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SHIP2FAIR – INTEGRATION OF SOLAR HEAT IN AGRO-FOOD INDUSTRY PROCESSES: THE MARTINI & ROSSI CASE

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Abstract *Energy scarcity is one of the world greatest challenges for the next decades. In order to efficiently address this issue, a multidisciplinary and cross-sectorial approach has to be adopted, which spans from the supply of novel clean and reliable energy to the increase of energy efficiency at the distribution and consumption stages. The industrial sector uses more delivered energy than any other end-use sector, consuming about 54% of the world's total produced energy. As far as the European industry is concerned, most of the consumed energy is used for heating purposes, and mainly for process heat generation. Improving the deployment of renewable industrial process heat as well as the efficiency of process heat utilization is a key factor to obtain a significant reduction of the overall consumption and dependence on conventional non-renewable energy sources, hence to reduce the environmental impact of the European industry.*

SHIP2FAIR is an H2020 European funded project, which aims to foster the integration of solar heat in industrial processes belonging to the agro-food sector, by developing and demonstrating at four real industrial sites a set of tools and methods for the development of industrial solar heat projects during their whole life-cycle.

Based both on the analysis of industrial processes for different alcoholic beverages production and on the case-study of the environmental and boundary conditions at the Martini & Rossi plant – one of the demo-sites of the SHIP2FAIR project – in Pessione (Italy), this paper presents the preliminary results which guided the choice of a suitable solar collector and the definition of the thermo-economic parameters of the solar energy harvesting plant to be integrated within the facility. Moreover, the requirements in terms of storage capacity are evaluated with respect to the industrial needs of the analysed processes. Finally, the expected economic and environmental impact assessment is presented, based on the foreseen thermal energy generation capacity of the solar collectors and on the savings obtained by avoiding the power generation through classical methods.

1. INTRODUCTION

Agro-food industry is one of the major energy consumers in Europe accounting for 17% of the EU's gross energy consumption in 2013, as outlined in [1]. The gross inland energy consumption in the EU-28 in 2016 was nearly 1640 Mtoe [2], 13.2% of which generated exploiting renewable energy sources. As the renewable energies shares continuously increase over the years, with a raise of over 200% since 1990, the need of suitable methodologies and tools to support this energy transformation is everyday more urgent.
This paper presents a preliminary analysis of the impact of solar heat integration in agro-food industrial processes. A real world use case – the Martini & Rossi industrial process – will be taken as a reference to highlight the different aspects which must be considered for the formulation of a proper solar heat integration strategy. Technological aspects will be analysed as well as economic and environmental impacts of the proposed solar thermal generation system. The methodology for the assessment is articulated in three main phases: characterization of the existing industrial processes from a thermal point of view, assessment of technical and economic feasibility for the application of a specific solar thermal technology, and finally a preliminary evaluation of the impact of the solar heat integration within the existing processes based on a heterogeneous set of performance indicators.

2. THERMAL CHARACTERIZATION OF AGRO-FOOD PROCESSES

As stated in [1], the food sector is a complex industrial branch based on heterogeneous feedstock and involving several specific production steps. A characterization of the agro-food processes energy demand is possible only targeting a specific sector, even though the methodologies applied to conduct the analysis are applicable independently from the industrial segment. In this paper, a case belonging to the spirit production sector is addressed, taking as a reference an Italian alcoholic beverage company – Martini & Rossi – primarily associated with the Martini brand of vermouth. It is worth noting that, according to [5], during the period 2008-2013 the EU annual production of spirits amounted to €22 billion. Moreover, the companies engaged in distilling, rectifying and blending of spirits in the EU are over 5,500.
With regards to the Martini & Rossi industrial process, the thermal characterization phase started with the identification of the demand target temperatures, the overall consumptions and their distribution over specific operations horizons. The analysis led to the identification of two saturated steam loops with different pressure levels: the first one at around 3 bar / 130 °C, the second one at around 9 bar / 175 °C. The thermal demand distribution resulted to follow a season-dependent pattern, which is depicted in Figure 1.
The analysis continued with a deeper study of the Piping & Instrumentation Diagram of the thermal facility, in order to define the dynamical behaviour of the heat generation systems and of the thermal loads. The existing generation system consists of three 3900 kW natural gas boilers and one 860 kW_t CHP. All the steam generated by the boilers is used to feed the high pressure loop at 9 bar, which is then partially deviated through a mechanically controlled throttling valve to produce steam at 3 bar / 130 °C.

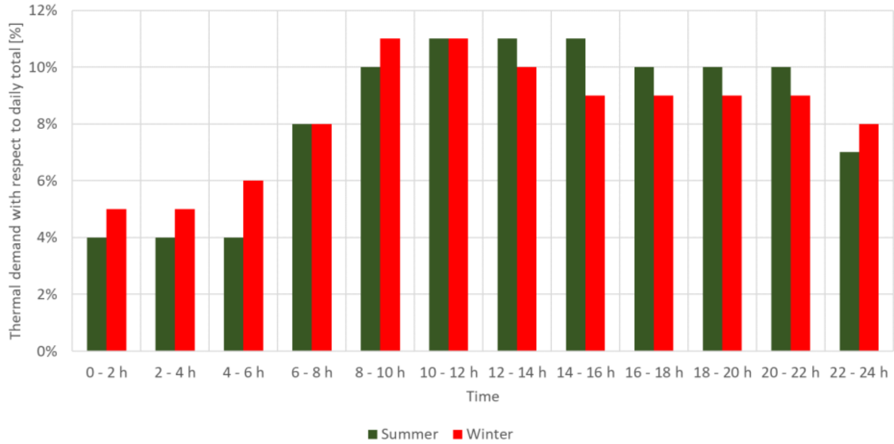

Figure 1: Martini & Rossi daily thermal demand distribution

A further fundamental aspect to consider for the dimensioning and feasibility study of the solar power generation systems are the environmental conditions: the key factors to outline are the surface availability and typology (tilt angle, bearing capacity, etc.) and the solar potential at the specific geographical location under analysis. The solar potential is typically considered in terms of global and direct irradiance, and in Pessione (Italy) – site of the Martini & Rossi plant – it follows a yearly-based pattern as shown in Figure 2.

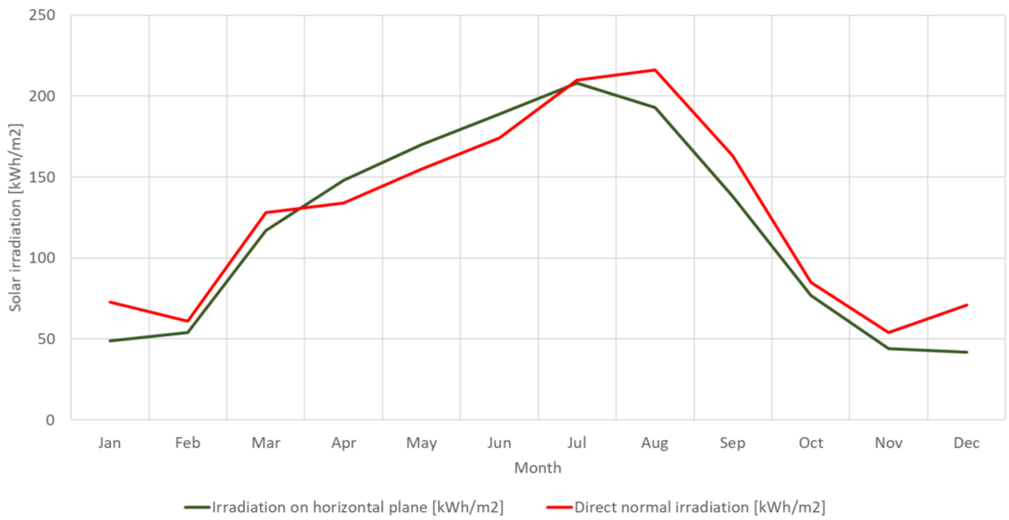

Figure 2: solar irradiance at Martini & Rossi facility in Pessione (Italy)

3. INTEGRATION OF SOLAR THERMAL TECHNOLOGIES

As far as the Martini & Rossi case is concerned, the required pressure and temperature levels of the steam feeding system were the key parameter which guided the preliminary choice of the solar thermal technology towards the linear Fresnel collector solution. As

outlined in [6], this technology relies on an array of linear mirror strips which concentrate light rays into a fixed receiver mounted on a linear tower. The Linear Fresnel reflector (LFR) field can be imagined as a broken-up parabolic trough reflector: large absorbers can be constructed and the absorber does not have to move. One parameter to consider with the LFR technology is the avoidance of shading and blocking between adjacent reflectors. The avoidance of large reflector spacing and tower heights is an important aspect when array substructure cost and steam line thermal losses are considered. When the solar harvesting system has to be located in an area with limited land availability, high array ground coverage can lead to maximum system output for a given ground area. Linear Fresnel technology allows a non-invasive process integration with respect to the control logic and setpoints adopted by the Martini & Rossi operators, whom simply operates the generation system at its ideal working conditions while relying on the thermal expansion valve to keep the pressures in the two feeding loops at the desired values.
Once the choice of a suitable solar thermal technology was consolidated, a preliminary estimate of the power production was performed using Equation 1:

$$E_{sol} = DNI_{avg} * \eta * S * OF \qquad \text{(Eq. 1)}$$

where E_{sol} is the expected solar power generation (GWh/year), DNI_{avg} is the yearly average direct radiation (GWh/m^2), η is the solar collector thermal efficiency, S is the available surface at Martini & Rossi facility (m^2) and OF is an operating factor. For the Martini & Rossi case E_{sol} is equal to about 1.8 GWh/year. Figure 3 is showing the expected thermal energy generation for the solar thermal facility to be installed in Pessione (Italy), on an annual basis.

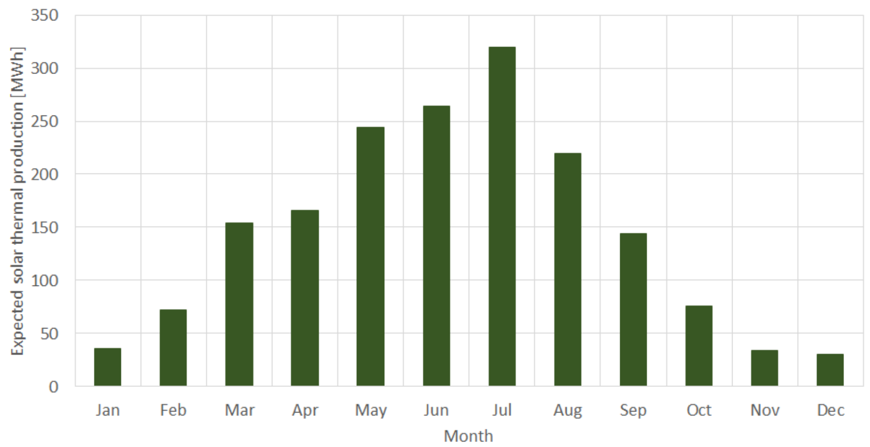

Figure 3: expected monthly thermal production at Martini & Rossi

4. IMPACTS OF SOLAR THERMAL TECHNOLOGIES

In the final phase of this preliminary evaluation the impact of the integration of solar thermal technologies was assessed through the definition of a set of heterogeneous indicators, as reported in [3], which are intended to be an exhaustive and project-independent list of

objective criteria potentially applicable to other future industrial solar heat integration projects.
From a technical point of view, the final assessment mainly focused on the potentially delivered solar energy over a suitable operations horizon. This analysis was performed starting from the physics of the heat generation system, taking into account among the other aspects the thermal demand of the industrial processes to be fed. Important aspects to consider are the satisfaction of the required temperature levels and the exploration of the dynamical behaviour of the thermal generation systems when coupled with thermal storage. Indeed, the presence of a thermal storage unit (such as the thermocline thermal storage shown in Figure 4) is crucial to enable the overall system to operate at optimal conditions avoiding losing energy and ensuring the highest possible thermal energy availability. In this regard, one of the most significant indicators to consider is the "time fraction at partial thermal power satisfied" which can be computed through Equation 2:

$$TF = \frac{\sum_0^{n-1} p_i . t_i}{P * T} \qquad \text{(Eq. 2)}$$

where TF is the time fraction at partial thermal power satisfied, n is the total number of time slots considered within the operations time horizon, p_i is the averaged thermal power over period t_i (kW), t_i is the period duration (hours), P is the required thermal power (kW) and T is the duration of required thermal power (hours). Equation 2 is one of the indicators used for the dimensioning of the thermal storage unit.

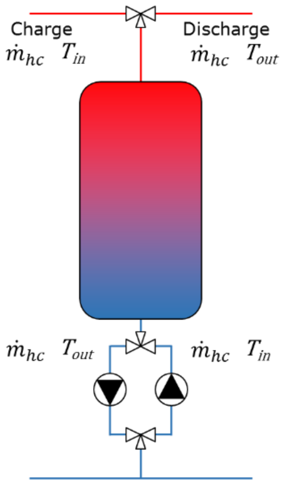

Figure 4: general schematics of a thermocline thermal storage unit

The analysis of the technical impacts allows to make economic considerations. The economic analysis embraced a wide number of aspects and some specific indicators, including CAPEX, OPEX, ROI and payback period. In the Martini & Rossi case, considering the natural gas market prices in 2017 (approximately 0.30 €/m^3) and the savings expected from the integration of the solar thermal system the payback period in terms of energy costs savings resulted to be about 8.82 year. One of the fundamental indicators in this regard is the solar energy cost (€/kWh), expressed as the Levelized Cost of Heat (LCoH) [4]. This index evaluates the cost of heat produced by solar thermal systems over their life time, enabling the comparison of different designs and technical solutions. The indicator is computed from the combination of CAPEX and OPEX over the expected and actual lifetime of the solar plant.

Another area of interest strictly correlated with the technical analysis of the integrated thermal system is the environmental impact assessment. This study evaluates the fossil fuel savings, thus enabling some considerations on the CO_2 savings (expected to be around 436 ton/year of CO_2 for the Martini & Rossi facility) and on reduction of other sources of pollution and waste.

Finally, regulatory and policy issues have been considered all along the definition of the indicators. These aspects are considered with respect to both the potential incentives enlarged by local or national public institutions and to the potential critical aspects regarding the national regulations. As far as the Martini & Rossi is considered, the Italian national law and the local regulations have not special nor critical requirements for the installation and operation of solar plants. Nevertheless, the implementation of a pressurized thermal storage unit is covered under the EU Pressure Equipment Directive 2014/68 which sets out the standards for the design and fabrication of pressure equipment. On the other side, incentives have to be considered in a more detailed analysis to perform a reliable assessment of different economic indicators such as the payback period.

5. CONCLUSIONS

This paper presented the preliminary analysis performed for the integration of a solar thermal generation system within the Martini & Rossi industrial process. Starting from the characterization of the existing scenario, i.e. the thermal generation and consumption processes, a suitable solar harvesting technology has been chosen. The impacts of the integration of a solar thermal system based on this technology has been then assessed through the definition of a set of heterogeneous indicators. The results show that an effective solar thermal installation with payback period below 10 years can be achieved: in this regard, EU's incentives play a crucial role to enable the deployment of such solar solutions which significantly contribute to the 2050 long-term strategy of the European Commission for a climate-neutral Europe, allowing to further reduce the 10-years final payback period for such solar thermal installations. Finally, it is important to note that this work represents a preliminary analysis which does not fully consider some physical constrains as the specification of the solar plant has not been completely defined yet. As a consequence, critical aspects not identified within this preliminary analysis may arise and lead to more stringent requirements.

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