The development of the Sunridge® ICS system: an orientation independent solar system

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Abstract

In order to realize Nearly Zero Energy Buildings and make the existing building stock energy efficient, the energy demand for heating and cooling and the electrical energy consumption needs to be reduced drastically. The next step in the so-called Trias Energetica is the local production of renewable energy, both electricity and thermal energy. A large (growing) part of the energy demand is related to hot water consumption. Here thermal solar energy can play an important role. Therefore, development of easy to integrate and install, efficient thermal solar systems is essential. Moreover, the main disadvantage of thermal solar energy systems, i.e. the required south orientation on z tilted roof and the competition with PV systems needs to be tackled to increase the applicability of such systems. In this paper the development of the Sunridge® system, a ridge integrated solar domestic hot water system, is described. A tube in tube concept as SDHW is developed and is placed on the ridge of the roof. The outer tube contains the spectral selective layer and the inner tube is the storage volume, a transparent cover is placed as outer layer. Heat is transferred from the outer tube to the inner tube by means of the effective boiling and condensation of water under low pressure between the two cylinders. The system will be inherent safe for overheating and freezing. The performance and end user price target is to be in the order of the price /performance of a standard SDHW system, nowadays on the market. The final design for the system is ready and pre-production takes place. In 2018 the first systems will go to the market.

Keywords: Integrated collector system, Solar domestic hot water, system, ridge integrated solar energy system,

1. Introduction

In order to realize Nearly Zero Energy buildings not only renewable electricity has to be produced, but also energy consumption needs to be reduced as well as renewable heat needs to be generated and used effectively. The heat demand of existing and new buildings is about 1.5 to 3 times higher than the electricity demand. A large part of the energy consumption in buildings is for space heating, space cooling and hot tap water production. The yearly energy needed for hot tap water is about the same as the yearly electricity demand for a household. In the next years the demand for electricity will increase, the demand for house heating will decrease but the energy needed for hot tap water will increase (comfort!). Better insulation of the buildings, energy efficient windows, and heat recovery results in a lower space heating demand in the building. For the reduction of the energy consumption for hot tap water production, new high efficient equipment such as HE gas burners and heat pumps offers possibilities, but still fossil energy is needed. For hot tap water production, the solar domestic hot water system is a good alternative. Thermal solar energy systems can reduce the heat demand and especially the heat demand for hot water production. However, thermal solar energy systems have some draw backs. These are among others:

- a required south orientation on z tilted roofs,
- competition for suited roofs space with PV systems,
- competition with windows in the roof

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- the space needed in the house for the water tank.
- an easy to integrate and install, efficient thermal solar system is under development.
- aesthetics

These main disadvantages are tackled through the development of the Sunridge® system. This development of a ridge integrated solar domestic hot water system, is in this paper further described. As ridge integrated system, the Sunridge® system is truly orientation independent. The system under development is a tube in tube concept placed on the ridge of the roof (see fig 1) . The ridge integrated solar energy system offers the integration of a solar product at a place of the building (the ridge) which has a low attention factor (aesthetics), is not in competition with other energy systems at that place, integrates also the water tank (no extra space in the building needed), is scalable to fit the ridge length and the Sunridge® product deviates not too much from ridge caps or upper roof tiles. From street level the system is almost invisible. For safety and health reasons the hot water temperature should be higher than ca. 60 °C. So the energy consumption in the built environment will be more and more dominated by the energy needed for the hot water production, at relative high temperature. A typical SDHW system reduces the conventional energy consumption by about 50%. Since the Sunridge® product will be very well suited for especially the existing one family buildings the market potential is huge (approx. 120 million existing dwellings across Europe are suited). The product is orientation independent, suited for both tilted roofs and flat roofs and modular adaptive to the length of the ridge. The calculated energy performance for 3 modules is that more than 50% of the energy consumption needed for hot water will be produced by the Sunridge® system. This performance will, of course, vary according to the climate, the number of modules and the hot water consumption. Higher contribution (>75%) in the South of Europe and lower contribution in the Northern countries of Europe (approx. 40%).

Fig 1 Artist impression of the. Sunridge® system on the ridge of a dwelling.

2. Technology of the Sunridge® system.

The Sunridge® product is a solar system in which the absorber for solar energy and the storage tank, for the hot water, have been merged into one unit.(see figure 2). The product consists of two tubes whereby one tube is assembled into the other. The inner tube is the container for (hot) tap water. The outer tube (copper) will be provided with a special layer with which the absorbed solar energy is efficiently transferred into heat. Water is placed in the space under low pressure between the inner and outer tube in order to transport the solar heat form the outer tube to the inner tube. When the outer tube is heated by solar energy, the water evaporates. The evaporated water condenses at the inner tube and transfers in this way the heat from the outer tube

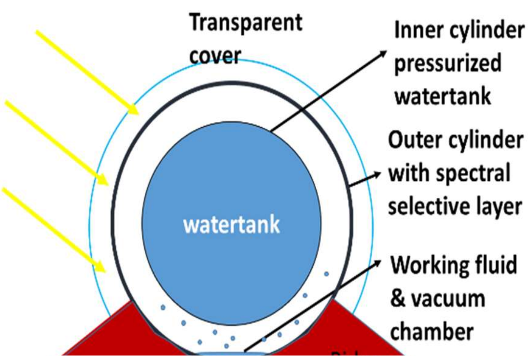

Fig 2. Scheme of the Sunridge® system.

to the inner tube. The condensed water drips of the inner tube and the whole process of evaporation and condensing starts again. In case of absence of solar energy, the heat transfer from the inner tube to the outer tube is only possible through radiation because the inner tube does not come direct into contact with water.

The inner tube serves as storage tank for the hot water. When the outer tube is heated, this water evaporates and consequently condenses on the colder side of the inner tube. In this way the solar heat is efficiently transported to the storage tank. Because the space between the inner and the outer tube is vacuumed, as a result of which the storage tank works as a thermos flask.

In figure 3 the physical process, used in the modelling are shown. The solar irradiation passes the outer transparent cover. For the largest part of the solar radiation passes heats the first copper cylinder. heats the outer surface of the outer tube. Heat losses are occurring due to re-radiation and convection. The first cylinder is equipped with the spectral selective layer. The radiation losses are low due to the low emissivity of the layer. The space between the tubes is under very low pressure enabling the water to evaporate and condensate to the inner tube, filled with tap water. In this way the solar heat is transferred to the inner tube and heats the tap water storage tank.

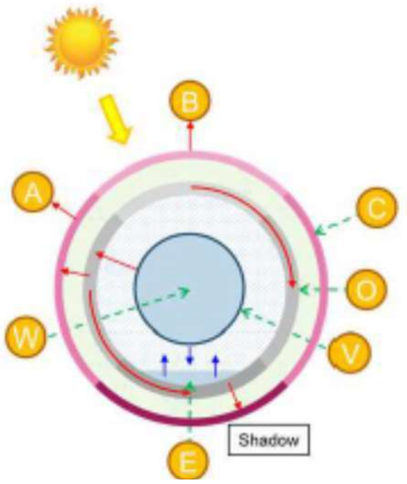

Fig. 3 Energy flows in the Sunridge® System

The Sunridge® product is placed on the ridge of the dwelling and placed in series of modules in order to reach the required volume for storing the hot water. Dependent on the number of modules connected the volume can go up to 130 liters, for a typical Dutch one family house. Due to the characteristic of the tubular SUnridge® system and the placement of the system at the ridge of the roof, the system performance is now almost independent of the orientation of the dwelling. Another advantage of the integrated system is the fact that in this concept an extra storage tank for hot water is not needed inside the dwelling, but is integrated at the roof. In this way a large market for SDHW systems now becomes available especially in refurbishment sector.

3. Experience with previous system

The first development of the Sunridge® system (Ekonok system) started some years ago. The manufacturing of tube in tube construction with vacuum has been carried out successfully. The principle of heat transport and diode function through the water/vapor under low pressure was tested and the performance is designed. The long-term performance and durability of the system was demonstrated in a field test over more than 10 years. After first market introduction, the market development stagnated at that time. The overall system concept had some drawbacks. These were:

- Installing the system on the roof and the connection to the tap water circuits was too complex, due to the connection of the modules connection under the roof.
- Deterioration of the transparent polymeric cover was going too quick
- The heat losses were high, for reasons of not having a spectral selective layer
- Industrial redesign of the system and production process was delayed

The system concept has been proven over the years. Therefor the redevelopment of the Sunridge system started with the help of the InnoEnergy innovation project. In order to get a good starting point for this development a module of the old system was tested at IREC.

In Figure 4 the calculated output of the DST test is presented. Under Dutch conditions the Sunridge system (consisting of 3 elements) had a performance of 2.6 GJ based on 100 L/day from 10°C to 65°C, preheated by the system, tested outdoors according to the DST test method in 2002. Since than the DST method is using other climatic conditions and is using other testing parameters. Nowadays the performance would be in the order of about 2.75 GJ.

A module of the old system has been tested at IREC. In figure 4 is shown that the module produced in 2015 without spectral selective layer gives the performance comparable to the old system.

The new design of the Sunridge system is based on spectral selective layer and new other materials is opting for 3. GJ for the Dutch conditions.

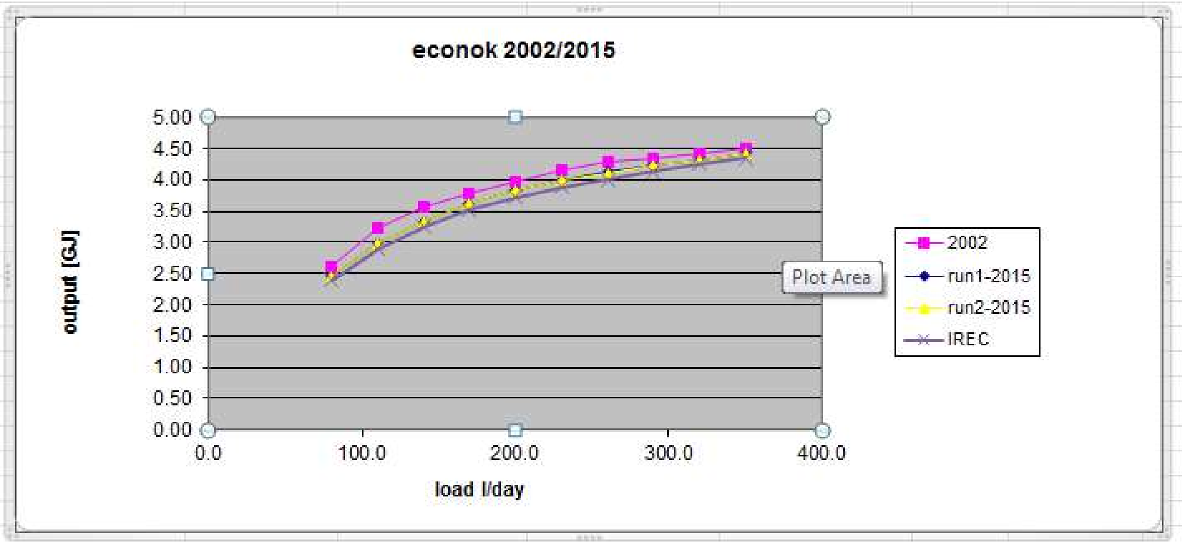

Fig 4. The output of the old Sunridge® system based on the DST test.

4. The Industrial Design.

As described in chapter 3 the old system had some drawbacks, reasons why parties in the market could not enter the market well enough. Some developments were needed and at that point of time this investment could not be made.

Since InnoEnergy (Knowledge Innovation Community of European Institute of Technology) started in 2010, a new vehicle became available supporting the further developments of products with a relative high TRL(technology readiness level) level from about TRL=6. This opportunity was used to develop a KIC InnoEnergy innovation project [1]. The Sunridge® product is since end 2014 under development to realize a competitive product for the market by 2018. The following aspects are under development:

- improve the performance of the systems (higher solar absorption and lower heat losses);
- make an inherent safe product for overheating and freezing;
- an esthetic, simple and scalable ridge integration for new and existing dwellings;
- Easy to be installed by roofers and installers
- Robust and quick connection for the modules;

Furthermore, the goal of the development in this InnoEnergy innovation project is to develop the pilot prototype production line, showing the manufacturing process at small scale, proving the realistic end price of the system and showing the high performance under realistic conditions.

The program of requirements was made with the following main aspects:

- The product has to withstand all the tests according to the standard and internal Monier standards for roofing product, such as wind, ventilation, hail, durability and safety.
- The product must be easy adaptable to different widths of the roof.
- Product should be easy to install by roofing companies
- Installation connections: only at one place of the roof connection through the roof for connection the water pipes to the aux and mains water supply.
- Inherent safe overheating and freezing protection.

Based on these requirements the industrial design of the Sunridge system was made, leading to the following important systems parts to be further developed and tested. These are

- The transparent outer cover. The choice has been made to use glass tubes.
- Stainless steel as the material for the inner tank containing the drinking water. Copper as material for the outer tank with water under very low pressure for the heat transfer between the outer and the inner tube.
- Spectral selective layer applied on the outer copper tank.
- Supporting construction for quick installation between the ridge and the system, in the form of dedicated aluminum profiles.

In the following figures 5 to 9 the results of the industrial design are showed.

Besides the solar and thermal performance, the durability, safety and ecological performance must be excellent. And of course, last but not least the price performance ratio must be competing with normal solar domestic hot water system.

The roofing company Monier is participant in this project and has the rights for the first market introduction. For this reason, the systems overall performance and the integration in the roof should fulfill all the requirement of the quality of products which are standard at Monier. For this reason, the durability and safety tests will be performed by Monier in their roof testing Centre in Heusenstamm, Germany.

Fig 5. Spectral layer on copper tube

Fig 6. Mock-up of the Sunridge®

Fig 7. Ridge profile, upper for the system, under profile to the beam of the ridge

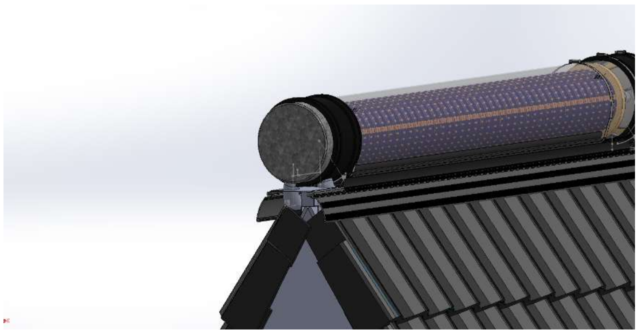

Fig 8. End cap for the module

Fig 9. Detail of the tube on the aluminium profile

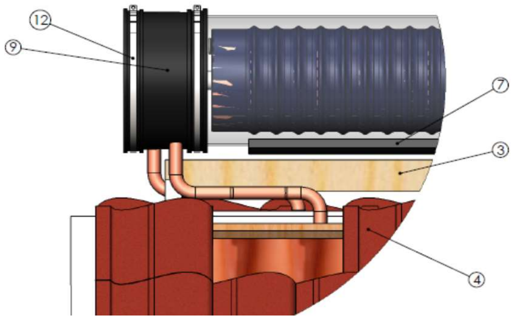

Fig 10. Inlet-outlet connection to the module Spectral layer on copper tube

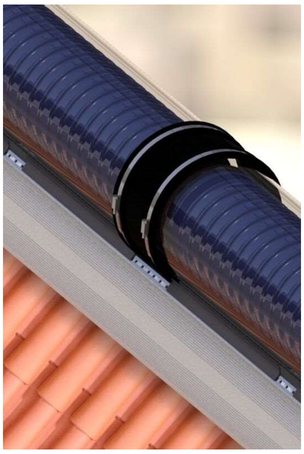

Fig 11. **Connenction between the modules**

5. Testing the new Sunrise system

In the spring 2017 one module for the Sunridge system consisting of the spectral selective layer and glass transparent layer was delivered at IREC, for outdoor performance testing. In figure 12 the system placed at the testing roof at IREC is shown.

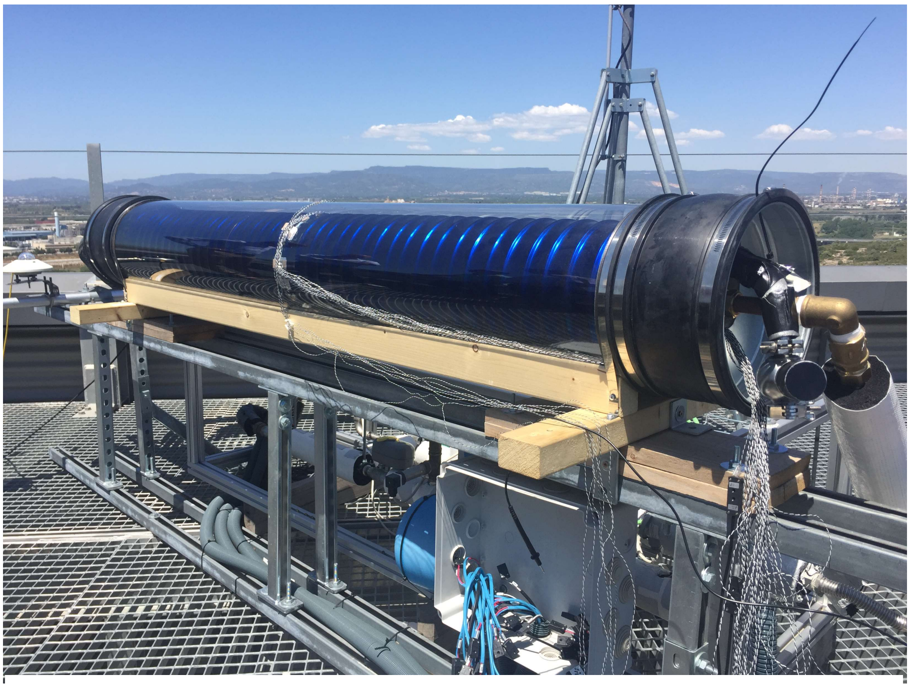

Fig. 12. The Sunrise system at test facility at IREC(Taragona Spain)

During summer 2017 one module of the Sunridge system was tested. This module was 1.4 m long and had a tap water content of 35 l.

5.1 Performance testing

The system was tested according to the DST test method described in the EN 12976. The performance of the new Sunridge module is compared to the old Econok system. Based on the test results obtained in summer 2017 the DST parameters were established. These parameters are used for the long term performance calculations for various climatic conditions and tap water consumptions. In figure 13 the outcome of the new module is presented and compared to the old module. The results shown are for one module. For typical one family conditions about 3-4 modules will be used.

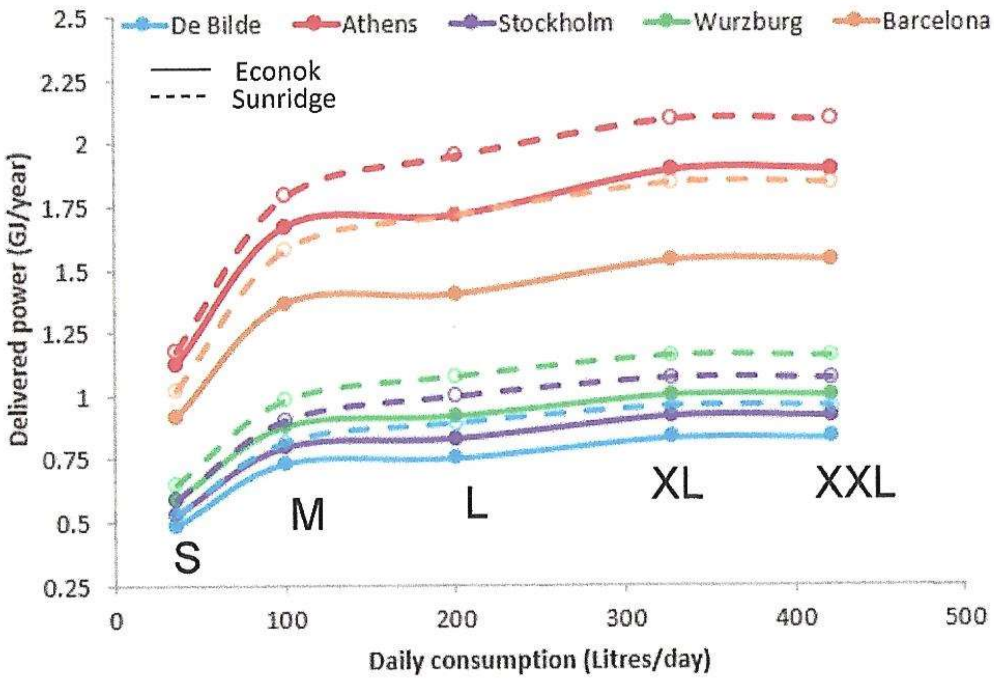

Fig. 13. Results from the DST test. Yearly energy output for one module for various climatic zones and different daily hot water consumptions. Comparison between the old Eocnok module and the new Sunrise module

From the testing the following conclusions for the Sunridge system under development were drawn, incomparison to the previous (Ekonk) system:

- The DST model parameters points at lower storage losses
- The DST parameters point sat significant mixing during draw-off
- The performance increase is in the order of 10 to 25%

Based on the test results for only one module it is shown that the goal set for the performance improvement of at least 10% for Dutch conditions is clearly met. Complete Sunrise® system, consisting of 3 modules, will be demonstrated end 2017 and beginning 2018 in The Netherlands. Moreover, in April 2018 the solar key mark testing for the complete system will start.

Based on the tests at IREC summer 2017 the design model of the system is validated. This design model is a dedicated TRNSYS model for the Sunrise system. Moreover, a detailed model for the Sunrise system has been developed at TNO. With this model the effective collector efficiency curve can be calculated. This effective collector curve is used in the design model. W

With the design model the lay-out of the system can be calculated based on the climate and predicted hot water consumption. The result is a predicted performance, energy savings and number of modules needed.

5.2 Outdoor Shock test

As part of the testing at IREC, internal and external shock test have taken place and the stagnation temperature has been characterized. These tests have been performed according to the EN12975-2 standards.

Fig. 14. Condensation after the first external shock test.

The stagnation temperature measured for the system fully filled with tap water reached a value of 63,4 °C. using the standard conditions of the EN 12975-2 means that this a value is 67,7 °C.

The internal and external thermal shock tests were performed and the results showed no damages or leakage. Moreover, the vapor pressure of the vacuum space between the tubes showed no significant changes. At the first external shock test significant condensation at the glass tube was detected visually (see fig 14).

5.3 Overheating and freezing test

As discussed in 5.2 the stagnation temperature of the system has been measured. In the case of long period of absence (holiday) and high solar radiation the temperature in the tank of the Sunridge system can be very high, even higher than 100 °C. for this reason a well-known safety control will always be a part of the installed installation.

Since the complete system is place outside freezing during winter conditions can occur. For this reason, the Sunridge will be equipped with an electrical tracer. The typical vulnerable aspects in the design are in the inlet and outlet tap water piping and the connecting pipes between the modules (see fig 14 and 15).

Fig. 15. Tracer on the connection pipe between the modules

Fig. 16. Electrical tracer to the inlet and outlet pipe of the module.

In a freezing cabinet at TNO the Sunridge system including the installed electrical tracers were tested according the requirements of EN 12976-2. The complete system has to withstand an outdoor temperature of -20°C during a period of 12 hours with a start temperature of the tap water of 5 °C In fig. 17 the test results are shown.

The system was tested under -20°C for more than 30 hours. The temperatures of T203, T204 and T205 are around 0°C, but the more critical temperatures of the connecting pipes are above 15°C. The temperatures T deep and T shallow drop to a still safe level of slightly below 3°C.

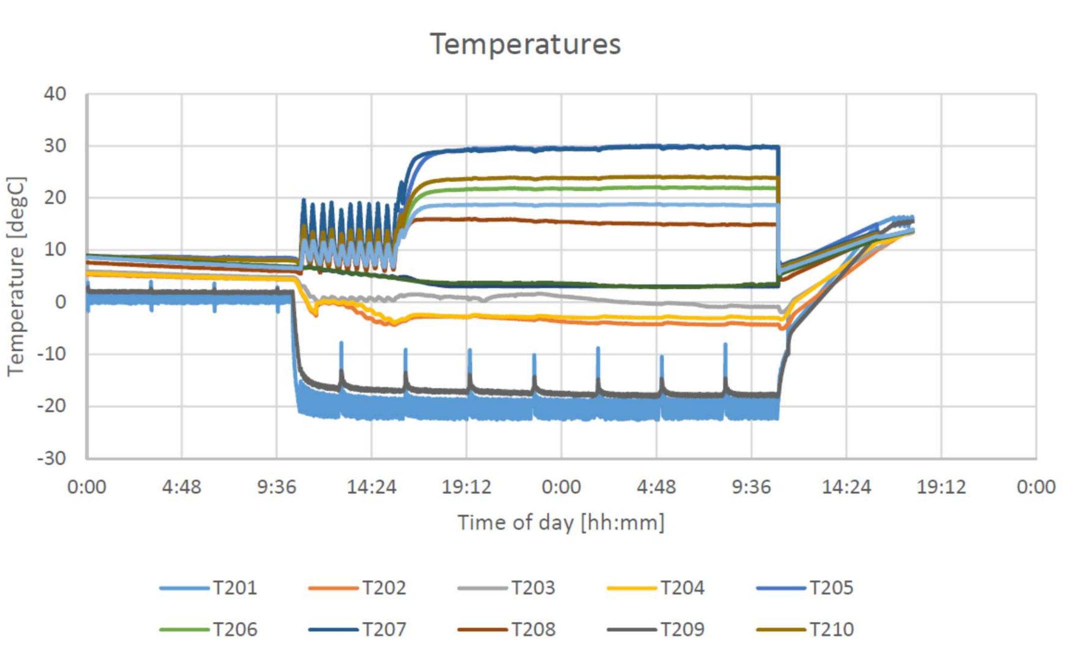

Fig. 17. Temperatures in the and around the Sunridge®water tank during the freeze testing

The conclusion from the test was that the Sunridge® system equipped with the electrical traces and the clckon sensor placed on the right position, fulfills the EN12975-2 requirements with respect to withstanding freezing.

5.4 Wind load design

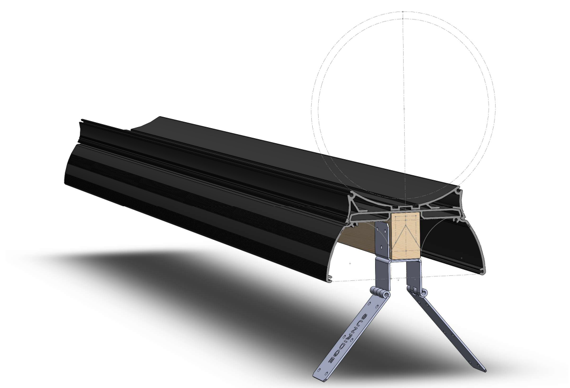

Fig 18. The aluminum profile connected to the beam and the clamp for holding the wooden beam for connection to the roof plates.

The Sunridge® system is mounted on an aluminum profile. This profile clicks in to a profile that is connected to the ridge. The wooden beam for the ridge is connected to the roof plates by means of a number of clamps. Wind loads will come on the glass tube of the Sunridge® system. These forces will generate momentum to the roof. The connection from the system to the roof plates have to withstand severe wind loads. For this the most severe conditions from the standards are taken. In this case that is the British Standard for wind loads on roofs. The glass tube is mounted on the aluminum support profile. The profile is screwed on the beam of the ridge. This is a new wooden beam mounted with ridge batten holders on the roof plates. A dedicated design has been made for the ridge batten because they form a constructive unit with profiles. In order to with stand the wind load, the place and thickness of the screws was calculated. Moreover, this was also carried out for the clamps and ridge batten holder. Hereafter this was manually tested at the test roof set-up at Monier. A first quite simple tests showed that the steel support for the beam were not strong enough. Redesign was carried out and this ended up with thicker clamps. In figure 19 the testing of the system and forces are shown.

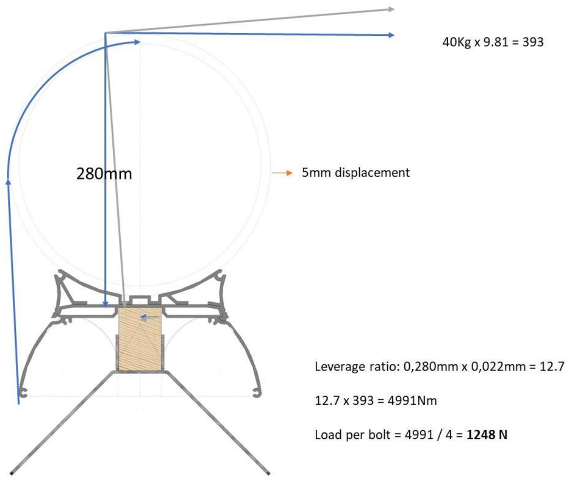

Fig. 19 Forces on the Sunridge system

6. .Production

An important aspect of the project is the cost price of the Sunrise® product. The cost price is among others determined by the bill of materials, bill of labor and the production process.
The flow chart for the production process is developed. A very import step in the production is the welding process of the end caps for the tubes with the tap water connections. Since the pressure between the copper outer and stainless steel inner tube is very low, leakage can occur. For the welding process an excellent supplier has been selected. The welding of the copper tube and the stainless steel tube is performed at a manufacturing plant with an automated rolling and welding process. The next step is the welding of the end caps first to the stainless-steel tanks. Here the connecting pipes for inlet and outlet tap water are welded to the caps.
Then stainless-steel end caps are welded to the copper tube with connecting water pipes through this end caps. This welding of the end caps is a very critical production step. The welding has to be airtight since a very low pressure between the tubes is needed for the working of the Sunridge® system.

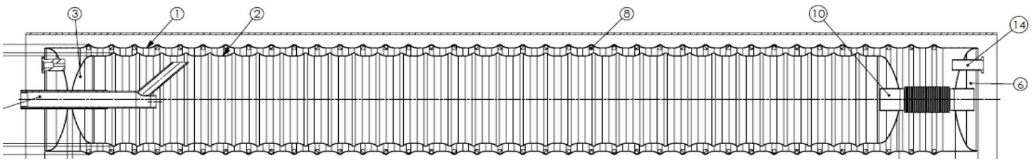

Fig. 20: Industrially designed module complete with caps and the tap water connections between the modules.

Fig. 21 Welding of the copper tube.

In figure 20 the industrial design of a module is presented. In the figures 21-24 the welding process is shown.
The field demo modules are produced in March 2017. About 25 modules will be produced. From this demo modules a number of about 15 modules will be used for performance testing and testing as demo in the field. Other modules will be used for risk assessment test at Monier test Center in Heusenstamm.
Based on the test results for the performance, installing in the demo, risk assessment testing and other new information the final design will be made during 2017/2018. This also will lead to a final production plan with bill of materials and bill of labor. In the end the cost price will be determined. During 2018 first modules will be sold to the market through the channels of Monier.

Fig.22. The end cap with tap water connection. Welding of copper tube, stainless steel cap and copper water tube.

Fig.22. The longitudinal automatic welding machine.

7. Conclusions

In this paper the development of the ridge integrated solar water heating system, Sunridge® is described. The Sunridge system consist of a number of modules coupled and placed on the ridge of the roof. With this flexible design for the system, the solar energy contribution to the hot tap water can be tuned to the demand, the climate and the dwelling. The energy performance of the ridge integrated system can be about 50% of the energy demand for hot tap water and most important this is orientation independent. Moreover, the ridge integration enables the roof of the dwelling being used for other purposes, such as photo voltaic panels and/or roof windows.

The Sunridge system is a preheater for hot tap water with the tap water storage tank placed outside the dwelling, on the roof. The design of the system enables an inherent safe product, easy to install and to connect to the hot water system in the dwelling.

The industrial production process is designed in order to produce the system at high quality in a professional way. The overall cost price including installing the system is expected to be competitive the standard solar thermal domestic hot water systems. The production process can be up scaled to large numbers in a due time, due to the modular set-up of the system and production. In 2018 the Sunridge® product will be introduced in the market in The Netherlands.

8. Acknowledgements

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- TNO research Institute in The Netherlands,
- IREC Renewable Energy laboratories,
- RTB de Beijer innovative SME company
- ArtEnergy bv SME company

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