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Simulation of a Solar Assisted CounterFlow Tunnel Dehydrator

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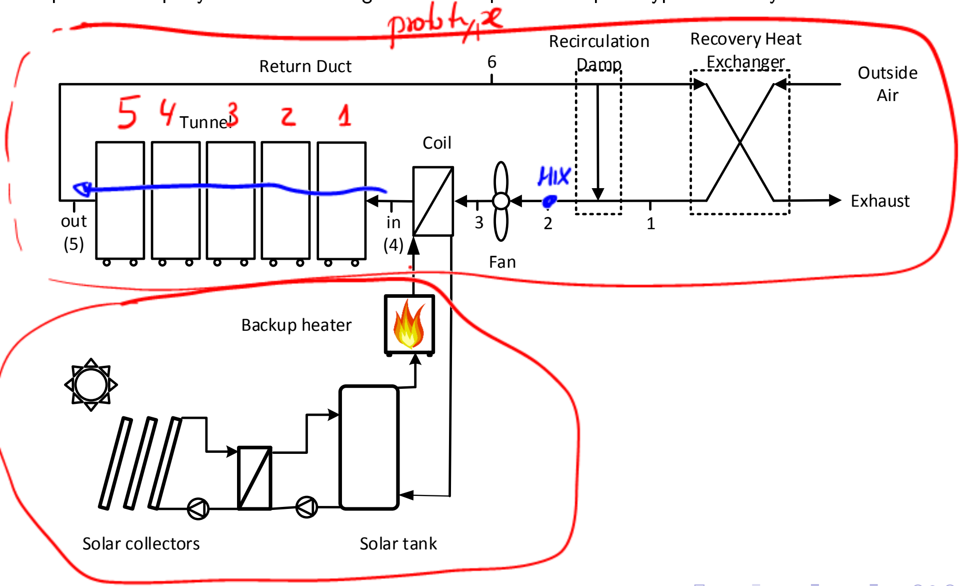
About us

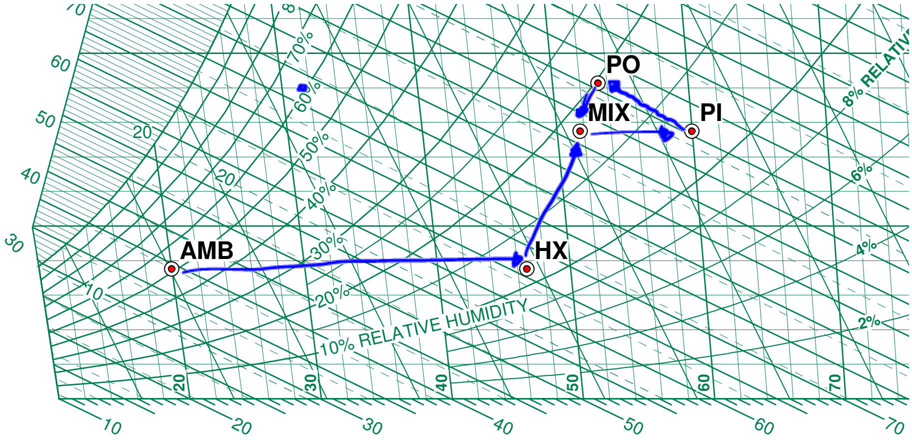
- GEUMA (Grupo de Energética de la Universidad de Málaga)
- Industrial Engineering School
- Modeling and simulation of thermal systems: HVAC, Buildings, Solar...

Tunnel and truck dehydrator

A private company located in Malaga has developed a first prototype of a dehydrator



Psychrometric chart



Tunnel and truck dehydrator

Truck loaded with sliced bananas

Objectives

The GEUMA is contacted to perform two tasks:

- Analyze the energy performance of the dryer prototype
- Evaluate the potential of using solar energy to reduce fuel consumption

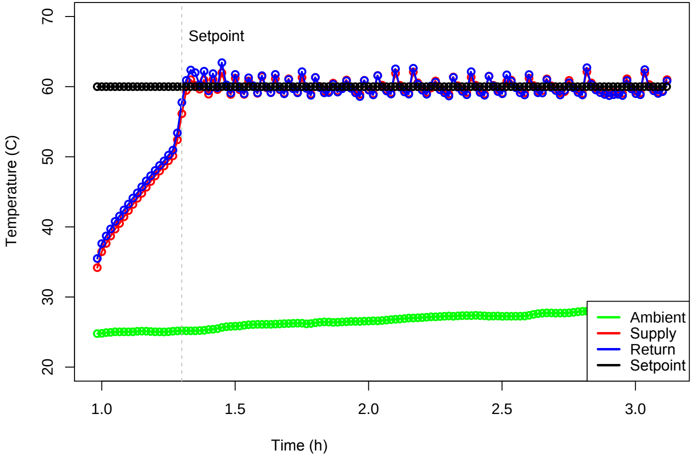
Methodology:

- Experimental analysis of the prototype
- Thermal model of the dehydrator
- Thermal model of the solar system
- Simulation of the solar assisted dehydrator

Experimental analysis of the prototype

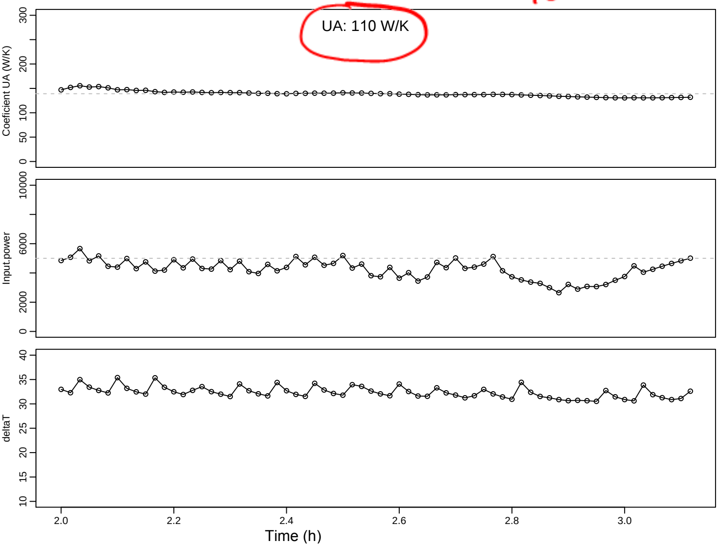
Global heat loss coefficient UA experimental determination

Empty tunnel. 100 % recirculation



Global heat loss coefficient UA experimental determination

4000 Watts



Reference test

Tray loaded with sliced bananas

Reference test

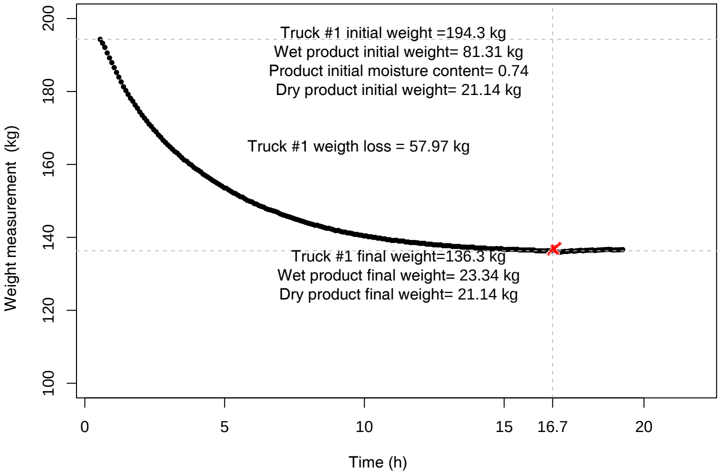
Truck loaded with sliced bananas

Reference test parameters

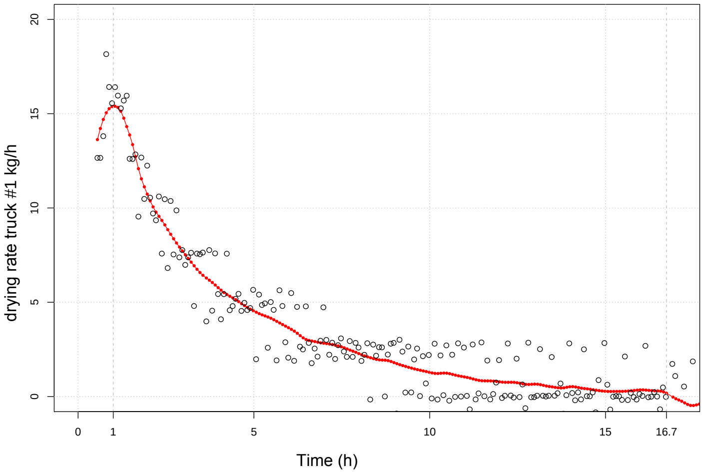
Table 1. Parameters and measurements of the reference test. Only the truck #1 is loaded with sliced bananas.

Parameter	Value	Comment
Outside air temperature (°C) and relative humidity (%)	Around 20°C 50 %	Measured
Process air setpoint temperature (°C)	60	Measured
Process air mass flow rate (kg/h)	18906	Measured with digital vane probe
Exhaust air mass flow rate (kg/h)	945	Measured, it is 5% of the process flow rate
Global heat loss coefficient UA (W/C)	110	Determined from stationary heating tests
Heat recovery efficiency	0.8	Calculated from measurements
Fan motor electrical consumption (kW)	2.35	Measured
Wet product initial weight per truck (kg)	81.3	Measured
Dry product weight per truck (kg)	21.1	Estimated

Experimental reference test. Truck #1 weight measurement

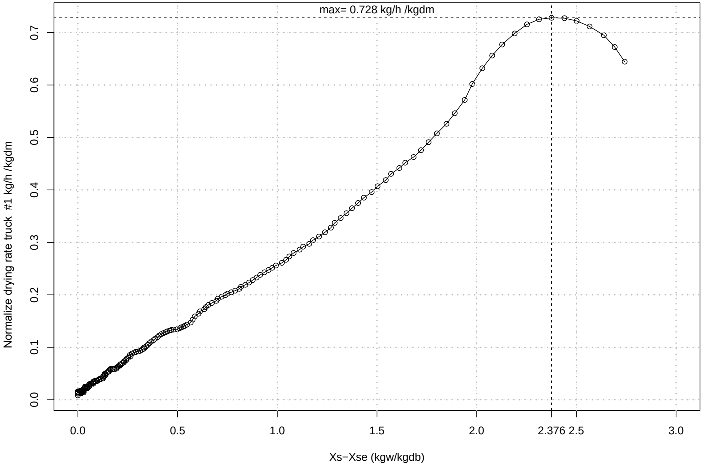


Experimental reference test. Truck #1 drying rate



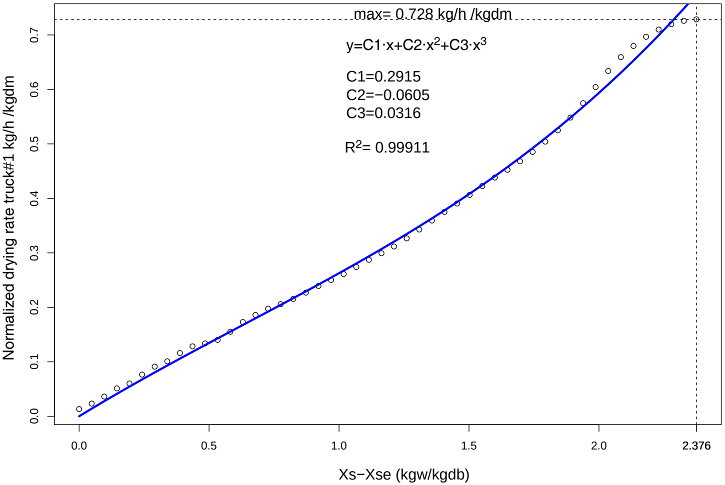
Experimental reference test normalized drying rate

Dry basis - Process air setpoint: 60 °C



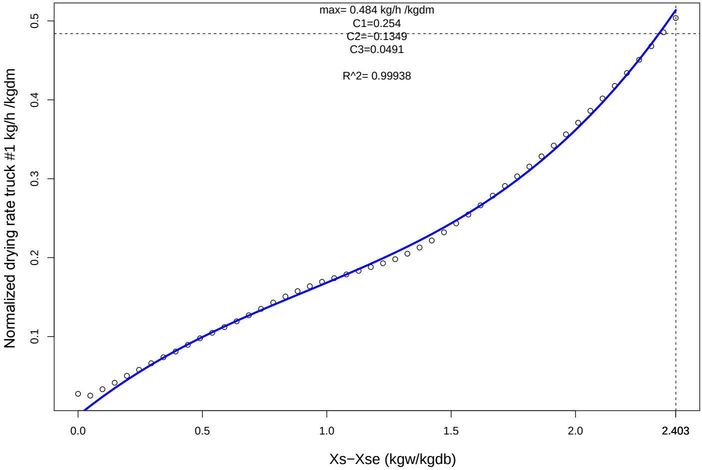
Experimental reference test normalized drying rate

Dry basis - Process air setpoint: 60 °C

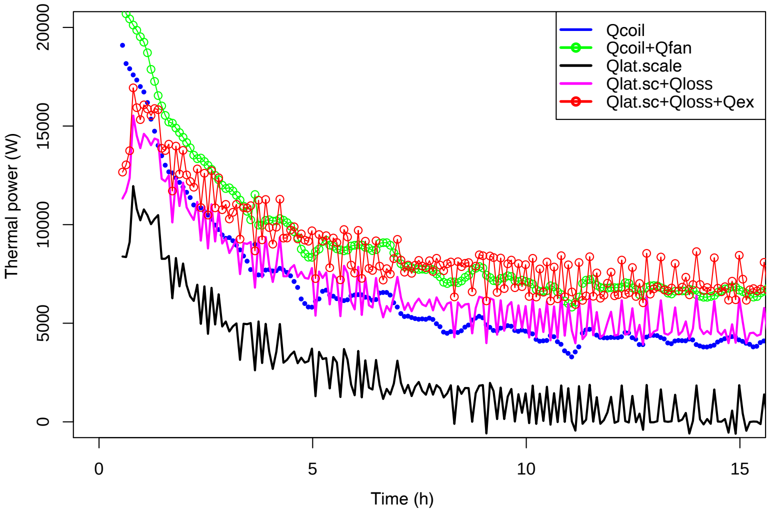


Experimental reference test normalized drying rate

Dry basis - Process air setpoint: 50 °C

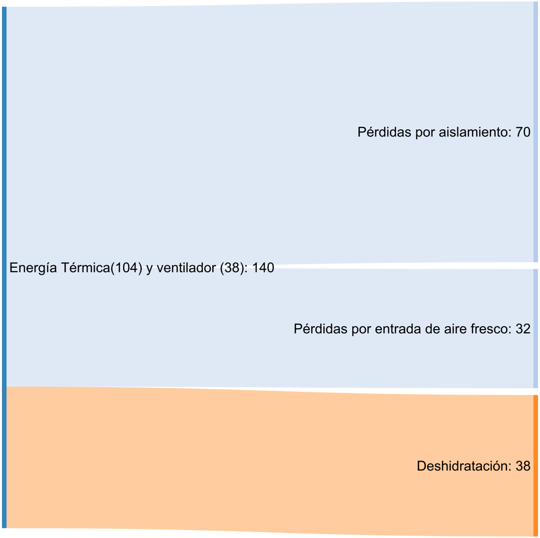


Experimental reference test. Energy balance



Sankey diagram (kWh)

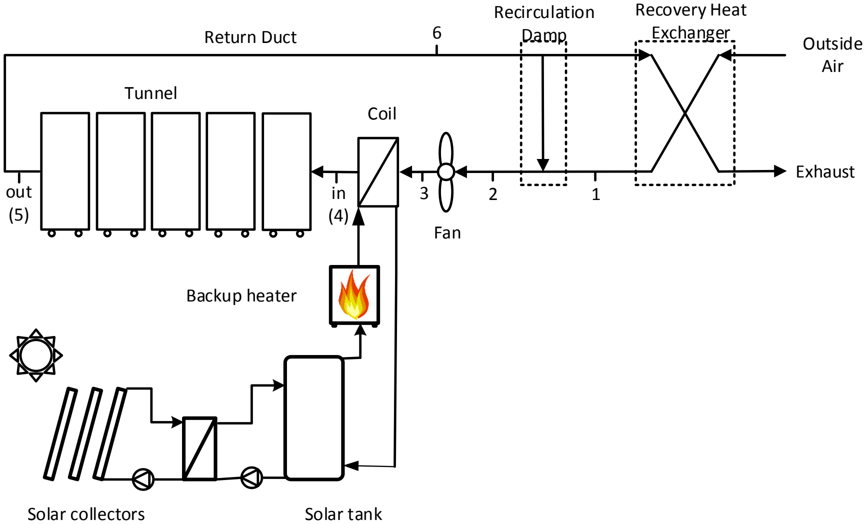
Global Efficiency 27 %



Dehydrator thermal model

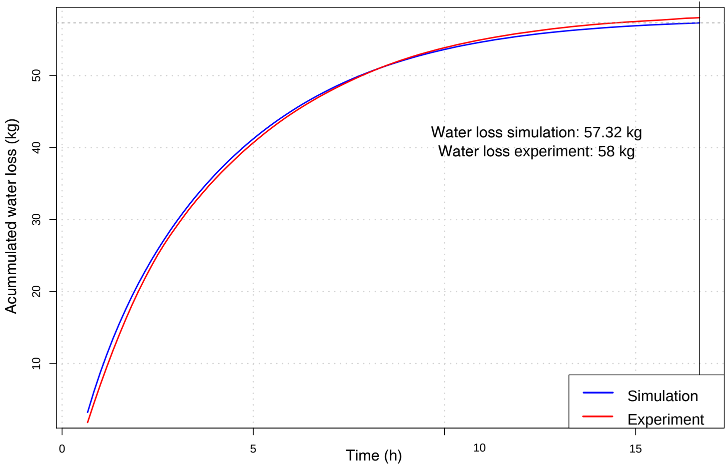
Why a dehydrator model?

Engineering Equation Solver EES



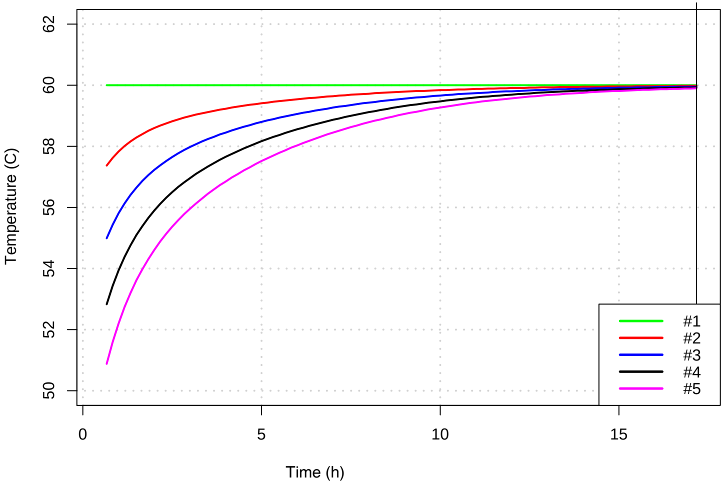
Reference test. Simulation vs Experimental

Good agreement



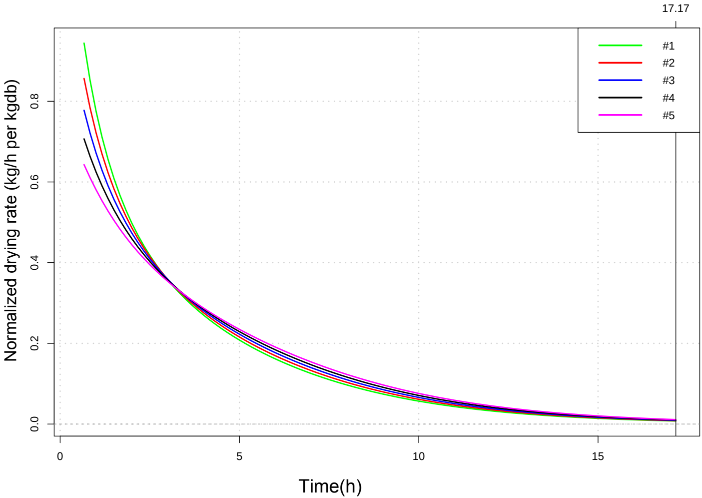
Dehydrator simulation - Full load - Process air temperature

Process air temperature at each truck inlet

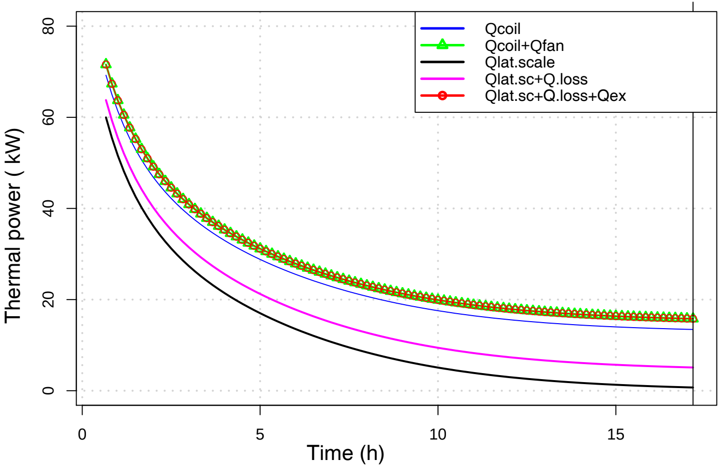


Dehydrator simulation - Full load - Drying rate

Different drying rate



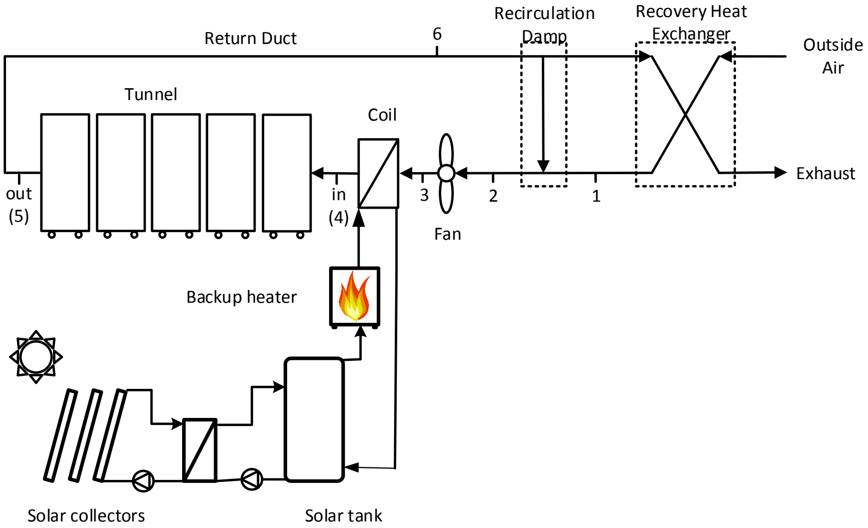
Dehydrator simulation - Full load - Energy Balance



Solar system model

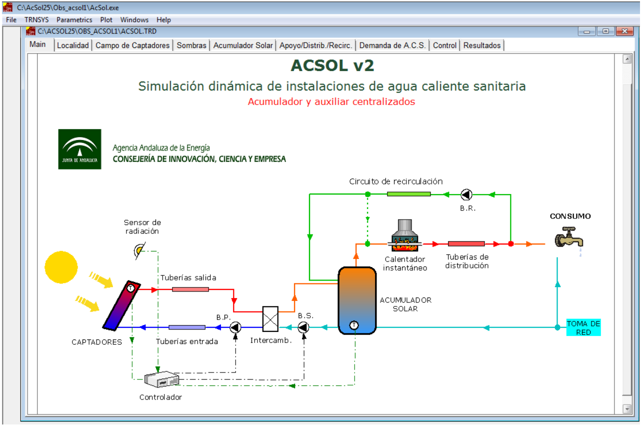
Solar system model

ACSOL (TRNSYS)



Solar system model

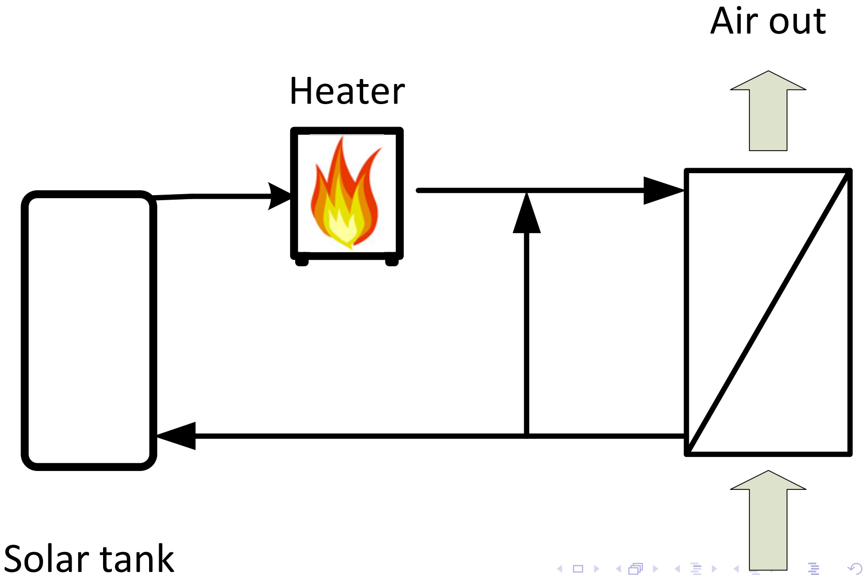
ACSOL (TRNSYS)



Solar system simulation - parameters

Parameter	Value	Comment
Weather file	Tenerife.EPW	EnergyPlus weather data [4]. Lat: 28.47 °N
Energy demand from drehydrator (kW)	Qcoil from Fig 7	A batch operation is assumed starting at 16h every day of the year and finishing at 9h next day.
Collector type	select. flat plate	Co=0.809 C1=4.030 W/m2K C2=0.007 W/m^2K^2
Slope and azimuth	30 ° facing south	Typical parameters
Collector area (m^2)	50 to 300	Aperture area
Solar tank volume to col. area ratio VA (l/m^2)	50-75-100	Typical range
Collectors arrangement	2 units in series	Typical arrangement
Solar field flow rate ratio (l/hm^2)	40	Nominal value for the selected collector.
Thermal losses in piping	Neglected	This is a preliminary analysis
Solar tank insulation	100 mm	k=0.04 W/mK
Maximum temperature allowed in tank (°C)	90	Typical value
Back-up heater position	Series with tank	An "ideal" back-up heater is assumed
Back-up heater setpoint temperature (°C)	80 or variable	Two different control strategies, see text
Heating coil nominal thermal power (kW)	70	Data from the simulation of the full load test Fig7
Heating coil air flow rate (kg/h)	18906	Actual air flow rate in the prototype
Heating coil water flow rate (kg/h)	4225	A balanced heat exchanger is assumed
Heating coil nominal air temperatures (°C)	47 inlet 60 outlet	60 °C is the process air setpoint, 47 °C from simulation of the full load scenario Fig.7.
Heating coil nominal water temp. (°C)	80 inlet 67 outlet	80 °C is the water temperature setpoint of the boiler of the prototype.
Heating coil exchange effectiveness	0.4	Calculated from assumptions above

Solar system simulation - heater setpoint control



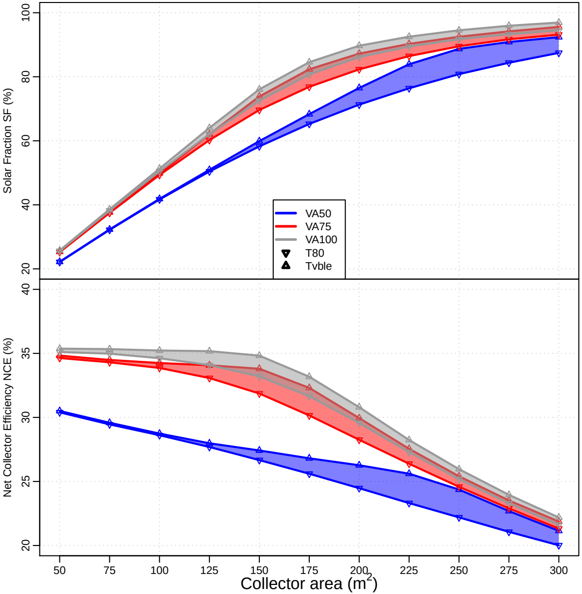
Solar system simulation - Performance

Figures of merit

$$\text{Solar Fraction (SF)} = \frac{Q_{solar}}{Q_{load}} = 1 - \frac{Q_{aux}}{Q_{load}}$$

$$\text{Net Collector Efficiency (NCE)} = \frac{Q_{solar}}{A_{col} \cdot H}$$

Solar system simulation - Performance



Conclusions

Conclusions

- An energy analysis of a experimental dryer prototype has been completed and thermal models of the dryer and of a solar water heating system have been developed.
- This is an energy intensive process: large collector area and storage volume are needed to get a significant solar fraction.
- VA ratios of about 75 l/m2 seems OK.
- The variable backup heater setpoint control has a positive impact on solar fraction.

Future work

- There are still many aspects that could be improved in the dehydrator design to increase its efficiency
- The drying kinetics modeling approach can be improved
- Other control strategies and operating conditions can be investigated

Thank you!