Techno-economical evaluation of a solar steam production system for a case study in a canning fruit industry

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INTRODUCTION AND MOTIVATION

In Chile, the main primary energy source is fossil fuel, with oil, coal and natural gas sharing more than 60% of the matrix. The industrial sector demands 40% of the final energy consumption, being the food industry the second biggest industry in this sector. Agriculture and food industry account for 8% of Chilean GDP and 25% of exports and is the most important exporting sector after copper.

In particular, Chile ranks 3rd in world exports of canned peaches, with a production of 66,020 tons in 2016. The present study aims to investigate the solar heat integration in the canned peaches industry and the techno-economic benefits of it.

METHODOLOGY

The annual heat demand profile was determined by analyzing the growing and harvest season, and the different heat process related to the canning process. The steam demand depends directly of the production level of the plant, therefore, three production levels were analyzed: 20.000, 10.000 and 5.000 tons of canned peaches. The location selected is San Felipe, in the central valley of Chile. Hourly meteorological data from the Explorador Solar of Universidad de Chile (Molina, A. et al, 2017) was used.

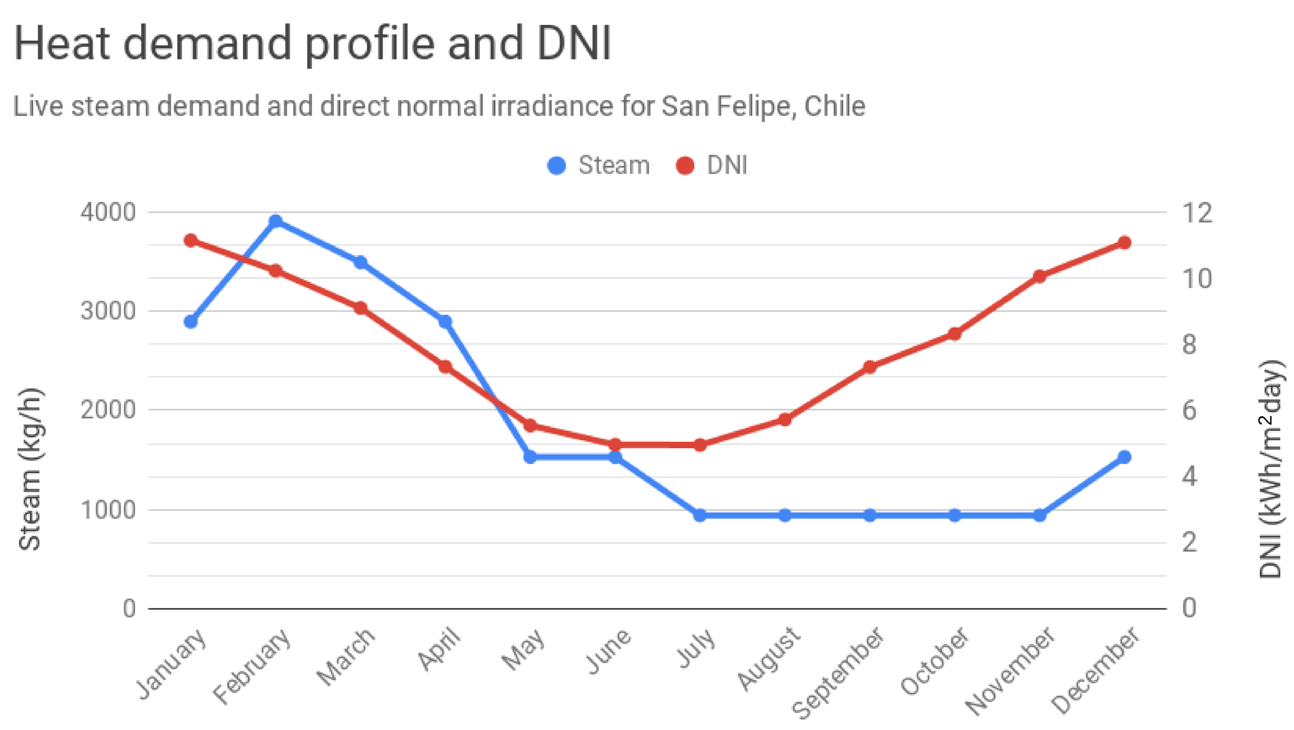

Figure 1. Heat demand profile for a production of 10,000 tons canned peaches and daily direct normal irradiation on San Felipe.

Two different solar thermal solutions were studied: Indirect solar steam generation (ISSG) and solar heating of boiler feed water (SHBFW). For both solutions, parabolic trough collector were used. Solar fraction of 10%, 20%, 30% were studied for ISSG solution. Instead, only a solar fraction of 10% was studied for SHBFW solution. The simulation of the solar integration was developed using TRNSYS software.

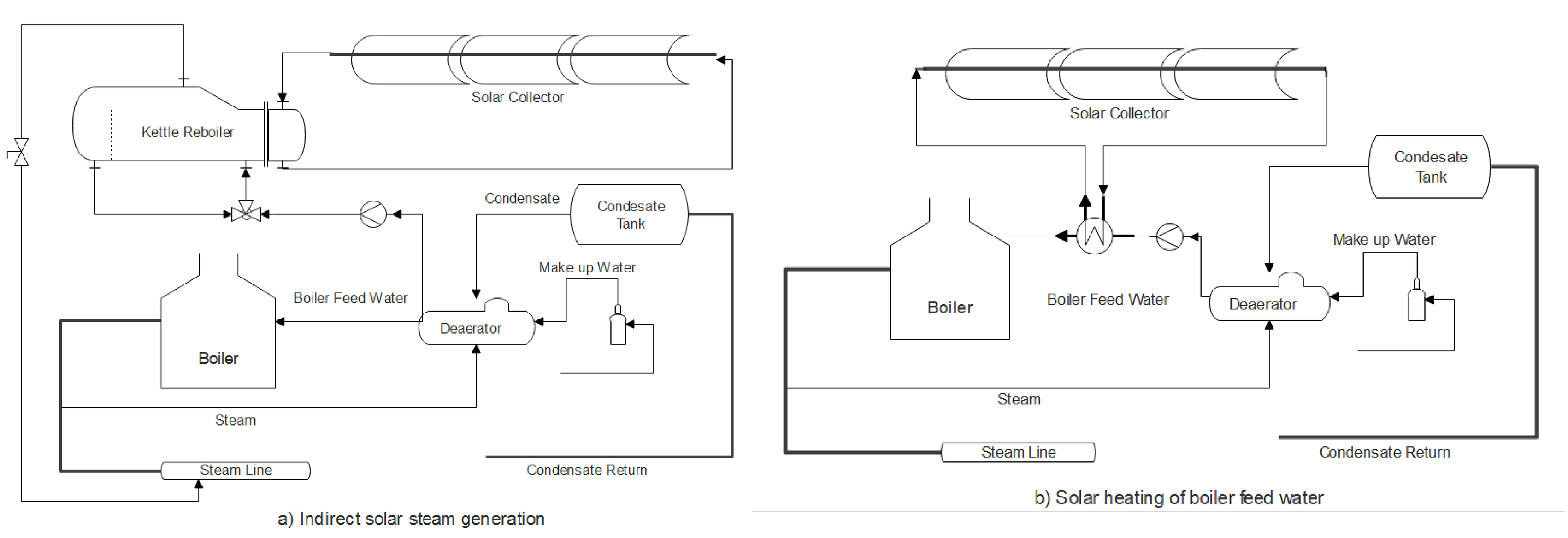

Figure 2. Solar thermal solutions studied. a) Indirect solar steam generation, b) solar heating of boiler feed water.

ECONOMIC PARAMETERS

The investment cost considered the solar collector field and the heat exchanger used. In the ISSG integration, a kettle reboiler was used; in the SHBFW integration, a plate and frame heat exchanger was used. The reference cost for the parabolic trough collector was 300 USD/m^2. O&M cost considered was 5% of total investment. The process heat produced by the solar field was considered as a fuel saving benefit. The price of the natural gas used was USD 12/mmBTU.

The economic parameters selected to assess the integration of solar were the Net Present Value (NPV) and Levelized Cost of Heat (LCOH). A discount rate of 10% and a lifetime of 20 years were used in both.

Additionally, to assess the solar collector cost influence on LCOH and NPV, a range of cost between 150 to 360 USD/m^2 was analyzed.

RESULTS AND DISCUSSION

The LCOH and NPV of each solution are shown in Fig. 3. The LCOH minimum is found for SHBFW integration with an annual production of 20,000 tons, with a value of 0.078 USD/$\mathrm{kWh_{th}}$ and the NPV maximum is found for SHBFW integration with an annual production of 5,000 tons, with a value of USD -$88.048.

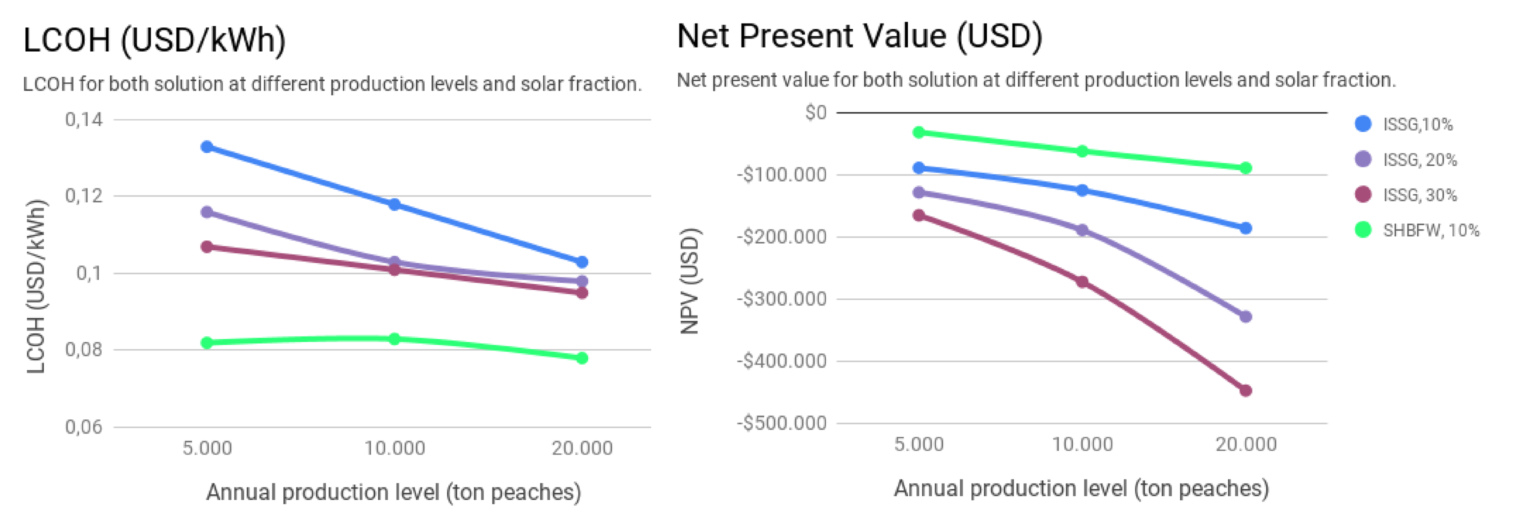

Figure 3. LCOH and NPV for different solution studied. Production: 5.000, 10.000, 20.000 tons of peaches. SF: 10%, 20%, 30%.

The SHBFW integration was selected to evaluate the influence of the solar collector cost. At a cost approx. of 240 USD/m^2, the NPV change to positives values. The LCOH at 240 USD/m^2 is approx. 0.065 USD/$\mathrm{kWh_{th}}$ for three production levels.

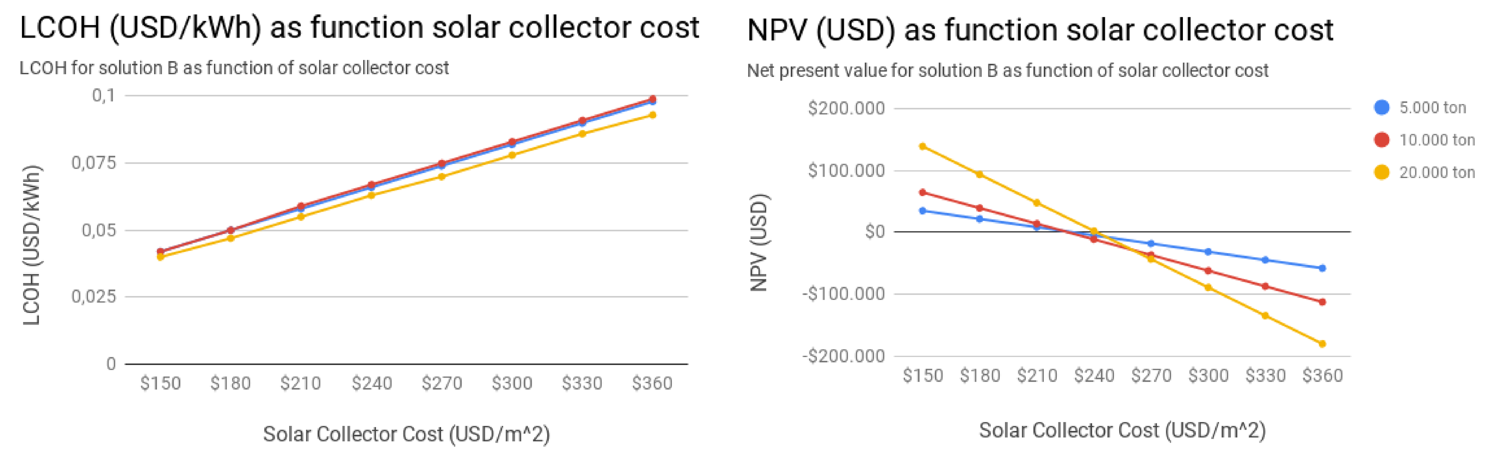

Figure 4. LCOH and NPV for solution SHBFW as a function of solar collector cost and solar fraction.

CONCLUSIONS

- The SHBFW integration had lower LCOH and higher NPV than ISSG solution at same production level.
- Integration with plants with higher production levels, decrease the NPV and LCOH of the project. When increasing the solar fraction, the NPV and LCOH decrease.
- At a solar collector cost of 240 USD/m^2 or lower, NPV had positives values.

Reference: Molina, A. Falvey, M. Rondanelli, R. A solar radiation database for Chile. Scientific Report 7, 14823 (2017).

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