DSH
DIGITAL SOLAR HEAT

WHITE PAPER: NEW SOLAR HEATING SYSTEM WORKS IN CANADIAN CLIMATES

A 5 YEAR DATA MODELING ASSESSMENT FOR A 5,000 SQFT WAREHOUSE IN CALGARY, ALBERTA.

COMPLETED JULY 2020

ABSTRACT

Introduction by M/Dir of Digital Solar Corp.

DSH have been heating buildings using solar energy and interseasonal storage since 2004. The system was recently redesigned and patented in 2017 to now function in Alberta, Canada.

Early in 2020, Digital Solar Corp, on the guidance of the NRC (National Research Council), commissioned TESS (Thermal Energy System Specialists), an offshoot of the University of Wisconsin, to model a full scale, arm's length, 3rd party modelling of the DSH system performance. The requested modelling time frame was 5 years, focusing on the expected thermal performance of the DSH system in the cold climate of Calgary, Alberta, Canada.

The brief was simple, DSH provided a typical DSH equipped 5,000SqFt (464.5 M2) warehouse design that also included a front office to be kept at a higher temperature. The geographic location chosen for the modelling was Calgary, Alberta, due to its reasonable consistent insolation, and it's extreme cold winters.

5 Years of modelling was chosen specifically because the massive TES (Thermal Storage System), takes significant time initially to come to a reasonable thermal storage level. Performance improves over the first few years. It can be compared to turning on a kettle: at first nothing seems to happen, then it starts to come up to temperature.

Initially TESS came back with a long list of question that drilled down into the DSH system design in this environment. These question were solid indications of the depth the assessors were going to, to model the system.

Interestingly, the DSH solar collectors perform well even at -30c, adding to the overall performance in all seasons. In the case of the assessed 5,000SqFt design, given the results, DSH feels it could have increased the number of collectors to provide closer to 99% of interseasonal heating and hot water without risking the integrity of the TES..

As you will see, and what follows are the truly impressive results of the modelling.

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OVERVIEW

In the spring of 2020, Thermal Energy System Specialists, a Madison WI USA based consulting company that specializes in detailed energy modeling and simulation, analyzed an innovative solar seasonal storage design proposed by Digital Solar Heat for a warehouse/office building in Calgary, Alberta.

The design features evacuated tube solar collectors that capture solar energy and can either directly feed a radiant floor heating system embedded in the slab of the building or store the heat in the soil below the slab for use at a later time. Detailed study of the collection, distribution, and storage systems, along with the controls to run the systems, shows that the system holds great potential for efficiently meeting the heating needs of the building in the harsh Calgary winter conditions.

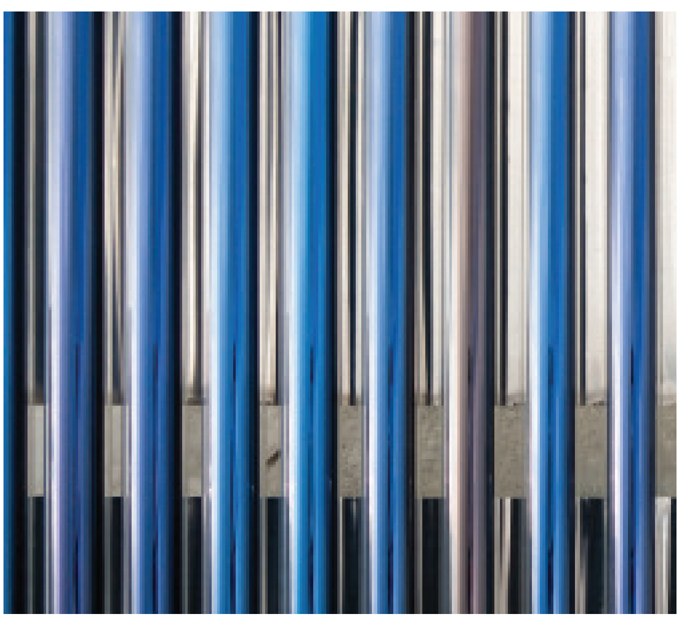
ANALYSIS

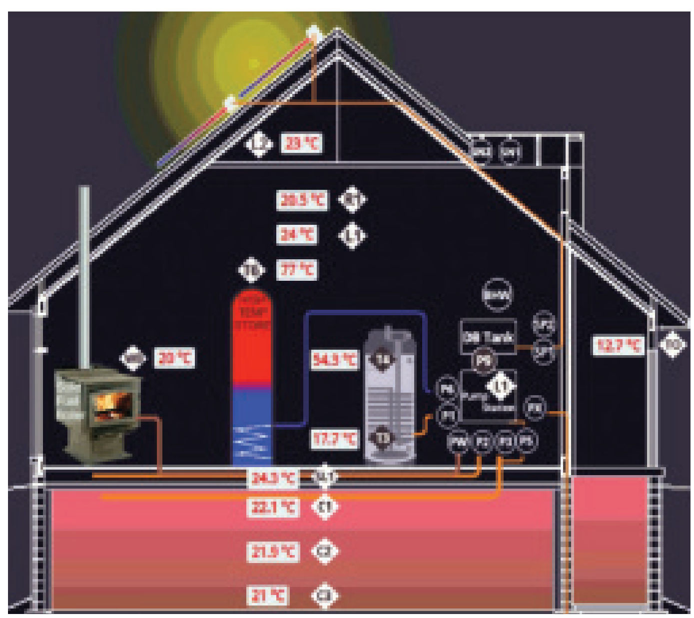
To study the performance of this system, a detailed system simulation was created in the TRNSYS simulation software. TRNSYS is an excellent tool for this analysis and features fundamental models of the collectors, pumps, pipes, building, controls, heat exchangers, and the soil storage system. These components are connected together in the simulation program much like the real system is connected together via pipes and wires.

TRNSYS then simulated this design at 3-minute time steps for a period of 5-years to evaluate the transient performance of the system.

CATEGORY	YEAR 1 ENERGY (KWH)	YEAR 5 ENERGY (KWH)
Solar Heat Transferred to the Storage/ Distribution System	118,100	113,900
Distribution Pipe Losses	7,200	8,000
Auxiliary Energy Added	28,900	9,900
Soil Storage Losses/Energy Storage	71,300	50,500
Heating Load Met	69,000	65,800
Pump Energy to Loop	500	400

Load Met by Solar	58%	85%
Efficiency of Soil Storage (Out/In)	33%	50%



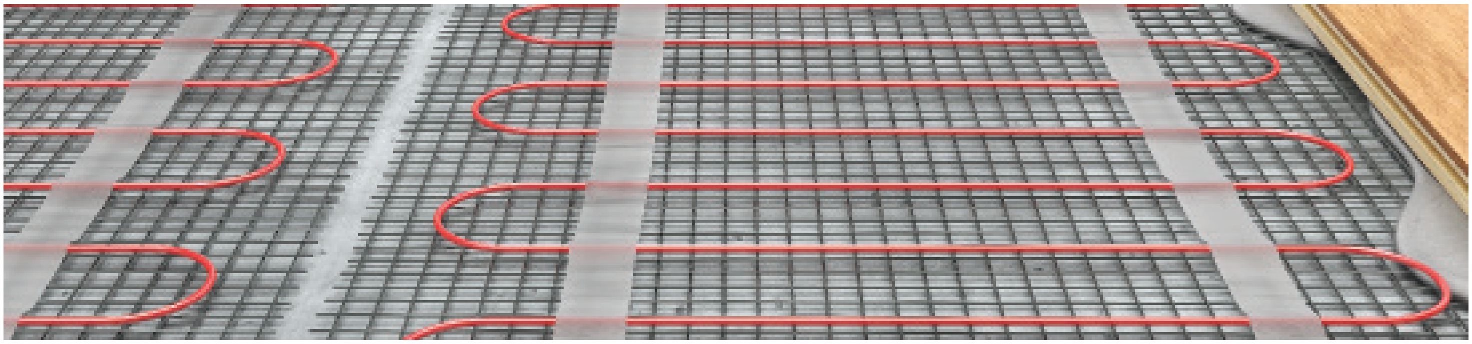


WHAT IS A DSH SYSTEM

The concept behind the Digital Solar Heat system is pretty simple; use efficient solar thermal collectors to convert incident solar radiation into useful heat for the target building. But the issue for many parts of the world is that the solar radiation is highest during the warm summer months when building heat isn't needed and the lowest during the cold winter months when the heat is needed. This seasonal imbalance makes many standard solar thermal heating systems ineffective for many projects. The trick then becomes to efficiently collect and STORE the excess solar energy during the spring, summer, and fall months and then retrieve it throughout the winter when it is most needed.

While this sounds simple to do, storage of large amount of thermal energy can be a very difficult task – often resulting in huge amounts of contained water or expensive chemical storage solutions. The innovative Digital Solar Heat solution is to use the soil UNDER the building to store the excess solar energy for later retrieval. Solar heat storage in the ground isn't unique and has been used successfully in many large projects around the world. But relatively few small-scale systems have shown promise due to the inefficiencies of the ground to store the heat.

With very cold soil common to most heating dominated climates, most of the heat stored in the summer in small systems is lost over the course of several weeks or months and nothing useful is left when the winter heating season begins. What little energy is left is then difficult to get back out of storage at a rate which allows it to be used to meet the peak heating demands of the building. The key then to the whole problem is to collect the heat efficiently, store the heat efficiently, and then be able to retrieve it quickly enough to meet the load and avoid using the auxiliary heating devices.



THE MODELING

The design from Digital Solar Heat that we studied utilizes a thick layer of insulation located just below the building slab (to keep the heat out of the building in the summer), a layer of insulation at the depth of the footers (used to keep the heat from dissipating out the bottom of the soil storage), and a layer of vertical insulation along the sides of the building (to keep the heat from leaving through the sides of the storage). In effect this creates an insulated soil storage "box" in which the solar heat is stored. To get the heat into and out of the soil storage, a network of buried pipes are embedded throughout the soil in two layers of piping. The building for this study has a 373 square meter warehouse area and a 62 square meter office space – both contained within the rectangular footprint of the building.

Evacuated tube solar collectors collect the solar heat and these collectors were chosen as they are more efficient than standard flat plate collectors at the low ambient temperature conditions common to Calgary. For this project, approximately 208 square meters of collectors were installed on the roof of the building. These collectors face due south and are sloped at 45 degrees to maximize the annual incident solar radiation. A glycol solution is pumped through the collectors and the heat is transferred to the storage/distribution loop through the use of external heat exchangers. During periods when the building is not calling for heat, the solar heated fluid is pumped into the soil storage piping network and slowly raises the temperature of the surrounding soil storage.

CANADIAN CITY	AVERAGE INSOLATION LEVEL
Calgary	5.5
Kamloops	5.2
Saskatoon	5.8
Ottawa	5.0
Fredricton	4.7
Whitehorse	4.8

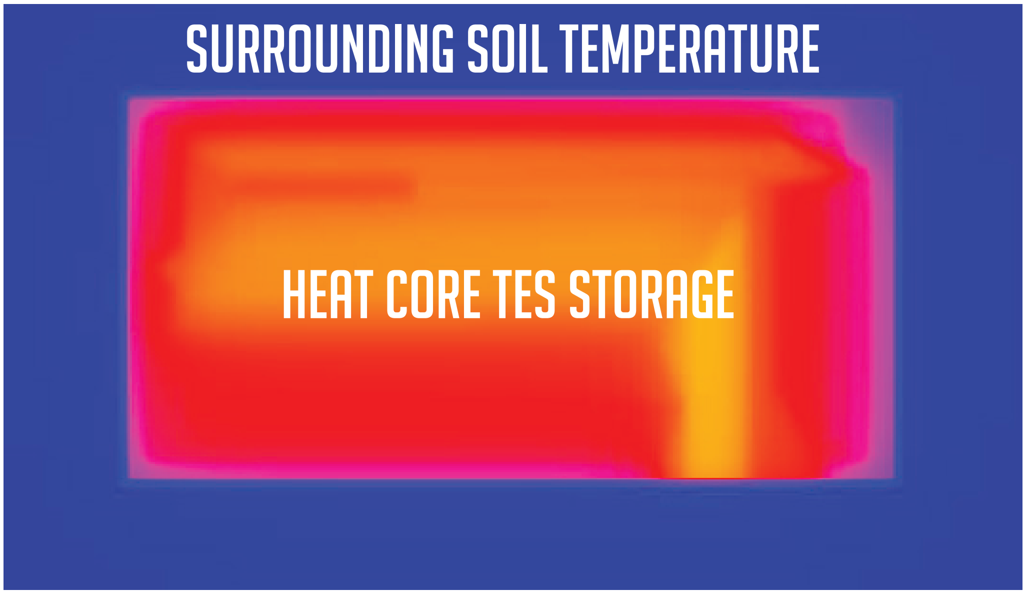
High °F	Low °F		High °C	Low °C
32	12	January	0	-11
29	9	February	-2	-13
39	19	March	4	-7
51	29	April	10	-2
62	39	May	17	4
69	47	June	20	8
75	52	July	24	11
74	50	August	23	10
64	42	September	18	5
53	31	October	11	-1
38	18	November	3	-8
30	11	December	-1	-12
51	30	Year	11	-1

When the building is calling for heat, and solar energy is being collected, the heated fluid is directed to the radiant floor heating system in the building. When the building is calling for heat but there is not active solar collection, return fluid from the floor heating system is either sent to the soil storage to retrieve some of the energy stored in the soil, or heated with an auxiliary gas heating device if the soil storage cannot supply the energy necessary to heat the building. It's important to note that it might take a year or more for the soil storage to become fully charged and enter into a steady-periodic condition.

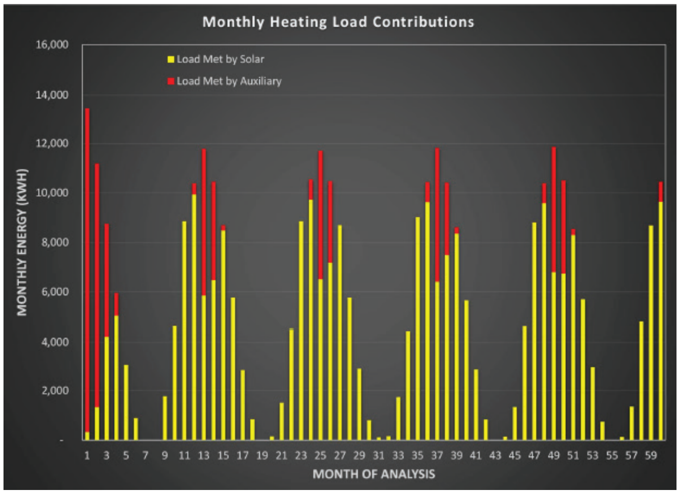
SUMMARY

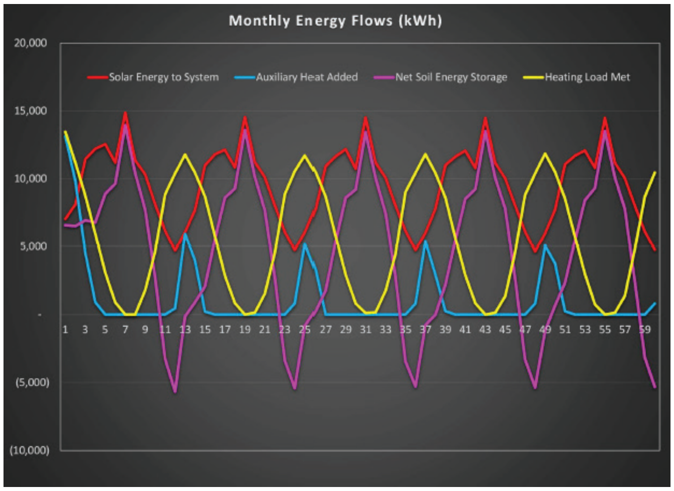
Overall we found that the Digital Solar Heat design for the Calgary warehouse does an admirable job of meeting the heating load using solar energy and seasonal storage. The Digital Solar Heat design features relatively large up-front costs for the collectors, insulation, and piping installation but has very low operating costs (just pumps and a little bit of auxiliary heat) compared to low up-front costs and much higher operating costs for standard heating technologies. In the end, economics and near zero operating carbon emissions will ultimately determine if this design can compete against incumbent heating technologies.

% OF HEATING MET BY THE DSH SYSTEM	
Year 1	58%
Year 2	82%
Year 5	85%



GRAPHS


Monthly Heating Load Contributions
Load Met by Solar
Load Met by Auxiliary
MONTHLY ENERGY (KWH)
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
-
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53 55 57 59
MONTH OF ANALYSIS


Monthly Energy Flows (kWh)
Solar Energy to System
Auxiliary Heat Added
Net Soil Energy Storage
Heating Load Met
20,000
15,000
10,000
5,000
-
(5,000)
(10,000)
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53 55 57 59