Improved Solar Biosolids Dryers

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Solar energy is cost and carbon free. However, the intensity of solar radiation depends on weather, climate and season. It is ironic that solar biosolids dryers were first developed in Germany, a rather cool country with little sunshine, at least during fall and winter. Required footprint and the costs of greenhouses depend on solar energy input, and both can be very large where the climatic conditions are less than ideal.

Another common problem is odor generation. This happens where pasty and non-porous sludge cake is fed, becomes anaerobic and develops volatile and odorous fatty acids.

Operator access should be kept to an absolute minimum due to high infection risks. Biosolids are usually not disinfected and the greenhouse air contains many pathogens.

Goals and Objectives
Solar dryers should be:

- effective and efficient, independent of climate and weather,
- virtually odor-free, i.e. anaerobic conditions must be prevented,
- fully automated and very reliable, including their feeding, moving and discharge equipment.

Keywords

Biosolids Drying, Solar Dryer, supplemental heat, heat pump, continuous operation

Introduction

Huber Technology, Inc. started the first solar dryer system in 2003. The first US installation is currently under construction in UT. At this time there are 33 installations world wide with more than 45 turning devices installed.

Solar Dryer Design

In general Huber's solar dryer installation as any other solar dryer requires a green house. A standard commercial green house can be used if material of the structure and covers are suitable for the conditions. In general galvanized steel for the structure is sufficient. The following standard green house cover materials are also sufficient: glass, sheets of polycarbonate or polyethylene foil (double layer). The material is mainly determined by the meteorological conditions like snow load, temperature and wind loads.

The main piece of the installation is the sludge turning device. It is a stainless steel structure and runs on guide rails which are located on both sides of the greenhouse. The turning device is travelling along the entire length of the green house. When travelling the drum, which consists of rotation-symmetrical buckets with S-shaped cross section, is turning continuously. It is picking up the material from the floor and discharges it after one revolution.

The drum has two buckets - 180° apart – the bucket who picks up the material last is making the space for the material picked up previously. The material is moving step by step down the entire length of the green house. While the entire system is moving and material is continuously scooped up and discharged, it moves a little closer to the dry end of the green house. This ensures that the material is gradually moving away from the wet side of the green house (feeding) through the dryer. It will reach the dry end after the moisture content has dropped down to the desired level (10 – 25%).

The time it takes to the reach the discharge end of the dryer is determined by the weather conditions. The sludge is moving very quickly during summer (the turning device might operate continuously). The sludge moves much slower during the season with less insolation (winter) – because the available energy is much less. E.g. in Raleigh, North Carolina the available energy in summer is up to 1900 BTU/sft/d and it decreases to less than 650 BTU/sft/d during the winter month (see figure 1).

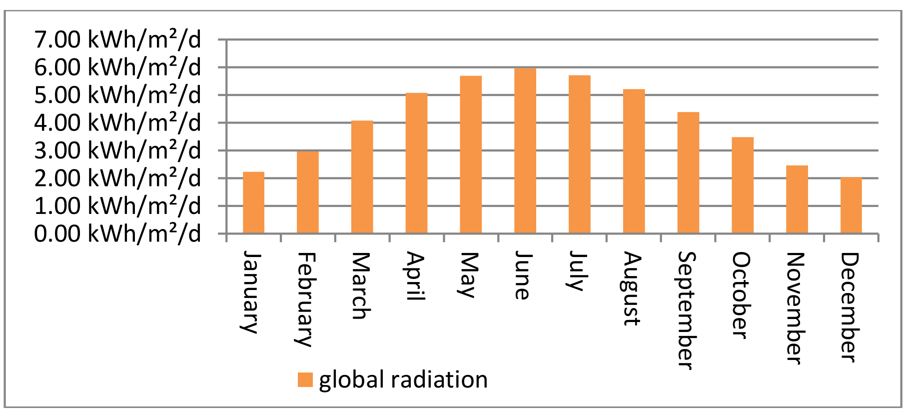

Figure 1: solar radiation – Raleigh, NC

The evaporated water is removed from the system by replacing the water vapor loaded air with fresh air. The humid air is leaving the green house through the roof openings. The air is replaced with fresh air which is pulled in by fans, located at the opposite side of the air intake. The roof flaps and the fans are controlled by the temperature and humidity level inside the greenhouse.

The circulation inside the green house is maintained by several fans mounted at the ceiling of the green house structure. The movement of the air is very important because it ensures an even drying process throughout the green house. The number of fans is determined by the meteorological conditions and the characteristics of the dewatered sludge coming in.

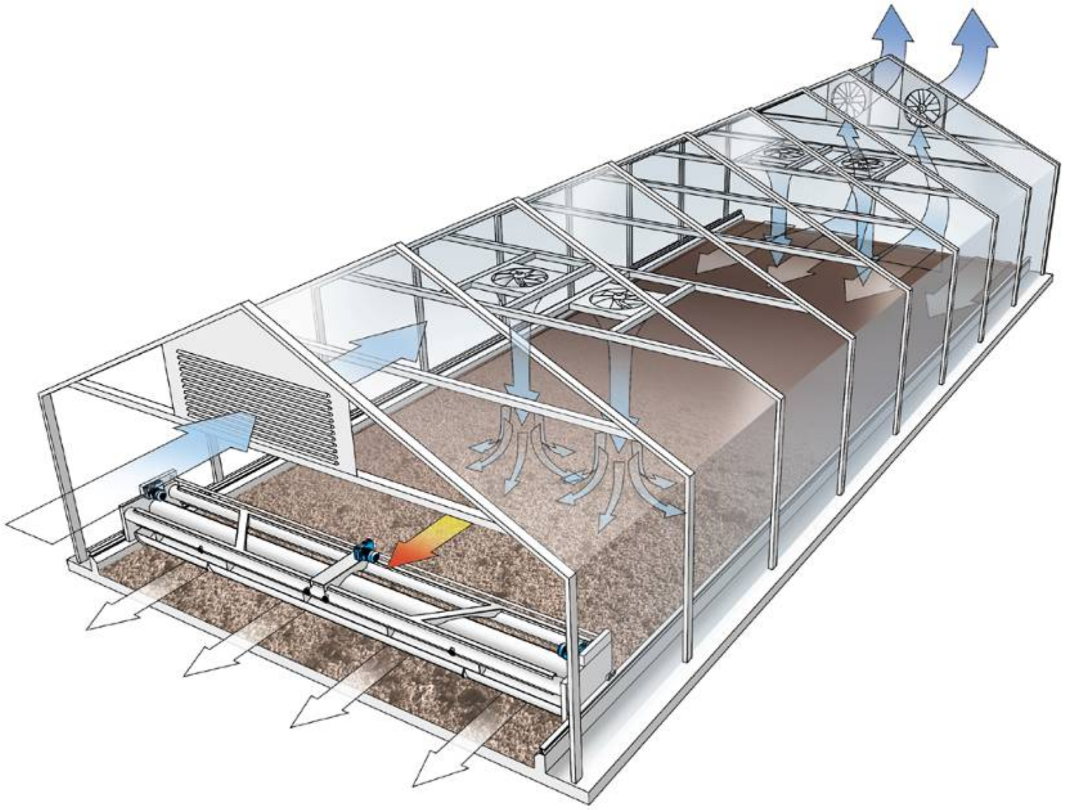

Figure 2: General Arrangement Solar Dryer, SRT

The design of the solar dryer comprises the following main benefits, which are necessary to allow a continuous operation of the solar dryer:

- aerates the sludge by turning sludge over (reduces/eliminates odor issues)
- sludge is transported through the green house
- back mixing: pasty material / sludge with high moisture content
- three different sizes (turning device length from approx. 20 ft to maximum 36 ft)
- automatic sludge feed and removal system


Figure 3: four dryer lines - SRT 9


Figure 4: Huber solar dryer, SRT 11

The turning device consists of the following motors/drives (example for the largest size unit):

Power Supply:	Voltage / Hz	Power [kW] / [hp]	FLA [Amps]	operation mode	VFD
Turning device main drive 1	460 V / 60 Hz	4.0 / 5.0	6.5	Continuous, consumption: 3.25 kWh	Yes, max. speed 43ft/min
Turning device main drive 1	460 V / 60 Hz	4.0 / 5.0	6.5	Continuous consumption: 3.25 kWh	Yes
Paddle drive	460 V / 60 Hz	4.0 / 5.0	6.5	Continuous Consumption: 3.25 kWh	Yes, rotational speed 10 rpm
Shield lifting motor	460 V / 60 Hz	0.66 / 0.75	1.9	Intermittent consumption: 0.5 kWh	No
Air intake fan 1 to 4	460 V / 60 Hz	1.5 / 2.0	3.4	Intermittent Consumption: 3.5 kWh	No
Air Circulation fan 1 to 8	460 V / 60 Hz	1.5 / 2.0	3.4	Intermittent Consumption: 3.5 kWh	No
			Overall power consumption	30 – 43 kWh / t water evaporated	
			Average evaporation efficiency	1253 W/kg 1938 BTU/lbs	0.3 – 1.0 lbs water / sft / d

Figure 5: energy consumption and nominal energy demand SRT

The design of the solar dryer is based on the following data:

- amount of dry solids t DS / a
- cake solids of dewatered sludge
- desired moisture content of final product
- meteorological data:
    - temperature [°F]
    - humidity [RH %]
    - solar radiation [kWh / m^2/ d] or [BTU/ft^2/d]
- storage capacity for winter month: liquid sludge, dewatered sludge, additional greenhouse surface
- use of final product (might be different in winter month)

The solar dryer capacity is calculated on a monthly basis. The system will have the highest capacity in summer – the available surface area is calculated to ensure that the storage is empty at the end of the summer month. The reduced drying capacity during the cooler months is backed up by the storage. Sludge is transferred into storage until the solar dryer capacity increase in spring, when sludge can be taken out of the storage. The size and number of greenhouses need to be determined by the available storage capacity.

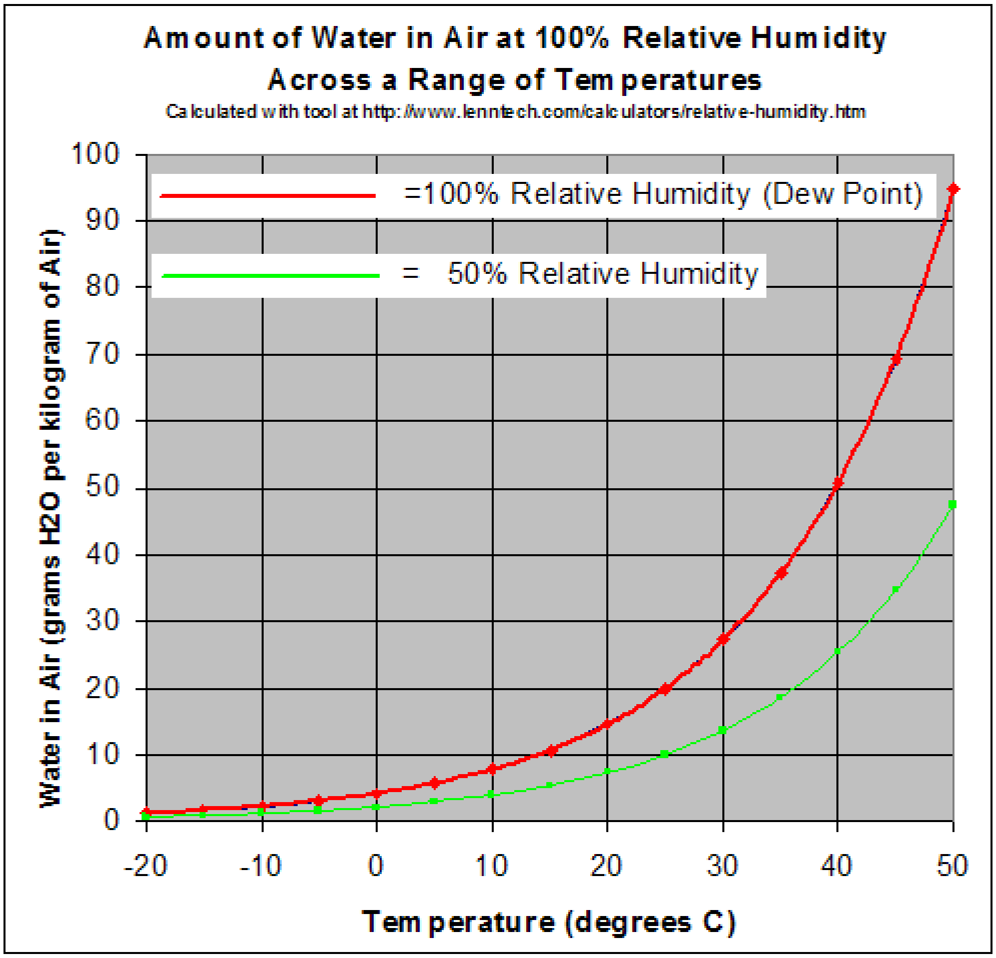

Figure 6: water loading rate of air

Automatic Feeding System

The continuous operation requires a constant feeding of the solar dryer. Therefore several options were developed to feed the dryer with conveying systems and eliminating the need of operators entering the green house with e.g. front end loaders. The following pictures show options used with the Huber SRT:

- overhead screw conveyor installation (stationary conveyor) (figure 7 and 8)
- screw conveyor (moving conveyor system) (figure 9)
- belt conveyor (figure 10)
- bucket conveyor (figure 11)

Figure 7: overhead screw conveyor design

Figure 8: connection between green house and dewatering building


Figure 9: moving screw conveyor design


Figure 10: belt conveyor

Figure 11: bucket conveyor

Dried Material Discharge

The solar dryer system also provides several options for the removal of the dried material from the green house. The system can be provided with a storage area for the dried material at the end of the green house. The material can be removed by means of a front end loader (standard design of the SRT).

The huge benefit of the continuous operation is that the operator does not have to enter the green house during normal operation. The operator does not have to enter the system at all, with an automatic removal of the dried material.

The dried material is discharged into the screw conveyor mounted into a trench at the end of the drying bed. The auger removes the dried material from the green house and discharges the sludge into a dumpster. The sludge can be also conveyed into a silo.

The design of the turning device provides another option. The turning device can be utilized as a conveying system. Therefore the discharge of the solar dryer can be also located at the feeding end of the green house. This type of arrangement has several advantages:

- dried material can be stored in close proximity to the dewatering building
- less restrictions in greenhouse design
- less doors required

Figure 12: trench with discharge conveyor

The SRT offers different types setups planning,

1. Feeding and discharging with front loader, discharging into a recess at the end of the greenhouse (standard)
2. Feeding with distribution screw, discharging in a recess at the end of the greenhouse
3. Feeding with a front loader, discharging in a screw at the end of the greenhouse
4. Feeding with distribution screw, discharging in a recess at the same side of the greenhouse
5. Feeding with a front loader, discharging in a screw at the same side of the greenhouse
6. Feeding with distribution screw, discharging in a screw at the same side of the greenhouse
7. Feeding with distribution screw, discharging in a screw at the end of the greenhouse

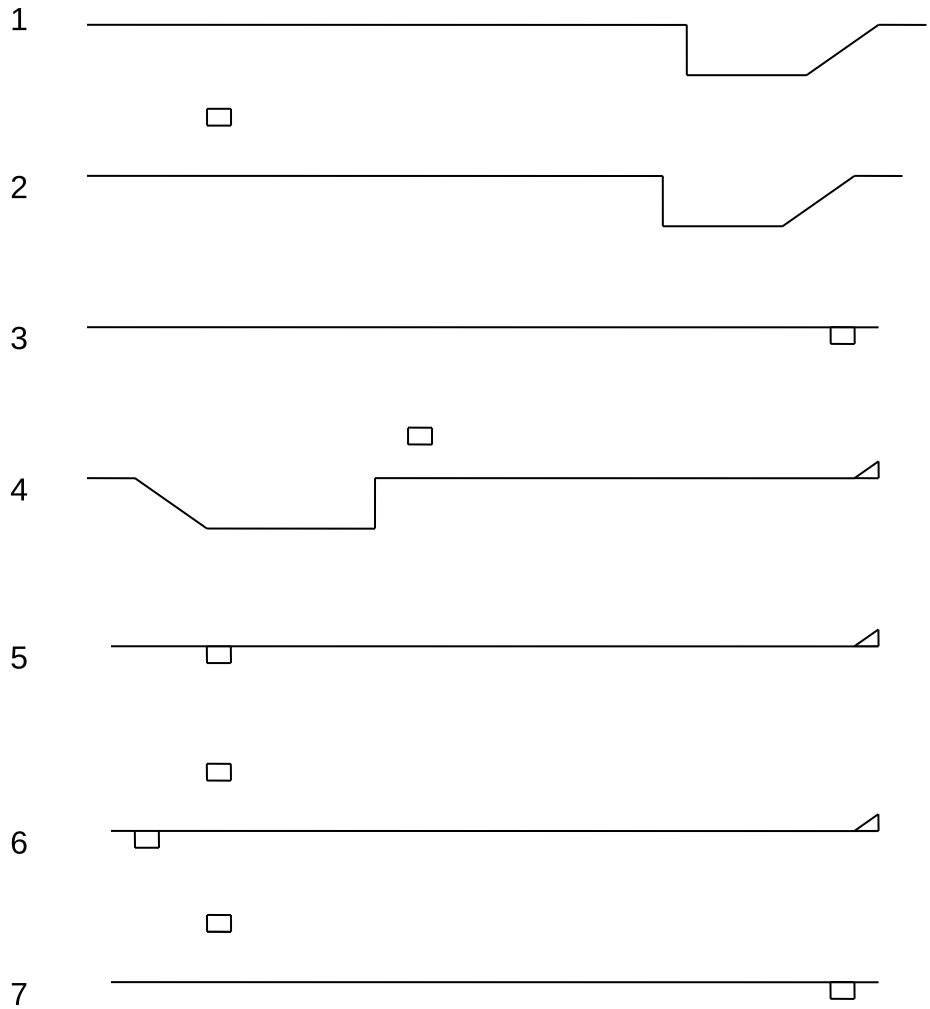

Figure 13: schematic solar dryer design (feed, discharge options)

Control Philosophy

The Huber solar dryer SRT allows a very flexible operation which utilizes the multi functional turning device. The system can execute up to 10 different operations to ensure:

- Drying: aeration and conveying (without sludge feeding)
- Drying: aeration and conveying (with sludge feeding)
- Aeration only, no conveying
- Back mixing
- Sludge height control – frequency and travel / rotation speed can be adjusted (picture shows maximum sludge level at position 6000)
- Distributing the sludge over the width of the solar dryer at the feed side
- Sludge transport

- Increased storage capacity

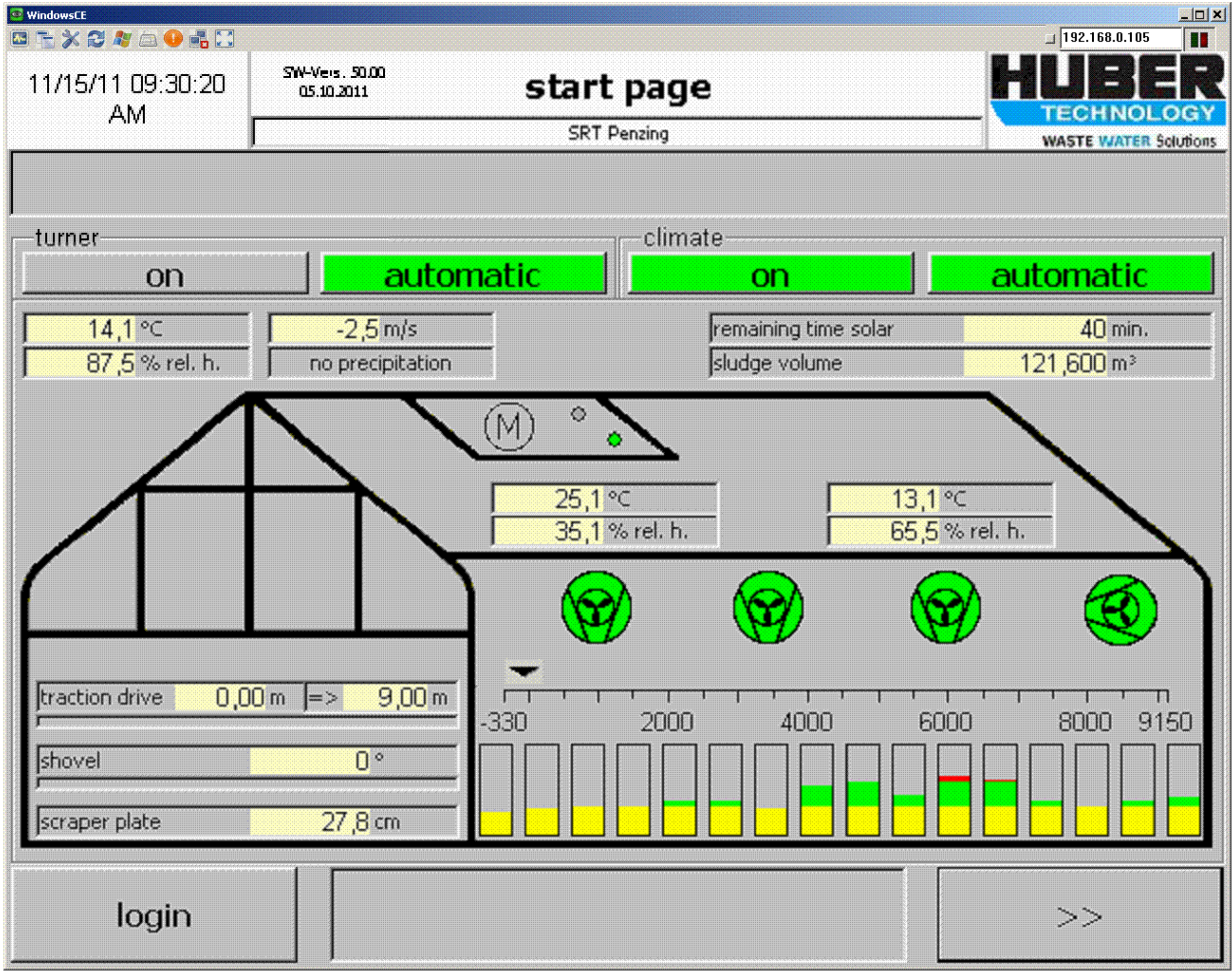

Figure 14: main page – HMI

The solar dryer operation is mainly developed to ensure the material will reach the desired moisture content at the end of the solar dryer. There are different ways to get to this point and the high flexibility of the SRT system allows a huge variety of combinations.

The height of the sludge across the length of the dryer can be set to maximum 10 inches. The sludge height would increase with the progress of the drying process. The speed adjustments allow a much higher sludge loading capacity – which is very important during summer. The operation needs to be adjusted to ensure optimum use of the high solar radiation.

The capacity of the system is determined by the maximum speed and conveying capacity of the turning device which also puts a limit to the maximum length of the greenhouse. The main factor for the design is still the available energy from the sun: solar radiation. The available heat BTU/sft/d determines the maximum evaporation rate of the system. The meteorological conditions are also driving the control system (determined by a weather station loacted at the top of the greenhouse):


Figure 15: weather station

The following parameters are monitored and sent to the control unit of the solar dryer:

- Actual wind speed
- Ambient temperature
- Humidity

These data together with the internal conditions at the dryer (temperature and humidity) unit are the driving factors for the operation.

The data are collected at the PLC and whenever the limits are reached the system adjusts the operation accordingly:

- Open/closes the roof vent
- Turns on/off the fresh air intake
- Operates the circulation fans

The system runs on a patented “climate control” sequence which ensures the maximum evaporation rate and most efficient drying process.

Supplemental heat

Unfortunately the most scientific and sofisticated control system does not help a solar dryer to do its work, if the available radiation is too low. The only way to improve the performance during times with low solar energy is the use of supplemental heat.

The solar drying process is a “green” technology and favors a carbon neutral process. As already indicated the system has a very low energy demand (electrical power). Therefore it does not make sense to use primary energy like natural gas to provide additional heat.
The use of other carbon neutral sources is prefered:

- Heat from co-generation units, running on biogas (anaerobic digester)
- Waste heat from existing plants (power plants or other industrial facilities)
- Solar (might be not an option because solar energy is low when supplemental heat is required, makes only sense if huge areas are available. In this case the installation of more solar dryer lines might be the better option)
- Sewage / plant effluent as heat source

The co-generation units are a well established technology – the heated water can be introduced into the system by means of radiators or most efficiently through a floor heating system.

The latter one is also the prefered scenario when using the sewage as a heat source. The sewage system provides all year a very consistent temperature level – which can be used for heating purposes. The recent developed RoWin turns the sewage into a “green” energy source.

Figure 16: RoWin

The RoWin is a heat exchanger suitable for sewage: screened sewage is pumped to the equipment and the heat is transferred to a medium circulating inside of the heat exchanger. The temperature of the sewage drops by 2 – 3 K and is returned to the sewage system. The heat transfer medium feeds a heat pump which generates the hot water for the floor heating. These heat pumps are well know and used for cooling and heating of buildings and appartments. They just rely on a suitable energy source and this is where the RoWin steps in and makes a huge amount of energy available.

This system can be used not just for solar drying, its potential is reaching out to:

- Industrial applications
- Office buildings
- Appartment complexes

- Hotels, resorts
- and many more

The design for a solar dryer can be based on the minimum flow and the temperature levels.

Conclusion

The Huber solar dryer SRT is designed around the major goal to provide the most flexibility in installation and operation. The SRT utilizes commercial greenhouses as any other solar dryer system. The outstanding features are the flexibility in feeding and discharging the material. It allows the most economic solar dryer design and can help to utilize the available space in its most functional way. The design of the controls and their basic philosophy were described and underline the high flexibility of the system.