Final report

1.1 Project details

Project title	Foil CSP
Project identification (program abbrev. and file)	Foil CSP 64014-0569
Name of the programme which has funded the project	EUDP
Project managing company/institution (name and address)	Heliac Aps, Savsvinget 4, DK-2970 Hørsholm
Project partners	Aalborg CSP Inmold
CVR (central business register)	35841911
Date for submission	28/2-2018

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Relevant links

(the guidelines should be deleted – they should NOT be included in the final report)

GUIDELINES FOR FINAL REPORT

General

Depending of project type, project size and project complexity the **number of pages** in the final report may vary. For smaller **demonstration** projects the final report normally should not be more than 20 pages plus possible relevant appendices. For **research and development** projects the final report should not be more tha 50 pages.

The final report will be used for dissemination purposes and the information given in the final report should be suitable for dissemination, cf. point 1.4.

1.2 Short description of project objective and results

- *English version*

The objective of the project was to demonstrate that polymer foils made by a novel manufacturing method could be used to collect solar heat for energy purposes in a technologically effective and economically feasible way. This should be done by using surface structured polymer foils to focus sunlight onto a receiver which heats a circulating liquid. Main focus is to demonstrate a suitable geometry of the solar collectors and demonstrate the concept on a unit level.

- *Danish version*

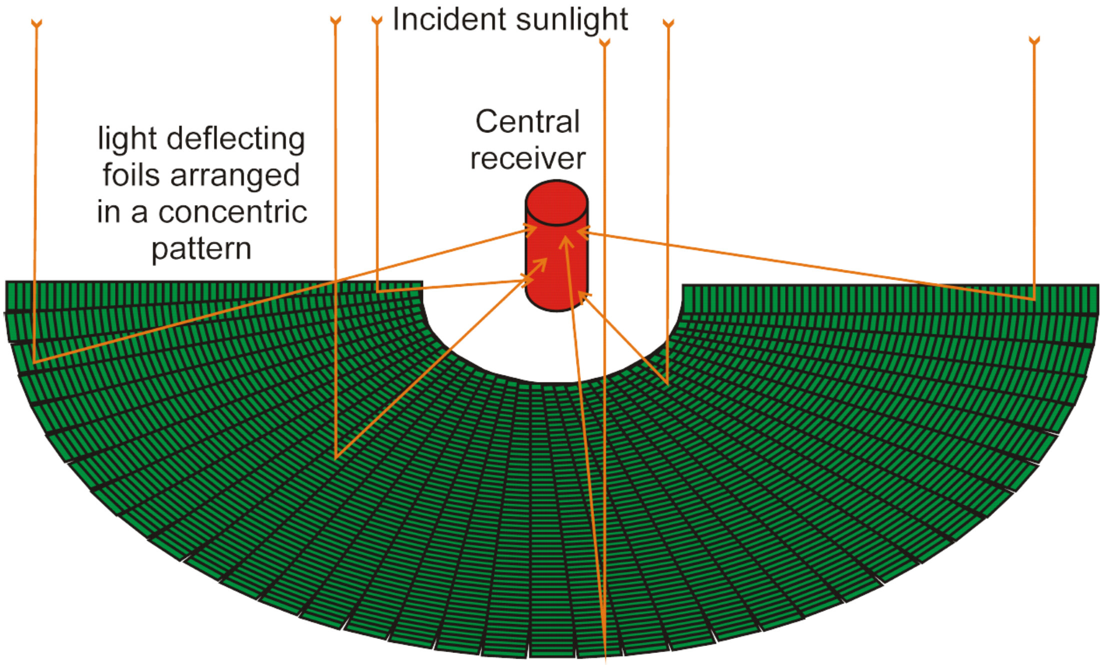
Formålet med projektet har været at demonstrere brugen af en nyligt udviklet polymerfolie inden for koncentreret solenergi. Projektet har skulle demonstrere at et produkt (en solfanger) kunne fremstilles på en teknisk effektiv og økonomisk attraktiv måde. Dette skulle gøres ved at udforme polymerfolien så den fokuserer solens lys på en modtager der kan varme en cirkulerende væske op, hvor varmen så kan bruges til forskellige formål. Hovedfokus har været at demonstrere dette på enkelt-solfanger-niveau.

1.3 Executive summary

The project has overall succeeded to accomplish the goals set. A suitable manufacturing method for the focusing lenses has been developed, the lenses has been demonstrated to have a high efficiency of approximately 75%, a suitable mounting method of the lenses has been developed, a solar tracker with the required technical and economic specifications has been developed, a receiver has been developed, and the whole system has been demonstrated on a unit level (see figure below), with an efficiency (output heat/total incident sunlight) of 70% +/- 8%.

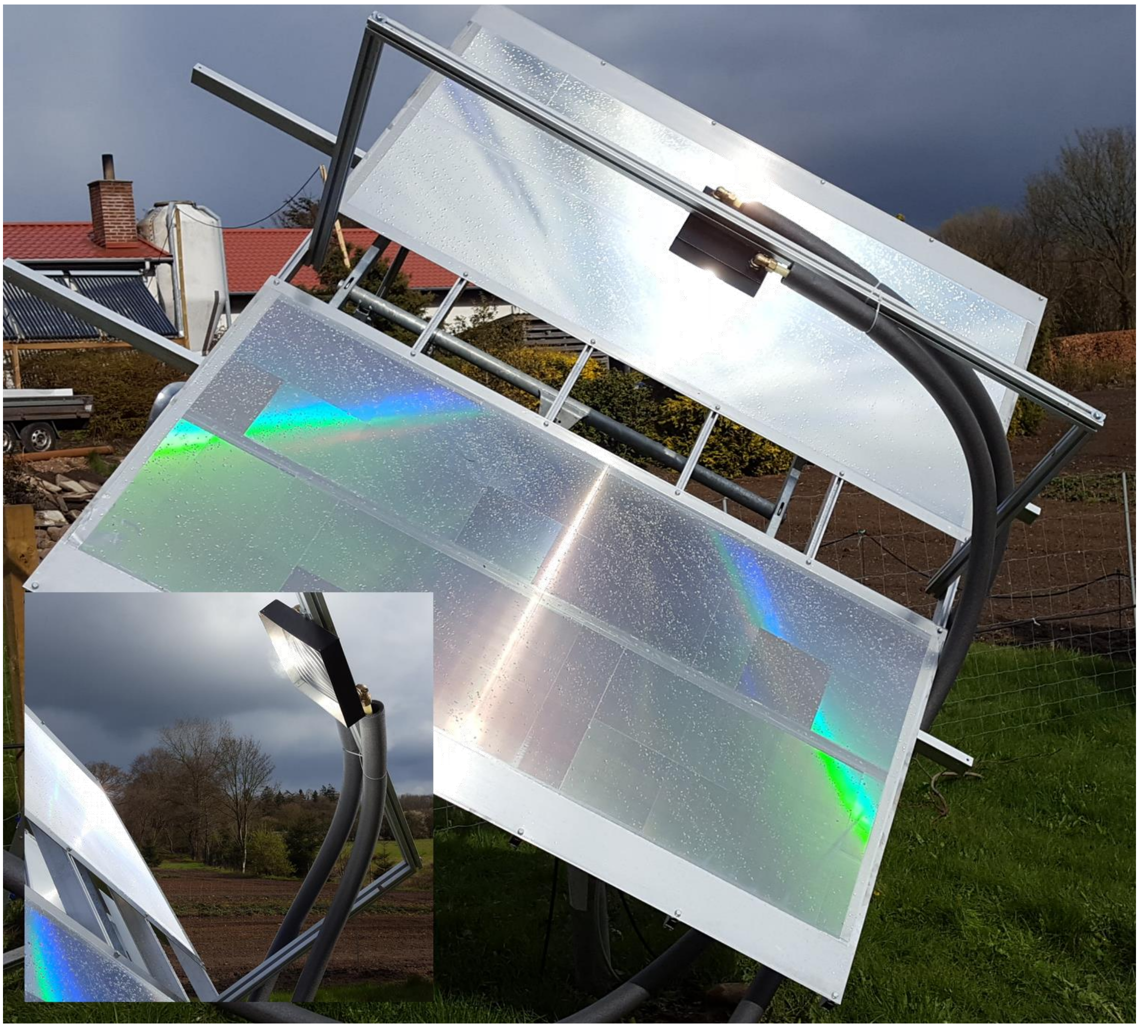
1.4 Project objectives

The project objectives were to implement the use of a new technological possibility, namely the manufacturing of low-cost surface structured polymer foils into a solar thermal product. The first version of the implementation was a rather large unit of 75 m2 using a linear and reflective polymer foil to focus the incident sunlight on a cylindrical receiver, see below.



The construction of the first iteration solar collector was begun, but due to delays in the delivery of some of the key components, another more feasible concept was developed in the meantime. The second version concept made use of smaller reflective lenses, which were more suitable for scaling, as they mostly used standard components. A special receiver for the concept was developed in close collaboration with Alfa Laval, and common (Heliac and Alfa Laval) IP protection has been sought on the receiver concept.

First 12-unit plant (before mounting of receivers)



Reflective unit with receiver in focal point.

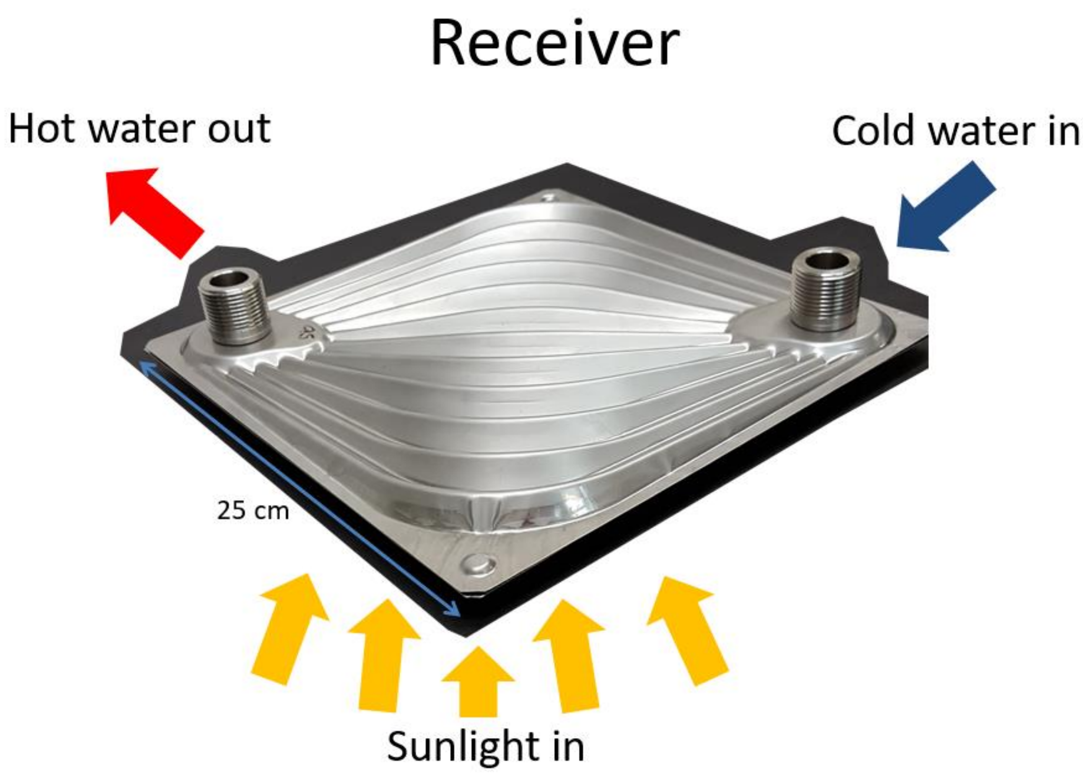
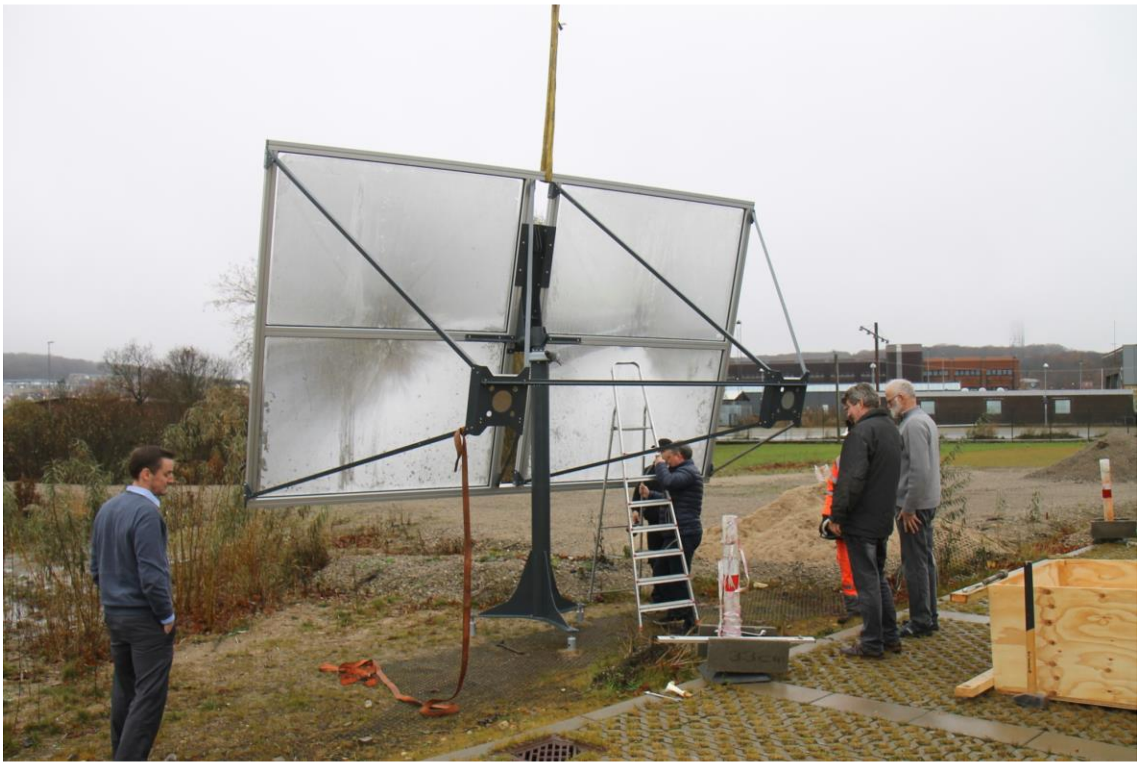


Image of the second iteration unit and a schematic of the receiver. By making a geometry that both serves as liquid channels on the inside and retro-reflector structures on the outside, an efficient and cheap receiver can be made using conventional steel manufacturing technologies.

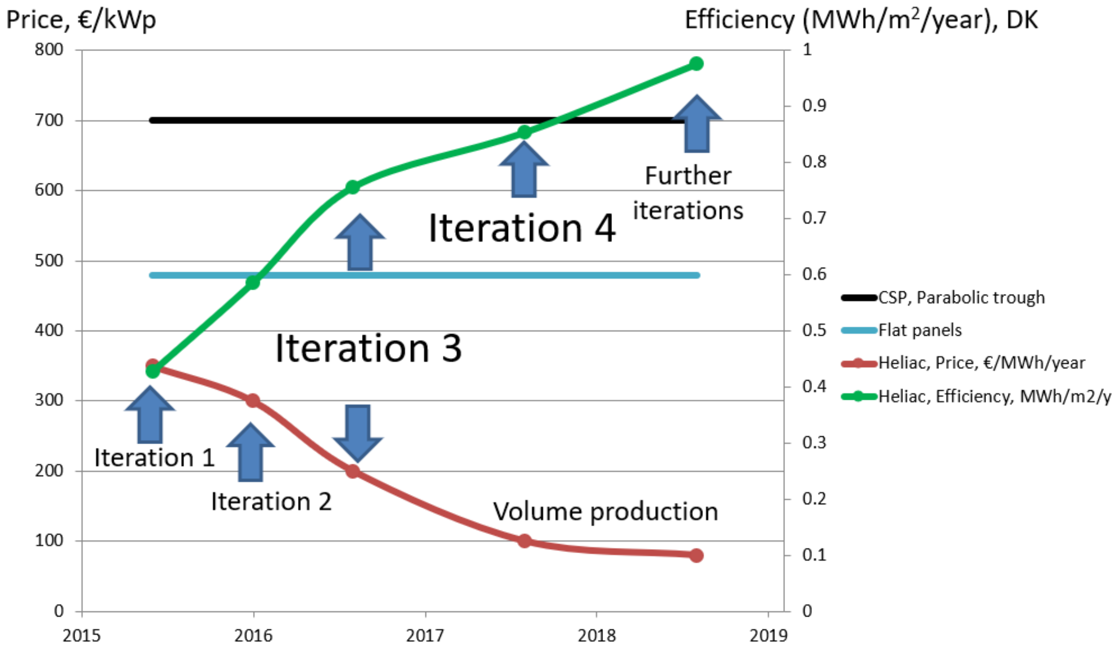
To further improve the efficiency of the unit and to rationalize manufacturing cost, a third iteration of the product was made. This was using a transparent lens, as big as possible on the current manufacturing platform (half-lenses, each 3 m2) with as good focus as possible.



Here an image of the installation of the third iteration at Aalborg CSP is shown.
However, the focus was too good (focal spot 1-2 cm diameter), resulting in cavitation on the backside of the receiver, and when not cooled, problems with melting of the steel (measured temperatures in the focal point of >1200C). This strong focus also gave rise to safety issues, such as potential eye and skin damage.
These issues resulted in the development if the fourth iteration, where the 6 m2 lens with small focus was replaced with a 2m2 lens with a broader focus (focal spot ø80 mm), not giving rise to cavitation or other safety issues (although one should still not look into the sun, also not through this lens)

The fourth iteration is the currently best performing product (see image at executive summary) due to the transparent lens which is highly effective, the construction where the polymer lens is protected from dirt and UV radiation by a planar window glass, and the suitable size of 16 m2, delivering 11-12 kWp thermal power.
Below is shown a schematic view of the components in the product.

All components, except the foil and the receivers are standard components. The solar unit can be manufactured at a cost making the concept competitive to fossil fuels and biomass in Denmark (with its relatively low level of sunshine).
Iterations of the product were expected at project start, but the level of improvement of both efficiency and cost exceeded the expectations. A graph showing the starting point and the development during the project is shown below.



Many problems and challenges were experienced, but a good collaboration between the partners and external companies made sure that they were solved, and that a feasible product was demonstrated.

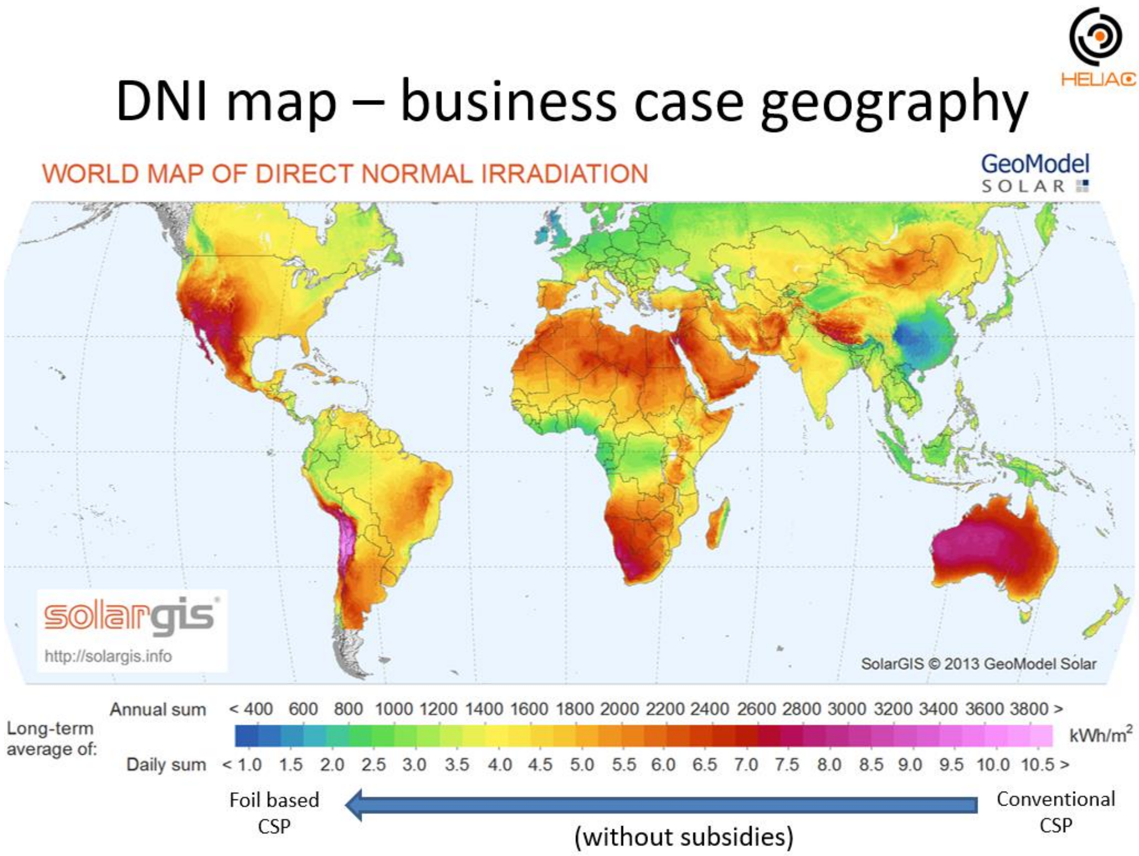
1.5 Project results and dissemination of results

The current product is currently being implemented into the first full-scale energy plant from Heliac, where 144 units of 16 m2 is being built during 2018 at Eon Lendemarke Fjernvarmeværk, and expected to be able to deliver 1.7 MWpt, which can supply the users with their full consumption during summer and supplement the current biomass plant the rest of the year. Going from the initial concept to a feasible product has been the main result of the project. However, several sub-milestones have been reached as a prerequisite to this goal.

- Development of a solar concentrator geometry allowing the use of standard components. This has formed the basis of the cost-reduction and scalability of the product. To choose the right components and solutions has been key in making a good and functional product.
- Development of an effective lens. This builds on transmittive Fresnel technology, which has been known for several centuries. However, finding the right size of gratings that both can be produced using 3 processing steps (mastering, tooling and mass-replication) and still give an adequate optical efficiency has taken several attempts. Furthermore, the foil manufacturing process needed to be adapted to the type and size of lens, as well as finding a suitable adhesive between glass and foil has been a research area.
- Development of an effective receiver. This development has been more extensive than initially presumed, as several manufacturing problems were encountered, especially during shaping of the receiver geometry. Also, several solar absorbing coatings has been tried, where not only absorption efficiency, but also coating method compatibility with the receiver geometry has been a critical issue. The choice has been a vacuum PVD deposition of a coating alike the coating used on flat-panel solar absorbers.
- Development of a suitable tracker. The trackers available at project start can be divided into two major groups: PV trackers and Solar Tower Heliostats. The PV trackers can typically not track the sun in all directions (typically uses two linear actuators, limiting the directions it can face), and Solar Tower Heliostats are too expensive, as the requirement s for their main use is a precision of 1-10 milidegrees. The requirement for our purpose is 250-500 milidegrees, and hence a novel tracker was to be developed. The development of this tracker has been performed as three parallel tracks with three tracker developers (one internal and two external companies). Currently two types are being considered for the first full scale plant.
- Development of a liquid system. How to circulate liquid in the system having both moving and stationary parts, how to reduce the pressure loss through the system and how to be able to do this at a relevant low cost has taken much consideration. Currently, the liquid system has reached an acceptable cost, but further reduction can be foreseen as more data will be generated during construction of the first full scale plant.

The project has received media interest and articles has been published in both Energy Supply and Ingeniøren, as well as several local media. Heliac has also presented the developed solution in Danish Tech Challenge where it reached the final and presented for the general public and H.K.H. Kronprins Frederik.

The project is expected to generate significant turnover as soon as demonstrated on a system level. Currently, the economical feasibility of a full project has to be demonstrated, but current prediction of the first 1.7 MWpt plant results in a levelized cost of heat of approximately 30€/MWh (relative to the current biomass fuel cost at the plant of 40€/MWh), with short term reduction (second and third plant) to around 20€/MWh, and long term reduction to 10-15€/MWh (all numbers using DK DNI of 1050 kWh/m2/year), and substantially lower costs in more sunny regions of the world. This cost reduction will make concentrated solar power (CSP) economically feasible at lower DNI than current technology, increasing the geographical markets for CSP greatly, see below figure.



1.6 Utilization of project results

After demonstration of the first full scale plant, Heliac plant to scale the concept and offer the concept worldwide. This will be done through collaboration partners such as Aalborg CSP, who are experts in Engineering, Procurement and Construction (EPC's). The EPC's are the typical bidders for projects being offered, have the sales channels and local workforce etc. This means that Heliac can focus on improving the product and scale without having to set up a large, costly global organization.

Several patents have been applied for during the project. Both on polymer foil manufacturing, system construction features and the specific receiver geometry.

The result of the project once demonstrated on a system level can give policymakers new possibilities. Today, most discussions about the future energy system involves increased electrification of the heating system. This concept can offer the opposite, namely a way to produce solar energy in a storable form (as heat), that can be partly converted to electricity when needed and still feed the district heating system in the same way as thermal plants has traditionally done.

1.7 Project conclusion and perspective

The conclusion is that the project has achieved the expected results and more, delivering a method for making thermal solar energy cheaper than the cheapest fossil or biomass alternatives.
Future work is focused on proving this on system level, and to continue the improvement of the concept, where challenges may still lie in further increase of efficiency, durability and cost reduction.

Furthermore, work in supplementary technologies such as energy storage has commenced in the Sun-Charge project, which is expected to increase the potential use of solar thermal power, as the main barrier for further implementation is the ability to store the solar power for later use.