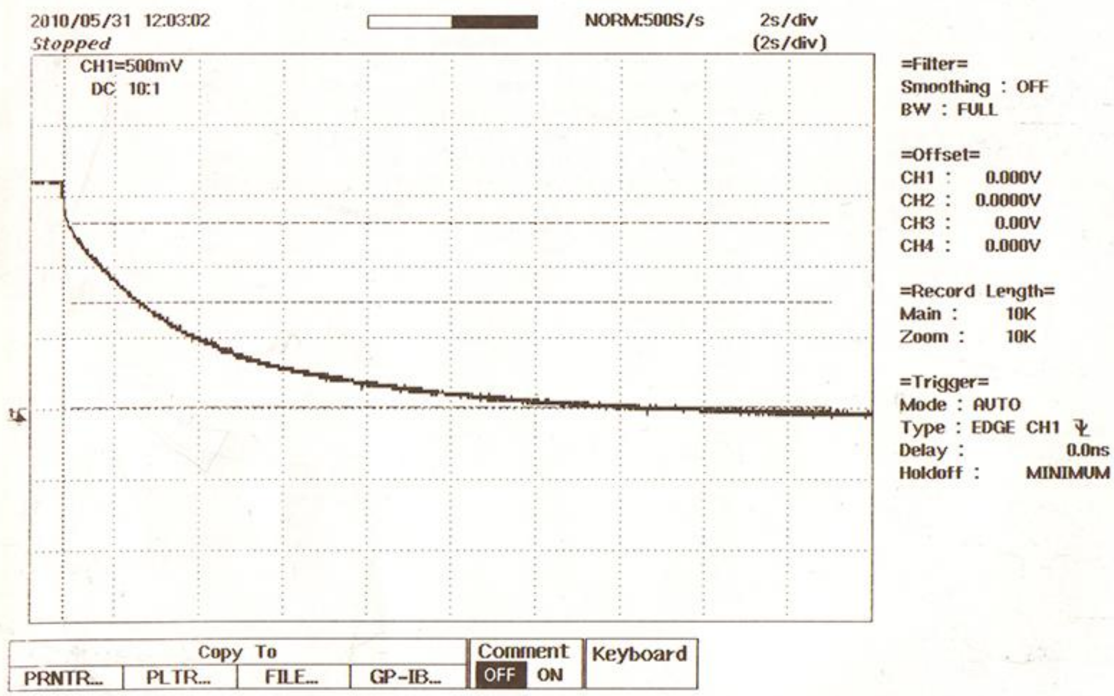
This means: Only TVs with an energy efficiency at least 20% better than the current average can be placed on the market (corresponding to energy efficiency class "C" or better in the new labelling system for TVs).

13.2. Annex II Printed results of the laboratory experiment.

Measure Values

Trace1		Trace2		Trace3		Trace4	
P-P	---	P-P	---	P-P	---	P-P	---
Max	1.480V	Max	---	Max	---	Max	---
Min	-80.00mV	Min	---	Min	---	Min	---
Rms	---	Rms	---	Rms	---	Rms	---
Avg	215.1mV	Avg	---	Avg	---	Avg	---
-Ovr	---	-Ovr	---	-Ovr	---	-Ovr	---
+Ovr	---	+Ovr	---	+Ovr	---	+Ovr	---
High	1.320V	High	---	High	---	High	---
Low	-40.00mV	Low	---	Low	---	Low	---
Rise	---	Rise	---	Rise	---	Rise	---
Fall	---	Fall	---	Fall	---	Fall	---
Freq	---	Freq	---	Freq	---	Freq	---
Prod	---	Prod	---	Prod	---	Prod	---
+Wd	---	+Wd	---	+Wd	---	+Wd	---
-Wd	---	-Wd	---	-Wd	---	-Wd	---
Duty	---	Duty	---	Duty	---	Duty	---
I1TY	4.26E+00	I1TY	---	I1TY	---	I1TY	---
I2TY	4.09E+00	I2TY	---	I2TY	---	I2TY	---
I1XY	---	Brst	---	Brst	---	Brst	---
I2XY	---	PlsN	---	PlsN	---	PlsN	---
Brst	---	Dly	---	Dly	---	Dly	---
PlsN	---						
Dly	---						





Setup Information

1.Vertical

	CH1	CH2	CH3	CH4
V/Div	500mV	5mV	5V	500mV
Coupling	DC	DC	DC	DC
Probe	10:1	1:1	1:1	10:1
Offset	0mV	0.0mV	0.00V	0mV
Position	-0.98div	0.00div	0.00div	-2.94div
Invert	OFF	ON	OFF	OFF

2.Horizontal

T/Div	2s/div
Acquisition	Normal
Sample Rate	500 S/s
Record Length	Main:10K
	Zoom:10K
Time Base	INTERNAL
Smoothing	OFF
Bandwidth	FULL

3.Trigger

Mode	AUTO
Type	EDGE
Coupling	DC
HF-Rejection	OFF
Position	0.00div
Delay	0.0ps
Holdoff Time	OFF
Edge Source CH	CH1

Source	Ch1	Ch2	Ch3	Ch4	EXT
Level	-80mV	0.0mV	0.0V	0mV	0.15V
Slope	↓	↑	↑	↑	↑

13.3. Annex IV Meetings agenda (digital version)

13.4. Annex III Design and calculations of illumination of the house (PDF files)