The following proposal for the installation of a solar-thermal water installation for the ACLO sports center was developed in May and June 2012 by Chamon Suresh Gopal (MSc student Energy & Environmental Sciences) and Johannes Wilbertz (MSc student Molecular Biology & Biotechnology).

We became very enthusiastic about our own idea and we further detailed our proposal and decided to submit it to the Green Mind Award.

If you have question, do not hesitate to contact Johannes Wilbertz via J.Wilbertz@student.rug.nl or 0641581739.

Executive summary:

This proposal demonstrates that it is easy, practical, relatively cheap, and even fun to participate in the energy transition without having to decrease the quality of life. Solar-thermal heating of the shower water of the ACLO building is an ideal technical solution to reduce dependency on the traditional energy market and its ever rising prices. In the Netherlands the sun delivers energy of about 125 W/m^2. Realistically, a modern so-called evacuated-tube collector can effectively transmit 40 W/m2 to water. This equals 350 $kWh/year/m^2$ that can effectively be saved by this installation. Based on detailed assumptions we calculated that the ACLO sports center uses an equivalent of 397,850 kWh/year for showering alone. Here we, demonstrate that an adequate installation of around 1000 m^2 of solar-thermal heating panels can completely cover this demand and save at least 11,500 Euros annually. Rising gas prices will make our proposed system even more attractive.

Showering for the Climate: A solar-thermal water heating system for the University of Groningen Sports Center

-

A technology oriented proposal towards realistic sustainable actions

By Chamon Suresh Gopal and Johannes Wilbertz

June 2012

Contents

Summary 3

Introduction 3

Principles of solar-thermal installations and implementation into the sports center 5

Solar-thermal energy in the Netherlands 6

Solar-thermal energy for the ACLO sports center 7

Efficiencies of different solar-thermal heating systems 8

By means of conclusion: The road towards an installation 10

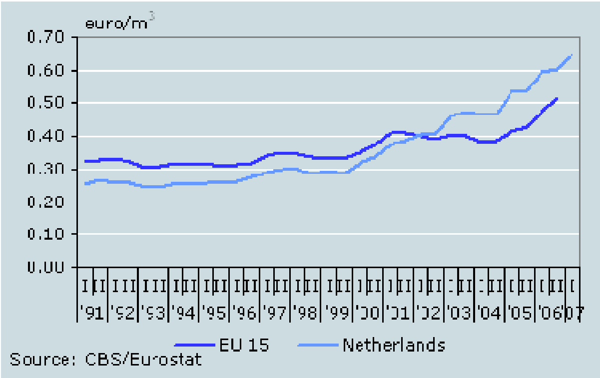
Bibliography 11

Summary

Our aim is to be part of the energy revolution and a decentralized energy market. This project demonstrates that it is easy, practical, relatively cheap, and even fun to participate in the energy transition without having to decrease the quality of life. Solar-thermal heating can be an ideal technical solution for institutions that are willing to reduce their dependency on the traditional energy market and its ever rising prices. Here, we present facts and figures about solar-thermal heating in order to underline its simplicity as well as the potential to greatly reduce the need for fossil fuels on a communal basis. Secondly, we show that solar-thermal heating offers real-life and short-term measureable benefits by presenting it in the context of the University of Groningen sports center (ACLO building) which offers an ideal environment. Furthermore, we highlight our conviction that technology alone will not be enough to manage the energy transition. It is of uttermost importance that the benefits, prerequisites, and linkages to present day challenges are clearly communicated. Only then an appreciation for technology can arise, which will translate into higher user numbers and enhanced use efficiency. We therefore aim to display the everyday benefits of solar-thermal heating *literally* visible to the student population. We believe that complex environmental challenges do not necessarily ask for equally complex solutions. We want to convince the presently responsible authorities, but especially the leaders of tomorrow, that tomorrow already has started today. Every decision of every person shapes the future.

Introduction

For at least the last 140 years the western societies have been highly depended on fossil fuels, traditionally including the use of coal, and more recently the use of oil and gas. Since the 1970s the demand has sharply increased due to, and among other reasons, industrial growth in Brazil, Russia, India and China. In addition, economic growth in general has led to higher needs in *all* countries. Within the next two decades the standard of living and therefore the materialistic demands of sub-Saharan as well as Southeast Asian counties, representing some of the most populous areas of the world, will drastically increase. The effects of these exponential developments are already visible, but will have a rising impact in the years to come. With our project we aim to reduce the dependence on fossil fuels and cut costs. We therefore focused on an approach including the solar-thermal heating of shower water in the University of Groningen Sports Center (ACLO building). Currently, all of the water is heated by natural gas. **Figure 1**, however, depicts that gas prices in the Netherlands are among the highest in Europe. Furthermore, since a few years gas prices are increasing drastically. Since 1998 the price per cubic meter natural gas has increased by more than 100%. Even though the university makes use of certain industrial-tariffs, which are lower than the regular ones, in the long run it will not be able to escape the realities of the market.



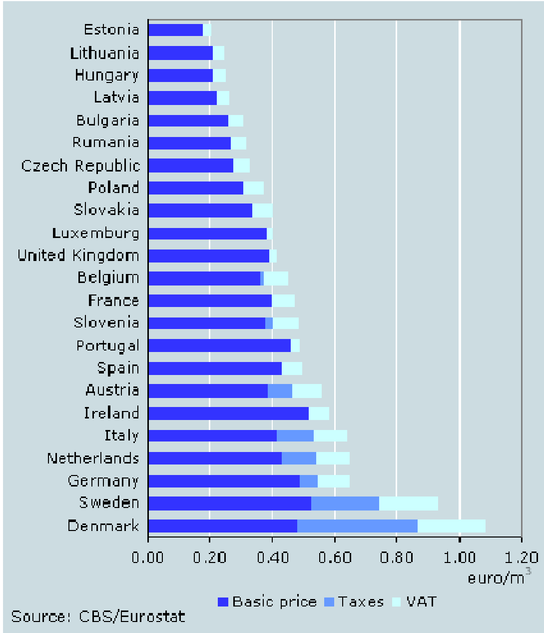


Figure 1: Statistical data on gas prices in the Netherlands and Europe. The left panel shows increase of natural gas prices in euro/m³ from 1991 to 2007. In the Netherlands prices are clearly increasing more than the European average. The right panel indicates that, as of 2007, the gas prices are amongst the highest in Europe. Taxes are only a minor part of the total costs. The described situation has changes little until 2012 and further rises are very likely.

In addition, the Dutch government has announced several measures concerning budget cuts in the higher education sector. In the worst case this would mean 18% less by 2015, measured against the money the sector received for 2009 [1]. It is therefore inevitable for the university to reduce costs in order to guarantee high standards in education and research. Nonetheless, the University is Groningen is already very progressive within the energy field. Still, and based on the following statements, we consider further investments into renewable energy-sources as inevitable and very fruitful:

1. Attractive subsidiary systems exist in the Netherlands and Europe for renewable energy sources

2. Interesting new technical solutions exist, but also very reliable "traditional" ones (which are partly being used).

3. Short payback times due to rising energy prices and the desire to become independent of traditional energy markets make installation attractive.

4. The need to cut costs on non-education and research quality affecting sectors is a necessity.

5. The modern image of the university, the theme "Sustainable Society" and its duty to set positive examples should motivate to take actions.

6. Being an important part of society the university must demonstrate that the energy transition in economically difficult times is possible and also attractive.

As elaborated below, several reasons make the ACLO sports center a very attractive place to demonstrate how effective technology is to reduce costs and raise awareness towards renewable energies. Concentrated Solar Power (CSP) is the most efficient way of pre-heating water when looking at systems that use the sun's thermal energy. However, CSP suffers from some specific drawbacks which make the use of other installations more attractive, namely evacuated tube collectors and flat panel collectors. Here, we analyze the benefits of these different solar-thermal heating systems in the context of the ACLO building and propose their implementation, based on the reasons described above.

Principles of solar-thermal installations and implementation into the sports center

When sunrays hit the surface of the sun collectors, they transmit approximately 60-75% of their energy to the heat-carrying oily fluids inside. A small pump transports the fluid to the heat-exchanger within the storage tank where it flows through several coil. Once a certain temperature has been reached, the heat carrying fluid transmits its warmth towards the colder water which is inside the storage tank. This pre-heated water can then be used for, for example, showering.

Attractiveness of the ACLO building

The ACLO building is an especially realistic target for such a system. Major positive aspects of the building include (1) its high demand of hot water due to showering indicating a larger saving potential, (2) its architectural composition which includes a flat roof surface and especially space within and outside the building to install the requires piping. (3) Next to the pipes, which are necessary to supply warm water and dissipate cooler water, also tanks need to be installed which are able to store transferred heat independently of the current weather and also enable showering when the sun is not shining. (4) Another positive aspect is the active participation of many students due to showering and the high degree of identification of students with sports. (5) Also a sports center symbolically stands for a modern, open-minded and active way of living which ideally coincides with our aims of promoting the energy transition. (6) Furthermore, the achievements of solar-thermal heating can easily be communicated with and demonstrated to the students by relating showering to a real environmental and financial impact that they themselves can make. **Figure 2** displays specific details of the implementation of solar-thermal heating at the sports center. Especially the roofs capability of carrying the applied load needs to be determined, since the ACLO building has a flat roof this can potentially pose stability problems.

Figure 2: Aerial view of the ACLO building. Red circles indicate possible locations for mirrors; the green circle indicates potential hot-water tank locations. White arrows roughly display were most water is consumed due to showering. The dotted line represents the available sunshine on an average day. Trees to the west produce shadowing (own representation, based on Google Earth).

In addition and in order to assess the practicability of our approach we concentrated on several other factors that will determine the performance of a solar-thermal installation at the proposed site.

Shadows

As the sun changes its angle of course also the shadows of neighbouring buildings and trees change in size and position during the day. Here, buildings are not the major problem; they are all not of a significant height or located at a convenient distance. The trees, however, are a strictly limiting factor. Most trees are located to the west of the building which decreases solar-thermal efficiencies during the later afternoon and evening. As there are no obstacles from north to southwest we still expect the efficiency to be satisfying. Another factor is the roof itself. The advantage of the flat roof is at the same time also a drawback when it comes to shadows. The installations are constructed in rows which can hinder each other. This can either be solved through increased distances towards each other or a framework onto which the installation is mounted which enables different heights.

Angle

In order to measure the sun's radiation the incoming angle and the angle of the installation is important. The incoming angle of course changes during the day and also during the year, but modern (programmable) sun trackers and a moveable installation make it easy to react on these changes conditions. Systems that cannot be equipped with a tracker, ideally should have a construction angle of 90° in relation to the suns height on March 21st and/or September 23rd. This ensures that during the summer months an ideal amount of thermal radiation can be collected.

Weather

The sun's radiation is next to the technical capabilities of the installation itself the most important factor determining the power output of solar-thermal energy. There is a difference between direct and indirect (diffuse) radiation. Direct radiation on clear days is of course most efficient, but also scattered light serves as energy source in non-CSP installations. To be more specific, the sun shines for ca. 1,500 h/year which is 17% of all hours/year. It is clear that this value can never reach 100% and that southern European locations are more suited for solar-thermal heating. However, 17% is more than one might expect from the wet coastal climate in the north.

A more detailed evaluation of the potential of solar-thermal energy in the Netherlands, Groningen, and the ACLO building follows below.

Solar-thermal energy in the Netherlands

The sun's thermal radiation energy which is hitting the earth's surface has an average value of about 165 W/m^2. To compare: An old-school light bulb needs about 60 W per hour and you need approximately 130 W to boil 1 Liter of water within 4 minutes. One can see that energy is consumed quite fast, but the amount of heat which is emitted onto the earth every day is more than 5,000 times the energy humanity uses within a day. Also the potential of solar-thermal radiation is bigger than all other forms of renewable energy combined [2].

However, it is important to realize that the received 165 W/m^2 can only partly be used. First of all this average value needs to be corrected for the location. In the Netherlands only about 125 W/m^2 are received. With help of the formula below, this E_0 value can be transformed into a value that is easier to handle, namely the amount of "work" that one would receive within one year for one square meter (called G_{solar}).

$$E_0 = \frac{W}{m^2} = G_{Solar} = \frac{kW/h}{year \cdot m^2}$$

This amount of work (kW/h) is used in everyday language to describe energy requirements of buildings. For solar-thermal installations it is therefore practical to relate kW/h to a surface area and a period of one year. Using the above formula, indicates that 1,100 kW/h per year and square meter are theoretically available in the Netherlands. Again something to compare: A 4-persons household consumes 4,500 kW/h per year. This of course means that using 4 m^2 of surface should theoretically supply a whole family of electric energy for one year.

Using the available 125 W/m^2 for systems which heat up water (solar-thermal water heating) and considering practical restraints and the laws of physics which determine the transmission of "radiation energy" into a fluid, leads to a more realistic availability of 350 kW/h which can be used in one year by making use of a one square meter surface. Considering this more realistic value, a 4-persons family would therefore need a installation of at least 13 m^2 to collect enough heat to supply the required energy. This is only 40 W/m^2 (instead of the original 125 W/m^2). It is, however, very important to realize that *the aim is to heat up only water and not to produce all the required energy*. Therefore, a surface of 13 m^2 would definitely be more than enough to provide a Dutch family with all the energy which normally would have to be used to heat up water for showering and washing clothes. Since in the Netherlands most water heating is achieved by burning gas, especially this resource would be saved.

Solar-thermal energy for the ACLO sports center

The ACLO sports center uses 274,400 m^3 of gas annually which comes at a price of roughly 0.30 €/m^3 causing gas energy costs of approximately 82,300 €/year [3]. Since the amount of gas that is used for heating up the water for showering is not separately measured, the financial potential of saving on showering costs has to be estimated as follows. As of 2012 the student sports association ACLO has 18,000 members [4]. It can be assumed that the average member sports once a week, which means that roughly 2,500 students use the sports center per day. One-fourth of them also shower there. 625 students who shower for 5 minutes consume at least 31,200 liters of water per day. Based on a temperature rise from 10°C to 40°C, the required energy can calculated based on the formula below:

$$Q = m \cdot c_p \cdot dT$$

This translates into: Energy for heating water (kW/h) = Amount of water (kg) x heat capacity of water (4.18 kJ/kg/K) x temperature difference (K) x (1 hour / 3600 seconds).

Filling in the previously discussed values indicates that **1,090 kW/h are used for heating every day**. Most water is heated by burning gas. Since burning of 1 m^3 of gas results in 10.35 kW/h, 105 m^3 of gas could be saved in one day. If solar-thermal heating systems were applied and covered all the showering gas requirements, **up to 11,500 € could be saved annually**, equaling a gas-cost reduction of 14%. This seems to be a realistic number since the number of students who shower can be higher, the amount of water per shower is probably higher, and gas prices will continue to rise in the future as indicated in the *Introduction*. Further, a coupling of the whole heating system to solar-thermal energy can lead to even higher savings, however the installation is more difficult and costs are higher. Therefore, in the following we will continue to concentrate on showering.

As demonstrated in the previous section 350 kW/h/year/m^2 is the available energy of a solar-thermal installation under ideal conditions in the Netherlands. When assuming a high efficiency of the installation and the earlier described 397,850 kW/h/year for showering (365 x 1,090 kw/h/day), **a surface are of at least 1,130 m^2 would be required** to cover the hot water energy demands. **The ACLO building even offers 1,500 m^2 of available roof surface** when considering only the indicated roofs in **Figure 3** with minimal shading and only the south-sides of tilted roofs.

Efficiencies of different solar-thermal heating systems

The final amount of needed roof surface, however, strongly depends on the efficiency of the used solar-thermal system. Logically, a 50% efficiency would result in a doubled required surface area. Efficiencies strongly depend on the construction of the used solar-thermal installation and one can distinguish three basic types of solar-thermal setups (**Figure 3**).

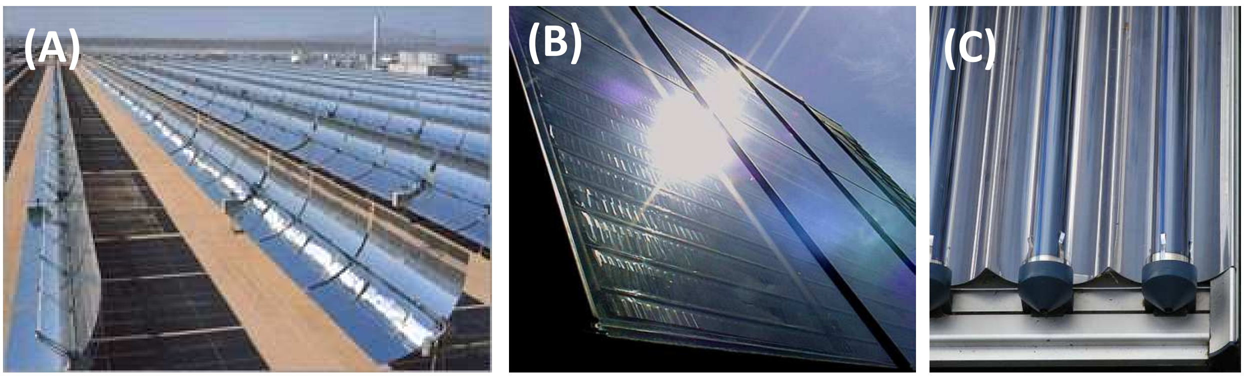


Figure 3: The three basic solar-thermal water heating systems. (A) Bowl- or concentrated solar power collector, (B) Flat panel collector, (C) Evacuated tube collector [5].

The first type of solar-thermal collectors are called bowl- or concentrated solar power collectors (**Figure 3 (A)**). When direct sunlight is available, these collectors by far offer the greatest efficiency and water heating potential. However, diffuse light conditions drastically reduce the capacity of this system. Traditionally, bowl collectors are therefore used in areas where there is a considerably higher amount of direct sun hours than in the Netherlands. Sun-tracking devices, which guarantee an optimal angle towards the sun, are not able to make up for these climatological factors. In addition, the weight is high, about 300 kg per collector, leading to smaller realizable sizes on top of the ACLO building. Currently also only large scale projects have been constructed, which leads to very high installation costs for a single building. Under he mentioned conditions the payback time for a solar-concentrating system would be at least 40 years and around 30 years considering rising gas prices. Based on its price and practical constraints this system is therefore not optimal for our proposed purpose.

The functional principle of flat panel collectors (**Figure 3 (B)**) is based on copper pipes running through a glass covered collector. As it is the case for most solar-thermal collectors also flat panel collectors are often connected to a water storage tank. This system is the cheapest of all three alternatives and has been proven to be reliable under various conditions for almost 30 years. However, during winter this system suffers from heat losses. Damages also require the replacements of a whole panel. The assumed payback time considering the roof surface and energy savings for the ACLO building would be approximately 20 years.

Evacuated tube collectors (**Figure 3 (C)**) use a glass tube with a vacuum inside and copper pipes running through the center. The advantage of this system is that it can extract heat also from the air and diffuse light conditions and is therefore also functioning when there is no direct sunlight. Further, non-optimal angels during the morning and evening do not reduce the efficiencies as much as in other systems. A drawback of this system, is that it has a lowered effective collection area per m^2 of roof surface, based on its tube construction. In case of damages single tubes can be replaced in place of a whole collector. Also for this system the payback time is relatively high considering the realistic calculations without a rising gas price: 25 years.

Water storage tanks drastically improve efficiencies and payback times

However, it is essential to note that all calculations do not include hot-water storage tanks which when installed at a suitable size (fitting the daily water consumption) greatly enhance the efficiency of all described systems. Tanks therefore allow to make use of solar-heated water on days where there might be no sunshine at all and the installations only produce a minimum of pre-heated water. This drastically reduces the needed collector surface because the efficiency per m^2 rises. The directly available 40 W/m^2 (see above) might therefore increase to theoretical 60 W/m^2 because the system can be used more frequently. In addition to this, also rising gas prices (low estimate: 4%/year) need to be taken into account. When considering these two important elements, payback times for systems **(B)** and **(C)** will be below 7 years. We consider this a realistic calculation and it indicates that manufactures payback times might be around 25% underestimated as they sometimes indicate payback times of 3-5 years for comparable situations.

There is no evidence that the two latter collector technologies differ in durability and maintenance costs. Therefore, we propose the installation of evacuated tube collectors or flat panel collectors on the roofs of the ACLO building. **A payback time of less than 7 years make both systems very attractive.**

By means of conclusion: The road towards an installation

Academics will shape the markets of tomorrow. For us it is therefore important that the everyday benefits of the applied technology are conveniently communicated and presented towards the student population. We want to show that technology has a positive connotation and energy saving does not necessarily mean that the quality of life must suffer. In order to do so we want to handle the slogan:

"Enjoy sports, enjoy the shower afterwards. Now showering helps to save the climate. Enjoy yourself, help the world."

Stickers and posters with this slogan and the basic energy saving facts could be distributed. Furthermore, we plan to install an informational display at the entrance of the sports center which translates the current saved energy into information which the students can comprehend, for example the equivalent of jogging or showering (**Figure 4**).

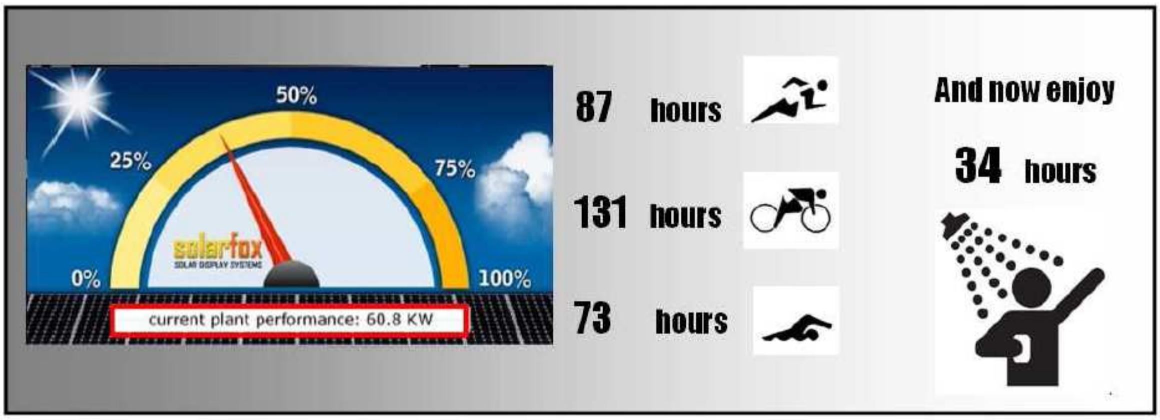


Figure 4: Informational display relating current energy savings to caloric values during sports.

For a successful implementation we, however, need the support of a wide range of people including the "Stuurgroep Duurzaamheid", external experts who proof our conclusions, the university board, and of course broad support by the student population and support of the idea by different fractions in the Universiteitsraad. Once these prerequisites are given, it becomes possible to make the project more concrete by evaluating bureaucratic procedures, financial attractiveness, evaluation of the location, and the actual construction itself. To a certain extent these aspects could result in a time-schedule covering approximately 1,5 years if some steps are performed in parallel. Important partial aspects can, however, be accomplished in less than one year.

1. Detailed research on feasibility which especially includes the evaluation of the sports enter itself, financial evaluation including research on available subsidies

and application for suitable ones, planning and communication with responsible board members, identification of potential companies (10 months).

2. Official project approval by university and municipality and public (EU-wide) bidding invitations (7 months).
3. Construction phase including custom made production and delivery (6 months).

We are convinced that solar-thermal heating is an attractive technology for the University of Groningen due to several reasons. This first case study demonstrates that implementation is realistic concerning time and location, financially wise, and will deliver an increased awareness for the challenges our society will have to solve, but also to live with during the next decades. If the University of Groningen takes it claims towards "Sustainable Society" and the implementation of an "Energy Academy" serious, this simple project can be made real.

Bibliography

1. Ritzen, J. From where I sit - National cuts call for joint action. *Times Higher Education* at <http://www.timeshighereducation.co.uk/story.asp?storycode=414889>
2. Desertec Clean Power From Deserts. (2007).at <http://www.desertec.org/fileadmin/downloads/DESERTEC-WhiteBook_en_small.pdf>
3. Personal communication with SWJ Arends.
4. Over ACLO - ACLO. at <http://www.aclosport.nl/nl/over-aclo>
5. Wikipedia contributors Solarthermie. *Wikipedia* (2012).at <http://de.wikipedia.org/w/index.php?title=Solarthermie&oldid=103677323>