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WUR measurement methods and results of screen properties

Report WP3 task 2b

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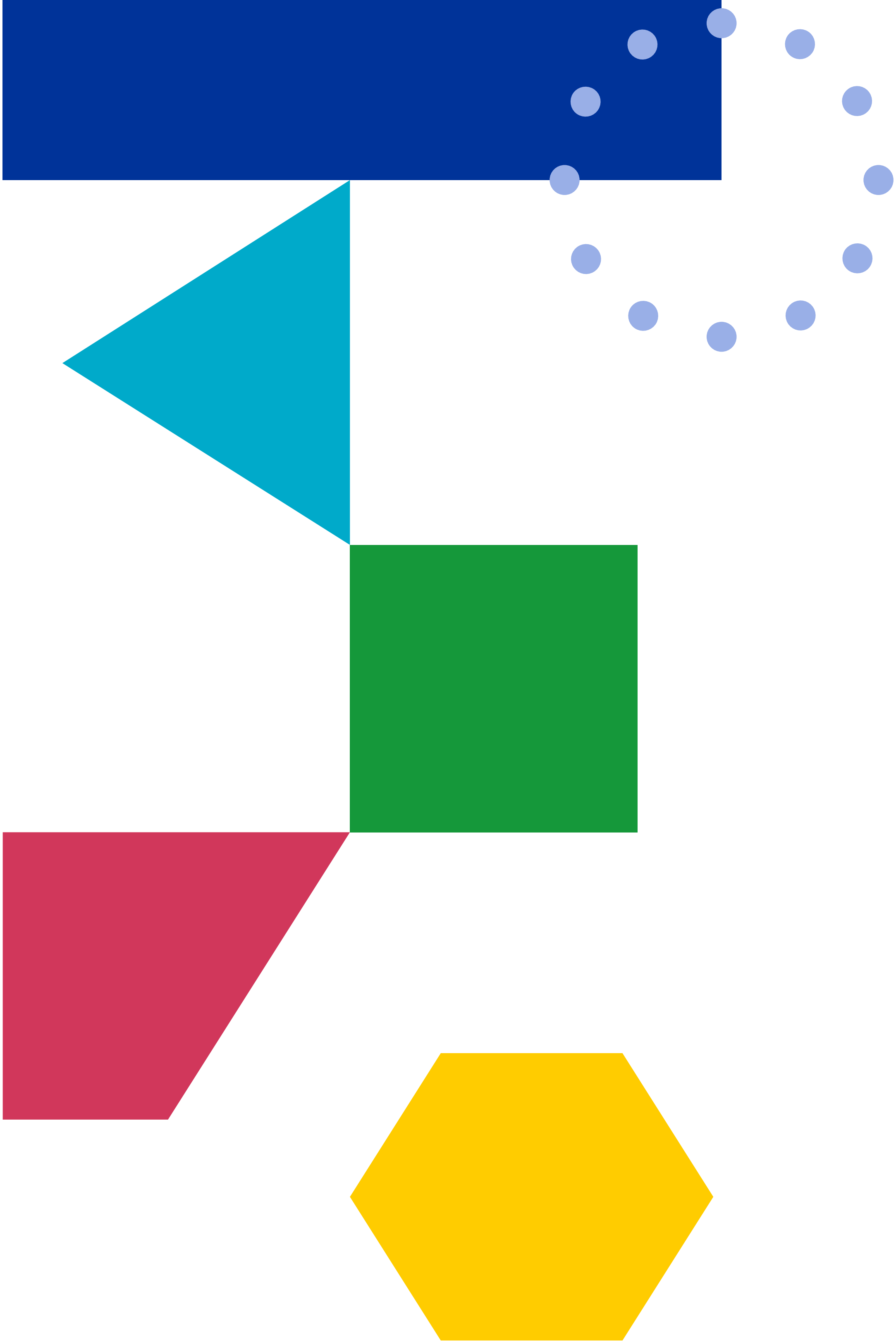
Inhoud

1. Equipment en measurement methods



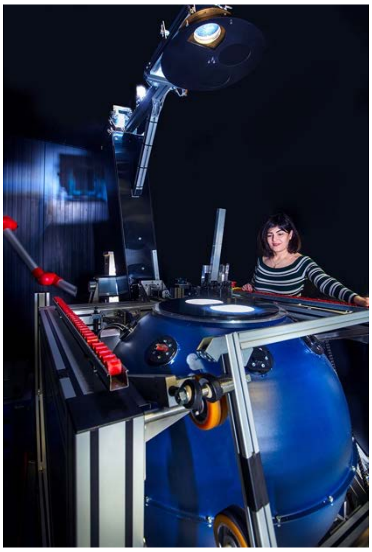
WUR LightLab has a wide variety of measuring devices available. Some of them have been designed in-house, but also standardized equipment is used. Measurement activities are objective and independent. The WUR LightLab is accredited for determining the optical characteristics of greenhouse coverings and screens in accordance with NEN2675:2028+C1. To characterize different screen types and properties, various equipment and measurement protocols have been used by WUR within the ENERGLIK project. In this report the equipment is described including the standard measurement methods and repeatability.

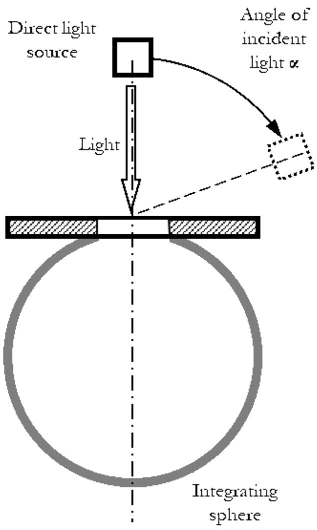
1.1 Transvision device

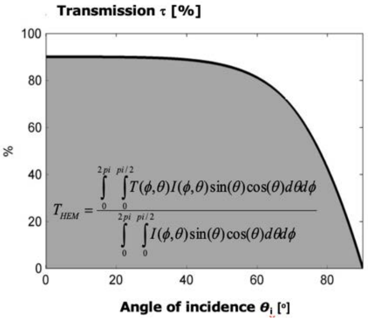
The lights transmissivity properties of (semi-)transparent screens are measured with the Transvision device at WUR. The Transvision device consists of a large integrating sphere with an internal diameter of 1 m, a CCD array spectrometer, a double-beam Xenon light source and is designed according to ISO 13468 by Swinkels (2012)[1] to measure hemispherical transmissivity based on the double-beam method.

The device is able to measure spectral transmittance τ_λ of (semi-transparent) material samples in the range of λ=350–2000 nm. It is able to measure the spectral transmissivity of a material under different angles of light incidence θ_i resulting in the angular transmittance τ_a for a=0-90° or the calculated hemispherical transmissivity τ_h. For the measurement the material is placed on the top of the sphere, and the light source is directed at the material as well as at an opening next to the material to act as a control. The spectrophotometer in the sphere determines how much light is transmitted by the material compared to the control. All angles of incidence are measured, simulating the movement of the sun in relation to the greenhouse cover.

The Transvision device can measure a wide range of materials: clear glass, diffused glass, glass with coatings, plastic sheets, screens, nets, temporary coatings.







1.1.1 Standardised measurements on the Transvision device and repeatability

Measurement methods and calculation protocols which were followed are described in NEN2675:2018+C1. The repeatability of the Transvision device is determined to be <0.5%. Measurements of PAR transmissivity through screens within ENERGLIK are done in accordance with NEN2675:2018 +C1.

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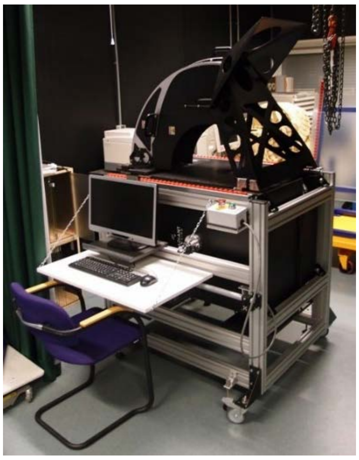
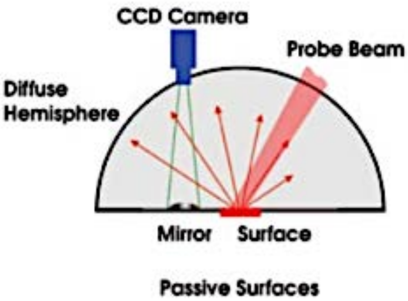
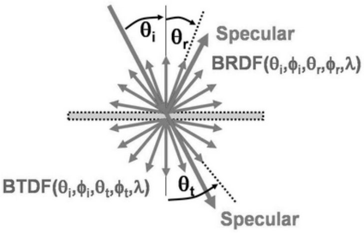
[1] Swinkels, G.L.A.M. (2012). TRANSVISION: A LIGHT TRANSMISSION MEASUREMENT SYSTEM FOR GREENHOUSE COVERING MATERIALS. Acta Hortic. 956, 563-568. https://doi.org/10.17660/ActaHortic.2012.956.67

1.2 ISSA device

The diffusion properties of screens are measured with the ISSA device at WUR to determine their Hortiscatter.
The Imaging Sphere for Scatter and Appearance device IS-SA^{TM} (Radiant Vision Systems LLC) consists of a half sphere with a ProMetric CCD camera with a resolution of 512x512 pixels and a halogen light source. It measures the angular spatial distribution of scattered light by a bi-directional transmittance (or reflectance) distribution function measurement BTDF $(\theta_i, \phi_i, \theta_t, \phi_t)$ (or BRDF$(\theta_i, \phi_i, \theta_t, \phi_t)$) of materials. The result of the measurement is a stack of images containing the scattering distributions *f*$(\theta_t, \phi_t)$for individual angles of incidence *f*(θ_i, ϕ_i), representing the way that a material affects the geometrical distribution of light intensity at every angle under the material. The BTDF is then used to calculate the Hortiscatter in accordance with NEN2675:2018+C1. The Hortiscatter indicates the extent to which incoming light is diffused by the material. The ideal level of light scattering (diffuse light) is known as Lambertian diffuser. The Hortiscatter value indicates in percentage terms how closely this ideal level has been achieved.







1.2.1 Standardised measurements on the ISSA device and repeatability

Measurement methods and calculation protocols which were followed are described in NEN2675:2018+C1. The repeatability of the ISSA device is determined to be <5%. Measurements of Hortiscatter through screens within ENERGLIK are carried out in accordance with NEN2675:2018+C1.

1.3 TransHumid device

The humidity transport through a screen material can be measured by the WUR TransHumid device. The goal of this work package is to quantify the amount of humidity transfer through different types of screen materials can be measured at pre-defined climate conditions with the TransHumid device at dry and wet condition.
The humidity transport device is designed as two air spaces separated by the screen sample of interest. The temperature and humidity settings can be specified for each of the spaces separately. Figure 1 shows a sketch of the principle and Figure 2 shows a picture of the realized device.

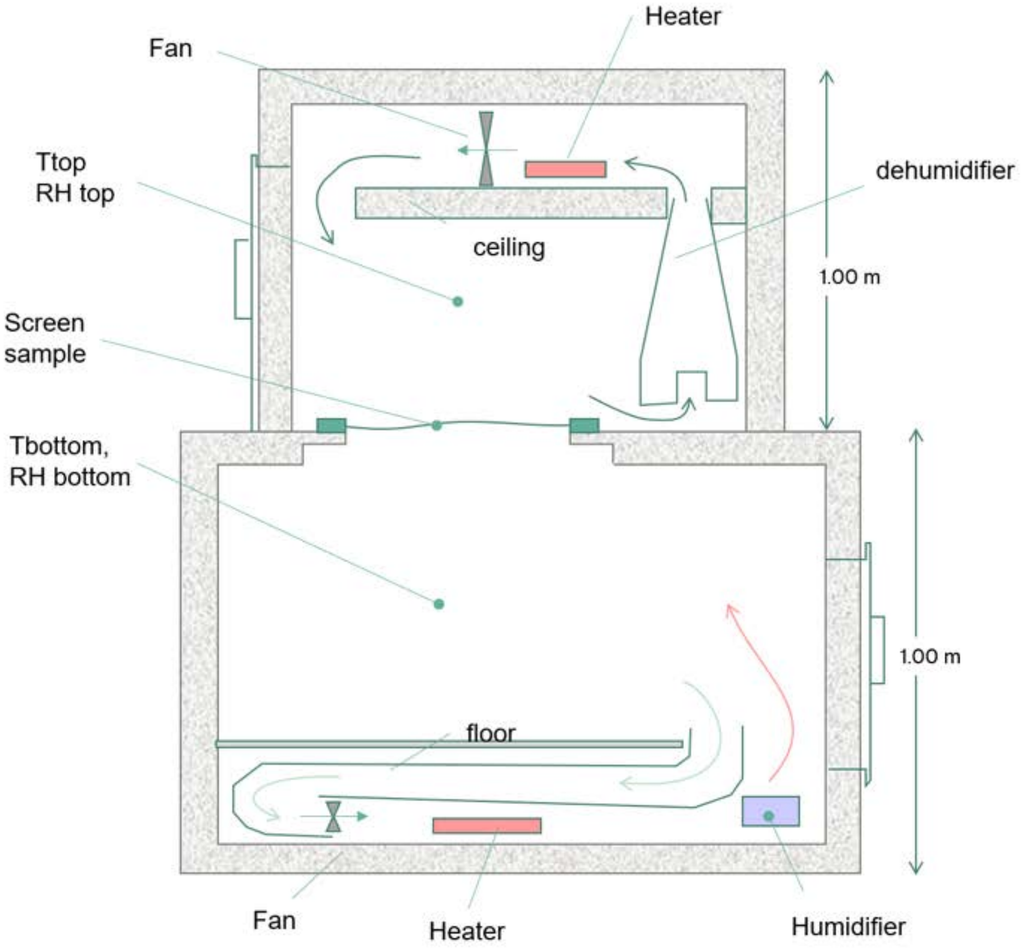


Figure 1 *Principle sketch of the TransHumid device where moisture is transported through the screen sample from the bottom to the top-compartment due to pre-defined temperature and humidity gradient at a pre-defined air velocity.*

The lower box mimics the climate conditions in the main compartment of a greenhouse in which an energy saving screen is used, that is the warm and humid volume. The upper box mimics the temperature and humidity conditions above the screen in customary winter-time conditions, that is the cold and dry volume.

Figure 2 *Picture of the TransHumid device as it is placed in a climatized room in one of the WUR laboratories.*

To realize a warm and humid bottom compartment, the compartment is equipped with

- A heating element (resistor-wire), to rise the temperature to the pre-defined value.
  The power to the heating element is controlled by an industrial PID-controller comparing the measured temperature in the bottom compartment with the pre-defined setpoint. Based on the observed temperature being too low or too high, a smaller or bigger fraction of full AC-power cycles is applied to the heating element. In this way a linear controllable heating power of 0 to 64 W can be applied.
- A humidifier, to rise the absolute humidity to the pre-defined value.
  The humidifier consists of an ultrasonic vibrating element that produces very small droplets of water that evaporate in the air. As the vibration is a mechanical process it adds energy to the system. The amount of moisture added to the bottom compartment is controlled by a short periods of on/off duty cycles of ultrasonic evaporators.
- A small fan is used to gently homogenize the climate in the box and simulate small wind speeds in a greenhouse, to be set at a pre-defined wind speed value.

The pictures in Figure 3 show details of the bottom box.

The upper box mimics the climate conditions in the top compartment of a greenhouse in which an energy saving screen is used. It is a cold and drier volume.

To achieve these conditions the top compartment is fitted with:

- A cooler/condenser, in which cold water (0-5 °C) is circulating,
- A heater to adjust the sensible/latent ration of the cooling and dehumidification process.
- A fan is used to gently homogenise the climate, to be set at a pre-defined wind speed value.

Pictures on details of the upper compartment are shown in Figure 5.

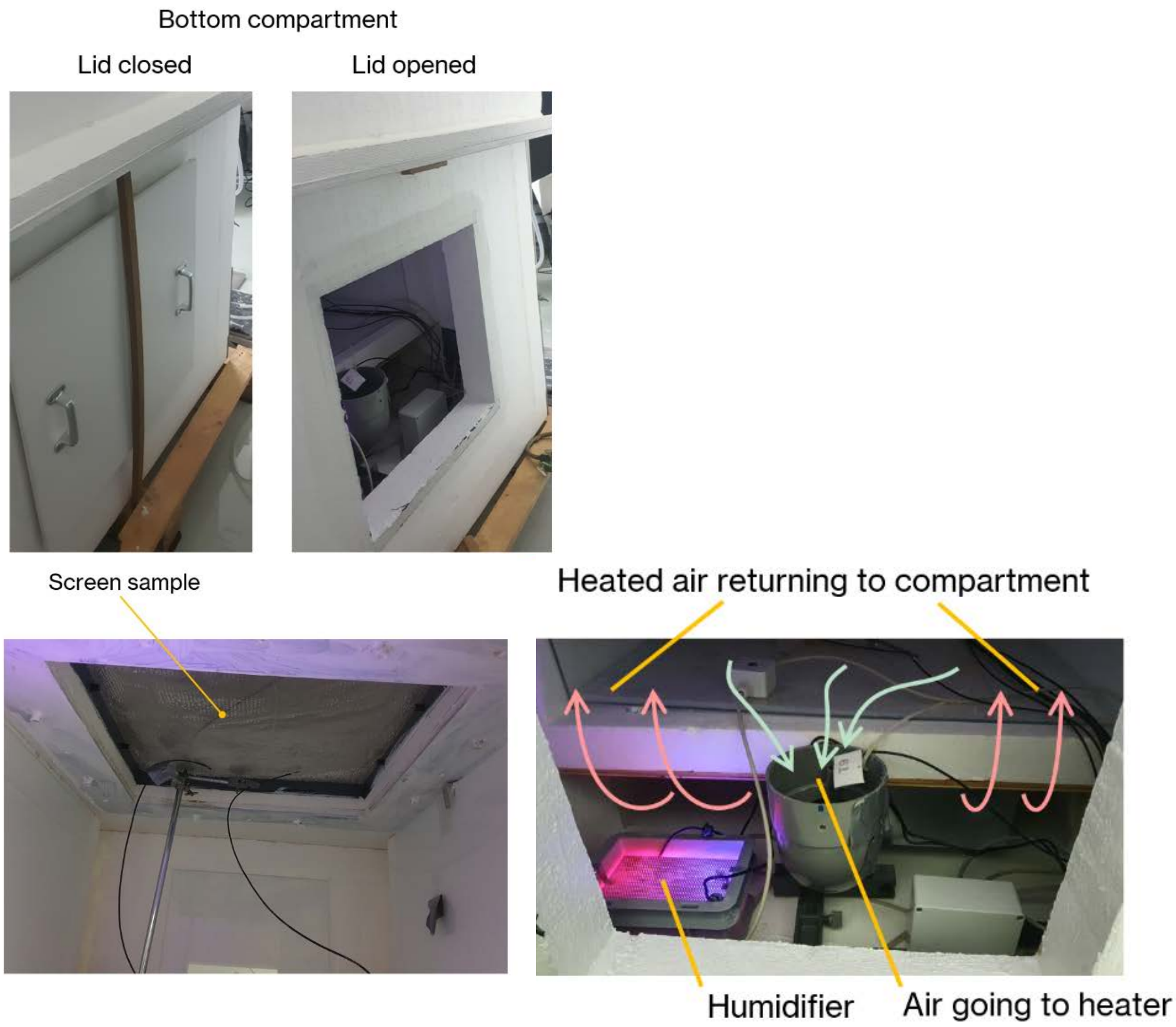


Figure 3 *Detailed pictures of the inner of the bottom compartment.*

The rate at which water evaporates is determined by keeping track of the weight reduction of a tank that replenishes the water level in the small container with the ultrasonic humidifiers (plural as for highly permeable screens 2 or even 3 humidifiers are used in parallel). Figure 4 shows this weighing scale.

Figure 4 *Tank from which water flows to the humidifier on a scale.*

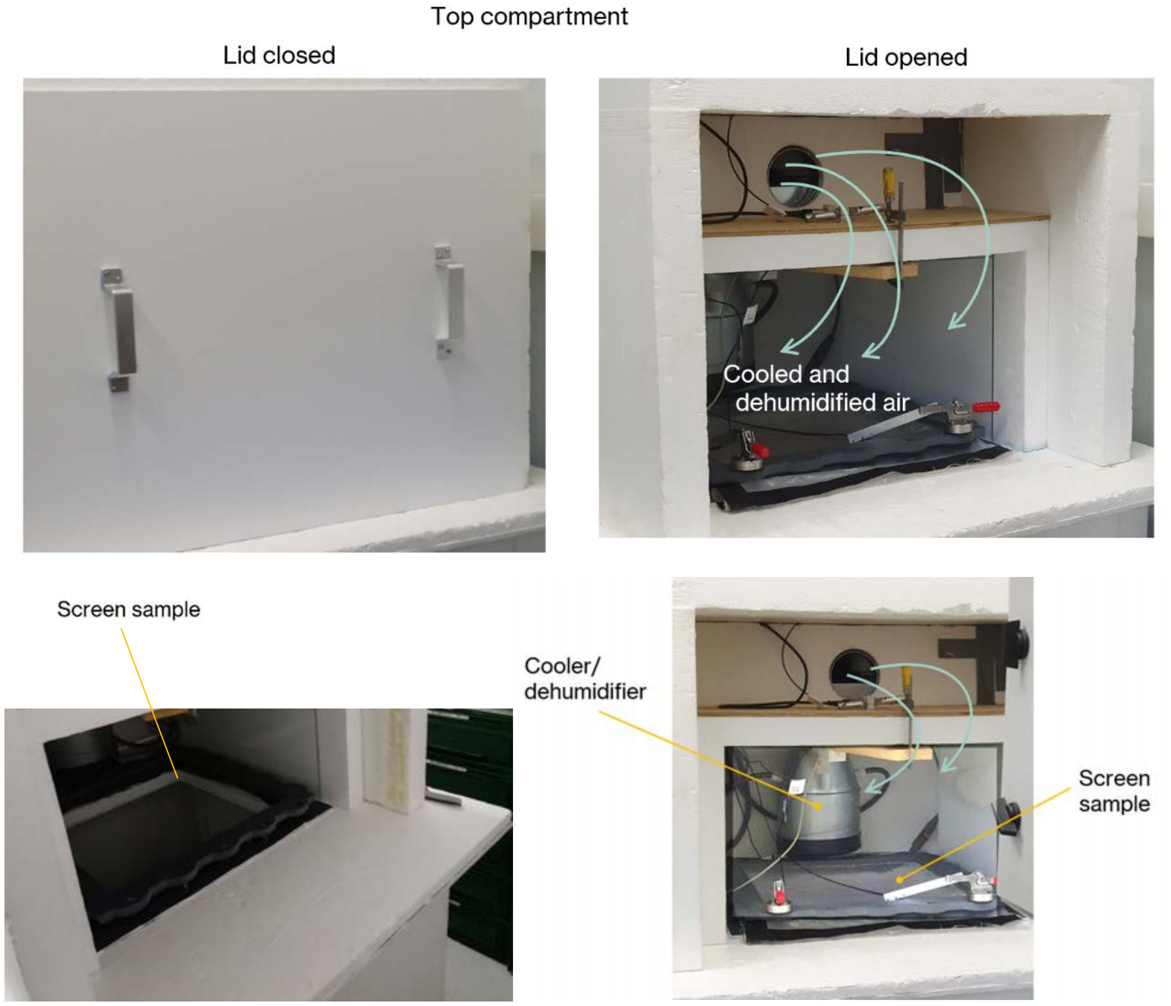


Figure 5 *Detail pictures of the inner of the upper compartment.*

The water that condenses at the dehumidifier is caught and directed to another scale. This water can come from nowhere else than by transfer through the screen.
Indeed, when a partly permeable screen sample is replaced by a non-permeable glass or foil the cooler remains dry and the water collection scale doesn't gain weight. However, when non-permeable samples are placed, some evaporation can occur in the bottom box. This is because of condensation at the bottom side of the sample. At a certain moment this water drips off. Dripping water is collected and weighed on a third scale.

The controller keeps track of the temperatures and humidity in the upper part. If the humidity becomes higher than the setpoint, the temperature of the cooling water flowing through the dehumidifier is lowered by adjusting a mixing valve. It can well be that, due to this, the temperature becomes too low. Then a heater will reheat the air in order to get both temperature and humidity at the desired level.
Figure 6 shows the mixing valve, together with the complete set of scales.

Figure 6 *Mixing valve to control the cooling and dehumidification and the scales that measure the water balance.*

The TransHumid device is equipped with a large number of sensors, both for monitoring the conditions accompanying the air and humidity transport as for the control itself. The sensors are listed in Table 1. Data are sampled with a 60 second frequency.

Table 1 *List of data channels stored*

Channel register	Details
date/time	-
T_{up}_chamber [°C]	Temperature of upper chamber
T_{low}_chamber [°C]	Temperature of lower chamber
Humidity up [%]	Relative humidity of upper chamber
Humidity_low [%]	Relative humidity of lower chamber
scale humidifier [g]	Weight of evaporated water
scale dehum coil [g]	Weight of condensed water on upper compartment
scale dropplets screen [g]	Weight of dripping water from screen
Tset_up [°C]	Temperature set point in the upper chamber
Tset_low [°C]	Temperature set point in the lower chamber
Rhset_up [%]	Relative humidity set point in the upper chamber
Rhset_low [%]	Relative humidity set point in the lower chamber
Fan speed Set_Up [%]	Set point fan of upper chamber
Fan speed Set_Low [%]	Set point fan of lower chamber
Fan speed_Up [%]	Fan speed on upper compartment
Heater_up [%]	Heater power in the upper compartment
Dehumidifier_Up [%]	Dehumidifier power in the upper compartment
Fan speed_Low [%]	Fan speed in the lower compartment
Heater_Low [%]	Heater power in the lower compartment
Humidifier_Low [%]	Humidifier level in the lower compartment

1.3.1 Standardised measurements on the TransHumid device

A standard measurement protocol to measure the humidity transfer through dry and wet screen materials has been developed and is used.

Typically, a measuring sequence consists of two stages. First a period of 8-10 hours in which the temperature and humidity conditions generated on both compartments are such that the screen remains dry. In this period the humidifier and dehumidifier work. And moisture can be transported from the bottom to the top compartment, but the screen temperature remains above dewpoint temperature. Such conditions can be realized by a temperature gradient of e.g. 8 °C across the screen with a lower compartment temperature of e.g. 10 °C and a humidity of e.g. 70%. In the second stage, the temperature gradient is kept the same, but the humidity in the lower compartment is increased to e.g. 90%.

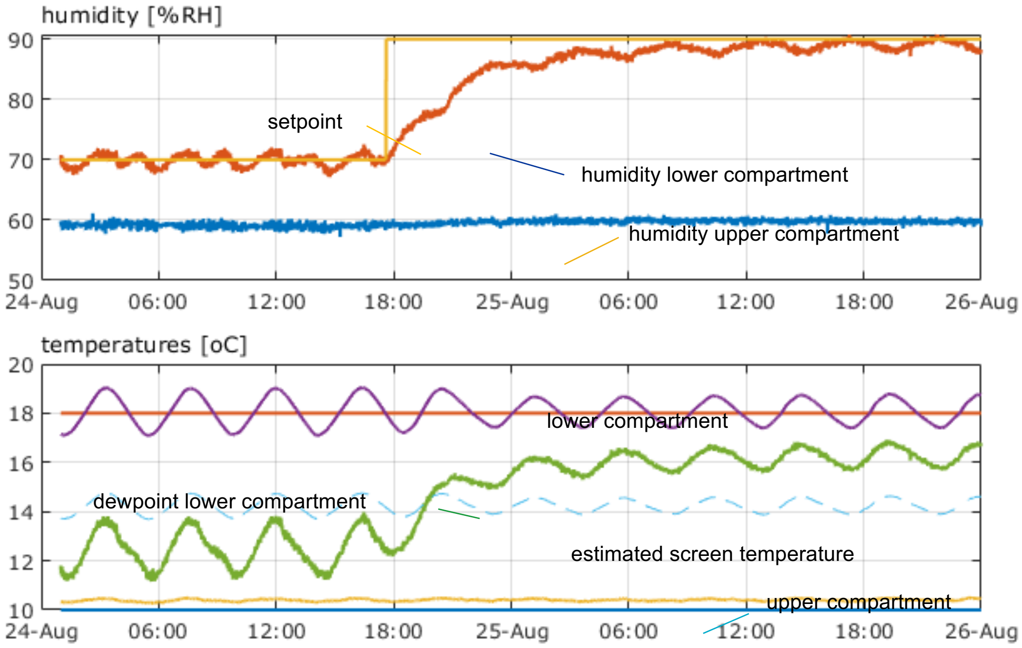


Figure 7 *Temperatures and humidity during the two stages of a measuring sequence.*

Figure 7 shows that the conditions in the upper compartment are very stable, but that the temperature and humidity in the lower compartment are fluctuating around the setpoint. However, as the measuring period is long and the fluctuations are very regular around the setpoints, these oscillations are considered not to be a problem.
In the measuring protocol, the whole period is observed, and two stable periods are selected. In the example showed, the conditions typical for the dry screen phase are the 16 hours from 1:00, August 24th till 17:00. The typical conditions for the wet screen phase are stated from 06:00 on the 25th till the end of the day.

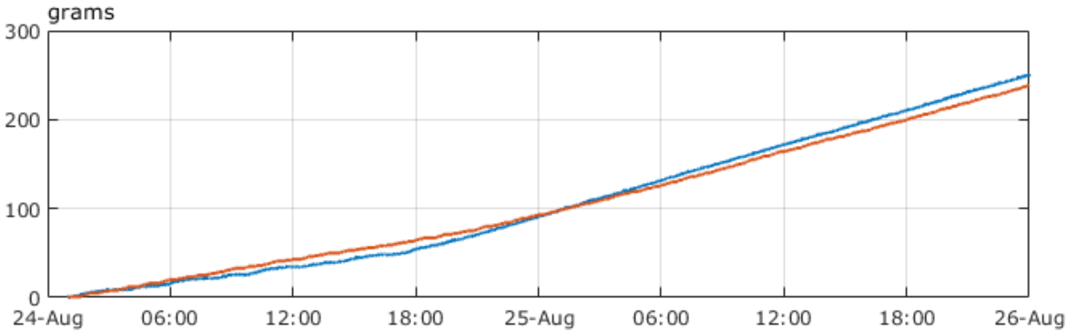


Figure 8 *Amount of water evaporated in the lower compartment by the humidifier (blue) and condensed at the dehumidifier in the upper compartment (red).*

Figure 8 shows the total amount of moisture evaporated in the bottom compartment and the total amount of water collected from the dehumidifier in the top-compartment in the same measurement sequence. Especially in the blue line of Figure 8, showing the amount of water that flowed out of the tank connected to the humidifier (Figure 4), there are clearly two slopes. A lower slope in the first 16 hours and a steeper slope in the second part. In this example in the first 16 hours, 49 gof water flowed from the tank to the humidifier, meaning an evaporation rate of 3 g/h. In the second part of the graph, from 06:00 on 25th of August till the end of the day, 250-130=120 g of water were drawn out of the tank, meaning a transpiration rate of 120/18=6.7 g/h.

When doing the same exercise on the weight gained by the scale that collects the condensate from the dehumidifier, the weight gained in the first 16 hours is 60 g and the weight gained in the last 18 hours is 112 g. So, based on the other scale, the moisture transport in the dry screen conditions would be 3.8 g/h and in the wet screen conditions is 112/18 = 6.2 g/h.

As the screen sample measures 0.25 m², all numbers on measured humidity transport are multiplied by 4 to get the moisture transport per m² per hour.

Since the humidity transport is largely dependent on the temperature differences and humidity gradients across the screen, measurement results are always calculated back at and reported at standard conditions. Reporting screen measurement results within ENERGLIK, these standard conditions were: top compartment 10°C/60%, bottom compartment 18°C/90%. Depending on the screen material types (woven, knitted, film with holes), the wet screen moisture transport capacity can also be influences by some hygroscopic exchange.

1.4 TNO emissivity device

The thermal properties of screens are measured at the TNO emissivity device and/or at a FTIR spectrophotometer at WUR. The goal of this work package is to quantify the amount of thermal infrared radiation and therefore radiative energy loss through different types of screens.

The emissivity device (Figure 9) measuring thermal properties of screen materials has been developed in the past by TNO. The device consists of two radiative half spheres kept on different temperatures. One half sphere has the room temperature and the other one is heated. The temperature difference is about 20 to 25 °C. Both half spheres have a built-in infrared sensor. The sensor consists of a large number of thermo-couples which are integrated on an IC. Herewith any increase or decrease in surface temperature is compared with the sensor temperature. The sensor is able to measure its own temperature and has a response time less than 0.1s. Emissivity (ε), thermal infrared reflectivity (ρ_{TIR}) and thermal infrared transmissivity (τ_{TIR}) are determined based on the known properties of glass and gold which are measured during calibration, as well as the reading of the empty device. Calibration is done with a gold standard. Regular performance check is done with a ETFE standard. The TNO emissivity device measures TIR transmissivity (τ_{TIR}) and TIR reflectivity (ρ_{TIR})., the emissivity (ε) results from $\varepsilon=1-\tau_{TIR}-\rho_{TIR}$.

Figure 9 *Picture and schematic drawing of the emissivity measurement device (TNO emissivity device).*

The following specifications are given on the device:

- The device is able to measure in between hemispherical and near normal incidence. By default, hemispherical values are used. The error depends on the material properties of the measured sample and is largest for smooth flat materials, around 2% for samples with TIR reflectivity around 50%. For screens the error is estimated to be smaller.
- For highly transparent samples (>50% TIR Transmissivity) the TIR reflectivity of the spheres should be taken into account. The TIR reflectivity of the spheres is estimated to be around 10%. A different algorithm is needed to measure highly transparent samples.
- The Melexis sensors (Figure 10) have a sensitivity for different thermal infrared wavelengths as in the following figure. The sensitivity of the sensors covers the range of 4-14μm, which represents an important part of the relevant spectrum, however, not the complete spectrum.

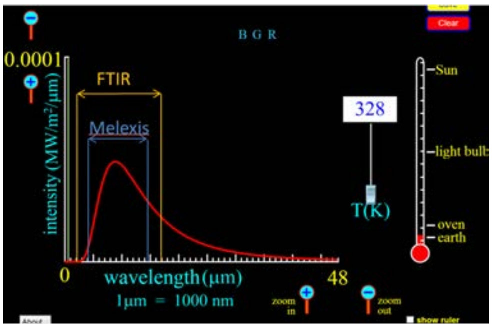


Figure 10 *The Melexis sensors window.*

Alternatively, screens can be measured on a FTIR spectrophotometer in a larger wavelength range 2-50µm, weighted by Planck's law at ambient temperature, resulting in spectral transmission and reflection values. A FTIR spectrophotometer is also suitable for the measurement of materials with high TIR transmissivity. However, these spectrophotometers do not measure at hemispherical incidence and only cover a very small surface area. Inhomogeneous screens are not suitable for these measurements, only homogeneous films can be investigated. That was the reason the TNO emissivity device had been developed in the past for screen materials.

Both devices, TNO emissivity device and FTIR spectrophotometer cannot be used with wet samples, as dripping water could damage the device or the drop structure would not be representative for a real condensation layer in a greenhouse. Since until now no suitable method is developed to quantify the thermal properties of wet screens in a reliable way by real measurements, the thermal properties of a wet material are estimated to be $\tau_{TIR}=0.05$, $\varepsilon_{TIR}=0.9$, $\rho_{TIR}=0.05$ at full wet stage.

Since until now also no reliable method to quantify the development, form and thickness of a real condensation layer on a screen material by real measurements has been developed, the stage of wetness is currently estimated by a dynamic model in which, if the dew point is reached, a condensation layer is build up to a defined maximum thickness and the thermal properties are linearly changed from measured dry to assumed wet thermal properties.

1.4.1 Standardised measurements on the TNO emissivity device and repeatability

A standard measurement protocol to measure the thermal properties of dry screen materials has been developed and is used.

Measurements of a standard reference samples give insight in the repeatability of the device. A defined ETFE film is used at WUR as standard reference material. This material is measured before an unknown screen sample is measured. Each time when the emissivity value of ETFE film was deviating too much from the expected value, the calibration of the TNO emissivity device is repeated. The more variations in the climate conditions of surrounding area, the more often new calibrations are needed. Therefore, WUR LightLab operates in a small T and RH window.

Typical results of measurements of ETFE film during different sessions are shown in Table 2. Regular measurements of the standard reference material (ETFE) show the repeatability of the equipment to be <5% for emissivity.

Table 2 *Thermal properties of a defined standard material (ETFE film) measured with the TNO emissivity device and repeatability of the equipment*

Reference WR16E1	ρ_{TIR}	τ_{TIR}	ε
M1	14	29	57
M2	17	31	52
M3	16	31	52
M4	15	29	56
M5	15	30	56
M6	17	33	50
M7	16	32	52
M8	17	31	53
M9	16	29	55
M10	15	29	56

Screen measurements within ENERGLIK were carried out on TNO emissivity device and reported. If materials were homogeneous (e.g. transparent film materials or aluminum foils) measurements were also carried out on a FTIR spectrophotometer. Spectral measurement results on a FTIR spectrophotometer are always weighted by the Planck's law at ambient temperature.

1.5 Permea device

The air permeability of screens is measured with the WUR Permea device.
Depending on the structure and purpose of a screen material, the air permeability might contribute to the energy balance of a greenhouse. While open screens also used for shading purposes have a high air permeability, closed films typically used as seasonal layer have a low or even no air permeability. Other screen types are typically in between these two extremes. The goal of this work package is to quantify the amount of air permeability through different types of screens in dry and wet condition.
The Permea device consists of a simple and accurate small and portable vertical wind tunnel (Figure 11).

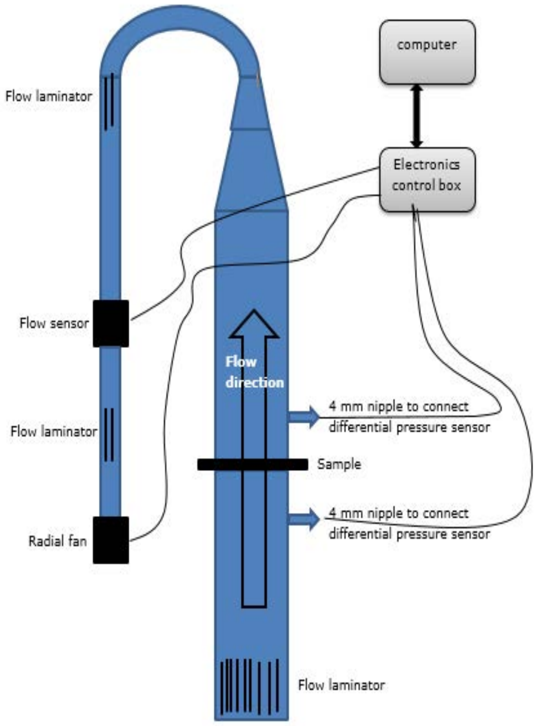


Figure 11 *Scheme of the Permea small wind tunnel device for the measurement of aerodynamic properties of dry/wet screen samples.*

This vertical wind tunnel is based on a stable low-volume controllable fan (Nidec Copal Electronics TF037E-2000-F), an accurate low volume flow sensor (Sensirion) and an accurate pressure transducer. They are marked in Figure 12.

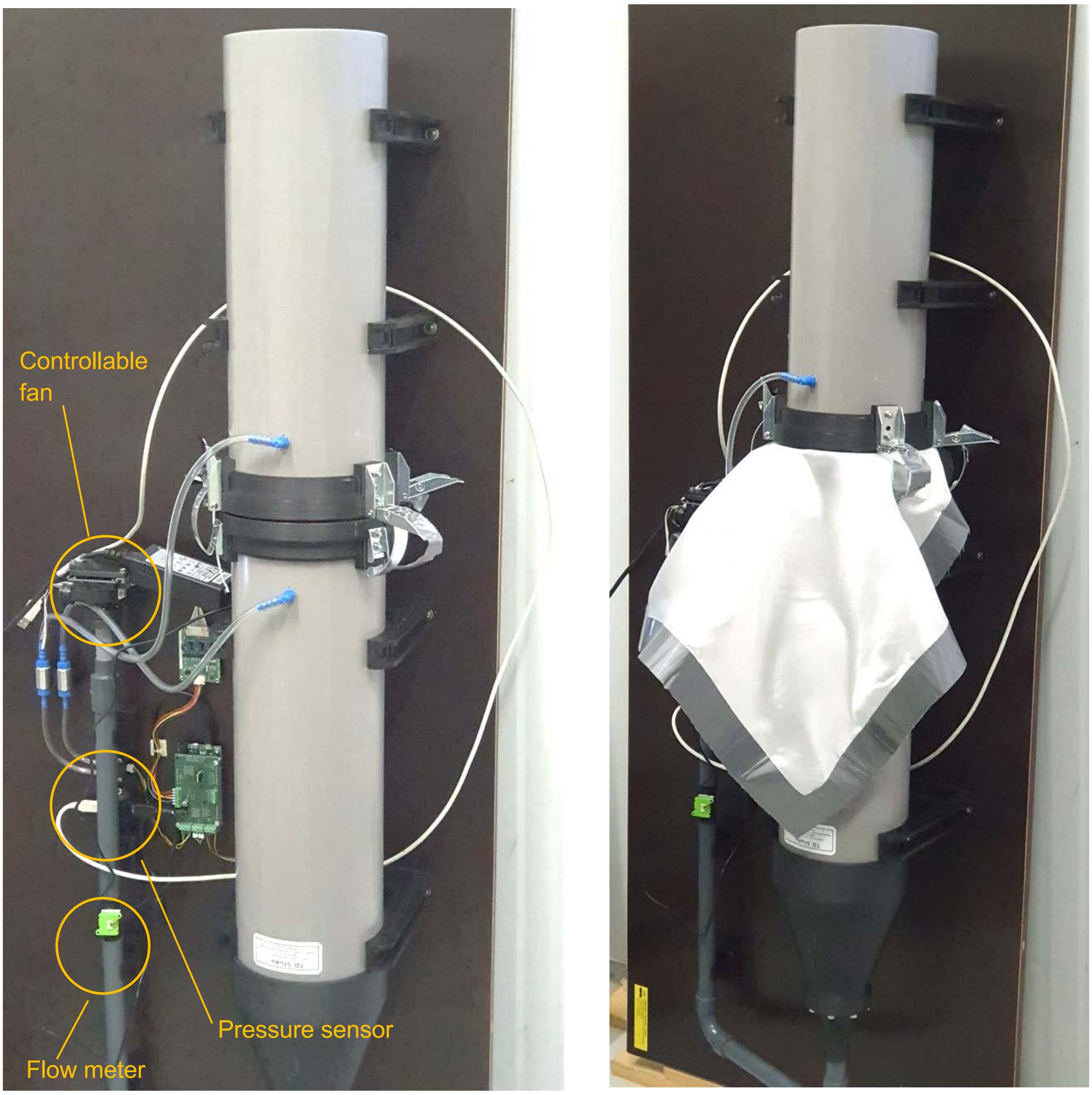


Figure 12 *Detailed pictures of the Permea device for measuring aerodynamic properties of dry and wet samples.*

The permeability on the Permea device is measured by speeding up the fan with small steps. At each step of the fan, the pressure difference and the air flow was registered. A typical series of such measurement points is shown in Figure 13.

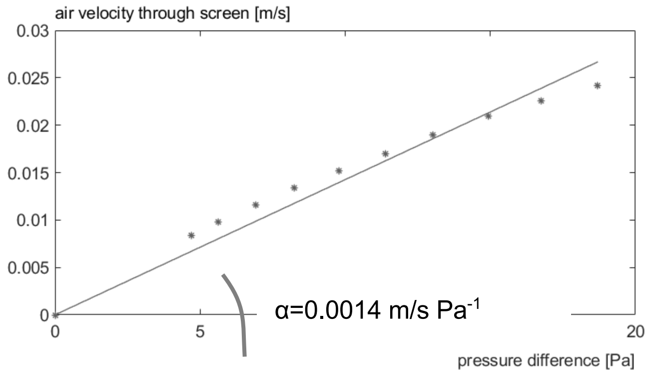


Figure 13 *Measurements of air velocity through screen under difference pressure differences on the Permea device with one screen sample.*

In this example a linear fit between pressure difference and air velocity shows an angle α, which is 0.0014 m/s of air movement through the screen per Pa pressure difference.
By definition, the air velocity is 0 without a pressure difference, so therefore the line is forced to start at (0,0). One measurement-session consists of a series of increasing fan speeds until either the pressure difference exceeds 20 Pa or the air speed exceeds 0.03 m/s. These boundaries are chosen because in an actual greenhouse, higher pressure differences or higher air-flows across a screen will not occur.
The picture shows that the linear representation of the relation between pressure difference and air velocity is a little deviating from the measured points. Still, the linear representation is considered to be good enough as it gives a simple relation between pressure difference and air flow for this application.

The slope multiplied by the viscosity is the permeability. The viscosity is dependent on the air temperature and is $1.789*10^{-5}$ [Pa s] for air of 15 °C. This 15 °C is the temperature of the room where the Permea device is normally used, but when the device is used at other temperatures, the viscosity is adapted by 0.005 (Pa s)/K (a higher temperature gives a higher viscosity).
In this example the permeability of the screen from which the characteristics are shown is therefore $0.0014 * 1.789*10^{-5} = 0.25*10^{-7}$. Given the unit of the slope (m/s Pa^{-1}) and the unit of viscosity (Pa s), the unit of the permeability is m.

The Permea device is also suitable to carry out measurements of wet screens. This is done by placing the wet screen samples on the device immediately after a humidity transport measurement in the TransHumid device. In this way the wetness of the screen is created in condensation conditions as close as possible to those in the greenhouse.

1.5.1 Standardised measurements on the Permea device and repeatability

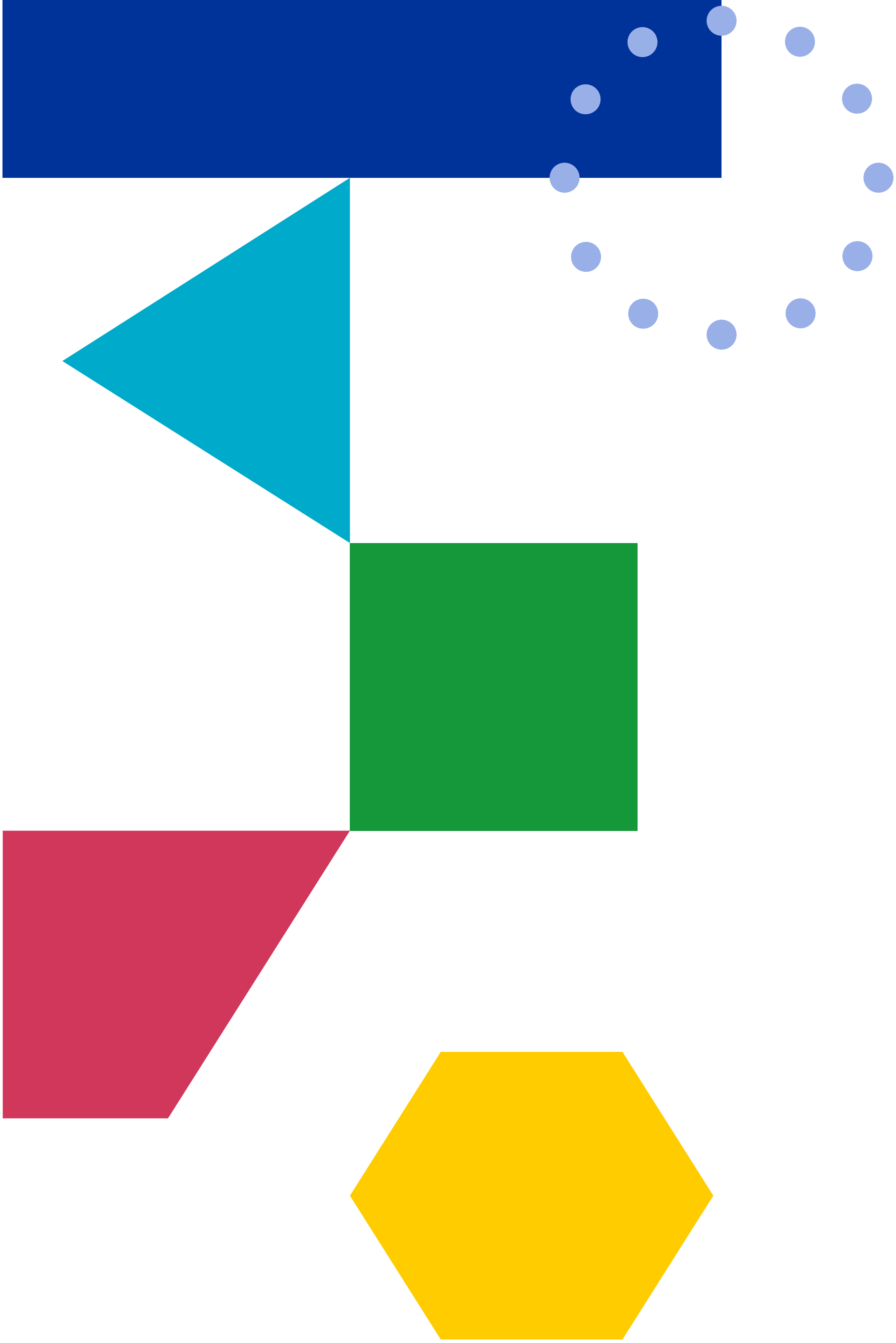
A detailed description of the standardised measurement protocol to measure dry and wet samples has been developed and is available.
Measurements of a standard reference samples give insight in the repeatability of the device. Every time before a measurement on the Permea device is taken, a control measurement of a defined standard material is taken with a known air permeability. In case of the Permea device this standard materials consist of a metal plate with fixed holes. By measuring this standard material regularly, the repeatability of measurement results can be obtained (Table 3). Next to that, these measurements serve as performance control of the equipment during daily operation.
The obtained absolute standard deviation of repeated measurements of the standard reference material (metal plate with fixed holes) is <5%.

Table 3 *Air permeability measurements of a defined standard materials (metal plate with fixed holes) to determine the repeatability of the equipment.*

Reference WR21P1	Permeability (m 10^{-7})	Reference WR21P1	Permeability (m 10^{-7})
M1	4.65	M11	4.40
M2	4.80	M12	4.21
M3	4.31	M13	4.36
M4	4.34	M14	4.37
M5	4.37	M15	4.42
M6	4.28	M16	4.42
M7	4.75	M17	4.34
M8	4.76	M18	4.46
M9	4.81	M19	4.37
M10	4.39	M20	4.36

Screen measurements within ENERGLIK were carried out on the Permea device and reported in dry and wet stage.

2. Measurement results Energlik screen properties



Different screen types with different properties have been developed by different screen producers. These materials have all been characterized on the various equipment and using the measurement methods described above within the ENERGLIK project. In this report the results of the measurement of screen properties are listed. Screens which have been used in different trials within the project in WP4 and WP5 are indicated.

ENERGLIK code			**Suitable for Dayscreen (D) Nightscreen (N)**	**Transvision**	**ISSA**	**TNO Box or Perkin Elmer FTIR**			**Permea**		**TransHumid**
				PAR Transmission [-]	**Hortiscatter [-]**	**TIR Reflectivity [-]**	**TIR Transmissivity [-]**	**TIR Emissivity [-]**	**dry [m 10^{-7}]**	**wet [m 10^{-7}]**	**top ca.10°C/60%, bottom ca. 18°C/ 90% [g/m^2/h]**
23LB	screen		D	0,71	0,22	0,24	0,71	0,04	0,23	0,02	12,43
23MB	**screen**	**PCH 2023/24**	**D**	**0,73**	**0,22**	**0,25**	**0,73**	**0,03**	**0,17**	**0,07**	**10,88**
23MB_ob						**0,21**	**0,77**	**0,02**			
23NB	screen		D	0,72	0,83	0,24	0,40	0,36	0,29	0,06	13,35
23OB	screen		N			0,67	0,10	0,24	0,34	0,28	9,18
23OB_ob						0,29	0,11	0,60			
23PB	screen		N			0,41	0,16	0,44	0,11	0,08	6,06
23QB	screen		N			0,40	0,08	0,52	0,25	0,20	9,69
23RB	screen		N			0,38	0,08	0,55	0,85	0,45	16,4
23SB	screen		N			0,56	0,06	0,38	0,54	0,61	7,43
23SB_ob						0,23	0,09	0,68			
23ZB	**screen**	**PSKW 2023/24, Botany 2024**	**N**			**0,67**	**0,03**	**0,30**	**0,05**	**0,10**	**4,74**
23ZB_ob						**0,23**	**0,04**	**0,73**			
24AB	**screen**	**Botany 2024**	**D**	**0,71**	**N/A**	**0,21**	**0,46**	**0,33**	**0,05**	**0,02**	**9,14**
24BB	**screen**		**D**	**0,73**	**N/A**	**0,17**	**0,37**	**0,47**	**1,59**	**0,13**	**8,56**
18HN	screen		D	0,69	N/A	0,19	0,30	0,51	0,53	0,52	11,6
22RN	screen		D	0,70	0,03	0,21	0,29	0,50	0,09	0,03	10,24
23DN	screen		N			0,61	0,05	0,34	0,35	0,38	14,28
23DN_ob						0,23	0,07	0,71			
24AN	screen		D	0,60	0,90	0,15	0,27	0,58	0,06	N/A	N/A
19CS	screen		D	0,74	N/A	0,20	0,33	0,47	0,57	0,75	25,5
23ES	double screen		N			0,74	0,06	0,21	0,40	0,43	14,32
23ES_ob						0,23	0,07	0,70			
23FS	double screen		N			0,73	0,06	0,20	0,24	0,26	9,41
23GS	double screen		N			0,18	0,05	0,76	0,26	0,29	13,06
23GS_ob						0,20	0,07	0,73			
23ES	**double screen**	**PCH 2023/24**	**N**			**0,74**	**0,06**	**0,21**	**0,40**	**0,43**	14,32
23ES_ob						**0,74**	**0,06**	**0,21**			

ENERGLIK code			Suitable for Dayscreen (D) Nightscreen (N)	Transvision	ISSA	TNO Box or Perkin Elmer FTIR			Permea		TransHumid
				PAR Transmission [-]	Hortiscatter [-]	TIR Reflectivity [-]	TIR Transmissivity [-]	TIR Emissivity [-]	dry [m 10^{-7}]	wet [m 10^{-7}]	top ca.10°C/60%, bottom ca. 18°C/ 90% [$g/m^2/h$]
23AD	double screen		D	0,55	N/A	0,25	0,40	0,36	0,34	0,29	14,41
23BD	screen		D	0,26	N/A	0,57	0,13	0,31	5,47	5,14	86,06
23BD_ob						0,23	0,15	0,63			
23CD	screen		D	0,22	N/A	0,61	0,11	0,28	3,76	3,23	55,33
23CD_ob						0,23	0,14	0,62			
23AW	film		N			0,98	0,00	0,02	0,00	0,00	N/A
23AW_ob						0,64	0,00	0,36			
23BW	film		N			0,94	0,01	0,05	0,00	0,00	N/A
23BW_ob						0,91	0,01	0,08			
23CW	film		N			0,93	0,01	0,06	0,00	0,00	N/A
23CW_ob						0,94	0,01	0,05			
23DW	film		N			0,94	0,00	0,06	0,00	0,00	N/A
23DW_ob						0,51	0,00	0,49			
23EW	film		N			0,95	0,02	0,03	0,36	0,25	14,76
23EW_ob						0,69	0,02	0,29			
23DO	film		D	0,81	N/A	0,05	0,37	0,58	0,00	0,00	N/A
23EO	**film**	**PSKW 2023/24**	**D**	**0,78**	**N/A**	**0,05**	**0,40**	**0,55**	**0,37**	**0,37**	**N/A**
23AA	**film**	**PCH 2023/24**	**D**	**0,87**	**N/A**	**0,04**	**0,31**	**0,65**	**0,00**	**0,00**	**N/A**
24AI	film		D	0,69	N/A	0,75	0,07	0,18	0,00	0,00	N/A
24BI	screen		D	0,59	0,13	0,62	0,06	0,32	0,85	0,94	21,78
24BI_ob						0,33	0,11	0,57			
24AT	screen		D	0,59	N/A	0,20	0,71	0,09	0,61	0,62	13,58
24AT_ob						0,21	0,71	0,09			
24BT	film		D	0,58	N/A	0,34	0,04	0,62	0,00	0,00	N/A
24CT	screen		N			0,15	0,22	0,63	1,44	1,27	24,33
24CT_ob						0,15	0,19	0,66			

Met de steun van:

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Vlaanderen-Nederland
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Energlik

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