# Project Highlights

In 3,5 years of research on material, processing and system level, SCOOP has generated a range of innovative solutions for polymeric solar thermal systems and components. The project yielded novel system concepts and innovative polymer based solutions ready to enter the solar thermal market. This newsletter contains the highlights of SCOOP's results which were also presented at the final project meeting in Rapperswil, Switzerland from 20-21 May 2015.

Fig. 1: Participants at the final SCOOP meeting in Rapperswil, Switzerland.

More information can be found on the project homepage http://eu-scoop.org or in various publications to follow.

## Coming soon

"Solving the production challenge for polymeric solar collectors." J. Rekstad, I. Skjelland, Y. Klinger et. al.

## Polymeric collectors put to field test

Functional models of the polymeric collectors developed in SCOOP were installed in three distinct climatic regions on outdoor test fields maintained by Fraunhofer ISE. All collectors were equipped with a set of different temperature sensors which monitored the temperature loads on the individual collector components 24/7. In combination with climatic data like ambient temperature, irradiation, wind loads and others, which were simultaneously monitored at each location, unique data was recorded over a long period of time. With the help of this data SCOOP researchers can improve the collector design and adjust the materials to the expected thermal loads. The three outdoor testing locations maintained by Fraunhofer ISE are located on Gran Canaria, Spain, with a maritime warm climate with high wind loads; in the desert Negev, Israel, which is in a similar latitude and has a typical arid climate with high temperatures and little precipitation and at the Fraunhofer ISE in Freiburg, Germany, with a moderate climate (fig. 2).

Fig. 2: The three outdoor testing locations [arid (left), maritime (middle), moderate (right)].

These climates are representative the different locations where polymeric collectors are applicable and have - together with the collectors design - significant influence on the service life time of the polymeric materials. Based on this data researchers involved in the qualification of new materials, absorbers and other components can develop new laboratory test methods to test for these conditions. In the future, this will make the optimization of materials and components for polymeric collectors to specific climatic loads easier and cheaper.

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## Design of solar thermal components and systems

Within the EU SCOOP project, AEE INTEC took a leading role in WP2 which dealt with the design of solar thermal collectors and systems. During the lifetime of the project, a portfolio of novel concepts for both individual components (absorber, collector) and systems (thermo-siphon system, storage collector system and pumped system) have been developed. These designs were specially aligned to the manufacturing technologies injection moulding (fig. 3), extrusion, and partly also adjusted to welding techniques for collectors and systems.

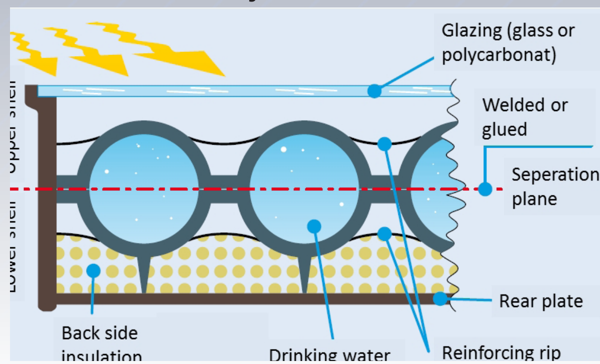


Fig. 3: ICS system concept with an injection moulded absorber. (Source: AEE INTEC and GREENoneTEC, 2013).

Besides experimental development of system components (e.g. innovative heat exchanger solutions for thermo-siphon systems), new adapted theoretical models for system simulations, optimizations and calculations of efficiencies could be determined. The research clearly shows that the continuous use of simulation models is indispensable. Already in the conceptual phase, these models improved decision making for a research success.

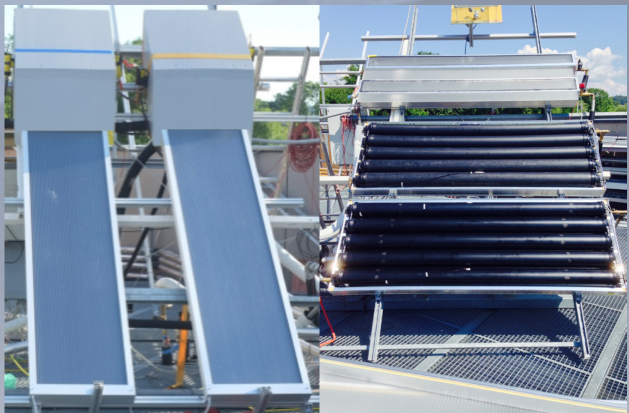

Fig. 4: Thermosiphon system (left) Integrated collector storage (ICS) (right). (Source: AEE INTEC)

Furthermore, AEE INTEC gained new knowledge and experience in outdoor testing for system performance characterization and yearly performance prediction of storage collectors and thermosiphon systems (fig. 4).

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## Testing of SCOOP prototypes

In WP 8, three systems [Polycrafte (GREENoneTEC), Aventa TSS (Aventa), and ThermX Prototype 2.1 (ISE)] and one collector by the company Aventa were transferred to SPF for performance assessments and quality tests. These prototypes were examined based on existing standards EN12975/ ISO9806 and EN12976.

The Aventa collector was tested with different durability tests such as outdoor exposure test, high temperature resistance tests, thermal shock and mechanical load tests (fig. 5).

Fig. 5: Mechanical load test: The positive and negative pressure loads are applied by means of evenly distributed pneumatically actuated suction cups.

For the thermal performance measurement the collector was installed on a solar tracker to assess also the biaxial behaviour of the incidence angle modifier given by the twin-wall transparent cover. Additional measurements were made on the SPF indoor solar simulator to investigate the flowrate dependency of the thermal performance even under very low flow conditions (fig. 6).

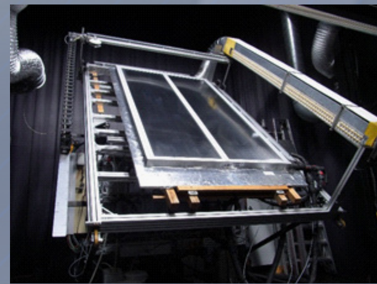

Fig. 6: Collector installed on the SPF Solar Simulator

Fig. 7: Thermosiphon system installed on the testing facility.

The measurements on the Polycraft system confirmed that the thermal performance is the same - within the uncertainty of the test method - as for the conventional Polycraft system. The thermal performance of the Aventa TSS system and the ISE ThermX prototypes were determined using the EN12976 Dynamic System Test method (fig. 7).

A major challenge is the testing of low-pressure systems as the draw-off rates required by the test method are sometimes difficult to achieve without exceeding the maximum allowed operating pressure. This could also be an explanation for the deviating results measured by SPF and AEE INTEC. In the future revisions of the standards this issue should be addressed to allow for the testing of the usually pressure-sensitive prototypes. In addition to the standard tests, all the samples were installed in the SPF climate chamber for a series of humidity-freeze tests.

During these test cycles the SCOOP prototypes were exposed to temperatures down to -20°C and extreme conditions regarding humidity (fig. 8) without observation of any damage or deterioration.

The tests of the SCOOP prototypes confirmed that the performance of polymeric collectors and systems can be compared to conventional products. The standardized test procedures are basically applicable to those products. However, the validity of prototype tests will be limited. Relevant technical input for the standards will be provided to the working groups which are in charge of the next revisions.

Fig. 8: The prototypes in the climate chamber during humidity-freeze test.

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## From laboratory to on-site measurements

The University of Oslo generated new knowledge to several aspects of the overall value chain: Mechanical testing and aging of polymeric components and joints, modelling of overheat protection by partial glazing and outdoor testing of prototypes at laboratory scale were performed for window-integrated polymeric absorbers and several modifications of the polymeric thermosiphon concept. In collaboration with a project supported by the Research Council of Norway, energy monitoring in one of the SCOOP demonstration projects was performed in the course of two years (fig. 9). This study received much attention by comparing the performance of two equal passive houses, one heated by solar energy and the other by air-to-water heat pump. It concluded that solar heating is competitive with regard to performance and costs, even under Norwegian conditions, with a performance better than 20%.

Fig. 9: Demonstration project in Oslo, Norway (Source: Tove Lauluten).

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## Luminescence spectroscopy for non-destructive characterization of polymers

Within the framework of the SCOOP project Humboldt University of Berlin developed quantitative, polymer-specific protocols for polymer degradation characterization by luminescence spectroscopy. Identified were consistent patterns in the luminescence spectra valid for a broad range of polymers as well as polymer-specific signals that can be used to evaluate polymer degradation. The latter also provides a means to discriminate between different polymer materials. In addition, kinetic analysis of the luminescence data may also provide information on the performance of additive compositions and support lifetime prediction. It was established that the luminescence method is particularly useful for the characterization of the early stages of polymer degradation, i.e. within the induction period.

In summary, HU Berlin was able to greatly advance the understanding of polymer luminescence in general and provided evidence that luminescence spectroscopy can be applied to polymer degradation characterization on a quantitative basis. This big step forward was made possible due to the close collaboration with other SCOOP partners providing different sample materials and complementary characterization methods.

These new insights enables the further establishment of luminescence spectroscopy as a tool for inspection and evaluation of polymer performance in different fields of application.

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## Solar thermal market potential

Worldwide, around 75% of all solar thermal systems installed are thermosiphon systems and 25% are pumped solar heating systems. In general, thermosiphon systems are more common in warm climates such as in Africa, South and East Asia (excluding China), Latin America, Southern Europe and the MENA region. Looking at these countries, a positive market growth is still recorded in regions like Latin America, Asia and also the USA/Canada. In most of these regions low cost thermosiphon systems are more common than pumped solar systems. This offers a great opportunity to enter the market with new polymer collectors and systems. Features like low weight, corrosion resistance against poor water quality and more cost efficiency are factors that facilitate the market uptake. Based on these basics GREENoneTEC continuous the work on polymers to be fit for market soon.

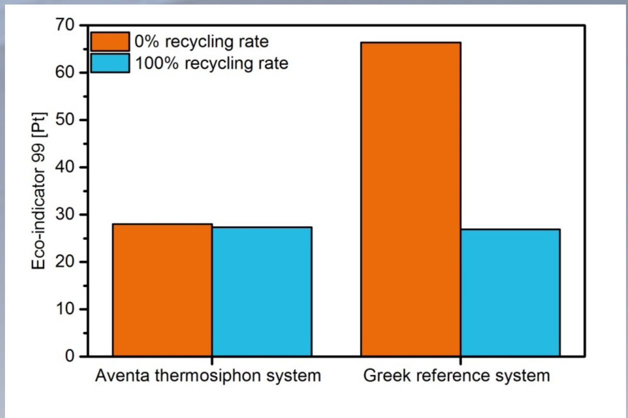


Fig. 10: Environmental contribution in Eco-indicator 99 H/A in accordance to the solar fraction for the total aperture area of 2.13 m² (Aventa thermosiphon system) and 1.91 m² (Greek reference system).

To identify the environmental impact of solar col lectors and also thermosiphon systems, a Life-Cycle-Analysis (LCA) was carried out (fig. 10). Results clearly indicate that solar products manufactured of polymers show lower ecological impact than those manufactured of conventional material (metals, glass and mineral wool).

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## Modern CFD technology increases innovation level of research projects and ensures their success

State-of-the-art CFD simulation techniques had a significant contribution to the realization of novel solar technologies developed in the EU project SCOOP. Physically well-grounded heat and flow simulations were crucial for finding the most efficient and promising concepts out of a variety of design options that modern polymers and their production methods provide.

Through the CFD analyses and expertise of the consortium partner Dr. Axel Müller-HTCO the best design concepts for polymeric collectors and thermosyphon systems (TSS) could be determined in advance. The effects of various material properties and design parameters such as wall thickness and surface shape on the performance were calculated virtually. The design of a tank-in-tank solution for a new TSS system was significantly influenced by the simulations of HTCO. Since the function of different tank designs could be made visible in the simulation, it could be clearly shown that the way of supplying or withdrawing water has a significant impact on the saturation, the storage capacity and the time to withdraw hot water of the tank. The conventional supply system led to mixing of hot and cold water in the tank and thus to a reduction of the warm water withdraw capacity. On the basis of these findings a new supply system was developed and its performance was proven virtually. The CFD simulation made it possible to develop a perfectly functioning system and to build only one final prototype. This was a significant contribution to the project since the construction of various prototypes would have been impossible or extremely costly and time consuming.

Another novelty that resulted from the research work of HTCO is the newly developed methodology to systematically simulate the thermal performance of any solar system during the entire course of a day. This virtual approach allows studying the influence of the mounting position as well as the geographic and climatic effects to the whole system without the need to produce various prototypes and perform costly measurements. In the future this method can be used by HTCO to virtually determine the best solar system design parameters for each potential market and adapt construction perfectly to its climatic conditions.

The R&D of polymeric solar systems in SCOOP showed that they can be very high performing when the system components and their interaction is adapted to the specific qualities of the polymeric materials. Reproducing conventional concepts for (metal) solar systems with polymers as well as the testing and standardization methods is not very promising since they do not take into account other important advantages of the new polymeric systems such as weight and cost per performance unit. Thus it is crucial to become a deep understanding of how the new systems really function and which factors contribute most to their performance. By means of CFD simulations HTCO essentially contributed to the project success by delivering profound know-how of the new systems, accelerating the progress of the design and product development, and securing the results in early project phases.

The research project SCOOP demonstrates that continuous and timely use of simulation technologies is crucial for efficient and solution-oriented R&D.

It provides fundamental and reliable knowledge as well as efficient optimization methods that ensure research success at early project stages. Moreover modern CFD technology enables the exploitation of additional innovation potentials and increases the innovation level of research projects considerably. The company HTCO has grown to a strategic partner for R&D and innovation processes and is looking forward to tackling new challenges with its expertise, novel ideas and modern simulation techniques.

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## Local aging of polyamide based absorbers – A fracture mechanics approach

The Institute of Polymeric Materials and Testing (IPMT) at the Johannes Kepler University Linz (JKU Linz, Austria) developed a unique method for the description of the local aging kinetics under superimposed environmental and mechanical loading conditions. Therefore, an in-situ test setup was implemented on an electrodynamic machine consisting of a media container with temperature control, a loading unit and a camera based crack detection system (fig. 11).

The test setup was used to characterize the crack growth behaviour of glass-fiber (PA) reinforced polyamides (PA66 GF30) in water heat carrier at enhanced temperatures and superimposed cyclic loads. This loading profile is of service relevance for single-loop integrated storage collectors with pressurized solar and domestic hot water loop (pressure up to 6 bar at maximum temperature of 95 °C).

For frictional welded compact tension specimen the crack growth kinetics was a factor of 2.5 lower compared to unwelded specimen. For absorbers with an internal diameter of 15 cm and a wall thickness of 3 mm the probability for crack growth with an initial crack length of 0.5 mm under internal pressure of 6 bar was marginal. The simulated crack intensity factor (KI) was significantly (factor > 2) below the threshold value even for the welded section of the absorber. Hence, the technical feasibility of pressurized PA GF30-absorbers for single-loop integrated storage collectors was unambiguously ascertained using advanced local aging characterization methods.

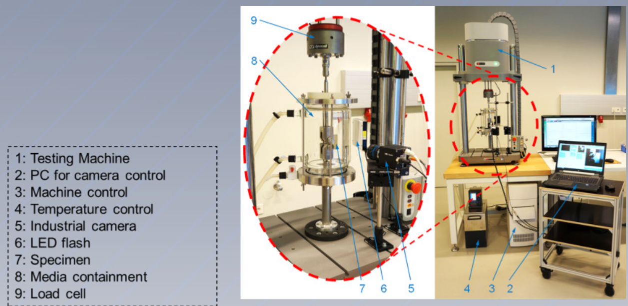


**Fig. 11: Machine for cyclic testing of materials in tempered media (Schläger et al., 2015).**

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## Development of polyamides with improved hydrolysis stability

A.P.C. is specialized in the development of polymer compounds meeting exactly customer´s demand. In the course of SCOOP A.P.C. developed a hydrolysis stable reactive modified polymer matrix based on a polyamide 66 (PA 66). To meet the challenging mechanical requirements (pressure up to 6 bar at T=100 °C) of our industry partners, reinforcing fillers e.g. short but also long glass fibers with a fiber content up to 50 wt. % glass fibers were added. In collaboration with the scientific partners the service life time of such compound was determined for more than 5 years at a constant temperature of 90 °C at a load >20 MPa.

The compound also perfectly fulfils the needs for high performance parts of the plant and engine building industry like components of centrifugal pumps for pulp and paper plants (fig. 12). This leads to a planned investment of A.P.C. and partners in a Direct Long Fiber Thermoplastic Molding (D-LFT) plant, which is especially suitable for the economical production of large-sized parts even at lower lot sizes.

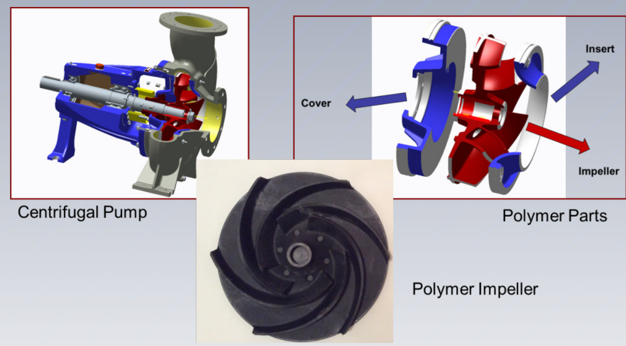


**Fig. 12: PA 66 Based Components of a Centrifugal Pump, D-LFT-Production**

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## Development of an innovative pressure tank

From the point of view of Polytec a significant result of the SCOOP project was the generation of a pressure tank. This tank is made out of polyamide with reinforced glass fibers. The tank withstands a pressure of 20 bar at a temperature of 23°C respectively a pressure of 6 bar at a temperature of 90°C. In particular, the focal point in this project for Polytec was the definition of the geometry of the edge of the half-shell parts and the optimization regarding the considered joining technology. By joining the two half shells the best results were achieved by frictional welding (see sketches in fig. 13/14).

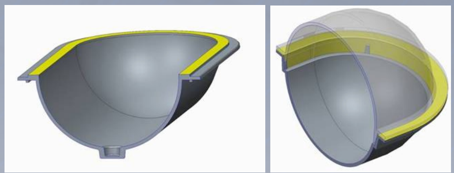

Fig. 13: Cross-section of the polyamide half shells.

Currently, a geometric modification is realized in the edge of the half-shell part, so that a shear loading at an adhesive joint is ensured. Due due this fact an alternative joining method to frictional welding is possible.

Fig. 14: Polymeric pressure tank by injection moulding and frictional welding.

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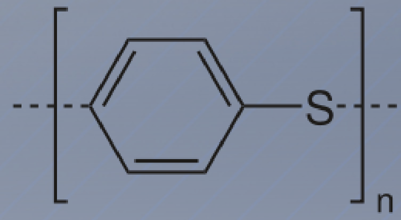
## DS Smith: Expertise in extrusion of PPS

DS Smith is recognised as an expert in extrusion of Polypropylene and Polycarbonate multiwall sheets for the markets of packaging, graphic and building industries, amongst others.




With the SCOOP project, experience has been acquired with Polyphenylene Sulfide (PPS). This polymer, well known for its high thermal and chemical resistance, is an ideal candidate for solar thermal application and is used to produce fittings obtained by an injection moulding process.

However, in the field of extrusion, the PPS is rarely used and no application with extruded twin wall sheets is known.

During the SCOOP project period, however, extrusion with PPS was made possible and several issues like for example improvement of thermal stability, surface aspect and health and safety have been solved.

Extrusion of PPS twin wall sheets for solar collector plates is now an industrial process and new markets are reachable. In addition to the market of solar thermal, other industries are also interested by the possibility to have access to extruded PPS twin wall sheets.

Thus, first contacts have been made in the field of sea water desalination and heat exchanger in automotive industry.

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## The AventaSolar collector - From fundamental research to demonstrated systems installed and operative

SCOOP has covered the value chain from fundamental research to final and demonstrated products. After major efforts with material suppliers and the processing experts DS Smith, the extrusion of PPS and PP to structured sheets is demonstrated as a favorable processing technique for absorber production. A breakthrough could be achieved in jointing polymeric absorber components by infrared (IR) welding, and a further milestone was reached by acquiring the Solar Keymark label in 2014.

### Demonstrating feasibility and attractiveness

Eight demonstration projects could be realized during the project period. These include the new AventaSolar collector concept architecturally integrated in the roof and facade in passive houses, in new built (fig. 15) and retrofit projects. Collaboration with major actors of the building industry was essential to demonstrate competitive solar thermal technology compared to conversional energy in terms of costs and performance.

Fig. 15: The houses at Stenbråtlia are built to meet passive house standards and have several qualities to secure high comfort and low energy consumption. "The housing estate demonstrates that comfortable indoor climate, renewable energy and aesthetic design can be successfully brought together" Egil Wahl, OBOS project leader. (Source: H. Kicker, JKU)

The innovative approach is that the polymeric solar collector is packed into a conventional facade product, which installers are used to handle at the building site and contribute to reduce installation barriers, time and costs. The building integrated concept with polymer collectors in pumped systems are already launched in Norway (fig. 16). The challenge is to find partners who can bring the technology to a broader international market.

Fig. 16: Integration of polymeric absorber convetional, glazed facade products. (Source: Agder, Aventa)

## Polymers for the global market

SCOOP has been a driving force and platform for the invention of new solar products for the global market, which can offer European industries excellent competitive positions compared to the present dominance by low cost producers. The production costs at industrial scale will be reduced by almost 50% for the polymer-based Aventa thermosiphon concept. A joint patent application has been filed by Aventa and Fraunhofer ISE protecting the technology, which is built on extruded structured sheets. Negotiations with potential producers for these patent protected concepts are ongoing. The final product should preferably be manufactured close to the actual areas where thermosiphon technology is feasible.

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## More information

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