INTEGRATED PLATFORM FOR ROOFTOP INSTALLATIONS OF FRESNEL COLLECTORS FOR SOLAR PROCESS HEAT GENERATION

Irapua Santos Ribeiro[1], Andreas Burger[1], Stephan Scherer[1] and Luís Miguel Braga[2]

[1] Industrial Solar GmbH, Freiburg (Germany)

[2] RAR – Refinarias de Açúcar Reunidas S.A., Porto (Portugal)

Abstract

The heat demand represents 74% of the total industrial energy demand worldwide (Solar-Payback, 2018). Solar process heat can supply a great share of this demand and provide process heat with diverse solar technologies such as the Fresnel collector. As industrial customers typically have limited ground availability, the rooftops are often the only option for the solar field installation, as represented in the project SHIP2FAIR. This article explains the main constraints for the installation of Fresnel collectors on rooftops and a novel concept of integrated lightweight platform walkways along the collector structure, overcoming a common hurdle of integration onto uneven roofs in industrial buildings. The article also presents a case study from an installation at a sugar refinery in Portugal.

Keywords: *solar process heat; linear Fresnel collector; industrial rooftop installation, solar energy, ship2fair*

1. Introduction

The share of energy demand in the industrial sector represents approximately 1/3 of the global energy demand (heat and electricity), of which about 74% is used for heating (Solar-Payback, 2018). Solar process heat technologies are already mature and can cover a large share of this demand, but it is often constrained by area availability. This is particularly challenging for concentrating technologies that have typically higher static and dynamic loads per foot point than non-concentrating technologies, as these have a higher amount of footpoints per collector area. Nevertheless, even non-concentrating solar collectors have their development delayed due to high roof integration costs (Juanicó, 2008).

Furthermore, linear concentrating technologies, such as the Fresnel collector, which is already proven on rooftops installations, still face two important constraints:

- The need of longer strings for reducing optical losses.
- Required even platforms for cost-efficient installation and maintenance activities, such as cleaning.

While roof areas are usually not used or interesting for other purposes, available ground areas are often reserved for a potential factory expansion and usually evaluated with a ground price that adds up to the overall costs of the solar system. In many cases, the available installation ground is far from the hydraulic integration points which leads to additional system costs, pressure head, and thermal losses.

Although efforts to integrate small-scale Fresnel collectors onto roofs have been attempted in the past, industrial-scale roof integration remains a main challenge and only a limited number of successful cases can be found in the literature (Sultana, Morrison, & Rosengarten, 2011). As an example of such constraints, at the SHIP2FAIR project (Solar Heat for Industrial Process towards Food and Agro Industries commitment in Renewables), three out of four demo sites are planned as rooftop installations using different solar thermal technologies, including the Fresnel collectors. The project aims to foster the integration and promote the use of solar process heat in industrial processes for the agro-food industry.

This paper presents the main features of a linear Fresnel collector and its installation characteristics, challenges, and possibilities in a variety of roof types. The proposed solution in this paper simplifies the building-integration of the Fresnel solar concentrators by using a design approach that integrates lightweight and cost-efficient walkways directly into the structure of the collector. In the end, a case study from one of the SHIP2FAIR demo sites at a sugar factory is discussed and further conclusions are drawn.

doi:10.18086/eurosun.2020.03.08 Available at http://proceedings.ises.org

2. Material and methods

Solar process heat generation using Fresnel collectors

A linear Fresnel collector is a concentrating solar technology that uses multiple primary mirrors to focus the sunlight onto an absorber. The modular LF-11 collector was designed to address the so-far untapped market potential previously described. Figure 1 below shows three LF-11 modules with main components and dimensions. The uniaxially tracked primary mirrors (a) and the secondary reflector (c) focus the irradiation onto an absorber tube (b). The heat is absorbed by the flowing fluid and transferred to the industrial production processes. The technology is suitable for generating heat at up to 400 °C and pressures up to 120 bars.

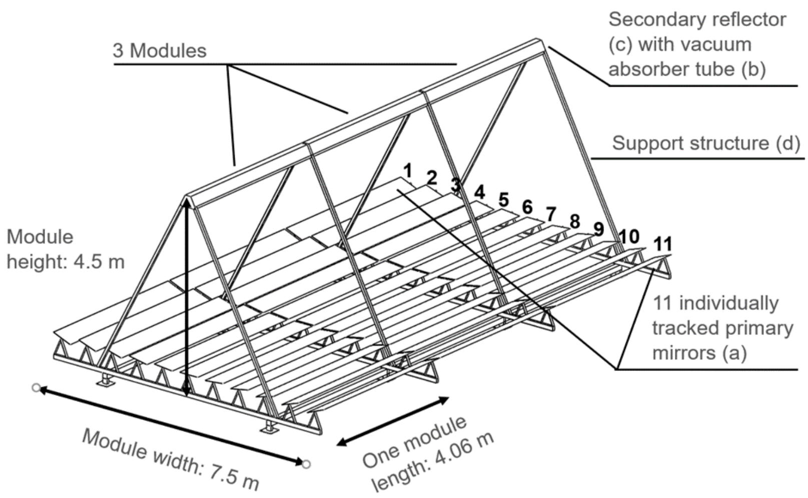


Figure 1 - Main characteristics of the LF-11 Fresnel Collector

The lightweight and modular structure (d) in combination with the high heat gain per installed area are designed for rooftop installations in industrial and utility facilities. The system generates steam directly (Mokhtar, et al., 2015) and can also be operated with different heat transfer fluids such as pressurised water and thermal oil. The solar process heat system can be integrated into customer's grids in various ways:

- Direct integration into steam grids.
- Direct or indirect integration into water or thermal oil heat grids.
- Indirect integration with a heat exchanger to heat any type of process.

Roof integration of Fresnel collectors

The LF-11 collector has been optimized for rooftop installations throughout several advancement steps. The collector design is optimized for high ground usage factor, low specific weight, low wind resistance during operation, and extremely low wind resistance during standby, as depicted in Figure 2.

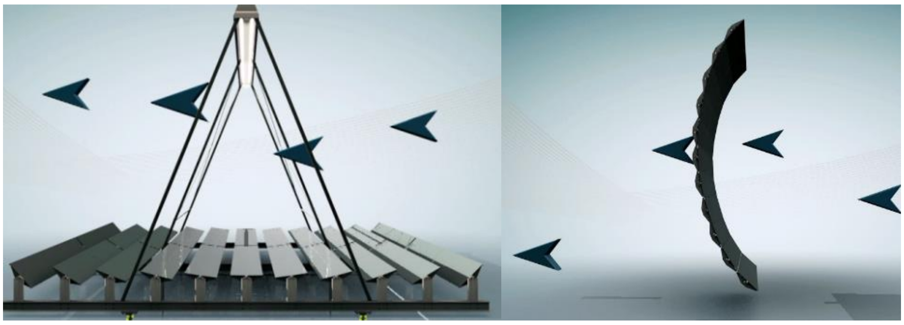


Figure 2 - Wind resistance of Linear Fresnel Collector (LFC) and Parabolic Trough Collector (PTC)

Another characteristic of the LF-11 is the simple building interface, which is a result of the extensive development of the collector design. A full collector string can be carried by only two horizontal I-beams or two rows of foundation points as shown in the red arrows from Figure 3 below:

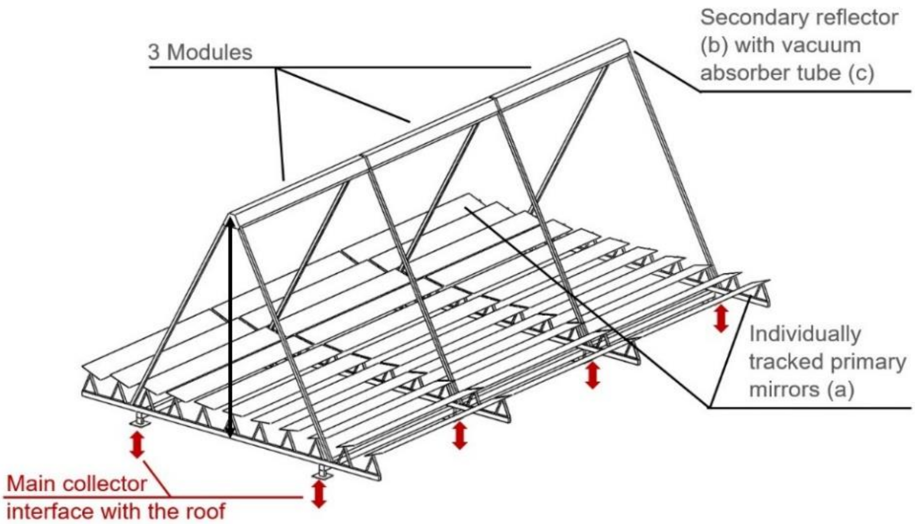


Figure 3 - LF-11 roof interface

From the LF-11 projects implemented so far by Industrial Solar, approximately 25% were assembled on the ground, whereas all others were rooftop installations. Less than 20% of the projects needed an additional walking platform, although the trend towards more rooftop projects with obstacles in their accessibility increases, as the examples of the two demo sites planned within the SHIP2FAIR project, with both projects requiring this additional accessibility effort.

The simplified collector to building interface of only two beams per collector string can be applied for buildings where the roof surface is suitable as walkways for construction and maintenance accessibility. For roofs requiring additional platforms due to the roof inclination or non-accessibility, many additional structural beams are required to carry the walkway platform resulting in a significant increase in the implementation costs and overall weight.

In order to overcome this issue, a simplified design that integrates lightweight walkways directly into the structure of the Fresnel collector is now presented. In this case, the cost-efficient solution uses walkways that are carried by the existing structure of the LF-11 collector. The main advantage is the avoidance of additional structural beams to carry the substructure. The number of interfaces to the customer's roof is thereby reduced, while weight and cost can be minimized. Typically, both the cost and weight of the required substructure can be reduced by more than 50% and the platform installation simplified and standardized for lowering installation efforts, time, and costs.

The basic configuration places these integrated platforms for maintenance purposes between each second longitudinal mirror row to access them from one side.

The walkways have combined skirting to increase safety. A walkway can also be realized along one side of the collector with a similar design. If needed, closed platforms at one or both ends of each collector string can also be realized using different profile designs, as shown in Figure 4, which allows a flat platform layout.

Figure 4 – Different structural profile designs for integrated platforms

Figure 5 below shows a configuration with standard paths inside the collector, one additional path outside the collector in a longitudinal direction, as well as a short platform at the end of the collector for easy access. Handrails, fencing, and other structural details are not shown but are foreseen to be incorporated in the integrated platform design.

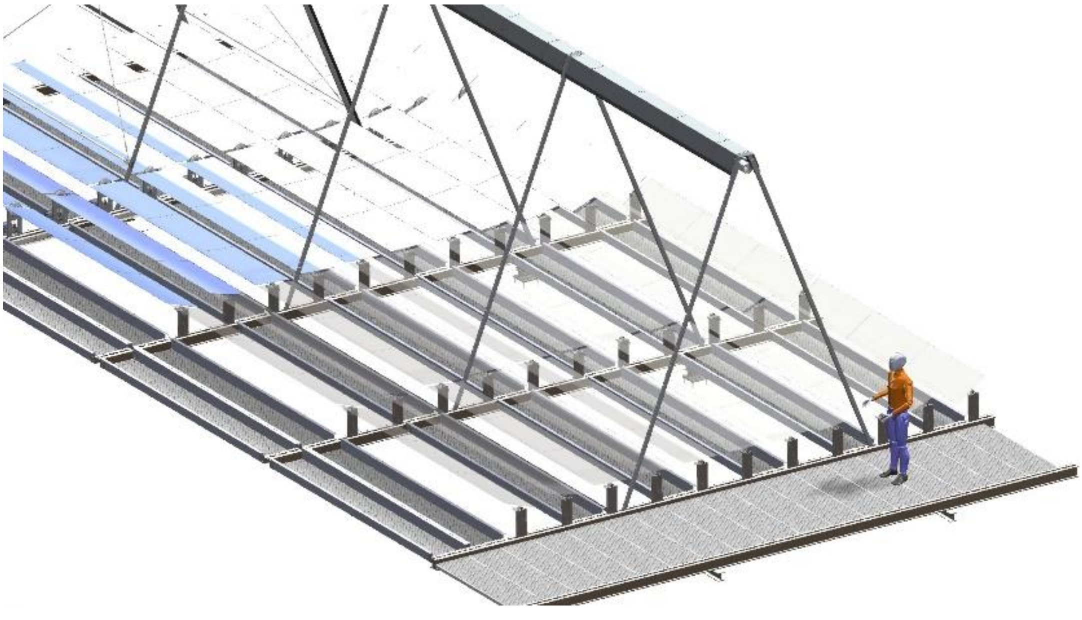
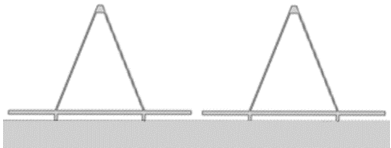
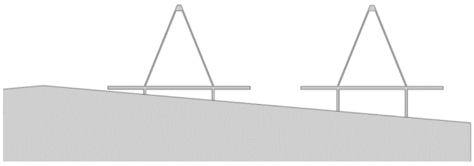
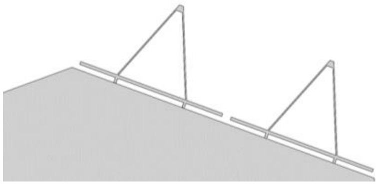
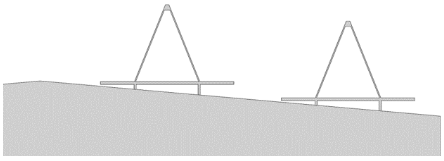
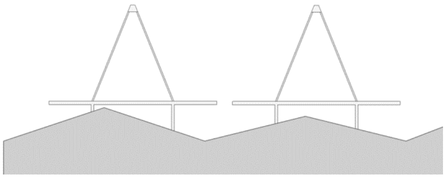
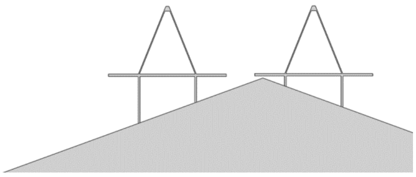
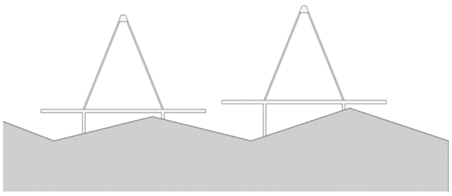
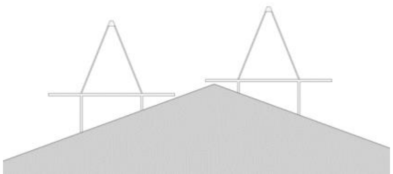


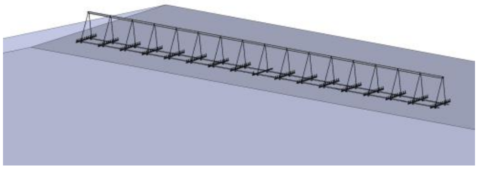
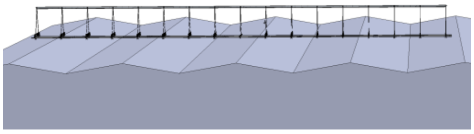
Figure 5 - Schematic configuration around a collector string

Different integration configurations can be designed to permit integration on different roof types and system layouts and to fulfil accessibility requirements depending on the size of the solar field.

In order to identify the suitable roof integration designs and to find the optimized number of walkways, several concepts were studied, as shown in Table 1 below. Concepts A - H show transversal views of the collector strings, whereas concepts I and J show longitudinal views. For each concept, there is an indication of the suitability and comments for the combination of different roof types and collector field design.

Table 1 - Rooftop collector field design concepts

Concept	Schematic collector field design	Suitability	Comments
A		Ideal	Easy access, no walking platforms needed.
B		Adequate	For mirror rows with > 50 cm from the roof surface, integrated walkway platforms are required.
C		Unsuitable	Transversal collector inclination is unsuitable.
D		Adequate	In direct steam systems, extra hydraulic components are required to compensate for height offset. For mirror rows with > 50 cm from the roof surface, integrated walkway platforms are required.
E		Adequate	For mirror rows with > 50 cm from the roof surface, integrated walkway platforms are required.
F		Adequate	For mirror rows with > 50 cm from the roof surface, integrated walkway platforms are required.
G		Adequate	In direct steam systems, extra hydraulic components are required to compensate for height offset. For mirror rows with > 50 cm from the roof surface, integrated walkway platforms are required.
H		Adequate	In direct steam systems, extra hydraulic components are required to compensate for height offset. For mirror rows with > 50 cm from the roof surface,

			integrated walkway platforms are required.
I		Unsuitable	Longitudinal collector inclination is unsuitable.
J		Ideal	For mirror rows with > 50 cm from the roof surface, integrated walkway platforms are required.

For inclined roofs, part of the mirror rows is accessible from the roof level while others need additional walkways. The main design criteria are to permit easy access at the level of primary mirrors from the walkways and/or roof, as seen in Figure 6, which shows a transversal view of the LF-11 collector with the main dimensions.

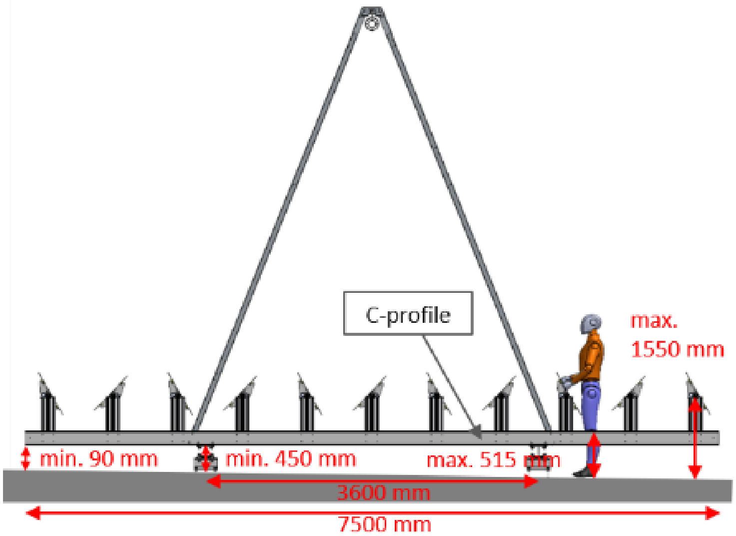


Figure 6 - LF-11 collector structural dimensions for access design

Table 2 below presents the design criteria of a minimum number of walking platforms inside the collector field depending on the inclination of the tilted roof.

Table 2 - Required number of walkways depending on roof inclination

Roof inclination	Platform walkways inside collector field	Platform walkways outside collector field	Extension of beams required	Total no. of platform walkways
1°	**0**	**-**	**-**	**0**
2°	**2**	**-**	**-**	**2**
3…6°	**3**	**-**	**-**	**3**
7 °	**3**	**1**	**-**	**4**
8°…15°	**4**	**1**	**yes**	**5**
> 15°	**5**	**1-2**	**yes**	**6-7**

- For flat roofs up to a maximum 1°, no platforms are needed: the height above structural elements is still low enough to access the field as indicated in Figure 6.
- For 2°, two walking platforms would be sufficient, whereas for systems of 7° four paths are needed.
- At angles higher than 15°, the maximum number of five walking platforms are needed inside the solar collector, as well as one or two at the longitudinal sides of the collector.

3. Case study

Reference case

In 2017 Industrial Solar realized a Fresnel project for direct steam generation with a collector layout of 3 x 19 LF-11 modules. The collector field was constructed over an inclined sandwich panel roof ─ a typical roof type for industrial buildings. The accesses between collector strings and in between mirror rows were built using standard grating covering the whole collector area including walkways around the collector. For the standard grating, specific weight of 22 kg/m² is assumed.

In addition to the longitudinal I-beams required for the LF-11 collector, as indicated in blue in Figure 7, several other beams were required to carry the grating platform.

This platform is considered as a reference case to evaluate the weight reduction potential which can be reached with the integrated platforms.

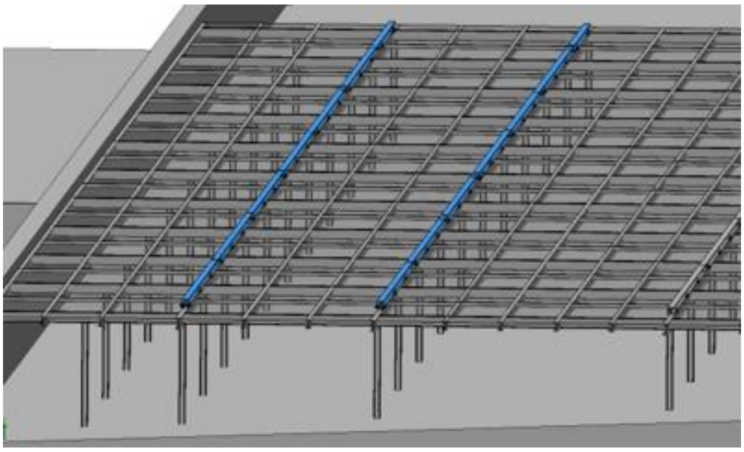


Figure 7 Structural beams for the Fresnel collector (blue) and support structure to carry a standard grating

RAR Project – SHIP2FAIR demo site

RAR (Refinarias de Açúcar Reunidas) is one of the partners in the SHIP2FAIR project that will receive a solar process heat system designed with the LF-11 collectors. The sugar refinery is located in the centre of Porto (Portugal). The available roof area is very limited with only about 1000 m², which requires a high space efficiency from the solar collector and optimisation of the overall substructure needed. The roof has an inclination of 14° and its surface is only partially accessible. The characteristic lightweight structure of the roof requires the reduction of the total weight.

The RAR demo site follows the concept of roof integration type “D”, as shown in Figure 8. The two collector strings in parallel are aligned with different levels and require additional walking platforms for installation and maintenance accessibility.

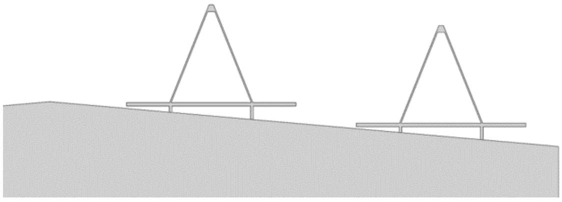


Figure 8 - Roof integration concept type "D" for two LF-11 collector strings

The weight reduction potential has been evaluated in two different integrated platform layouts: (i) fully covered collector area including side walkways at all outer sides, and (ii) reduced integrated platform layout with minimum walkways required to ensure accessibility to all mirror rows.

The evaluation showed that the main benefits of the integrated platforms result in the fact, that the new platforms need fewer substructure beams but can stay only with the two main longitudinal beams per collector string. Moreover, the skirting of the integrated platforms gives the opportunity of a partial platform layout which strongly reduces the platform weight.

- In the case of the full collector area covered by integrated platforms, the weight of platforms including support beams can be reduced by approx. 36 % in comparison to the reference case.
- For the reduced integrated platform layout with partial walkways in functional sections, the weight of the platforms including the required substructure can be reduced by approx. 66%.

4. Conclusion

The large demand for process heat opens a wide range of opportunities for concentrating solar collectors, that are available for a wide range of temperatures and heat transfer fluids. However, a suitable installation area is an important limiting factor that hampers the potential for solar process heat projects. With the characteristics of a high ground usage factor, low specific weight, low wind resistance, and a simple building interface, the LF-11 Fresnel collector overcome part of the hurdles and is optimized for roof installations. Nevertheless, many roofs require additional walkway platforms which add weight, cost, and complexity during installation.

With the main objectives of demonstrating and validating demo systems at industrial sites and promoting solar process heat projects during their whole life cycle, the SHIP2FAIR project brings together industrial customers and technology providers to find cost-efficient solutions and reduce complexity in order to complete successful systems.

This paper presented and discussed the potential of a new integrated platform design that uses the existing collector structure as a support for the platform and can be assembled in a variety of rooftop integration concepts. A weight comparison for a case study shows that the weight for the platform including the additionally required substructure can be reduced by up to 66%.

The weight reduction combined with a simplification of installation is expected to have an essential effect on the overall platform and substructure cost. For future projects, this can be further investigated in detail using different concepts in order to address each project characteristics and limitation, in order to unlock the large market potential of carbon-neutral solar process heat.

5. Acknowledgments

The project received funding from European Union’s Horizon 2020 research and innovation program under the grant agreement No 792276- Solar Heat for Industrial Process towards Food and Agro Industries Commitment in Renewables (SHIP2FAIR).

6. References

Juanicó, L. (2008). A New Design of Low-Cost Roof-Integrated Solar Collector for Household Heating and Cooling. *Proceedings of ISES World Congress 2007 (Vol. I – Vol. V).* Berlin, Heidelberg: Springer.

Mokhtar, M., Berger, M., Zahler, C., Krüger, D., Schenk, H., & Stieglitz, R. (2015). Direct Steam Generation for Process Heat using Fresnel Collectors. *Int. J. of Thermal & Environmental Engineering*, 3-9.

Solar-Payback. (2018). *Global Heat Demand in Industry*. Retrieved from Solar Payback: https://www.solar-payback.com/potential/

Sultana, T., Morrison, G. L., & Rosengarten, G. (2011). Thermal performance of a roof integrated solar microconcentrating collector. *AuSES Solar Conference.* Canberra, Australia.