ETV Test Plan
SolarVenti SV14

Danish Technological Institute
Refrigeration and Heat Pump Technology
J.no. 1201
Test no. 1 – Type-test

1. Table of Contents

2. Introduction

Environmental technology verification (ETV) is an independent (third party) assessment of the performance of a technology or a product for a specified application under defined conditions and quality assurance.

DANETV is a Danish center for the verification of environmental technology.

This test plan is the implementation of a test design developed for performance verification of an environmental technology according to the ETV method.

2.1. Verification Protocol Reference

J.no 1201 – SolarVenti - Verification Protocol

2.2. Name and Contact of Vendor

SolarVenti A/S
Attn: Hans Jørgen Christensen
Fabriksvej 8,
DK-8881 Thorsø
Phone:+45 86 96 67 00
E-mail: hjc@solarventi.dk

2.3. Name of centre/test responsible

Verification Center: Danish Technological Institute, Refrigeration and Heat Pump Technology, Building 2, Gregersensvej, DK-2630, Taastrup.

Verification responsible: Emil Jacobsen (EMJA), e-mail: emil.jacobsen@teknologisk.dk
Phone: +45 7220 2323

Internal reviewer: Bjarke Paaske (BJPA), e-mail: bjarke.paaske@teknologisk.dk
Phone: +45 7220 2037

2.4. Expert Group

The expert group assigned to this verification and responsible for review of the verification plan and report documents includes:

Simon Furbo (SF), DTU Civil Engineering, phone +45 45251857, e-mail: sf@byg.dtu.dk

3. Test Design

The DANETV solar air heater test is developed with the specific aim of making the test results as applicable, transparent and comprehensible as possible for the intended end user/homeowner/buyer.

Even though the EN 12975 standard for testing liquid heating collectors exits, this standard mainly deals with the robustness and thermal effectiveness of liquid heating collectors. Therefore, it is not applicable for open loop solar air heaters. Other previous tests of open loop air heaters, mainly centered on the effectiveness of the air heater, are very technical and not directly applicable for the intended end user/homeowner. Therefore, the DANETV test focuses on the verification of the vendor claims. The vendor claims are often related to energy savings, improved ventilation, improved indoor climate, or the like.

Furthermore, in order to give a better idea of how the solar air heater performs in an actual setting, a test rig has been built to simulate real running conditions comparable to those present when the air heater is mounted vertically on the side of a house or a garage. Establishing the actual performance characteristics of the air heater has a great advantage over laboratory tests with forced ventilation through the solar air heater as the fans are known to be very sensitive to pressure losses, both related to the heater itself and the downstream hot air channel. Tests performed on different models and makes are comparable by means of calculations based on data from the test rig and on regional climate data (design reference year data). Further information about the test, test rig and calculations can be found in Appendix 4 – In-House Test Methods.

This above mentioned test is done in order to verify the following target and effect(s):

The target of the product is:

- Supplementary heating and ventilation of summer houses, garages, etc.

The effect of this application is primarily:

- Improved indoor climate in unheated humid buildings

3.1. Test Site
The performance tests are carried out at an outdoor solar energy test site at Danish Technological Institute in Taastrup, Denmark.

3.2. Type of Site
The solar energy test site at Danish Technological Institute in Taastrup is a site used for various solar energy related field tests as well as for research and development. The site has a south facing facility building which is shade free year round.

3.3. Addresses
The address of the site is:
Danish Technological Institute, Refrigeration & Heat Pump Technology,
Gregersensvej, DK-2630 Taastrup

3.4. Descriptions
Open loop solar air heaters are characterized by simple devices which require very little or no maintenance. They usually consist of three major parts:
1) Either a cabinet with a translucent cover or a fixture with a heat pipe array
2) A solar cell
3) A ventilator with or without a temperature regulated controller

When the solar cell powers the ventilator, cold outdoor air is driven through air channels which are irradiated, whereby the air is heated. Subsequently, the heated air is channeled into the summer house or garage whereby it is ventilated, heated, dried, or a combination these (see Figure 1).
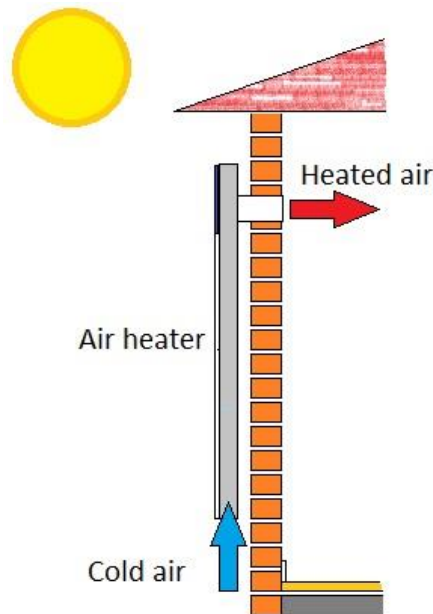
Figure 1 - drawing depicting the function of a solar air heater, the actual design may differ from the drawing.

3.5. Tests

3.5.1. Test Methods

The solar air heater is tested for compliance with manufacturer claims such as ventilation and dehumidification capacity, air temperature rise, and heat output under various operation conditions. Results from the tests are compared with manufacturer claims for input in a simulation model that quantifies the actual effects in relation to a normal year (design reference year) in a selected climatic region.

The test rig consists of a large sheet of plywood, where the solar air collector can be mounted the same way it would be mounted on the side of an actual building. A solar pyranometer and a shaded outdoor air temperature sensor are mounted next to the mounted solar air heater. Behind the plywood, a measurement channel connected to the solar air heater exhaust with (in the direction of the flow) a hot air temperature sensor, an air rectifier, and a flow velocity sensor is placed. The measurement channel is dimensioned in a larger diameter pipe than the exhaust channel in order to negate any flow induced pressure losses that would not be present under normal use of the solar air heater.

All relevant data from temperature sensors, etc. is logged with a data acquisition unit with a sampling interval ≤ 30 seconds.
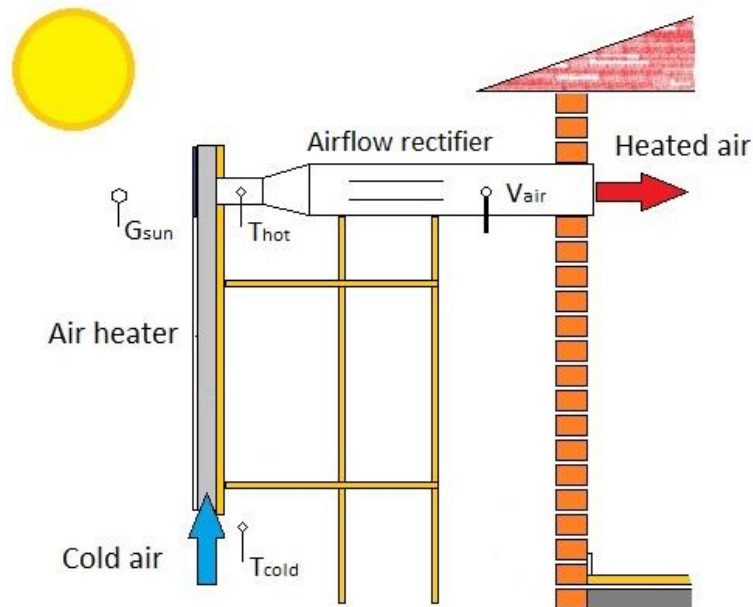
Figure 2 - Drawing depicting a solar air heater mounted in a test rig and the placement of various sensors; heated air temperature, T_{hot}, cold air temperature, T_{cold}, air velocity, V_{air}, and G_{sun}.

Once a suitable dataset[1] is logged, the different performance parameters are calculated by means of the following:

Volume Flow:

Please note: preferably a calibration should be done with a forced flow, a flow transducer and a positive displacement flow meter, i.e. a rotary vane meter, to establish a correlation between the volume flow and flow meter reading. Alternatively, the following approximating formula can be used for turbulent flows (Re > 4000):

$$\dot{V}_{air} = \frac{A_{cross,pipe}[m^2]}{V_{air}[m/s]}$$

Where:

A_cross,pipe   Cross sectional area of the pipe
V_air   Air velocity

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[1] See Appendix 4

Heat Output:

$$\dot{q} = \dot{V}_{air} \cdot \rho_{air} \cdot C_p \cdot (T_{hot} - T_{cold})$$

Where:

$\dot{V}_{air}$	Air volume flow [m^3/s]
ρ_{air}	Air density [kg/m^3]
C_p	Specific heat capacity of air [J/(kg·K)]
T	Outdoor and hot air temperatures

Using either volume flow measurement method, temperature corrections for air density and specific heat capacity should be applied as necessary.

For further details see Appendix 4 – In-House Test Methods.

Dehumidification:

The dehumidification capacity is calculated using simulation software BSim. The model calculates the changes in humidity in a defined control volume using an iterative calculation method on absolute moisture content of a defined control volume. Based on the new relative humidity of the air, equilibrium between the air and building materiel is generated which leads to a humidifying or a dehumidifying of the building material. This calculation is made for each room of the house on an hourly basis based on the outside temperature, house temperature, infiltration, ventilation and other relevant parameters. This results in a monthly average relative humidity as well as a moisture content of the building material.

3.5.2. Test staff
The test staff is:
Emil Jacobsen	Sampling and reporting
Ivan Katic	Head of laboratory

3.5.3. Test schedule
The test is planned for 2011/2012. The overall schedule is given in Table 1

Table 1 - Test schedule

Task	Timing
Application definition document	Oct. 2011
Verification protocol with test plan	Feb. - Apr. 2012
Test	March 2012
Test reporting	April 2012
Verification	April 2012
Verification report	April 2012
Verification statement	April 2012

3.5.4. Test equipment

The test equipment includes:

Air Heater
- Temperature sensors for the measurement of ambient air and heated air
- Hotwire anemometer for the calculation of air volume flow
- Pyranometer for the measurement of solar irradiation

All data is collected with a data acquisition unit with a sampling interval ≤ 30 seconds.

3.5.5. Operation Conditions

During operation, the air heater controller is adjusted to highest/warmest setting (if present/applicable)

3.5.6. Operation Measurements

The system was operated under various conditions before the performance test in order to ensure that everything worked correctly. Data collection from all measuring equipment was evaluated in order to check that the system was running as planned.

3.5.7. Test Matrix

The methods described in Appendix 4 - In-house test methods and Appendix 5 -In house data processing were applied during the test.

3.5.8. Product Maintenance

No maintenance was required for the testing of the product.

3.5.9. Health, Safety and Wastes

The use of this product does not imply special health, safety and waste issues. Work during testing complied with the general rules regarding safety at Danish Technological Institute.

4. Reference Analysis

4.1. Analytical Laboratory

No external analytical laboratories were used for this verification process. All measuring and data processing were executed by the test staff at Danish Technological Institute.

The test subbody was responsible for the following:

- That the performance test was carried out according to the test plan
- That the data processing was carried out according to the methods described in the test plan
- That adequate internal reviews were performed on both test setup and data processing
- That all procedures were carried out according to the Centre Quality Manual

4.2. Analytical Parameters

The parameters processed to verify the effect of the product were:

Air Heater:
- Ambient temperature and air heater outlet temperatures, T_{amb} and T_{out}
- Air velocity of air through outlet channel, v_{out}
- Solar irradiance planar to the air heater, G

4.3. Analytical Methods

Data related to the performance of the air heater were processed according to the description in Appendix 5 – In-House Data Processing.

4.4. Analytical Performance Requirements

A specially designed Excel spreadsheet file was used to calculate the performance of the measured parameters related to the air heater. Due to the large number of different measurement series, thorough reviews were performed as described in Appendix 5.

5. Data Management

5.1. Data Storage, Transfer and Control

The data to be compiled and stored are summarized in table below. Analytical raw data were filed and archived according to the specifications of the quality management system.

Data type	Data media	Data recorder	Data recording time	Data storage
Test plan and report	Protected PDF-Files	Test responsible	When approved	Files and archives at TI
Log files	In-house file format	Technician, TI	During collection	Files and archives at TI
Calculations	In-house application / excel file	Test responsible	During calculation	Files and archives at TI
Final result and verification report	Protected PDF-files	Test responsible	After testing	Files and archives at TI

6. Quality Assurance

6.1. Test Plan Review

Internal review of the test plan is made by Bjarke Paaske (BJPA).
External review of the test plan was made by the expert stated in chapter 2.4.

6.2. Performance Control

The appliance was thoroughly tested for functioning before the verification tests were initiated.

6.3. Test System Control

Test and measuring equipment was checked against references or calibrated to ensure accurate values as described in Appendix 4 – In-House Test Methods. This was done prior to the testing and no intermediate check or calibration was necessary throughout the test period.

6.4. Data Integrity Check Procedures

All data transfer of both handwritten and electronic data was subjected to 100 % control by a second person.

Approved spread sheets and calculation programs for calculation of results were subjected to 100 % control to ensure correct calculations and results.

Data input in spread sheets and calculation programs was subjected to 100 % control in order to secure correct calculations and results.

6.5. Test System Audits

No audit was performed

6.6. Test Report Review

Internal review of the test report was made by Bjarke Paaske (BJPA).
External review of the test report was made by the expert stated in chapter 2.4.

7. Test report

The test report will be included as an appendix in the verification report. The test report will contain the test plan except for this chapter which will be replaced by a Test result chapter according to the DANETV Centre Quality Manual, including 7.1 Test performance summary, 7.2 Test measurement summary, 7.3 Test quality assurance and 7.4 Deviations from test plan.

Appendix 1 Terms and Definitions used in the Verification Protocol

Terms and definitions used in the protocol are explained in table 1:

Table 1 - Terms and definitions used by the DANETV test centers

Word	DANETV	Comments on the DANETV approach
Analytical laboratory	Independent analytical laboratory used to analyze test samples	The test center may use an analytical laboratory as subcontractor
Application	The use of a product specified with respect to matrix, target, effect and limitations	The application must be defined with a precision that allows the user of a product verification to judge whether his needs are comparable to the verification conditions
DANETV	Danish center for verification of environmental technologies	None
(DANETV) test center	Preliminary name for the verification bodies in DANETV with a verification and a test subbody	Name will be changed, when the final nomenclature in the EU ETV has been set.
Effect	The way the target is affected	The effect could be reduced energy consumption, better cooling performance etc.
(Environmental) product	Ready to market or prototype stage product, process, system or service based on an environmental technology	The product is the item produced and sold, i.e. the item that a vendor submit for verification
Environmental technology	The practical application of knowledge in the environmental area	The term technology covers a variety of products, processes, systems and services.
Evaluation	Evaluation of test data for a technology product for performance and data quality	None
Experts	Independent persons qualified for the technology in the verification	These experts may be technical experts, QA experts for other ETV systems or regulatory experts

Word	DANETV	Comments on the DANETV approach
Matrix	The type of material that the product is intended for	Matrices could be cooling systems, cabinets, heat exchangers, etc.
Method	Generic document that provides rules, guidelines or characteristics for tests or analysis	An in-house method may be used in the absence of a standard, if prepared in compliance with the format and contents required for standards.
Performance claim	The effects foreseen by the vendor on the target(s) in the matrix of intended use	None
Performance parameters	Parameters that can be documented quantitatively in tests and that provide the relevant information on the performance of an environmental technology product	The performance parameters must be established considering the application(s) of the product, the requirements of society (regulations), customers (needs) and vendor claims
Procedure	Detailed description of the use of a standard or a method within one body	The procedure specifies the implementation of a standard or a method in terms of e.g.: equipment used
Producer	The party producing the product	None
Standard	Generic document established by consensus and approved by a recognized standardization body that provides rules, guidelines or characteristics for tests or analysis	None
Target	The property that is affected by the product	Targets could be temperature [° C], energy [kWh], etc.
Test center, test subbody	Subbody of the test center that plans and performs tests	None
Test center, verification subbody	Subbody of the test center that plans and performs the	None

Word	DANETV	Comments on the DANETV approach
	verification	
Test/testing	Determination of the performance of a product for parameters defined for the application	None
Vendor	The party delivering the product to the customer	Can be the producer
Verification	Evaluation of product performance parameters for a specified application under defined conditions and adequate quality assurance	None

Appendix 2 References
(verification protocols, requirement documents, standards, methods)

1. DANETV. Center Quality Manual, 2008

2. EN 12975-2:2006 Thermal solar systems and components - Solar collectors - Part 2: Test methods

3. DTU (2007): Effektivitet af luft/væskesolfanger, ISSN 1601-8605

4. By og Byg Anvisning 204 – Undersøgelse og vurdering af fugt og skimmelsvampe i bygninger (Investigation and Assessment of Humidity and Mold in Buildings)

5. SBi anvisning 224 – Fugt i bygning (Humidity in Buildings)

Appendix 3 Application and Performance Parameter Definitions

This appendix defines the application and the relevant performance parameters application as input for the verification and test of an environmental technology according to the DANETV method.

A3.1   Applications

A3.1.1   *The matrix is the type of material which the product is intended for.*

-    Residential houses up to 70 m^2

A3.1.2   Target(s)

A target is defined as the property affected by the product

The target of the product is:

-    Supplementary heating and ventilation

A3.1.3   Effects

The effect of this application is primarily:

-    Improved indoor climate in unheated humid buildings

Appendix 4 In-House Test Methods

The DANETV solar air heater test is developed with the specific aim of making the test results as applicable, transparent and comprehendible as possible for the intended end user/homeowner/buyer.

Even though the EN 12975 standard for testing liquid heating collectors exits, this standard mainly deals with the robustness and thermal effectiveness of liquid heating collectors. Therefore, it is not applicable for open loop solar air heaters. Other previous tests of open loop air heaters, mainly centered on the effectiveness of the air heater, are very technical and not directly applicable for the intended end user/homeowner. Therefore, the DANETV test focuses on the verification of the vendor claims. The vendor claims are often related to energy savings, improved ventilation, improved indoor climate, or the like.

Furthermore, in order to give a better idea of how the solar air heater performs in an actual setting, a test rig has been built to simulate real running conditions comparable to those present when the air heater is mounted vertically on the side of a house or garage. Establishing the actual performance characteristics of the air heater has a great advantage over laboratory tests with forced ventilation through the solar air heater as the fans are known to be very sensitive to pressure losses, both related to the heater itself and the downstream hot air channel. Tests performed on different models and makes are comparable by means of calculations based on data from the test rig and on regional climate data (design reference year data).

Type-Testing Procedure

The following tests are to be carried out by an independent ISO 17025 testing laboratory. One sample of the appliance to be tested is required for testing.

Test 1: Assessment of the User Manual

The assessment of the user manual is made as follows:

Step 1: Unpack the product. Using the manufacturer's installation instructions only, set up the system components in the test rig. Record any deviation problems encountered.

Step 2: Check if the instructions cover the following topics:

- Intended use
- Product installation
- Product operation
- Function test
- Prevention of accidents
- Service and maintenance

Acceptance criteria:
Setup must be straightforward and trouble-free. Moreover, the instructions should as a minimum cover the topics listed in step 2.

Test 2: Solar Air Heater Performance Test

Step 1: If not already mounted in the test rig; mount the solar air heater making sure that there is a snug fit between the air heater outlet and the test rig measuring pipe (Figure 1).
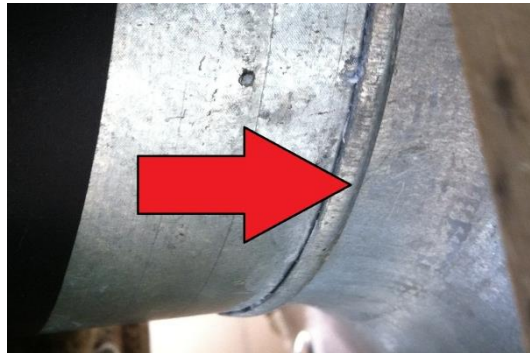

Figure 1 - Snug fit in the transition between air heater outlet and measuring pipe

Step 2: 1) Make sure that no shadows will affect any part of the solar air heater and check if the pyrometer is coplanar to the surface plane of the solar air heater. 2) Check the placement of both the outside air temperature probes and the temperature probe in the measuring pipe. 3) Visually inspect the hotwire anemometer making sure that it is centered correctly in the measuring pipe and that no debris is trapped in the proximity of the hotwire (Figure 2).

Figure 2 - Visually inspect the hotwire anemometer

Step 3: Prepare the data logger and name the file to be logged with the following format: [*<vendor name><run number X>.*txt]

Step 4: After checking all instrument and data logger connections, record the following parameters every 10 seconds or less continuously throughout an entire day (from sunrise to sunset) with cloudless skies:

- Ambient temperature and air heater outlet temperatures, T_{amb} and T_{out}
- Air velocity of air through outlet channel (measuring pipe), v_{out}
- Solar irradiance planar to the air heater, G

Step 5: Process data according to Appendix 5 – In-house data processing.

Data acceptance criteria:

Due to the thermal mass of the solar air heater and the thermal properties caused thereby, data will only be useable if no major fluctuations in the solar radiance were observed during the data collection (Figure 3). Alternatively, discard data 20 minutes after a minor radiance fluctuation (Figure 4).
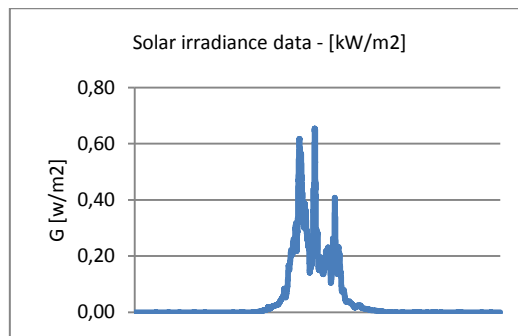

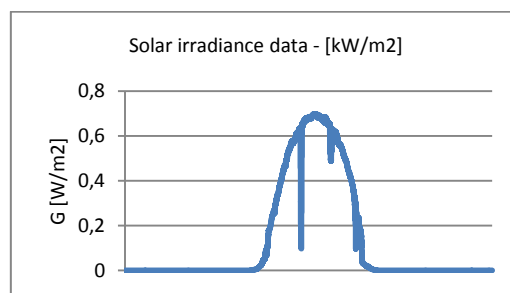Figure 3 - Data showing too many fluctuations in order to be usable - Discard everything.

Figure 4 - Data showing only minor fluctuations. Can be used after careful data processing

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Appendix 5 In-House Data Processing

Data Processing - Solar Air Heater Performance Test

The data processing consists of two separate workflows, which are linked together for a final result:

1. Collecting data and constructing a mathematical function/curve fit describing the temperature rise and volume flow relative to the measured solar radiation

2. Calculate the relevant performance parameters for heating, ventilation and dehumiditation using the previously established curve fits for temperature rise and volume flow and a prepared calculation sheet

1. Collecting Data and Constructing a Mathematical Function/Curve Fit

Raw Data

The raw data material consists of a named text file with time-stamped series of logged temperature, irradiation, and flow measurements:

[*<yyyy-dd-mm><vendor><run number X>.*txt]

The raw data file is imported to Microsoft Excel using the Excel file import dialog discarding the preamble (line 1-99) and defining the original file as a "Windows (ANSI)" file .
The imported data file is then named [*<vendor name>.*xls] and saved as a workbook

Data Preparation

A. If data is collected over a period of several days, data from each subsequent measuring day is cut and pasted into different worksheets within the same workbook. Each sheet is then named [*<yyyy-dd-mm><vendor>*] to clearly identify the different measuring days.

B. Using the principle outlined in Appendix 4 - In-House Test Methods, step 5, find the best suitable dataset using Excel's graphing function on column "E" (containing solar irradiance measurements)

C. The worksheet containing the best suitable dataset is kept, and the rest is discarded.

D. Columns (B:B) to (E:E) and (H:H) are averaged on a 10 minute basis and the analytical parameters are calculated in separate columns according to Test plan section 3.5.1.

E. Calculate a temperature rise in another column using to the 10 minute averaged in- and outlet temperatures using a simple subtraction formula.

Curve Fit - Temperature Rise vs. Solar Radiation

Using Excels graphing function, a XY (scatter) chart is created and a nth degree polynomial regression fit is applied, as illustrated in Figure 3, to the calculated and averaged data for temperature rise and solar radiation.

Temperature rise [K]

$$y = 4{,}820E\text{-}10x^4 - 1{,}406E\text{-}06x^3 + 1{,}446E\text{-}03x^2 - 6{,}075E\text{-}01x + 9{,}733E\text{+}01$$
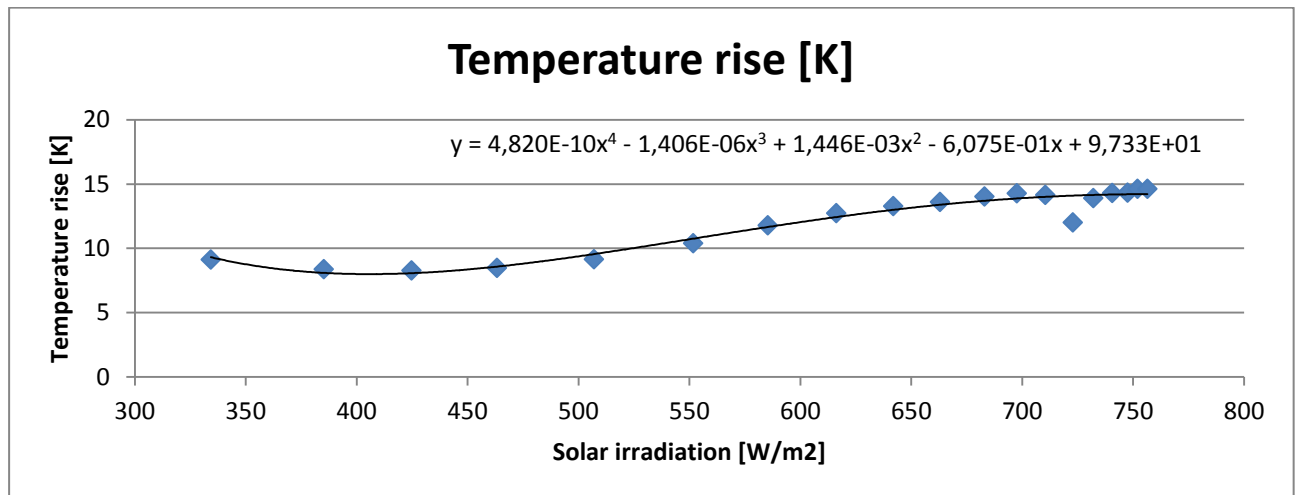
Figure 3 - Example of a 4th degree polynomial regression fit describing the air temperature rise through a solar air heater at a corresponding solar irradiation.

Curve Fit - Volume Flow Rate vs. Solar Radiation

Using Excels graphing function, a XY (scatter) chart is created and a nth degree polynomial regression fit is applied to the averaged data for volume flow rate and solar radiation.

Please note the averaged solar irradiation data point at which the ventilator starts and the highest averaged point for measured solar irradiation.

2. Calculation of Performance Parameters for Heating, Ventilation and Dehumiditation

After having constructed a mathematical function/curve fit describing the solar air temperature rise and volume flow rate, the obtained polynomial is used to model/simulate the solar air heater performance parameter in a reference year in an Excel workbook named "Vent_heat_dry calc.xlsx" prepared in advance using the following procedure:

A. A copy of the the Excel workbook named "Vent_heat_dry calc *<vendor>*.xlsx" is created (where <vendor> is the manufacturer name)

B. Find the DRY-data for Denmark, update column A-D in the excel sheet

C. The averaged solar irradiation data point at which the ventilator starts and the highest averaged point for measured solar irradiation are typed in cells (D:16) and (D:17), respectively (

D. Figure **4**)

E. The exponents corresponding to the nth degree polynomial coefficient and constant describing the volume flow rate are copied directly from the raw data file named

[*<vendor>.*xls] into cells (C:21;I:21)

F. The exponents corresponding to the nth degree polynomial coefficient and constant describing the temperature rise are copied directly from the raw data file named [*<vendor>.*xls] into cells (C:25;I:25)

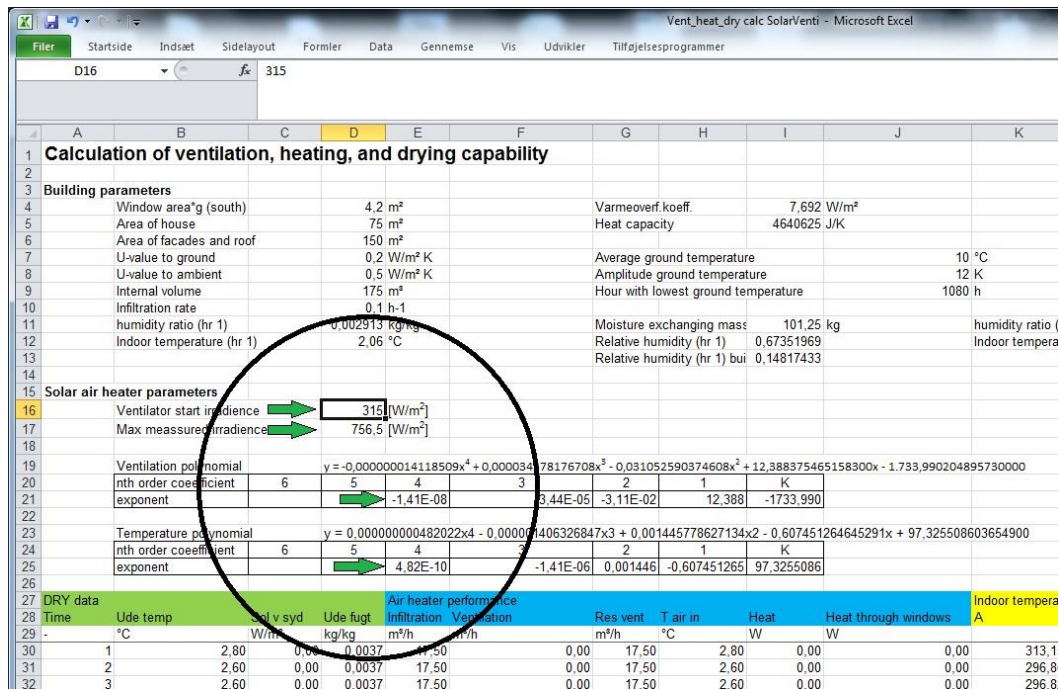G. The calculated performance parameters are read in result cell matrix [Q:13 S:25]

Figure 4 - Screenshot of the prepared calculation workbook for modeling/simulation of a solar air heater's performance parameters in a design reference year.
Green arrows indicate input cells

Humidity Data Processing

The effect to be verified of this DANETV solar air heater test is improved indoor climate in moist summer houses. In order to validate this effect, a model house has been created in the modeling software BSim. A further description of the model house can be found later in this appendix. The data processing is based on the data obtained during the test and calculated in the "Vent_heat_dry calc *<vendor>*.xlsx" sheet. A further description of the tests can be found in Appendix 4.

1) BSim needs input that describe the power supplied by the solar panel. This is calculated using the following equation $P = m \cdot cp \cdot (\Delta T)$; $\Delta T = (T_{outlet\ solar\ panel} - T_{out})$. The values can be found in column I

2) Calculate a monthly average, hour per hour of the mass flow rate and the furnish power from the solar panel

3) Open the Bsim file XXX and implement the mass flow rate and the power furnish by the solar panel in the Bsim program

4) Launch a simulation and recover the relative humidity of the house and the moisture content of the wall layers

5) Compare the results with the file XXX for the relative humidity and the file XXX for the moisture content and evaluate the solar panel effects. These parameters can be recovered by pressing the button file->export ->files->table

Apply this formula for the whole column and then make a monthly average hour per hour. Open the BSIM file XXX and implement the two monthly averages of the mass flow rate and the power furnish in the Bsim program. In order to do this, you should implement the mass flow rate as an infiltration rate, and add this mass flow rate to the natural air infiltration. Please note that the infiltration rate is set up as a volume of the house/hour and not as a volume flow. Enter the values into the schedule, month per month.

The power furnish is implemented as a heating load in the same way as the mass flow rate. Details concerning each step are described below.

Raw Data
The raw data material consists of a named file with time-stamped series of logged measurements with a preamble:

[*<vendor name><run number X>*.txt]

The raw data file is imported to Microsoft Excel using the Excel file import dialog discarding the preamble (line 1-102). The imported data file is named [*<vendor name><run number X>*.xls] and saved as a workbook

Average Hourly Solar Radiance
Using a photovoltaic simulation program[2], the average hourly radiance hitting the solar air heater throughout a reference year can be calculated with the input parameters matching the actual mounting of the air heater in the test rig:

Location/Latitude and longitude: Copenhagen/55°40'34"N 12°34'06"E
Azimuth: 0° South
Tilt angle: 90°

The output consists of a text file (.txt) with a chronological list containing 8760 hours showing the solar radiance hitting the specified location and orientation of the solar air heater throughout an average year.

As for the mass flow rate, the variable from the equation (Appendix 4, temperature rise vs. solar radiation) is replaced by the outside temperature from the DRY weather data.

Bsim Model

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[2] For this verification, PVSYST v. 5.53 is used to simulate the hourly average solar radiation

In order to make calculations and determine the relative humidity rate of a moist house, Bsim simulation software is used. Two simulations are set, one without solar panel and one with the solar panel, in order to compare them and see the effect of the solar panel on the moisture in the summer house.

A house of 60 m², the length of the house is 10 m and the width is 6 m². The house is oriented south.

The different components are defined in the table below and are based on materials usually found in a wooden summer house. All the data described below is contained in the Bsim model. However, to get a further understanding of the model, key elements are listed in the following text.

The top materials correspond to the inner construction:

	Composition	λ [m².k/W]	l [m]
roof	Pine wood PVC Stone wool PVC	2,04	0,10
walls	Pine wood PVC Stone wool PVC Pine wood	2,16	0,11
ground	PVC Stone wool PVC Concrete	2,05	0,237
door	climastop N diamant aluminium	1,2	0,06
windows	climastop N diamant aluminium	1,55	0,06

The house consists of four rooms, including one living room, a bathroom and two bed rooms. The two bed rooms and the bathroom open towards the living room in order to allow a flow of air in the house.

The living room features a sliding window of 3m² oriented south and an entrance door of 2.4 m² oriented north.

The bed room oriented south features a window of 1.4 m² oriented south, and the bed room oriented north features a window of 1.4 m² oriented east. The bathroom features a window of 1.4 m² oriented west.

Three walls are created to represent the trees around the house; on the east, west and south side of the house. Each wall is eight meters tall and eight meters away from the house.

In order to simulate the use of the house, the following people load is implemented. The people load represents the heat and moisture gain which they bring during their occupation

of the house in the summer. Their occupation was considered as a person of normal activity, one weekend a month from September to June and every weekend from July to September, including one full week for each of these months.

The living room is occupied by four persons of 50 % of the time from 8am to 22 pm. The bed rooms are occupied by two persons of 100 % of the time from 22 pm to 8 am. The bathroom is not occupied in this sense.

An infiltration rate was set up to a 5 % infiltration rate of the house volume every hour. In order to simulate a moist house, a moisture load of 0.006 kg/h per m² is added for each room. A schedule was made for winter, spring and summer, where the moisture load was modulated.

After the simulation, the inside temperature of the summer house for each room was recovered together with the relative humidity and the moisture content of one of the wall layers of each room. This simulation is named "simulation without solar panel" and it will be used as a reference.

Hereafter, a simulation is prepared as described at the top of this appendix. Before setting up a new simulation, the power supplied by the solar panel to the house is calculated using the following equation:

$$P(\text{solar panel}) = m*cp*\Delta T$$

With

M: mass flow rate of the solar panel, calculated previously
C_p: heating transfer mass of the air 1.004 J/kg at 20^{0}C
$\Delta T = (T_{outlet} - T_{inside})$ with T_{outlet}: outlet temperature of the solar panel calculated previously
T_{inside}: temperature inside the house, extracted from the previous simulation

Once the power supplied of the solar is found for each hour of the year, a monthly average of the power supply hour per hour is calculated. From June to August, the solar panel is out of function in that extra heating will cause excessive temperatures.

Ventilation (infiltration) and heating from the solar heater is implemented in the BSim model to simulate the effect of the product.

The fact of implementing the mass flow rate and the heat production of the solar panel does not represent a moving flow in the house, since the program does not include this when set up as an infiltration rate. Because of this, a mixing effect between the four rooms is added. This mixing effect is calculated as the average mass flow of air of the solar panel through the year, without considering the period from June to August as the solar panel is not used during this period.

The air mixing is calculated as a function of the area of each room, where 10% of the mass flow rate will be exfiltrated; the 90 % left is used for the mixing into the rooms.

Finally, the relative humidity in the house and the moisture content of the wall layers are extracted as in the simulation without the solar panel. This data is saved as "simulation with solar panel".

Appendix 6 Data Reporting Forms

All data are reported in the prepared Excel spreadsheets and EES Calculation files, as described in appendix 5. Results are collected and commented in the test report.