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Solar process heat for sustainable automobile manufacturing

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Abstract

Dürr is one of the world's leading suppliers of products, systems and services, mainly for automobile manufacturing. The range of products and services covers important stages of vehicle production. As a systems supplier, Dürr plans and builds complete paint shops and final assembly facilities. Industrial Solar – formerly known as Mirroxx – is the leading manufacturer of Fresnel process heat collectors and can look back on seven years operating experience with its systems.

Automotive industry is under considerable strain to make their products more environmentally sound. Not only the cars themselves, but also the whole value chain has to become more sustainable. One production process, which contributes a significant share to the carbon footprint of a car, is the curing of a car's paint. As the temperatures in the convection ovens are up to 200°C the application of market available flatplate or vacuum tube collectors was not an option, as these collector types cannot provide such high temperatures. Also the thermal power needed for a convection oven is well above the typical power range of solar collectors, which were originally designed for domestic hot water applications.

A pilot system of a solar driven convection oven has been installed on the Dürr Campus in Bietigheim-Bissingen near Stuttgart / Germany. An Industrial Solar Fresnel collector consisting of six modules with a total aperture area of 132 m^2 heats pressurized water to an outlet temperature of 180°C. A fossil fired backup boiler complements the solar thermal system to meet the thermal power demand of the convection oven. Finally the heat is dissipated in the convection oven via a pressurized water – air heat exchanger.

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1. Introduction

Industry is responsible for around one third of our total primary energy consumption, 60% of the energy used being process heat. To make industry more sustainable it is essential to supply a significant part of its energy demand using renewable energies. Production processes in the lower (<100 ° C) and medium (100 °C - 400 °C) temperature range can be fueled by solar thermal collectors.

Since a variety of industrial processes require high temperatures or steam as a heat transfer fluid, conventional, non-concentrating solar collectors can only provide solar process heat for a limited fraction of this demand. Concentrating solar collectors like Industrial Solar's Fresnel collector can generate higher temperatures and meet this demand.

Automotive industry is under considerable strain to make their products more environmentally sound. Not only the cars themselves, but the whole value chain has to become more sustainable. One production process, which contributes a significant share to the carbon footprint of a car, is the curing of a car's paint (see Fig. 1). The convection ovens for the curing of the paint on the car's body are operated at temperatures up to 200 °C, which are typically generated by gas burners.

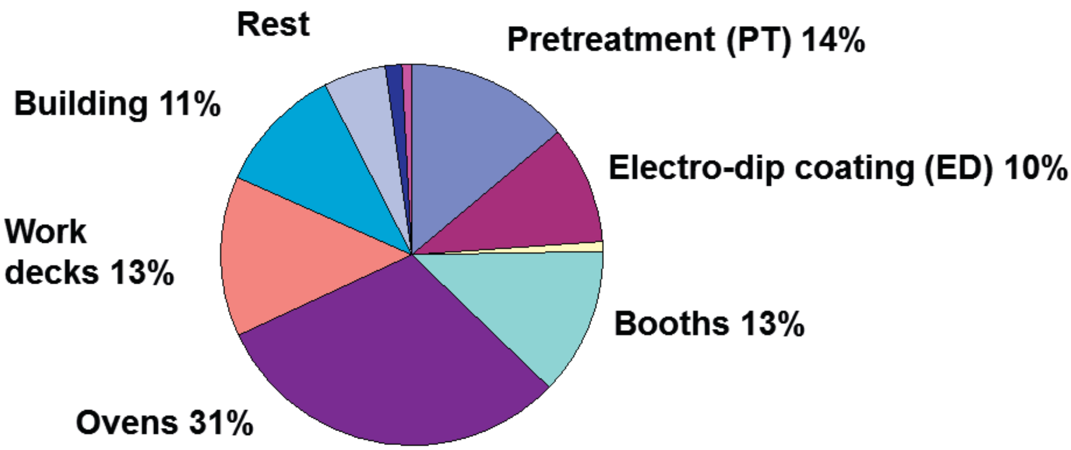

Fig. 1. Energy consumption for the car body painting process

Dürr as a leading supplier of production technology for automotive industry is addressing the need for a more sustainable automobile production with its Eco+Paintshop, which reduces as well the demand for energy and materials as the resultant emissions.

To cover the remaining process heat demand of the paintshop with renewable energies Dürr has teamed up with Industrial Solar, a leading manufacturer of a linear concentrating Fresnel process heat collector, which is capable of generating temperatures up to 400 °C in an industrial power range.

2. Applied technologies

2.1. LF-11 process heat collector

The Industrial Solar LF-11 Fresnel collector uses individually single-axis tracked mirror rows to concentrate the sunlight onto a vacuum receiver manufactured by Schott Solar reaching temperatures up to 400 °C. It is therefore ideally suited to provide process heat for industrial productions, to power multi-effect absorption chillers, or to generate electricity by means of small steam or ORC turbines. Depending on the application different heat transfer media - water, thermal oil or steam – can be used to transfer the thermal energy to the process. The collector can be installed directly on the rooftop of production halls or also on the ground. Moreover, it can be easily integrated into existing energy distribution networks and be combined with an existing fossil fired boiler ensuring absolute security of supply.

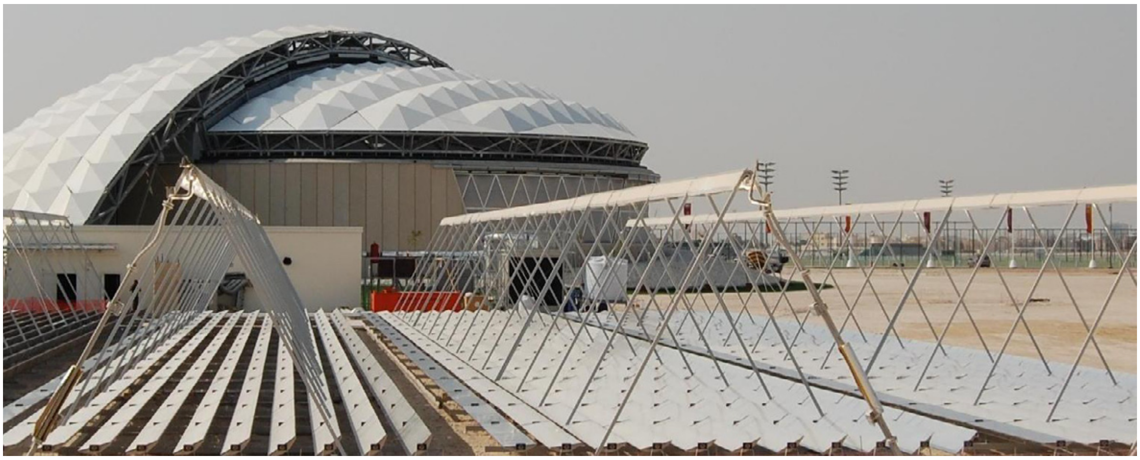

Fig. 2. LF-11 installation with 1408 m^2 aperture area powering a double-effect absorption chiller for a solar air-conditioning system of a football stadium in Doha / Qatar

As the temperatures in the convection ovens are up to 200°C the application of market available flatplate or vacuum tube collectors was not an option, as these collector types cannot provide such high temperatures. Also the thermal power needed for the different convection ovens of a paintshop is well above the typical power range of solar collectors, which were originally designed for domestic hot water applications.

The Fresnel collector of Industrial Solar is perfectly suited for this application as it is designed for

- Operating temperatures up to 400°C
- Power range in the Megawatt range
- Rooftop installation
- Precise and reliable temperature and power control
- Low pressure losses at high flow rates

2.2. Dürr Eco⊕Paintshop

In automotive car body production (see Fig. 3), painting is at the top of the list of energy consumers with an average energy consumption of 700 - 900 kWh per car body, and thus has a significant impact on the balance sheet value. The emissions created during the entire manufacturing process of an automobile corresponds to a distance driven of 40,000 km. At the same time, due to its great complexity the painting process offers many approaches to improve the use of energy, materials and space, as well as reduce emissions.

Dürr has analyzed and optimized these potentials and to this point has reduced its use of energy in the painting process by over 60 % with the Dürr Eco⊕Paintshop. To further reduce the primary energy consumption Dürr was looking for a way to integrate renewable heat sources like solar energy.

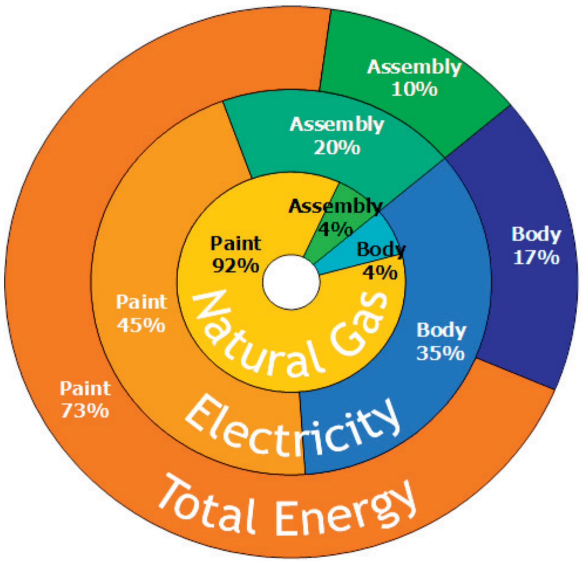

Fig. 3. Energy consumptions for car body production (partitioning between body, paint and assembly shop)

3. Pilot installation

In February 2012 a pilot system of a solar driven convection oven has been installed on the Dürr Campus in Bietigheim-Bissingen near Stuttgart / Germany. The commissioning was in April 2012 (see Fig. 4). An Industrial Solar Fresnel collector consisting of six modules with a total aperture area of 132 m^2 is heating pressurized water to an outlet temperature of 180°C. A fossil fired backup boiler is complementing the solar thermal system to meet the thermal power demand of the convection oven. Finally the heat is dissipated in the convection oven via a secondary pressurized water – air heat exchanger (see Fig. 5).

Fig. 4. Collector string of pilot installation

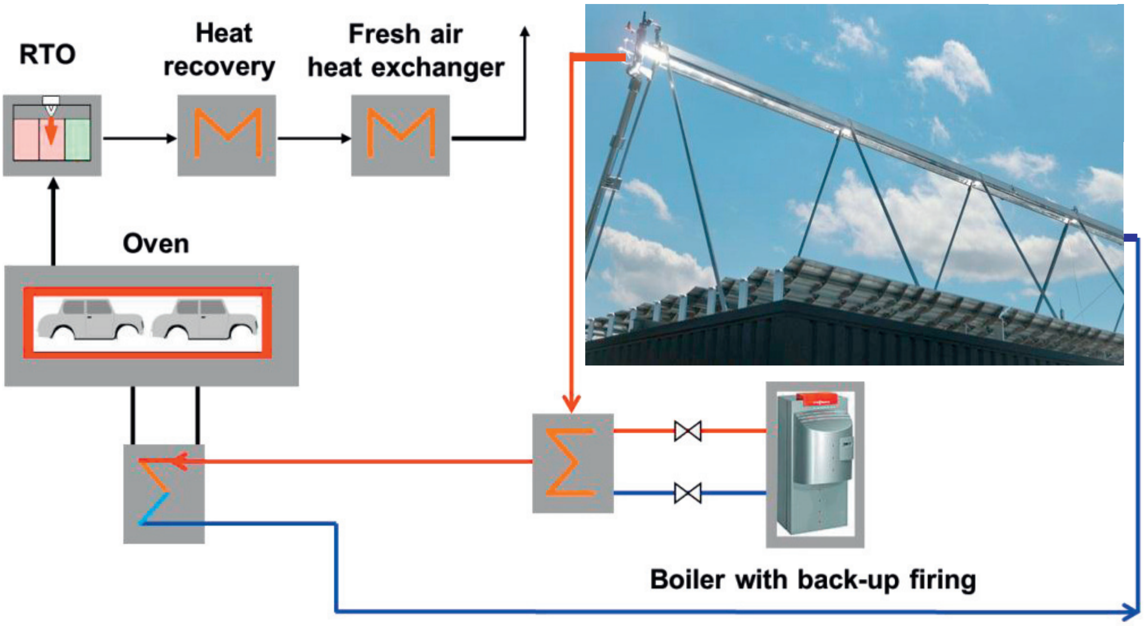

Fig. 5. System diagram

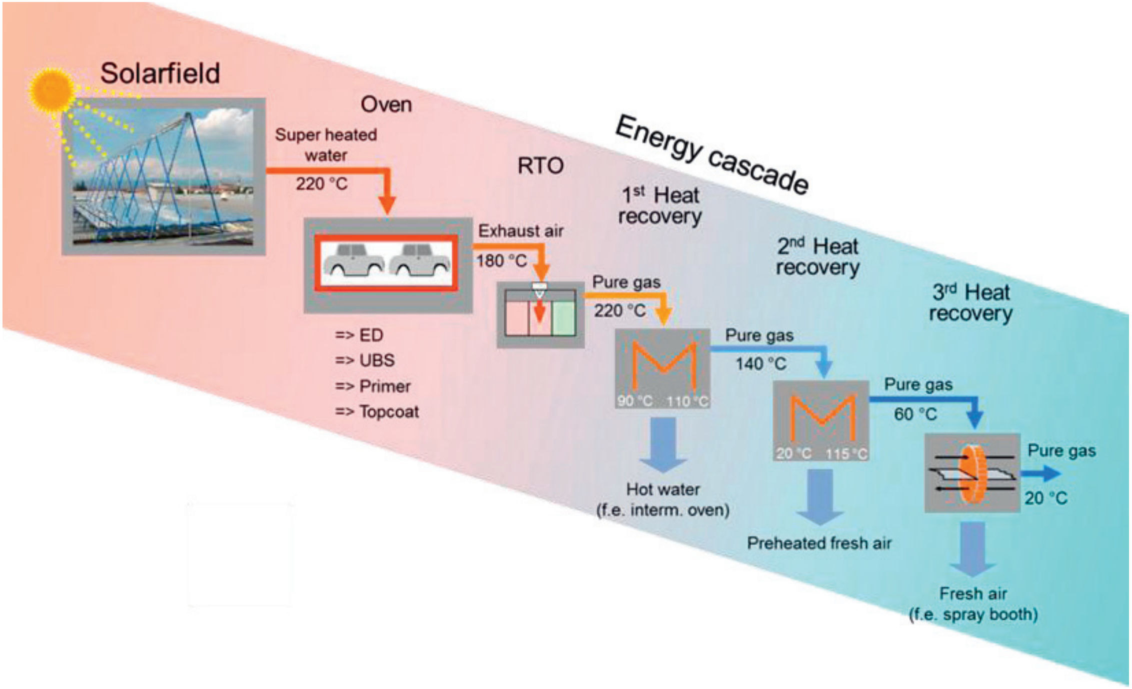

Fig. 6. Energy cascade in Dürr Eco⊕Paintshop

In regions with a high fraction of direct solar irradiation and an adequate buffer storage volume a solar fraction of up to 50% can be achieved. Further energy savings can be realized, if the collector is installed on a rooftop as it is shading the rooftop and thus reducing the cooling load of the building.

Several heat recovery systems are integrated in the exhaust air treatment and provide thermal energy in a temperature range from 20 °C to 115 °C, so that an integration of non-concentrating collectors would not make good sense (see Fig. 6).

4. Example: Paint shop in Morocco

First calculations and simulations for real-size Dürr Eco⊕Paintshops at locations with high direct solar irradiation have been made. Using the example of an existing paint shop in Morocco it can be shown that the available roof area is well proportionated to the thermal energy demand of the oven system. In Fig. 7 results of simulations for different locations are shown.

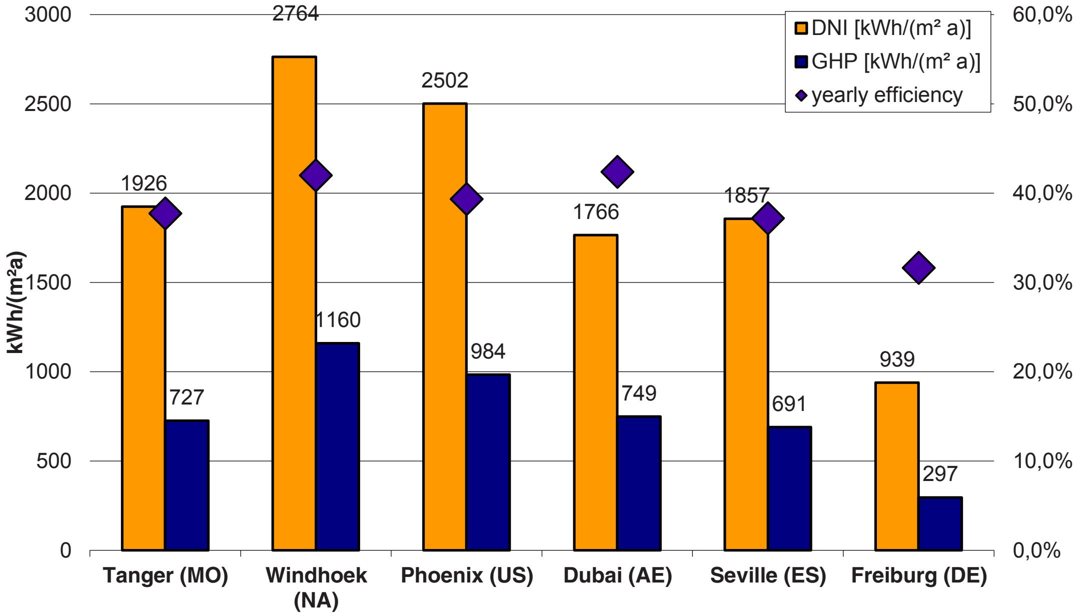

Fig. 7. Simulations of Gross Heat Production (GHP) and mean yearly efficiency LF-11 collector at different locations

Table 1 on the following page shows calculations for a system installed in Tanger / Morocco. With only 250 working days/year and without storage a solar fraction of 25% can be reached for the ovens. By integration of a storage or an absorption chiller the solar fraction can be further increased.

Table 1. Paint shop in Tanger / Morocco

Paint shop capacity	30 units/day
Operating hours per day	14 h
Operating days per year	250 d
Max. thermal demand	4,5 MW
Max. process temperature	200 °C
Yearly energy consumption	**15.750 MWh**
Available rooftop area	12.000 m^2
Collector aperture area	8.000 m^2
Specific thermal peak power at reference conditions*	562 W/ m^2
Thermal peak power of collector field	4,5 MW
Mean yearly efficiency in Tanger /MO	37,7 %
Yearly sum of DNI in Tanger / MO	1926 kWh/(m^2 a)
Yearly Gross Heat Production (GHP) of collector field	**5.810 MWh**
Usable GHP of collector field	**3.980 MWh**
Solar fraction (250 working days/year, no storage)	**25 %**

***(Reference conditions: 30°C ambient temperature, 160°C inflow temperature, 180°C outflow temperature, 900 W/m^2 direct normal radiation, azimuth angle 90°, zenith angle 30°)**

5. Summary and outlook

The technology demonstrated leads the way towards an environmentally friendly and carbon neutral production of automobiles. By integrating concentrating solar thermal collectors process heat at elevated temperature levels can be provided to industrial production lines and fossil fuel can be substituted - in automotive industry and many others. A pilot system has been designed and installed and will be monitored in the following months. Next steps will be an optimization and up-scaling of the current system design. We are looking forward to the first realization of this technology at a production site of an automotive company with high environmental awareness.

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