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

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Abstract

The heat demand represents 75% of the total industrial energy demand worldwide. Solar process heat can supply a great share of this demand and provide process heat with diverse solar collectors 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. Industrial heat demand and constrained area

The share of energy demand in the industrial sector represents approximately 1/3 of the total energy demand (heat and electricity), of which about 75% 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 foot points 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, that is already proven on rooftops installations, still face the constrain of needing longer strings and even platforms for cost-efficient installation and maintenance (e.g. longer strings for reduced optical end losses and even platforms for 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 which adds up to the price 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.

As an example of such constraints, at the SHIP2FAIR project (Solar Heat for Industrial Process towards Food and Agro Industries commitment in Renewables), which aims to foster the integration of solar process heat in industrial processes for the agro–food industry, three out of four demo sites are planned for rooftop installations using different solar thermal technologies. SHIP2FAIR is a project developed by 15 European partners, funded by the European Commission. The project will demonstrate and validate the systems at the industrial sites, also designing a set of tools and methods for the development of industrial solar heat projects during their whole life cycle.

2. Solar process heat generation using Fresnel collectors

A linear Fresnel collector is a concentrating collector which uses a set of primary mirrors to focus the sunlight onto an absorber. Industrial Solar is the world leader for SHIP systems with a Linear Fresnel collectors with the model LF-11 as their core product. The diagram 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.

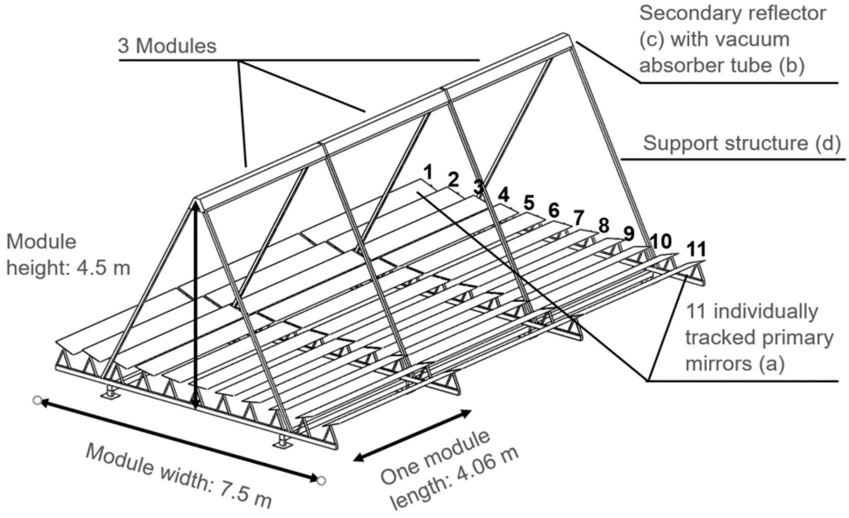


Figure 1 - Main characteristics of the LF-11 Fresnel Collector

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 and works with different heat transfer fluids such as pressurised water and thermal oil. The solar process heat system can be integrated 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;

3. Roof integration of Fresnel collectors

Although efforts to integrate small scale Fresnel collectors onto roofs have been attempted in the past, industrial-scale roof integration still remains a main challenge and only a limited number of successful cases can be found in literature (Sultana, Morrison, & Rosengarten, 2011).

The Industrial Solar LF-11 collector has been optimized for roof installations throughout several evolution 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.

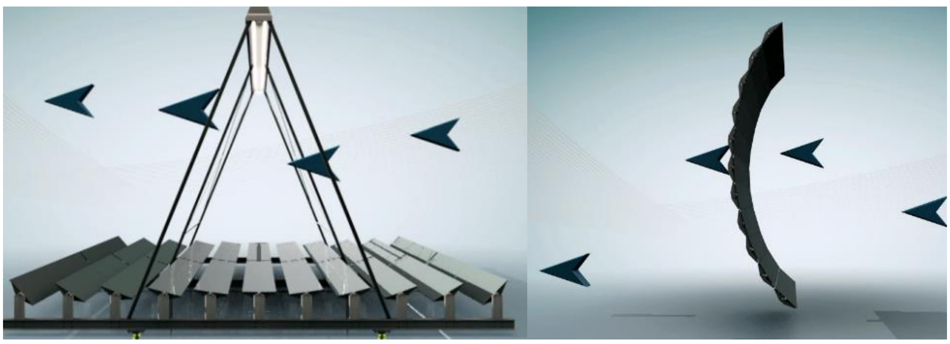


Figure 2 - Wind resistance of Linear Fresnel Collector (LFC) and Parabolic Trough Collector (PLC)

Another characteristic of the LF-11 is the simple building interface - a result of the long-track collector design evolution at Industrial Solar. A full collector string can be carried by only two horizontal I-beams or two rows of foundation points as shown in the graphic below:

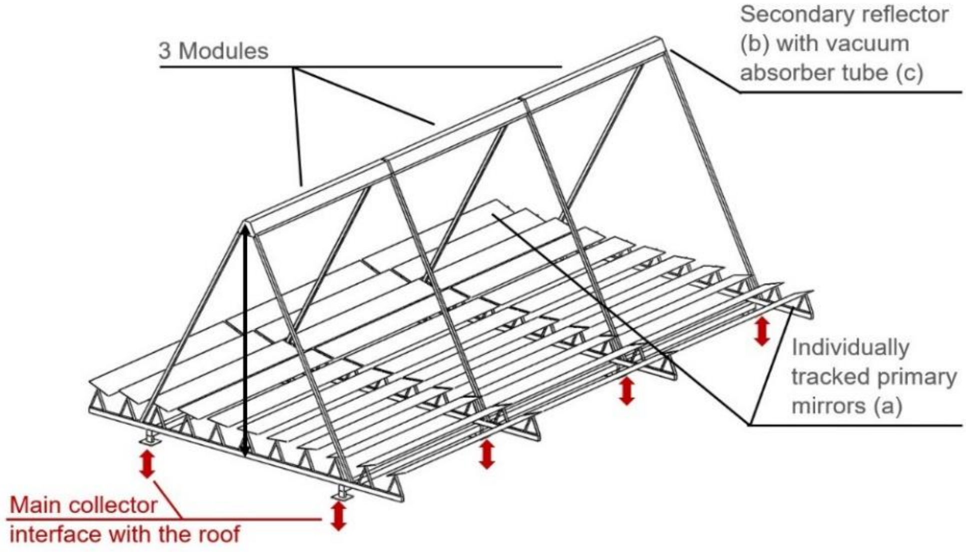


Figure 3 LF-11 roof interface

This simple collector to building interface of only two beams per collector string could be applied for buildings were the roof surface is a suitable walkway for installation and maintenance accessibility. For roofs which required an additional platform because of an inclined or non-accessible roof, many additional structural beams were required to carry the walkway platform resulting in a significant increase in the implementation costs and overall weight.

From the LF-11 projects implemented today, 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 first two demo sites planned within the SHIP2FAIR project, which both require this additional accessibility effort.

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 Fresnel collector. In this case the walkways are carried by the existing collector structure of the LF-11 collector. This has the main advantage that no additional structural beams are required 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 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 is to place these integrated platforms between each second longitudinal mirror row to access each of them from one side for maintenance purpose.

The walkways have integrated skirting to increase the safety. Along one side of the collector, a walkway can also be realized with a similar design. If needed, closed platforms at one or both ends of each collector string can be realized by using a different profile design that allow a flat platform design.

Figure 4 – Different structural profile designs for platforms

The figure below shows a configuration with standard paths inside the collector, one additional path outside the collector in 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 integrated in the integrated platform design.

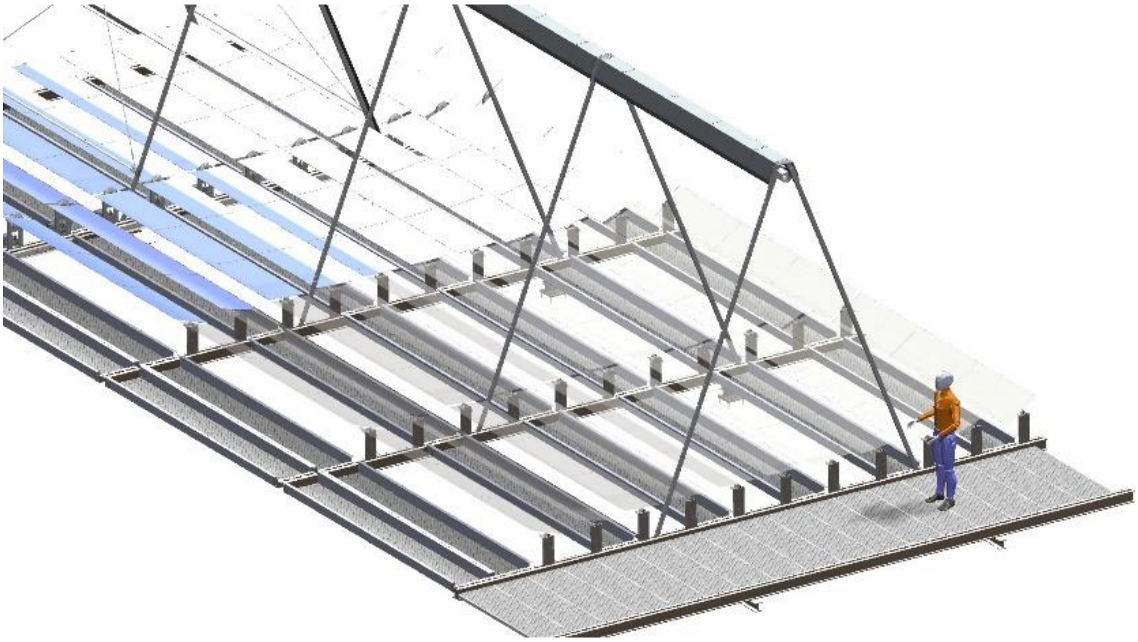
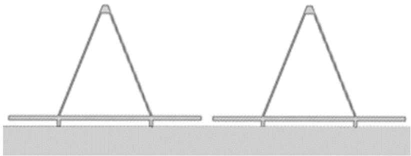
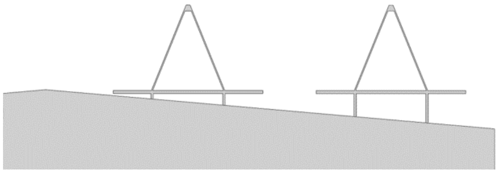
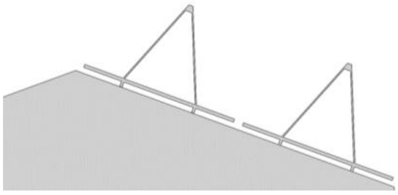
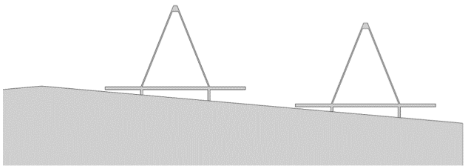
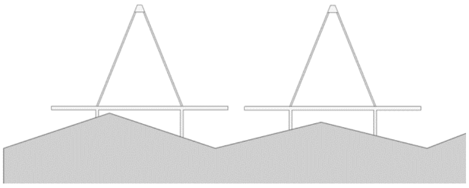
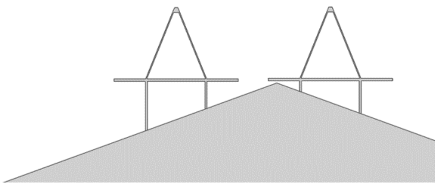
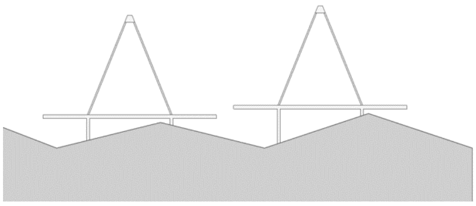
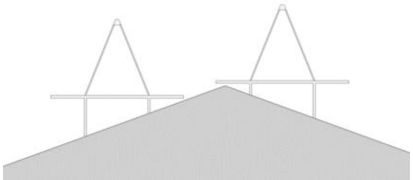
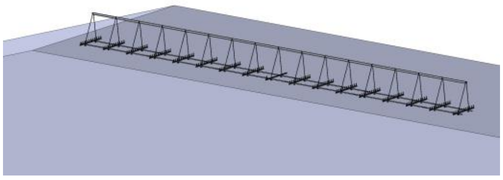
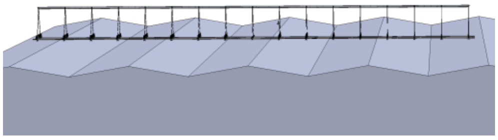


Figure 5 - Schematic configuration around a collector string

Different integration configurations were designed to permit integration on different roof types and system layouts, and to fulfil accessibility requirements depending on the solar field sizes. Additional features include handrails and skirting. The table below indicates several possible integration designs and their suitability for different roof types.

Table 1 - Rooftop collector field design options

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

H		Adequate	In direct steam systems, extra hydraulic components required to compensate height offset. For mirror rows with > 50 cm from roof surface integrated walkway platforms required.
I		Unsuitable	Transversal collector inclination unsuitable.
J		Ideal	For mirror rows with > 50 cm from roof surface integrated walkway platforms required.

For inclined roofs, part of the mirror rows are accessible from the roof level while others need additional walkways.

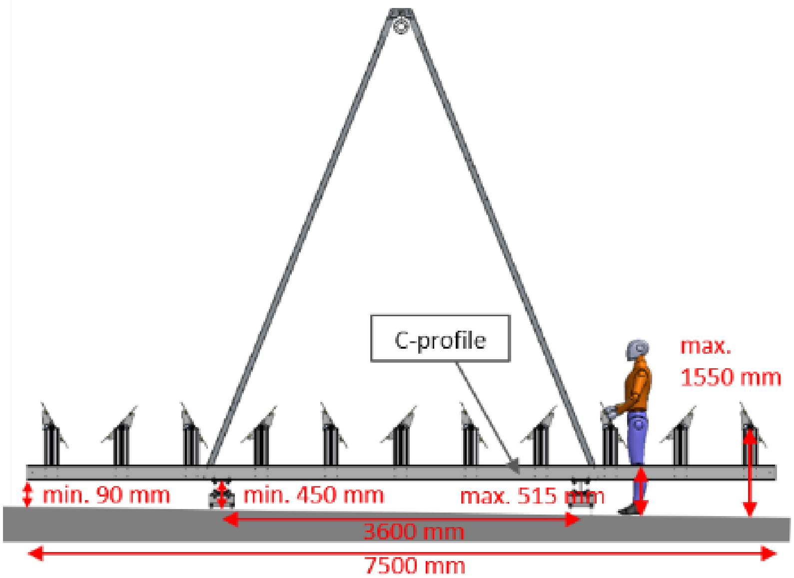


Figure 6 - LF-11 collector measures and access

The table below presents the minimum number of required walking platforms inside the collector field depending on the slope of the tilted roof.

Table 2 Required number of walkways depending on roof inclination

Roof angle	Platform walkways inside collector field	Platform workways 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	2	yes	6

- 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° only four paths are needed.
- At angles higher than 15°, the maximum number of six walking platforms are needed inside the solar collector, as well as one or two at the longitudinal sides of the collector.

4. Case study

In 2017 Industrial Solar had realized a Fresnel project for direct steam generation with a collector layout of 3 x 19 LF-11 modules. The collector area was an inclined sandwich panel roof ─ a typical roof type for an industrial building. The accessibility has been realized with standard grating covering the whole collector area including walkways around the collector. For the standard grating a specific weight of 22 kg/m² is assumed. In addition to the longitudinal I-beams required for the LF-11 collector (see Figure 7; blue beams), beams were required to carry the grating platform.

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

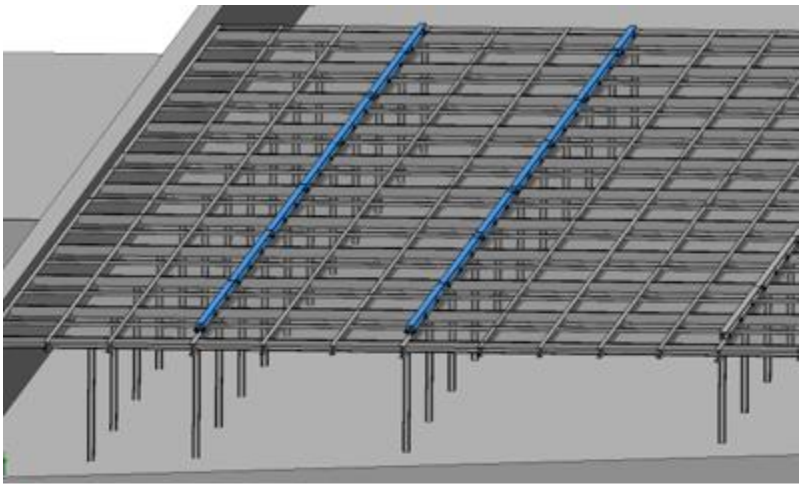


Figure 7 Structural beams for the Fresnel collector (blue) and support structure to carry a standard grating

RAR (Refinarias de Açúcar Reunidas) is a demo site partner in the Horizon 2020 project SHIP2FAIR. The sugar refinery is located in the center of Porto (Portugal). The available roof area is very limited with only about 1000m² ground space which requires a collector with high space efficiency such as the LF-11 collector. The roof has an inclination of 14 degrees and the roof surface is only partially accessible. The lightweight structure of the roof requires to minimize the total weight.

The RAR demo site illustrated below follows the concept of roof integration type “D” described in the previous section. The two collector strings in parallel are aligned with different levels and require additional walking platforms for installation and maintenance accessibility.

The weight reduction potential has been evaluated for different platform layouts from fully covered collector area including side walkways at all outer sides to the minimum required platform layout 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 less 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. If the integrated platforms cover the full collector area, the weight of platforms including support beams is expected to be reduced by approx. 36 % compared to the reference case. For partial walkways with only functional sections equipped with integrated platforms, the weight of the platforms including the required substructure can be reduced by approx. 66%.

5. Conclusion

The demand for solar process heat in huge and concentrating solar collectors are available for a wide range of temperatures and heat transfer fluids. However, suitable installation ground is an important limiting factor which is often out of the focus of potential studies. 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 is optimized for roof installations. Though, a large share of the roofs require additional walkway platforms which add weight, cost and complexity.

A newly developed integrated platform design uses the existing collector structure as basement for the platform. A weight comparison for a case study shows that the weight for the platform incl. 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 is a further step to access the huge market potential of carbon-neutral solar process heat.

6. Acknowledgments

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7. References

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