Hortinergy

Energy and climate analysis for

greenhouse project

Hortinergy Manual

An online software to simulate climate and energy consumption for greenhouse project

Version 01.09.2021

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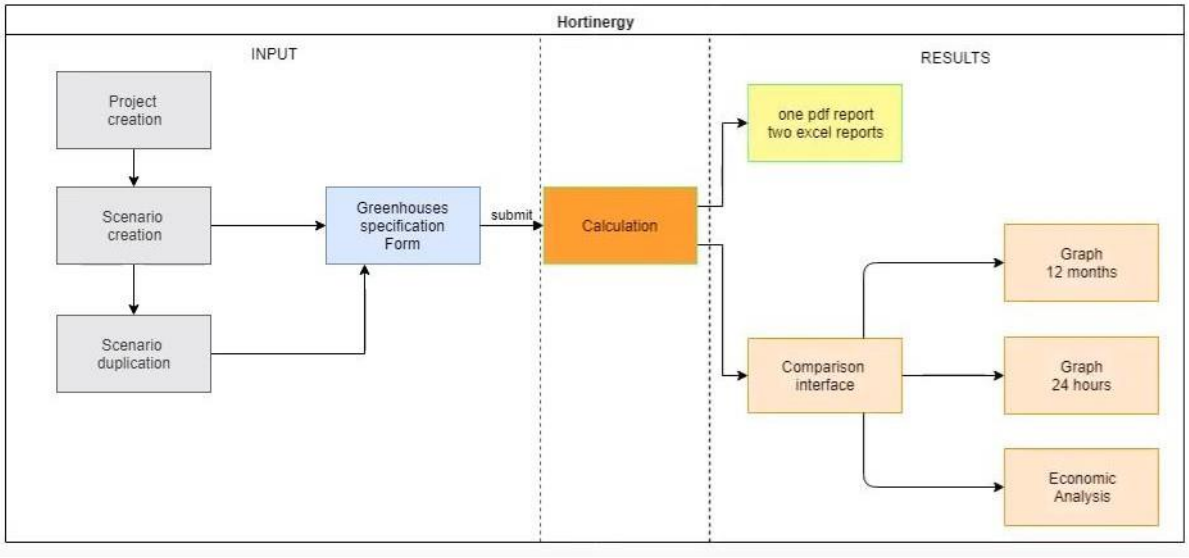
A. HOW DOES HORTINERGY WORK?



-> Before you start your project, here are some meanings on the icons on the "profile"page:

A project is the geographical coordinates of your greenhouse. Each variation you make on this project isa scenario.

Innovative algorithms take into account specific greenhouse parameters. Our weather file includes a typical year on an hourly basis based on the GPS coordinates with parameters suchas:

- Temperature,
- Relative humidity,
- Wind,
- Solar radiation (global, diffuse, PAR…)

Greenhouse covering includes :

- Type and shade of the greenhouses project (Venlo, gothic…)
- Orientation and dimension,
- Covering materials of each wall,
- Climate screens…

Hortinergy has a large material library. It is updated with the latest branded materials.

Hortinergy also takes into account the crop evapotranspiration. For this purpose, parametersabout crop management have to be filled in: crop types, growing medium types, transplantingdate and uprooting date, etc…

Hortinergy also considers climate control settings just as a climate computer would do:

- Temperature setpoints and relative humidity control,
- Screen regulation types,
- Morning revival

We can model standard and innovative equipment such as:

- Semi-closed and closed greenhouse,
- Pad and fan,
- Supplementary light (LED, HPS) …

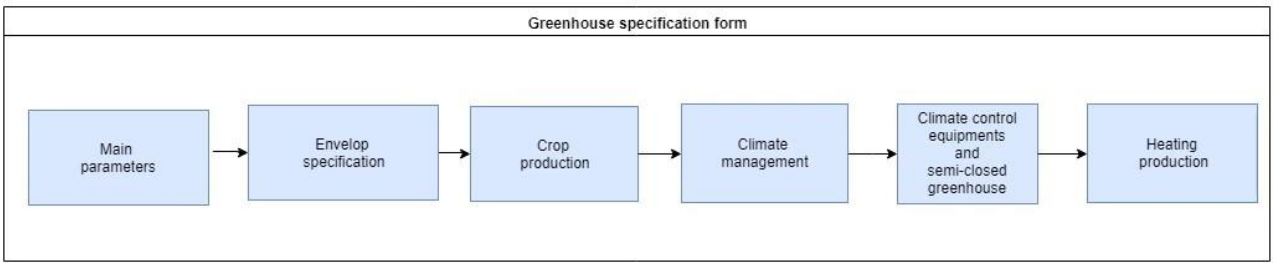
For heat production and storage, hortinergy includes:

- Energy source for primary and secondary systems,
- Heat production and distribution yield,
- Buffer tank: volume, regulation…

B. GREENHOUSES SPECIFICATION FORM

The form, **easy to fill out**, is divided into 7 parts represented by tabs:

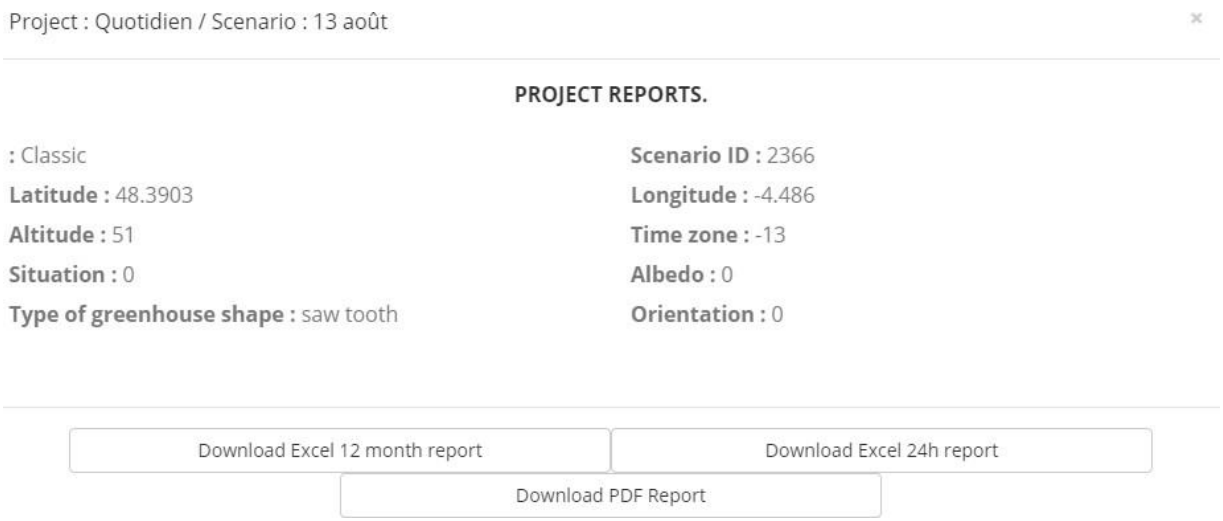
7 parts on the form



C. RESULTS

I Reports

The report is sent to you about 20 minutes after you submitted your form. It is available in PDF format, easy to download. You will receive three reports on your account. These reportscontain all the results of the calculation and many specifications about your project.



A PDF report summarizes specifications about your project and let you know:

- Energy consumption for heating,
- Inner climate (temperature, humidity, PAR reaching canopy),
- Energy consumption, cooling and dehumidification,
- PAR reaching canopy and artificial light required to reach day light integral,
- Climate analysis,
- Estimation of greenhouse Gas emitted

You also receive two Excel reports with detailed data:

- Monthly summary
- Hourly values during two typical year

You can see below examples of tables and charts in the report.

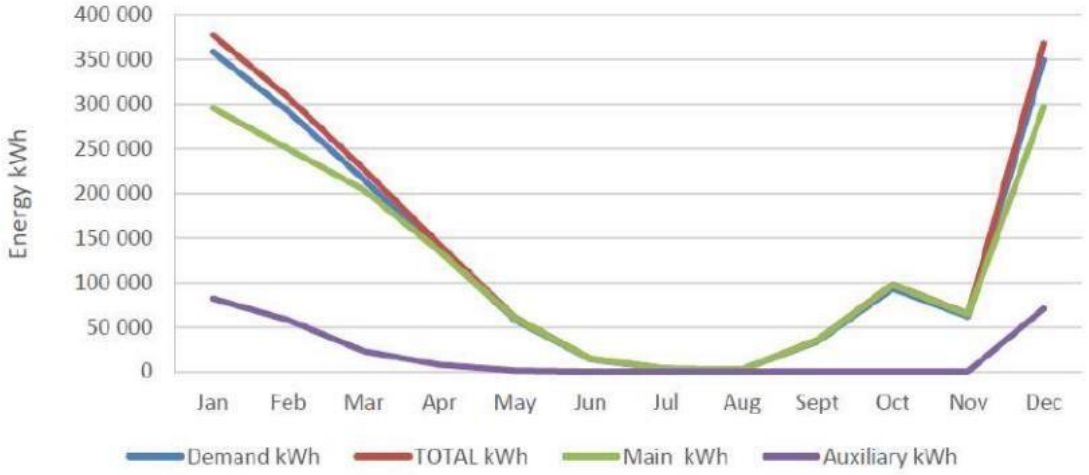
Energy consumption

You will find in the report the costs and energy consumption of your greenhouse, detailed inyour currency, but also the heating consumption of your greenhouse month by month.

Annual cost and energy consumption

	Total	Main	Auxiliary
Energy source		CHP - recovery heat	Gas
Unit price (€/MWh)		10	40
Expenditure (€)	24 196	14 588	9 607
€ /m²	2.5	1.5	1.0
Main vs Auxiliary (cost %)		60%	40%
Consumption MWh	1 702	1 459	240
Consumpt. / unit (kWh/m²)	177	152	25
Main vs Auxiliary (energy %)		86%	14%

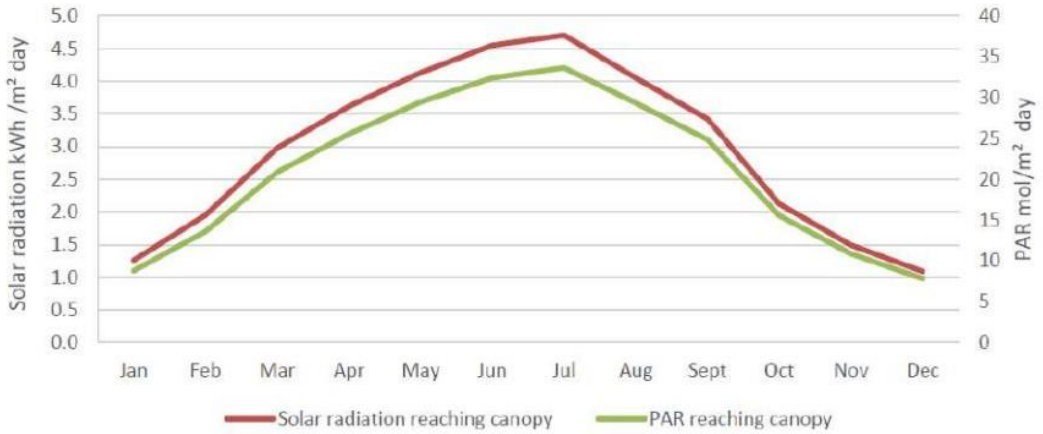
Monthly heating consumption



Light

Check the graph of the solar radiation on your greenhouse to see the evolution of solarradiation and photosynthetic radiation reaching the canopy.

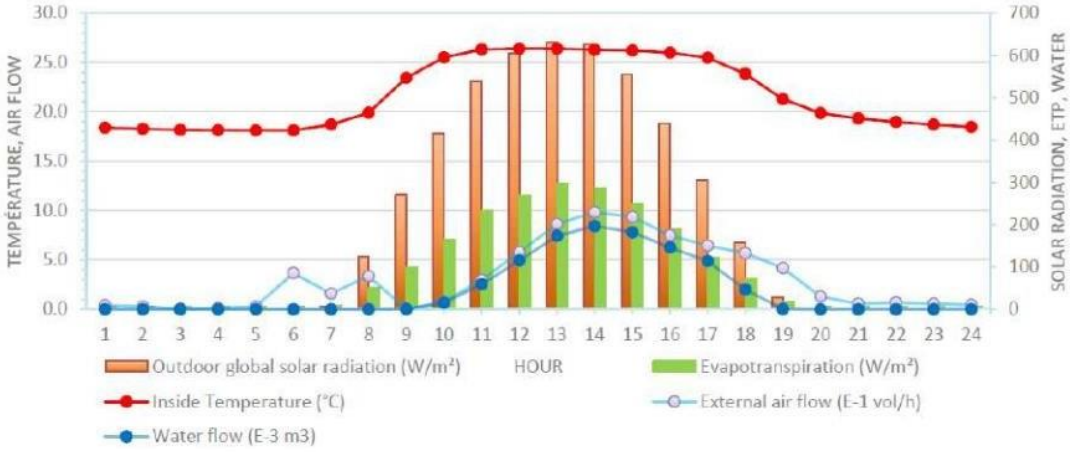
Solar radiation and PAR reaching canopy



Indoor climate simulation

Detailed charts of the indoor climate on typical days for different months of the year give you the opportunity to compare solar radiation, indoor temperature or evapotranspirationof the canopy.

Inner climate for an average day in

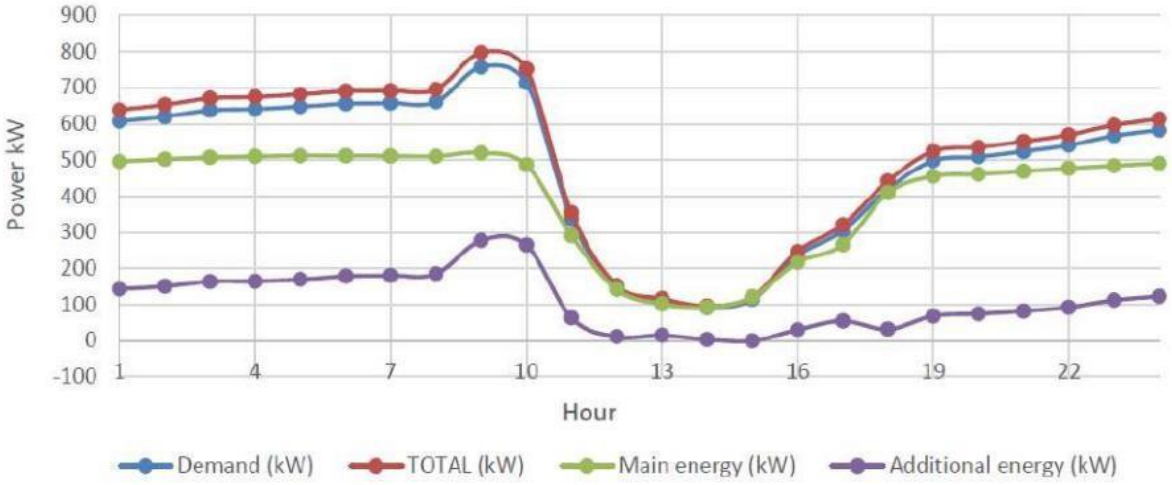


September

Hourly heating demand

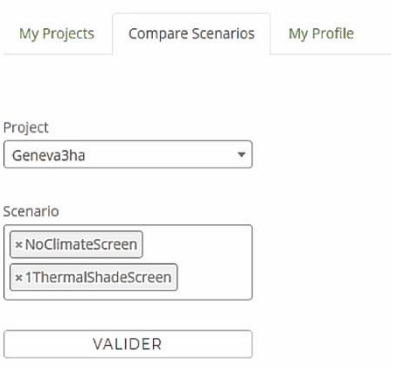
We also offer the possibility to see in kW the heating demand of your greenhouse for anaverage day each month.

Hourly heating demand for an average day



in January

II Online comparisons

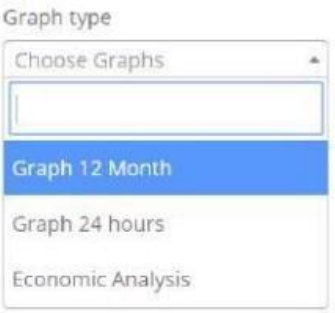


Thanks to the comparison interface, you can compare different scenarios that you have created from a greenhouse project.

You can proceed ton online comparisons of the technical solutions based on your different scenario, to compare your investment and find optimal configuration for your greenhouse project.

An online interface to compare scenarios and choose the most sustainableinvestment

You can choose between 12 months or 24 hours charts with differentcomparison possibilities.
For example, you will have these columns with 12 months graph:



Energy:

- Demand (MWh) depending on your greenhouse and cropspecification
- Total consumption including the yield of your heating system(MWh)
- Main heating device consumption (MWh)
- Auxiliary heating device consumption (MWh)

Costs:

- Total expenditure (according to your currency)
- Main heating expenditure (according to your currency)
- Auxiliary heating expenditure (according to your currency)

Dehumidification:

- Dehumidification (MWh)
- Dehumidification if heating (MWh)

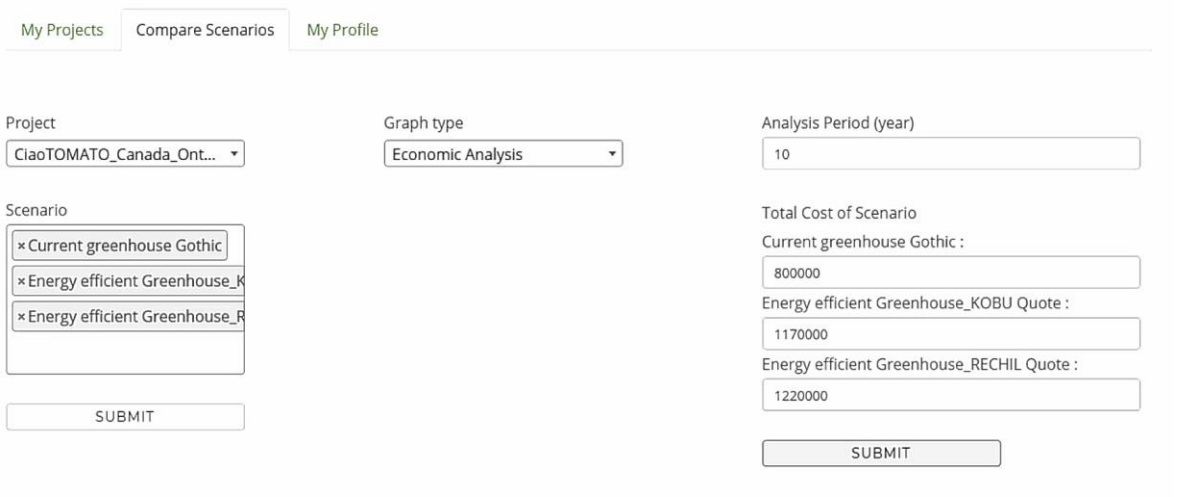
Solar radiation:

- External (kWh/m² day)
- Internal (kWh/m² day)

- PAR internal (mol/m² day)

Auxiliary :

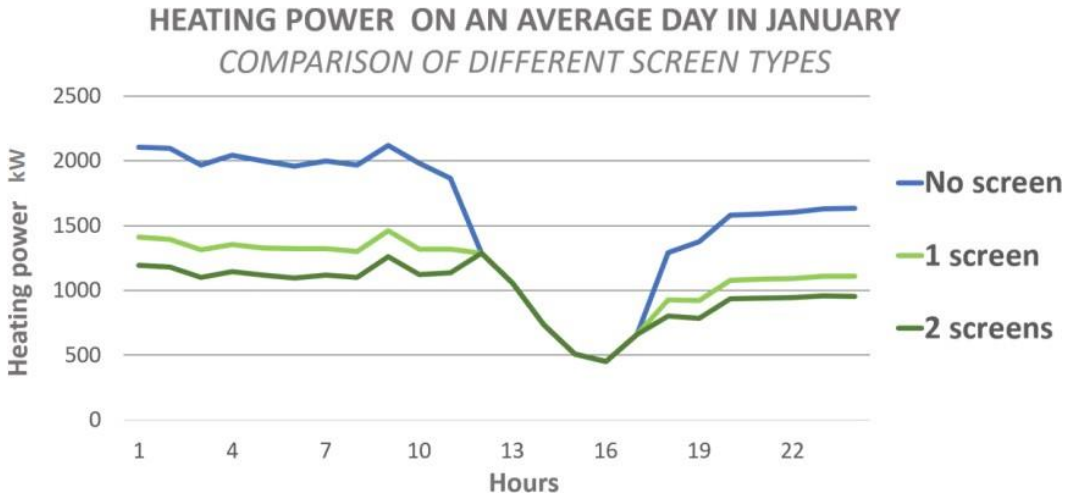
- Electricity (MWh)
- Water (m^3)



Data comparison

For example, here is the heating power on an average day in January graph, depending on thenumber of screens.

Moreover, you may also choose to compare different columns on the same graph.



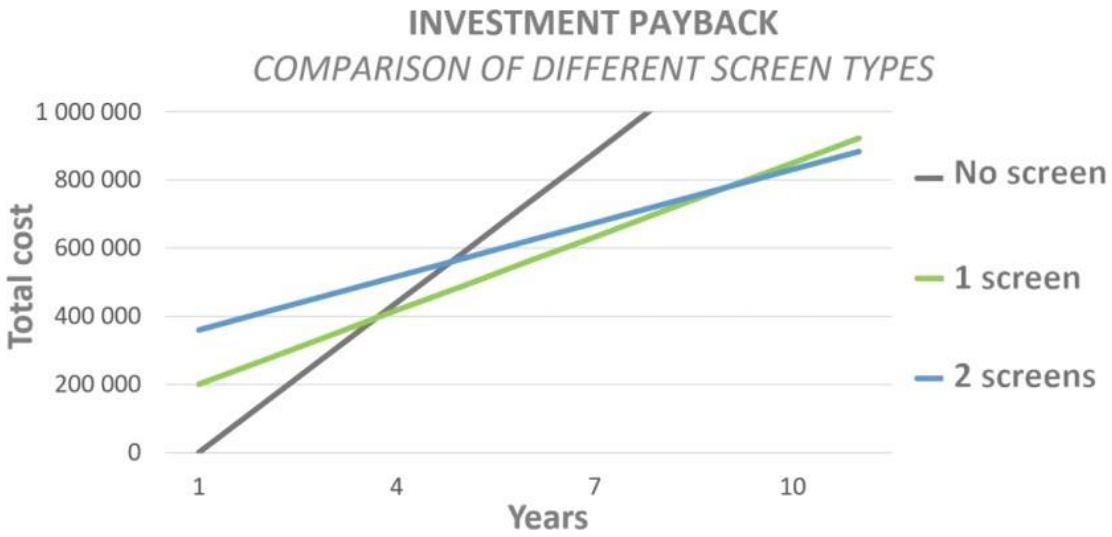
Economic analysis

You can also proceed to an economic analysis in relation to your greenhouse project.

This interface is really useful to compare different scenario for a same project. For instance:

- with/without thermal screen

- 4/6 mm glasses



Now we can create our project:

D. FORM

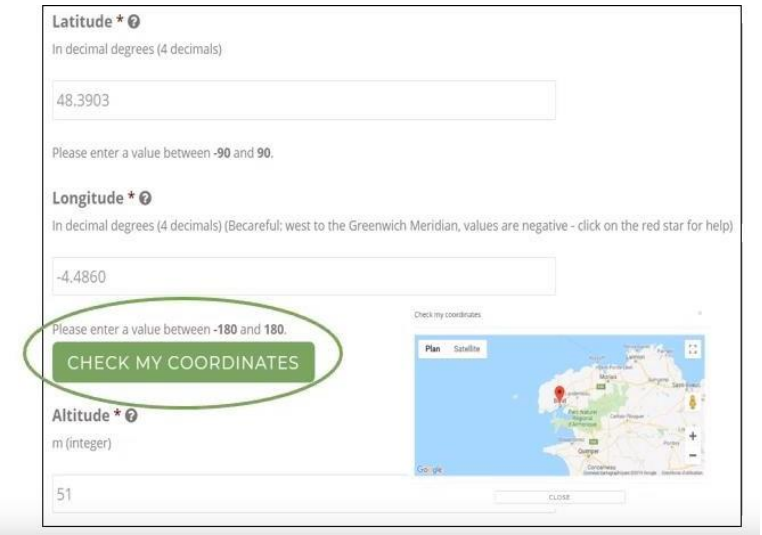
I Main parameters

Name of the project

Name of the scenario in this project

Location of your greenhouse

Type in the **geographical coordinates** of your greenhouses



Latitude:

To find the exact GPS latitude andlongitude coordinates of your project go to mapcoordinates.net

Longitude:

To find the exact GPS latitude and longitude coordinates of your project go to mapcoordinates.net Becareful: west to the Greenwich Meridian, values are negative! Ex: longitude coordinates for New-Yorkis -74.0059731 not 74.0059731

CHECK MY COORDINATES: *Check easily the coordinates by clicking on the button "check mycoordinates".*

Altitude: *To find the exact altitude of your project go to mapcoordinates.net*

1 Meteonorm

According to GPS coordinates of the greenhouse, Hortinergy displays in the report a typicalyear on an hourly basis including weather parameters, such as temperature, relative humidity, wind and solar radiation.

The weather file is generated by Meteonorm based on GPS coordinates of the greenhouse.

Meteonorm is a Swiss software generating weather files, used worldwide by designed ofsolar plants and buildings.

Meteonorm is embodied into Hortinergy.

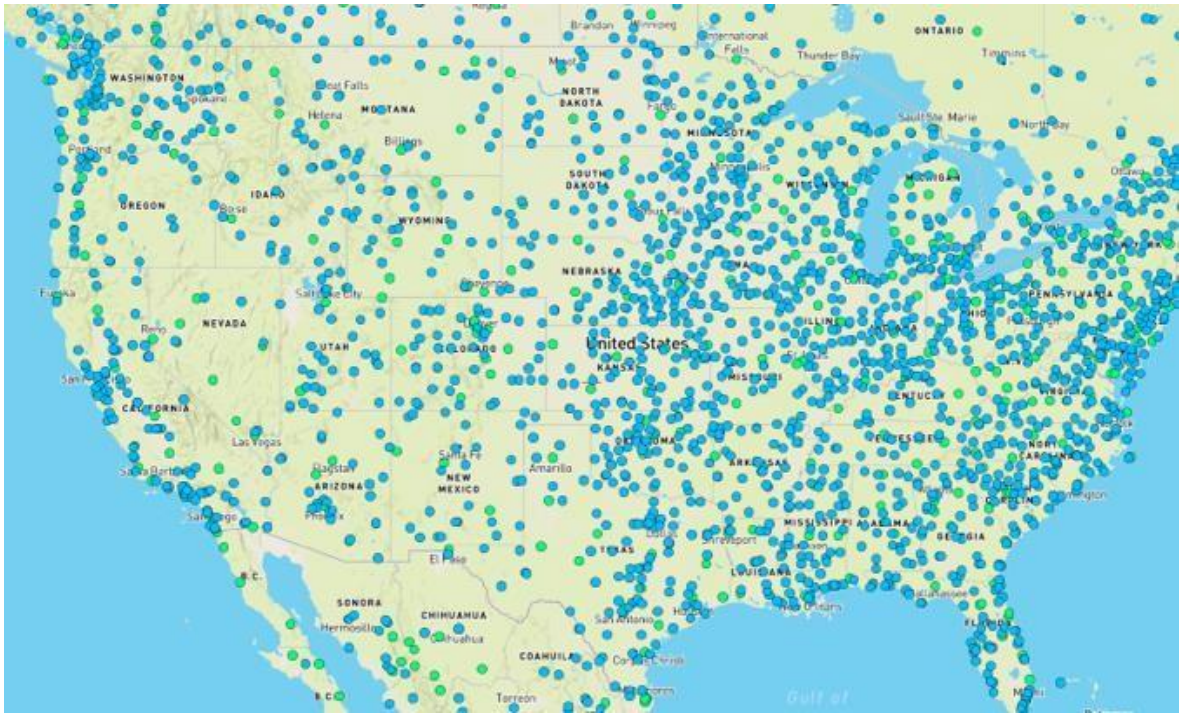
Combining satellite data and interpolation of weather stations, Meteonorm generates weatherfile for a typical year.

Weather file includes on an hourly basis for a typical year;

- Temperature
- Relative humidity
- Solar radiation: global horizontal, diffuse, normal
- PAR
- Wind direction and velocity
- Sky temperature
- Nebulosity

We show below maps of weather station in USA as an example. Other maps are in appendix.

USA :



See in appendix the list of the weather stations maps.

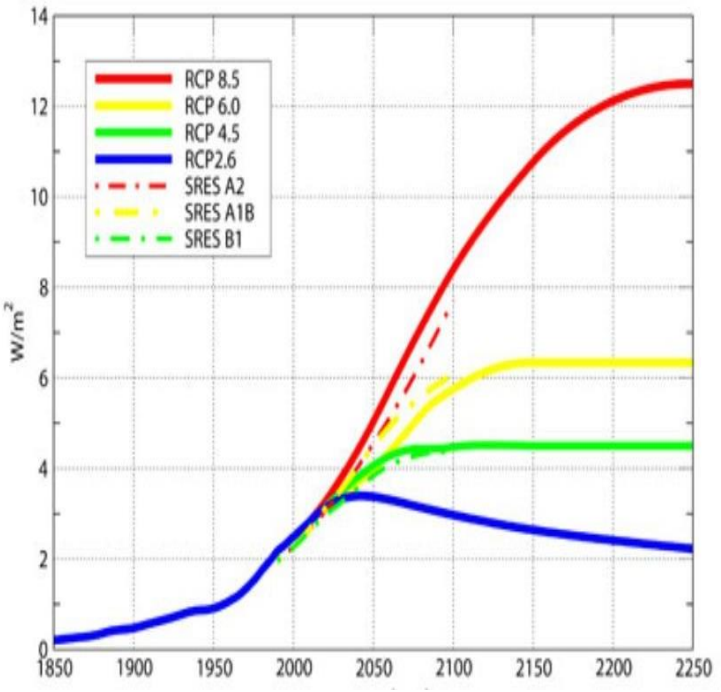
2 Climate change model

How does it work ?

A Representative Concentration Pathway (RCP) is a greenhouse gas concentration and emission adopted by the IPCC. In order to assess these pathways, a number has been set up, based on the planet's radiative balance.

Radiation balance (W/m²) = (solar radiation received) – (infrared radiation re-emitted)

The higher the value of radiation balance is, the less energy the planet re-emits, therebykeeping it into the atmosphere.



What are the Hortinergy parameters ?

With Hortinergy, it is possible to compare scenarios (RCP 2.6 – RCP 4.5 – RCP 8.5) of your installation.

Contemporary weather data or IPCC forecast scenarios *

Contemporary: typical year weather data (2020)

- ○ Contemporary
- ◉ **IPCC forecast scenarios**

IPCC Scenario *

- ○ No scenario
- ○ RCP 2.6
- ○ RCP 4.5
- ◉ **RCP 8.5**

IPCC year *

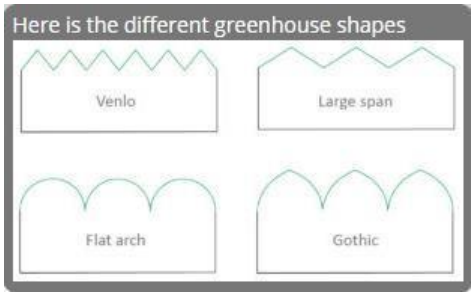
- ○ 2030
- ◉ **2040**
- ○ 2050
- ○ 2090

3 Characteristics of your greenhouse

Type of greenhouse shape * ?

Venlo

Enter **the type** of greenhouse



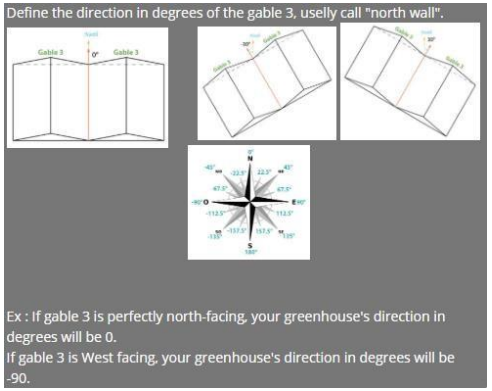
Orientation * ?

(integer) Direction in degrees of the "north wall"

0

Please enter a number from **-180** to **180**.

The orientation of the greenhouse



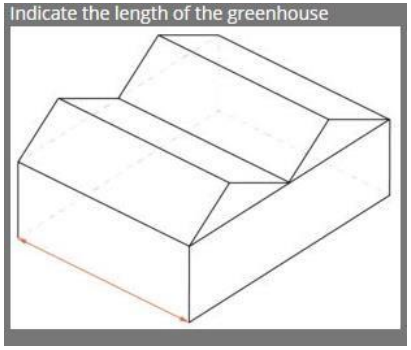
Length * ?

In m (2 decimals)

100

Please enter a number from **0.1** to **1000**.

The length of the greenhouse



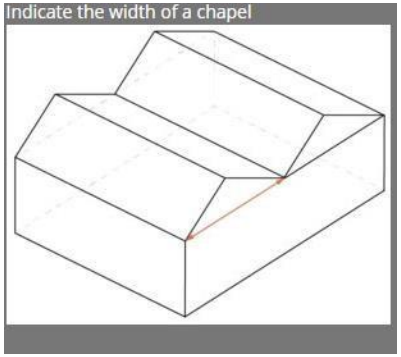
Span - chapel width *

In m (2 decimals) (gutter to gutter)

9.6

Please enter a number from **0.1** to **30**.

Indicate the **width of a chapel**



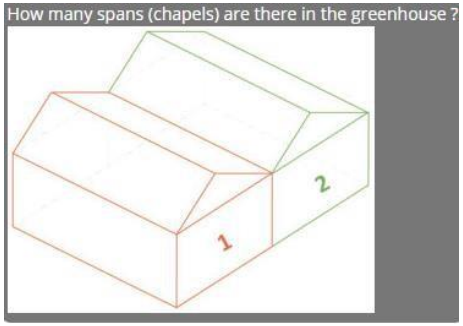
Number of span (chapel) *

(2 decimals)

10

Please enter a number from **1** to **100**.

Indicate the number **of spans**



Roof height and Gutter height:

Roof height * ?

(2 decimals)

7.8

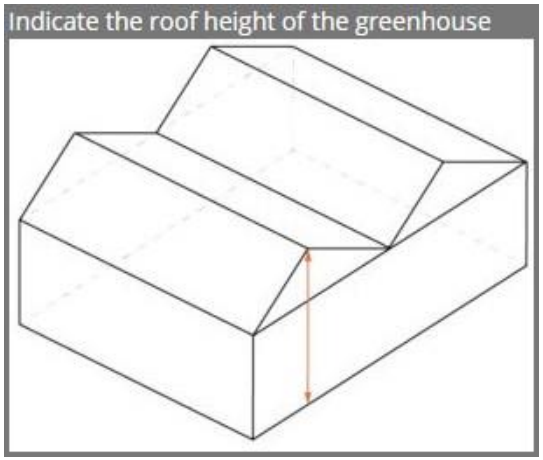
Please enter a number from **0.2** to **12**.

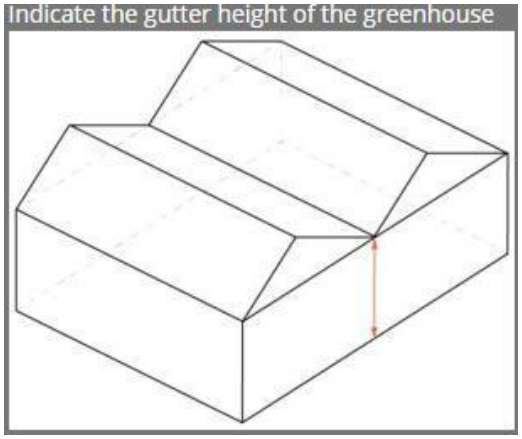
Gutter height - Ridge height * ?

(2 decimals)

7

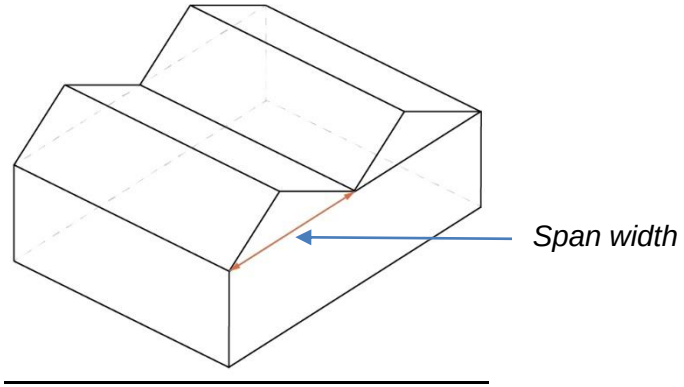
Please enter a number from **0.1** to **12**.





4 Greenhouse types

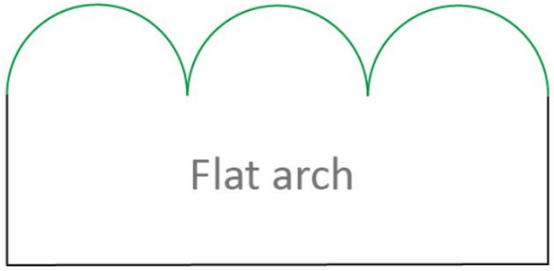
Hortinergy offers you plenty of greenhouse types for the greatest optimization of your installation.
Hereunder the greenhouse types :

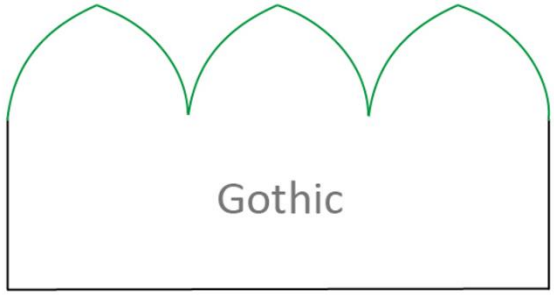


-Venlo greenhouse : fitted with glass, polycarbonate or ETFE. Usefull for large projects. Span width : post to post distance → 8 or 9.6m / gutter to gutter distance → 3.2 or 4m. This type of greenhouse is cheaper than large span one.

-Large span greenhouse : fitted with glass, ETFE or polycarbonate. Suitable for small-area planting. Span width : from 6 to 17m.

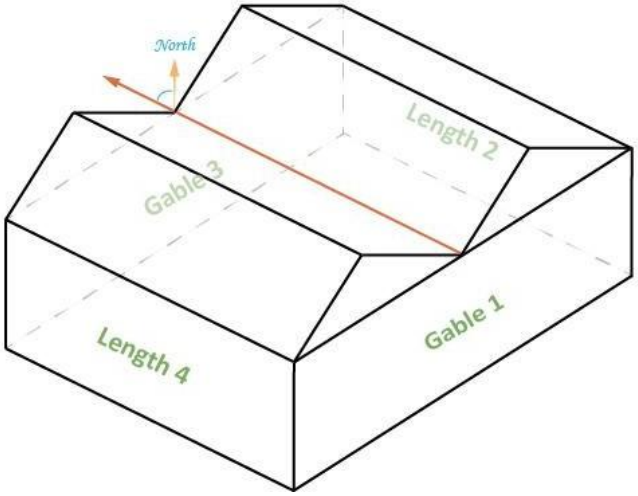
-Flat arch and gothic greenhouses : fitted with plastic. Suitable for large or small area planting.

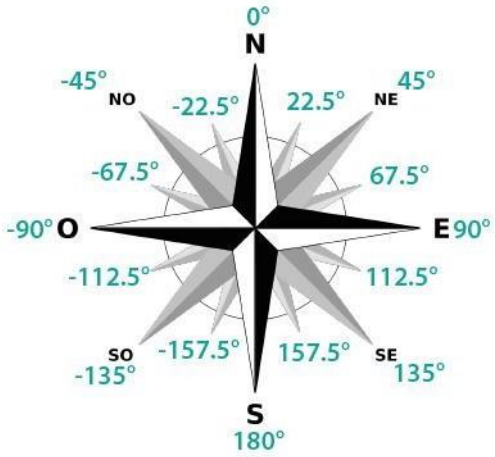




5 Orientation

How to set up the greenhouse dimensions ?





Hereunder the orientation setup of a greenhouse :

-Gable 1 : South wall.

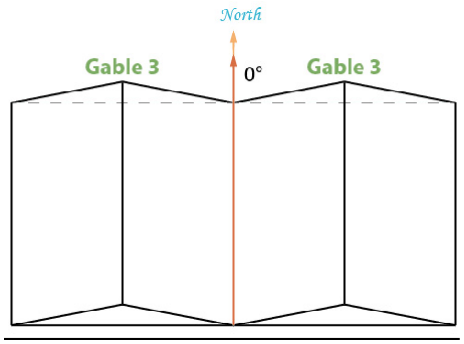
-Gable 3 : North wall.

-Length 2 : East wall.

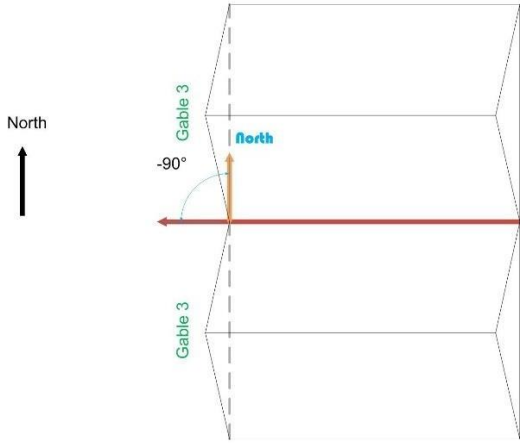
-Length 4 : West wall.

Orientation is based on gutter axis or Gable 3. For instance, it is negative if Length 2 is towards North-East, and positive if Length 2 is towardsSouth-East.

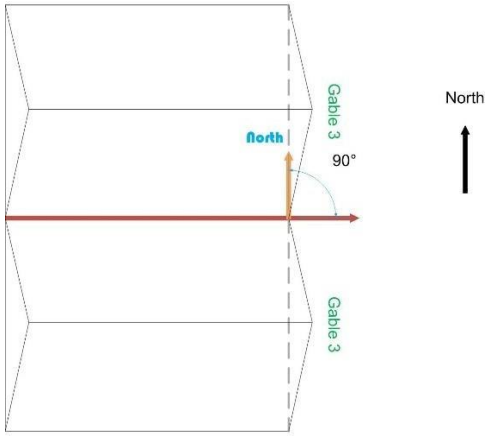
Examples :



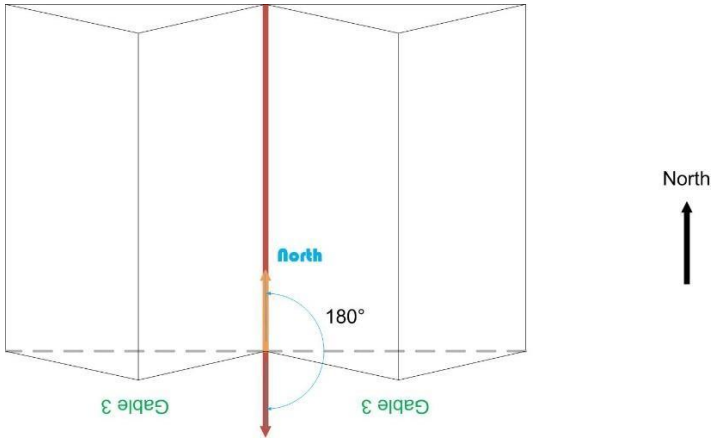
-If Gable 3 is perfectly north-facing, then your greenhouse's direction in degrees will be 0. It also means that Length 2 is totally east-facing,while Length 4 is west-facing.



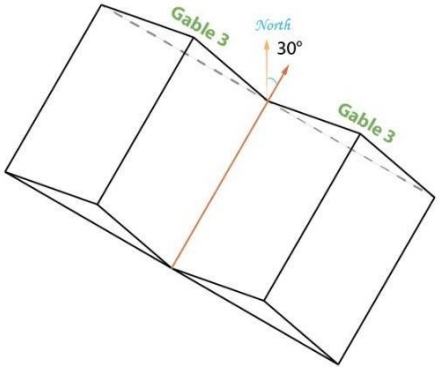
-If Gable 3 is west-facing, then your greenhouse's direction in degrees will be -90. It also means that Length 2 is north-facing, while Length 4 issouth-facing.



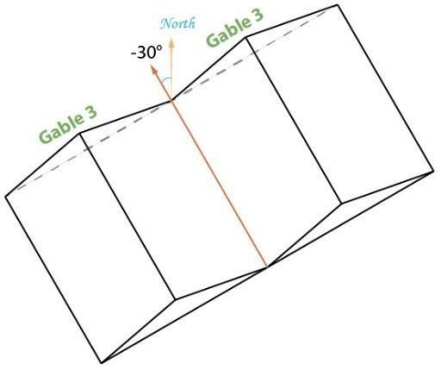
-If Gable 3 is east-facing, then your greenhouse’s direction in degrees will be 90. It also means that Length 2 is south facing, while Length 4 isnorth-facing.



-If Gable 3 is perfectly south-facing, then your greenhouse’s direction in degrees will be 180. It also means that Length 2 is west-facing, whileLength 4 is east-facing.



-If Gable 3’s direction is N-30°E, then Length 2’s direction is N-120°E and Length 4’s one is N-60°W.



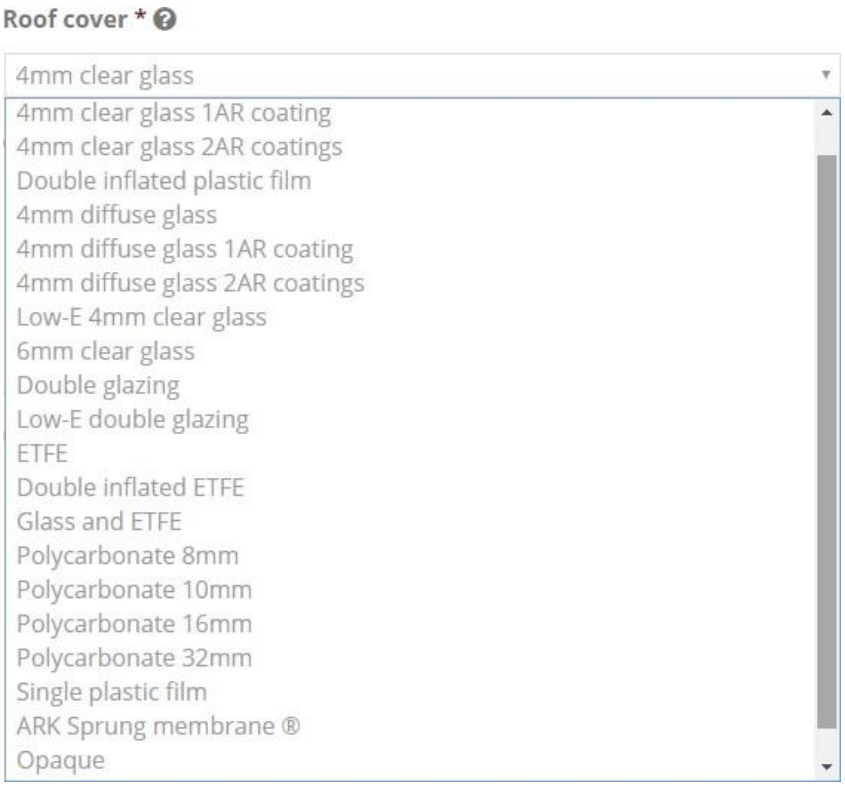
-If Gable 3’s direction is N-30°W, then Length 4’s direction is N-120°W and Length 2’s one is N-60°E.

II Envelop Specification

1 Cover specification

Hortinergy offers you the possibility of choosing several solutions of greenhouse cover. Hereunder the two parameters used for roof and vertical faces :

- Find the perfect cover for your project in our **large library**



Roof cover selection is automatically duplicated to the 4 vertical covers.
Gable cover selection is automatically duplicated to all other 3 vertical covers.
Length 2 cover selection is automatically duplicated to Length 4.

<u>Frame percentage :</u>
It is the opaque part of the roof, that is not transparent. It is usually 10% for glass greenhouse and 8% for plastic greenhouse.
User can modify manually its selection.

2 Screen specification

Screen types :

- Choose your screen type from our list and **set its characteristics**

A screen works as a curtain which can be installed vertically or horizontally. It aims to regulate inner temperature and humidity, reduce heat losses and control solar radiation, whatever the external climate surrounding the greenhouse.

What are the Hortinergy parameters ?

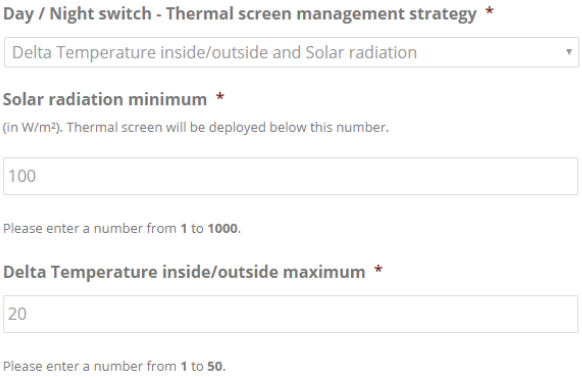
- (•) **Thermal**
- ( ) Thermal and Shade (aluminium)
- ( ) Thermal and Shade (white strips diffuse)
- ( ) Shade and Open (aluminium)
- ( ) Shade and Open (white strips diffuse)
- ( ) Black out

Transparent thermal screen : the major aim is to reduce energy loss. For instance, in order to maintain inner temperature during dark and cold period, it is deployed, thus keeping heat and radiation.

Hereunder a greenhouse composed with a transparent screen.

Thermal screen can be regulated according to 2 parameters:

- External solar radiation
- Temperature difference between outside and inside



During the night, morning, evening or cloudy days, when the incoming solar radiation is below 100 W/m², it is deployed to reduce heat losses and to let the solar radiation get in. On the other hand, when the incoming solar radiation is above 100 W/m², the thermal screen is undeployed.

- As regards the temperature difference between outside and inside, the screen is deployed if the difference is higher than the setting and undeployed if the difference is lower

For tomato crop, standard values for a temperate climate such the Netherlands are:

- External solar radiation: 100 W/m²
- Temperature difference between outside and inside

Shading screen : it is used to reduce direct radiation and the overall light level in the glasshouse to reduce overheating and to avoid burning leaves.
There are 2 types of materials for shade screen:

- aluminum
- white strips diffuse

There are also 2 types of structure for shade screen:

- open: space is open between shade strips -> good for ventilation, limited thermal effect
- closed: high thermal effect, chimney is required for ventilation

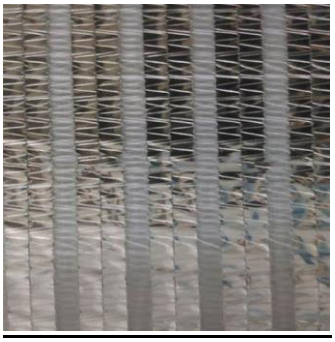
Shade and open – shade and thermal screens :

Diffuse screen :
-shades the light away
-diffuse light under the crop
-avoid burning the top of plants

Aluminum screen :
-shades the sunlight away
-highly reflective due to its material
-deploys at night to reduce the radiation heat losses, thereby provoking condensation on the plants

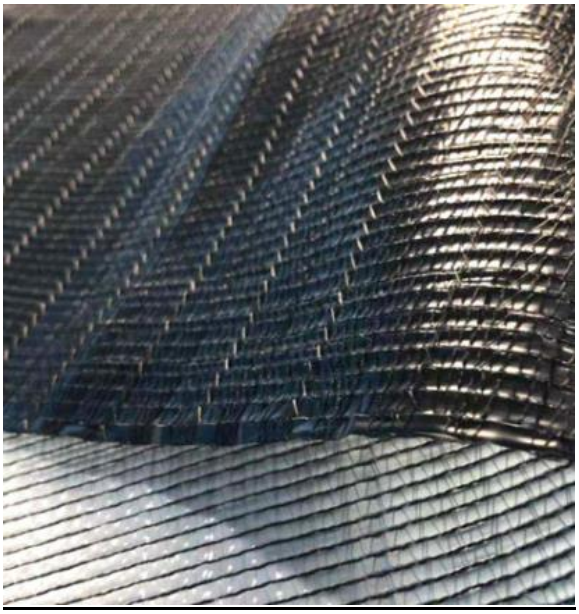
Hereabove a thermal and shading screen inside a greenhouse in northern Europe.
For instance, when incoming solar radiation is above 500 W/m², the shade screen is deployed.

Hereunder a shade and open screen with aluminum strips.



With an open shading screen, a natural ventilation of your greenhouse is possible. However, as regards the closed shading screen, a chimney is required to get a natural ventilation.
Hereunder an example of thermal shading screen with a chimney :

Black out screen : this screen prevents the plants from incoming solar radiation, from 99 to 100%. It is mostly used for the control of photoperiod and the prevent of light pollution to ensure an ideal growth of cannabis crops and ornamental plants.



3. Black out screen management strategy

Black out starting date

dd/mm/yyyy

Black out ending date

dd/mm/yyyy

Black out screen : number of hours per day without solar radiation

12

Please enter a number from **1** to **24.**

Let’s take as an example the crop of cannabis, which needs 12h of lighting a day.
In summer, the day light period is higher than 12h, therefore blackout screens are deployed to day length to 12h in the greenhouse
In winter, the day light period is lower than 12h, therefore assimilation lighting is required to reach 12h. Then black out screen is required to prevent the environment from light pollution. Thereby, the black out screen is pulled when light intensity is below 20 W/m².

3 Roof

Roof

Roof cover * ?

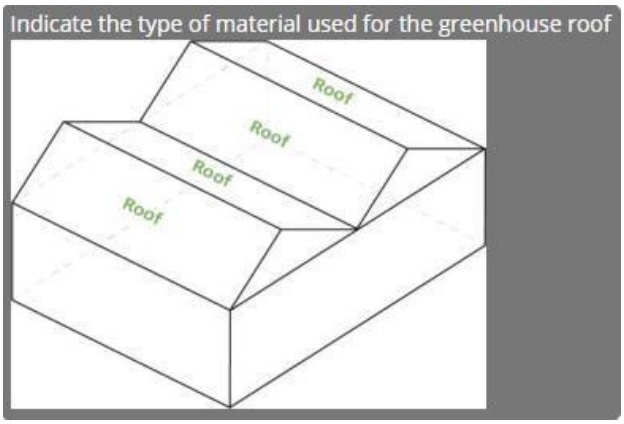
4mm clear glass

Frame percentage ?

It is the opaque part of roof.

10

Please enter a number from **1** to **99**.



Climate screen number:

- *How many climate screen is there on this side of the greenhouse?*

1st climate screen type:

- *Indicate the type of climate screen installed in this side of the greenhouse*

1st climate screen: shade percentage

1st climate screen: energy efficiency

1st climate screen: diffuse

2nd climate screen: type

- *Indicate the type of climate screen installed in this side of the greenhouse*

2nd climate screen: shade percentage

2nd climate screen: energy efficiency

2nd climate screen: diffuse

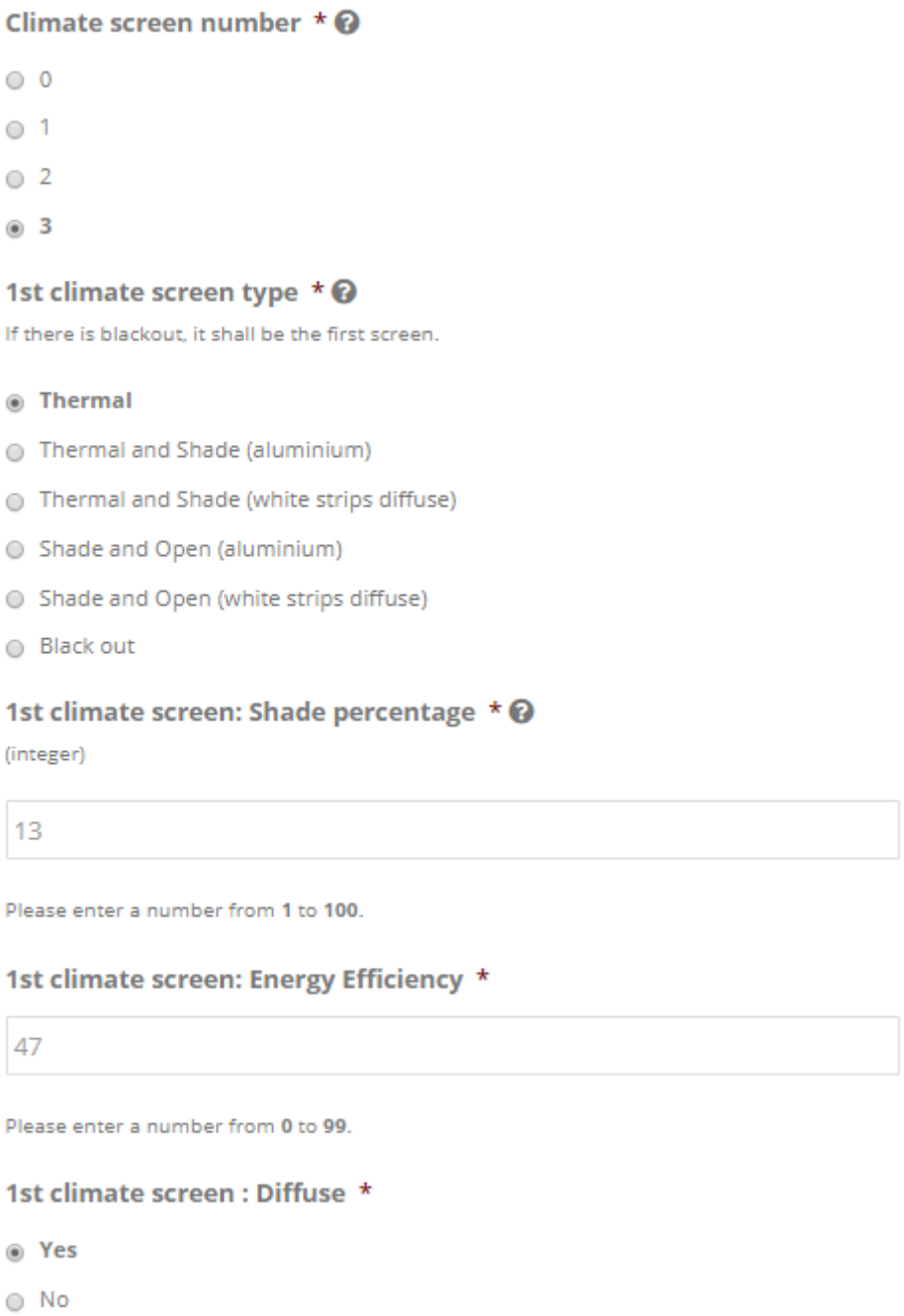
3rd climate screen: type

3rd climate screen: shade percentage

3rd climate screen: energy efficiency

3rd climate screen: diffuse

Example :



4 Vertical walls

Gable 1

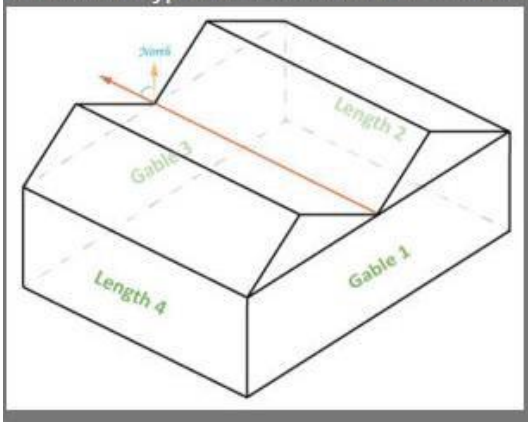
1. Wall cover * ?

4mm clear glass

1. There is a climate screen: * ?

- 0
- 1
- **2**

Indicate the type of material used for this wall of the greenhouse



1.1st climate screen type:

- (●) **Thermal**
- ( ) Thermal and Shade (aluminium)
- ( ) Thermal and Shade (white strips diffuse)
- ( ) Shade and Open (aluminium)
- ( ) Shade and Open (white strips diffuse)
- ( ) Black out

1st climate screen: Shade percentage * ?

(integer)

13

Please enter a number from **1** to **100**.

1st climate screen: Energy Efficiency *

47

Please enter a number from **0** to **99**.

1st climate screen : Diffuse *

- (●) **Yes**
- ( ) No

2nd climate screen : type * ?

- (●) **Thermal**
- ( ) Thermal and Shade (aluminium)
- ( ) Thermal and Shade (white strips diffuse)
- ( ) Shade and Open (aluminium)
- ( ) Shade and Open (white strips diffuse)
- ( ) Black out

2nd climate screen: Shade percentage

(integer)

13

Please enter a number from **1** to **100**.

2nd climate screen: Energy Efficiency *

47

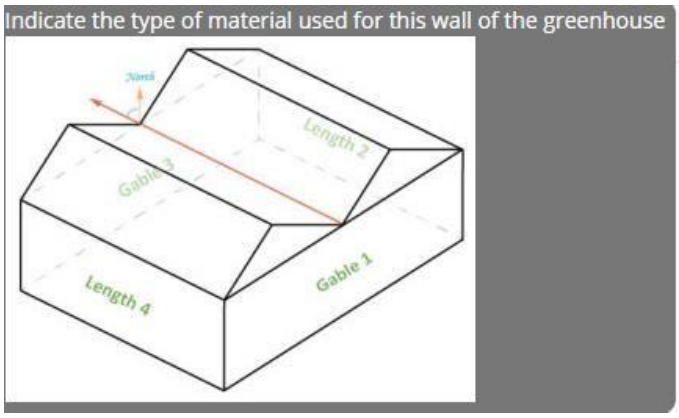
Please enter a number from **0** to **99**.

2nd climate screen : Diffuse *

- (●) **Yes**
- ( ) No

Length 2

2.Wall cover:



2. There is a climate screen

2.1 st climate screen: type

- *Indicate the type of climate screen installed in this side of the greenhouse*

2.1 st climate screen: shade percentage

2.1st climate screen: energy efficiency

2.1st climate screen: diffuse

2.2 nd climate screen: type

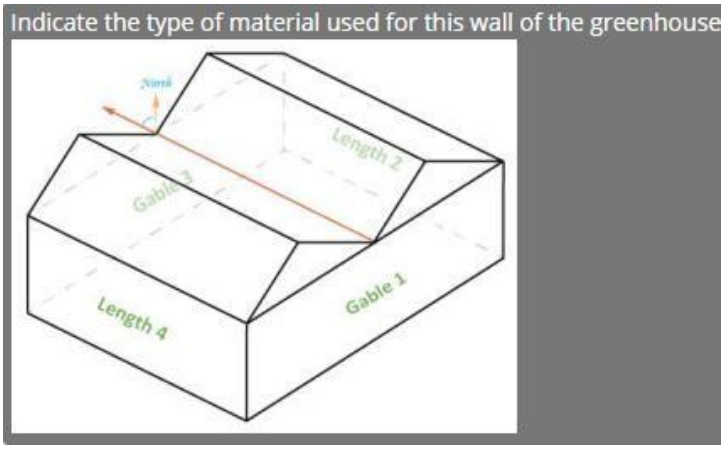
2.2nd climate screen: shade percentage

2.2nd climate screen: energy efficiency

2.2nd climate screen: diffuse

Gable 3

3. Wall cover:



3. There is a climate screen

3.1 st climate screen: type

3.1st climate screen: shade percentage

3.1st climate screen: energy efficiency

3.1st climate screen: diffuse

3.2 nd climate screen: type

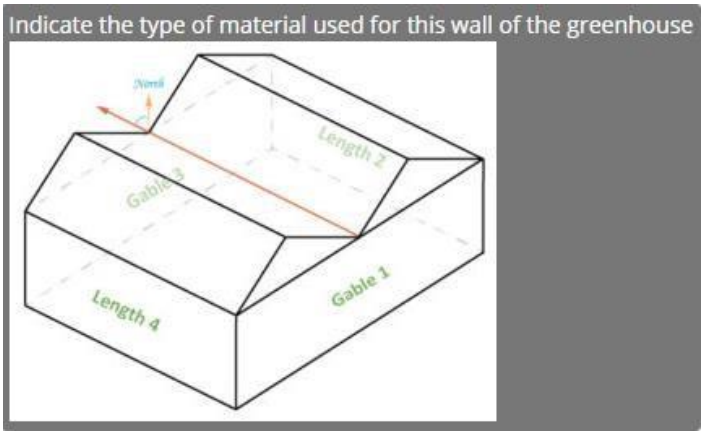
3.2nd climate screen: shade percentage

3.2nd climate screen: energy efficiency

3.2nd climate screen: diffuse

Length 4

4. Wall cover:



4. There is a climate screen

4.1st climate screen: type

- *Indicate the type of climate screen installed in this side of the greenhouse*

4.1st climate screen: shade percentage

4.1st climate screen: energy efficiency

4.1st climate screen: diffuse

4.2 nd climate screen: type

4.2nd climate screen: shade percentage

4.2nd climate screen: energy efficiency

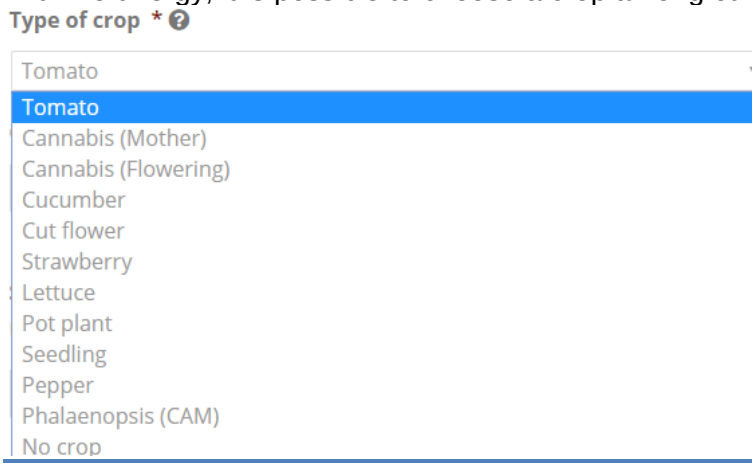
4.2nd climate screen: diffuse

III Crop production

1 Crop settings

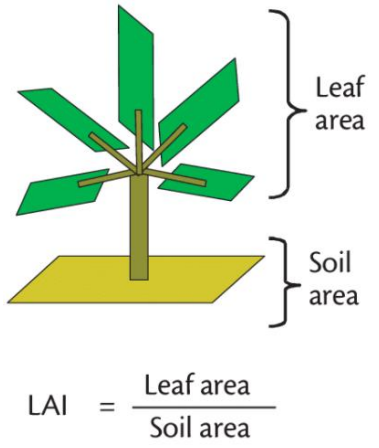
Crop library :

With Hortinergy, it is possible to choose a crop among others, thanks to its library.



2 Crop transpiration

Crop transpiration is calculated according to Penman-Monteith equation.based on crop type, LAI (Leaf Area Index), light (solar/supplementary), temperature, humidity and air velocity.
The higher solar radiation and inner temperature are, the higher crop transpiration is. But the higher relative humidity is, the lower crop transpiration is.
LAI is the link between leaf area and soil area covered by the leaves. The higher LAI is, the more important crop transpiration become.



The LAI is pre-defined in Hortinergy based on the type of crop, its transplantation date and seedling age. Cultivation starting and ending dates are also required.

Type of crop *

Tomato

Cultivation starting date *

05/12/2020

End of cultivation *

15/11/2021

Seedling age at transplanting *

In weeks

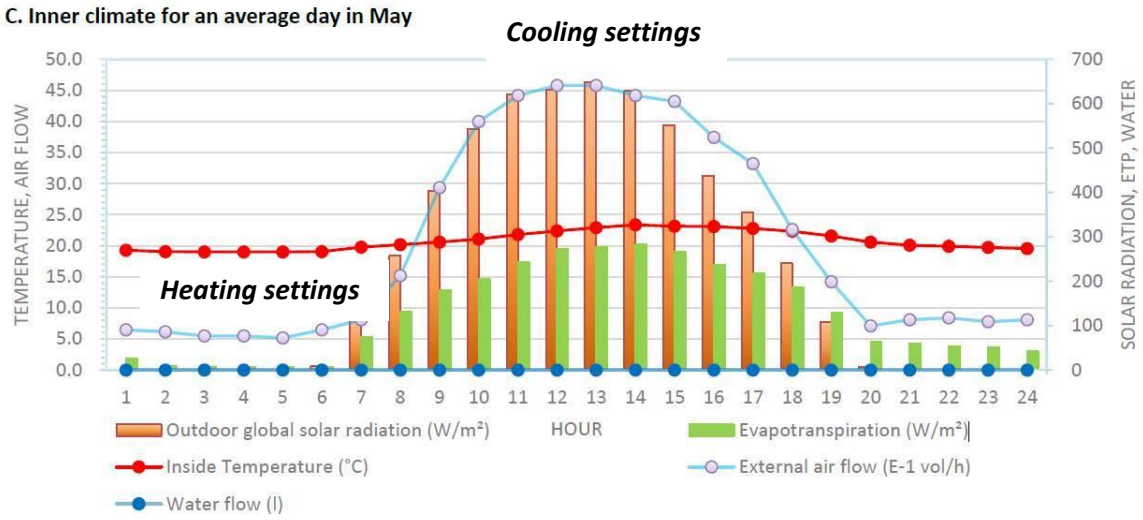
4

Please enter a number from **0** to **52**.

The seedling age at transplanting is the age, in weeks, of seeds before they get transplanted inside a greenhouse. The older seeds are, the faster crop growth and LAI will be, which means a transpiration more significant in a short period of time.

Results :

Hortinergy shows the water transpiration by the crop (that is more /less than irrigation needs-substrate transpiration (that is very low)).



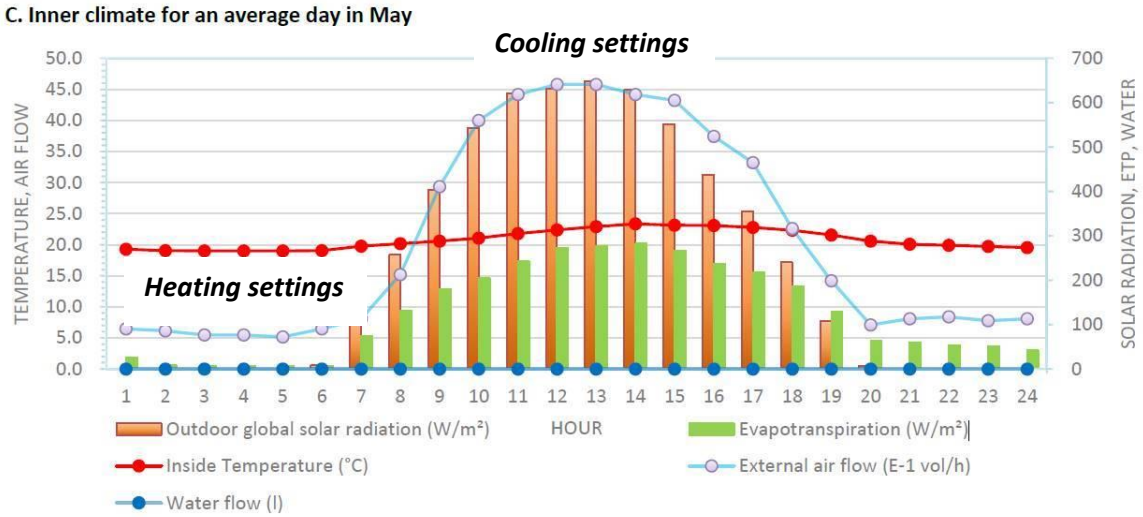
Evapotranspiration is the water transpiration by the crop. It is put in W/m² to show direct relation with solar radiation. The higher solar radiation and inner temperature are, the higher crop transpiration is.

Evapotranspiration for 1 l water = approx 0.68 kWh energy (depending on temperature)
These results are accurate for tomato in winter, but are theoretical in peak summer when other factors can limit transpiration (hydric stress, leaf temperature too high…).

IV Climate control setting

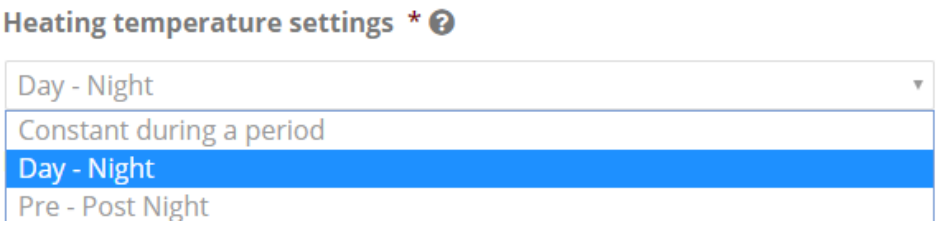
1 climate settings

Each crop shall have its own climate conditions to grow in a good environment. In response to that, Hortinergy takes into account 3 settings : heating, humidity and vents opening.
Heating system will be activated to prevent the inner temperature to drop below these settings. Then, due to insolation, inner temperature could go up fast. In that time, vents opening settings will be turned on to cool the inside of the greenhouse.



When humidity is higher than the settings, vents, active ventilation or dehumidification are activated.

Heating settings

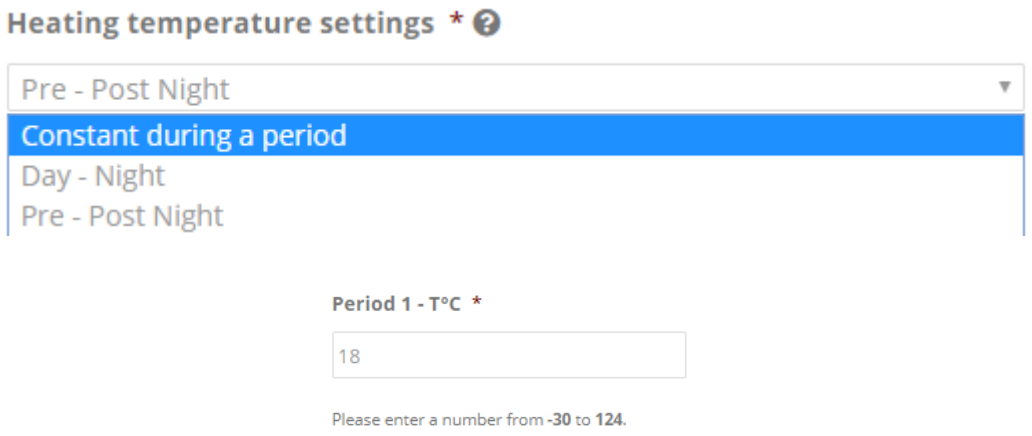


Heating system is turned on when temperature will not drop below the required inner temperature of the greenhouse.

<u>Hereabove the different temperature regulation modes :</u>

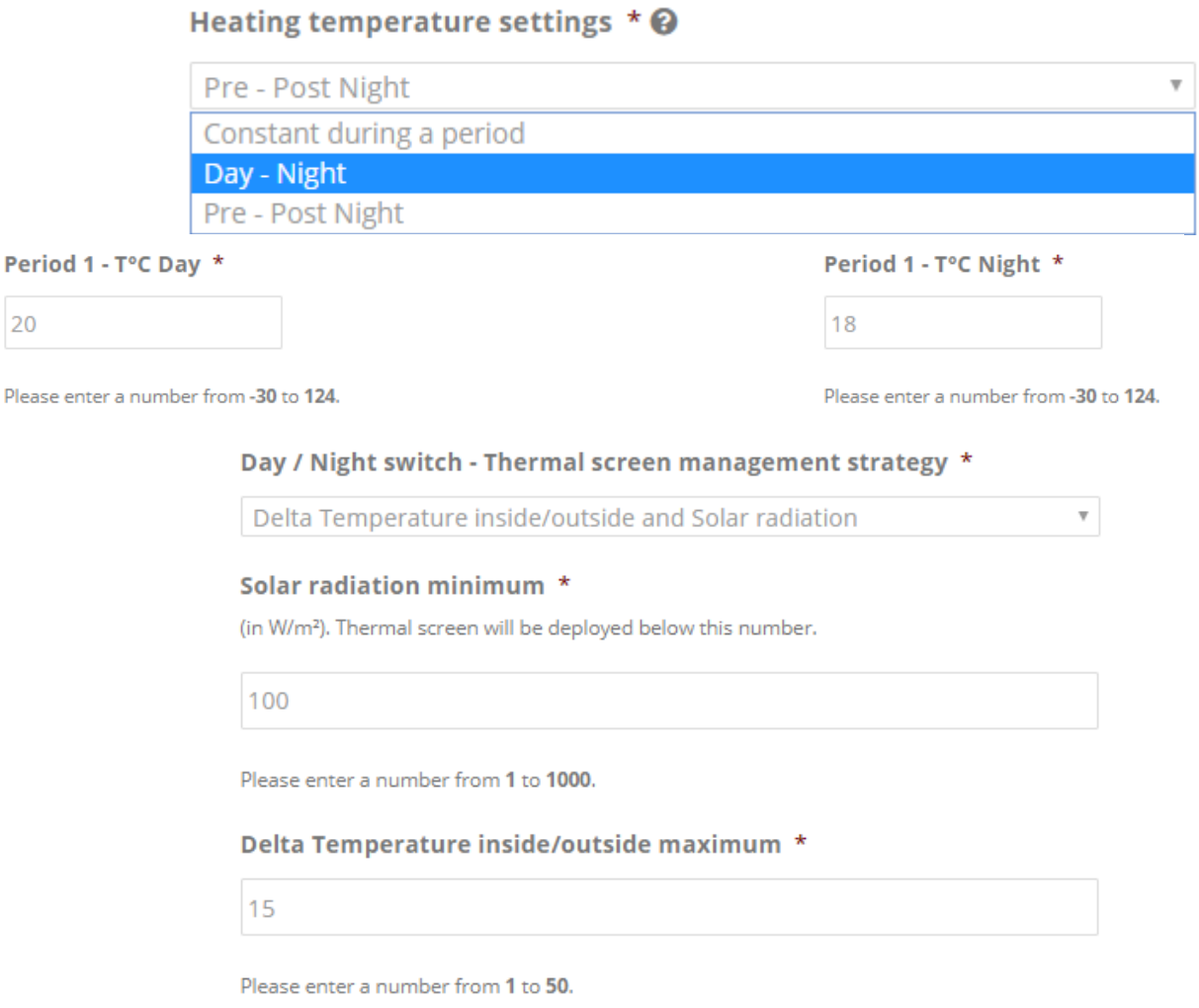
1. Constant during a period

First, the “Constant during a period” option, as indicated, means that the minimum temperature to heat the greenhouse during a day will be the same. However inner temperature can be higher due to external clilmate . Mostly used for pot plants.



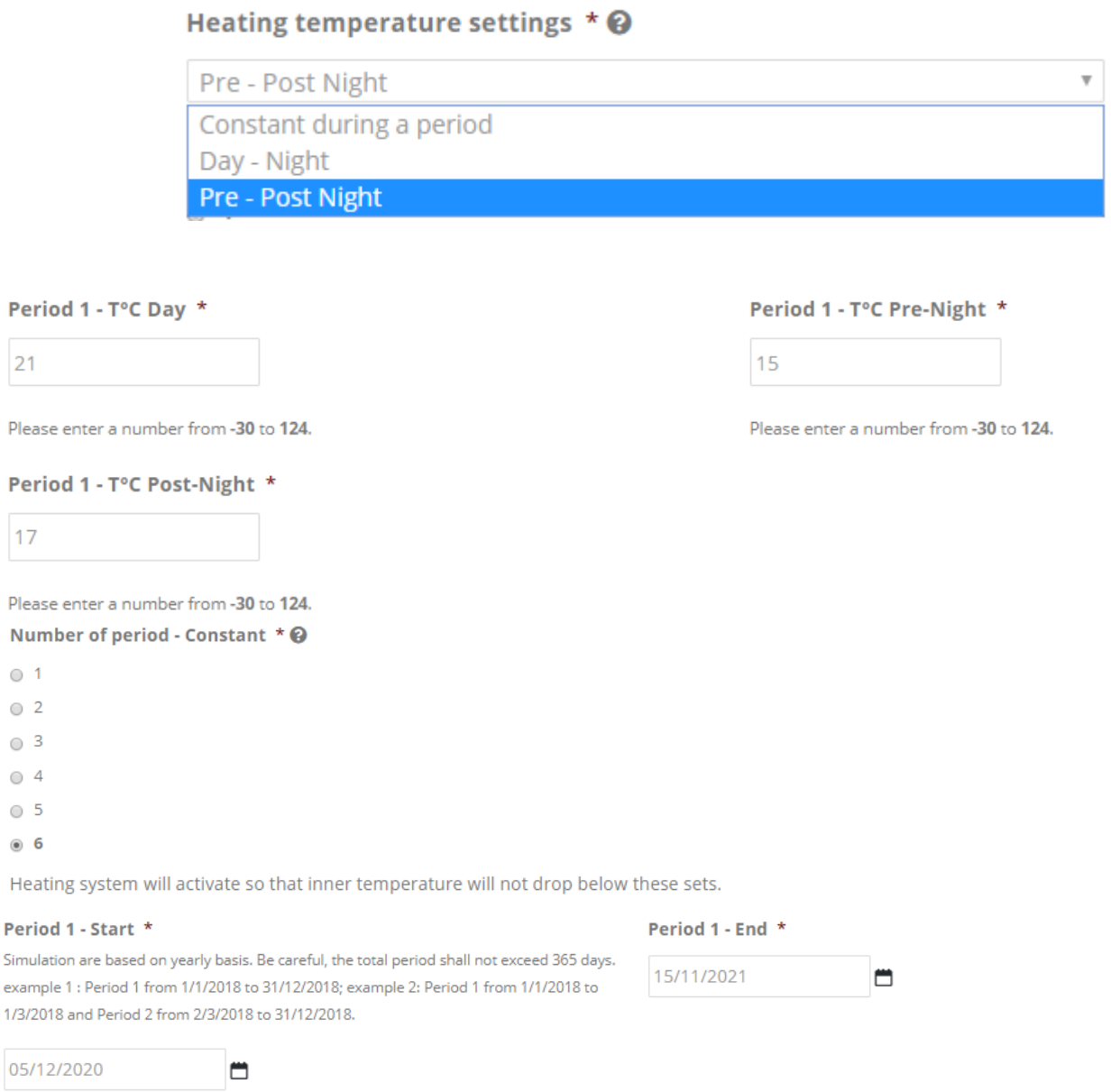
2. Day-Night

Then, with the “Day-Night” option, you need to insert the minimum required inner temperatures during the day and night. It is based on two parameters : the delta temperature inside/outside and the solar radiation, which will be used to deploy the thermal screen. Daytime setpoint temperature is usually higher than nightime one, so as to ensure a good growth of the crop and a better return on energy saving. Mostly used for the crop of cannabis.



3. Pre-Post night

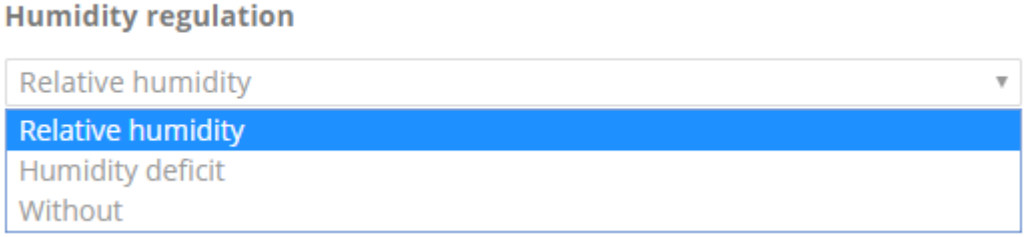
Finally, the “Pre-Post night” option is used to split the night in two. For instance, if the night lasts 8 hours, it will be composed of a 4 hours pre-night, followed by a 4 hours post-night. Pre-night setpoint temperature is usually lower than post-night one. Mostly used for tomato crop.



The duration of a period is set by the customer. For instance, a period may be from 12/01/2021 to 13/01/2021 or from 15/03/2021 to 18/09/2021. Moreover, in one year, 6 periods may be chosen.

b) Humidity settings

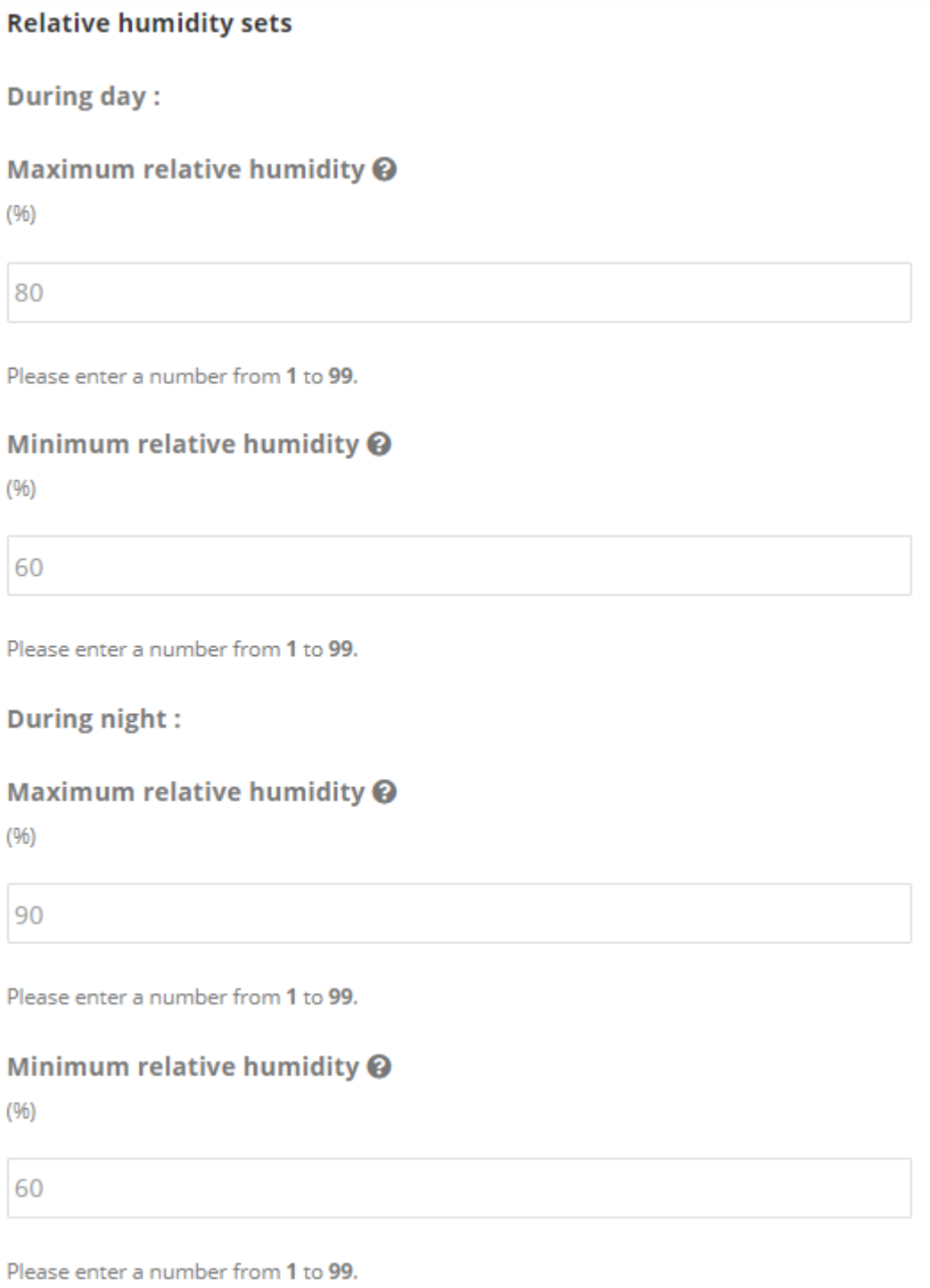
Besides, you can arrange the humidity settings, first by choosing between relative humidity and humidity deficit, then by setting maximum and minimum humidity rates during daytime and nightime :



Relative humidity : percentage of the saturated/maximum water vapour content at the actual temperature. RH = (actual water vapour content) / (maximum water vapour content) x 100.

Humidity deficit : difference between the maximum water vapour content at the actual temperature and the actual water vapour content. Unit in g.kg or g/m³.
You have also the possibility of not choosing any humidity regulation, which means that vents will stay closed at 100% of humidity.

Vents, exhaust fans or HVAC system will turn on as soon as :
- the inner humidity deficit is lower that the set one
- the inner relative humidity exceeds the set one



Humidity deficit sets

During day :

Minimum humidity deficit

(g water/ kg dry air)

4

Please enter a number from **0** to **20**.

Maximum humidity deficit

(g water/ kg dry air)

7

Please enter a number from **0** to **20**.

During night :

Minimum humidity deficit

(g water/ kg dry air)

1

Please enter a number from **0** to **20**.

Maximum humidity deficit

(g water/ kg dry air)

7

Please enter a number from **0** to **20**.

Vents opening settings

In a traditional greenhouse, vents will be opened to cool it as soon as the inner temperature exceeds the set one.

Ventilation opening temperature

30

Please enter a number from **0** to **124**.

2 Climate settings for different crops

Hereunder an example of climate settings for different crops :

	HEATING SETPOINT TEMPERATURE			HUMIDITY MAX
	PRE NIGHT	POST NIGHT	DAY	
TOMATO	15	17	21	85
CUCUMBER	19	19	21	90
BEL PEPPER	19	19	21	90
LETTUCE	15	15	17	80
STRAWBERRIES	8	8	16	85
ROSES	18	18	20	85
GERBERA	16	16	20	85
CHRYSANTHEMUM	18	18	19	85
PHALEANOPSIS VEGETATIVE STAGE	28	28	28	85
PHALEANOPSIS FLOWERING STAGE	20	20	20	85
ANTHURIUM	21	21	22	90
CANNABIS	20	20	24	60
GREEN POTPLANTS	20	20	22	90

3 screen settings for different crops

	1ST SCREEN CLOSURE DT	2ND SCREEN CLOSURE DT	UNTIL WHICH LIGHT LEVEL SCREEN CAN STAY CLOSED		
	DAY (IN CASE OF TRANSPARENT SCREEN)	DAY (IN CASE OF TRANSPARENT SCREEN)	TRANSPARENT 1ST	TRANSPARENT 2ND	NON TRANSPARENT
TOMATO	20	30	70	40	20
CUCUMBER	20	30	150	50	20
BEL PEPPER	20	25	150	50	20
LETTUCE	17	25	70	40	20
STRAWBERRIES	17	25	70	40	20
ROSES	20	25	100	40	20
GERBERA	20	25	100	40	20
CHRYSANTHEMUM	20	25	100	40	20
PHALEANOPSIS VEGETATIVE STAGE	15	20	200	100	20
PHALEANOPSIS FLOWERING STAGE	20	25	100	50	20
ANTHURIUM	15	20	200	100	20
CANNABIS	20	25	100	40	20
GREEN POTPLANTS	15	15	150	50	20

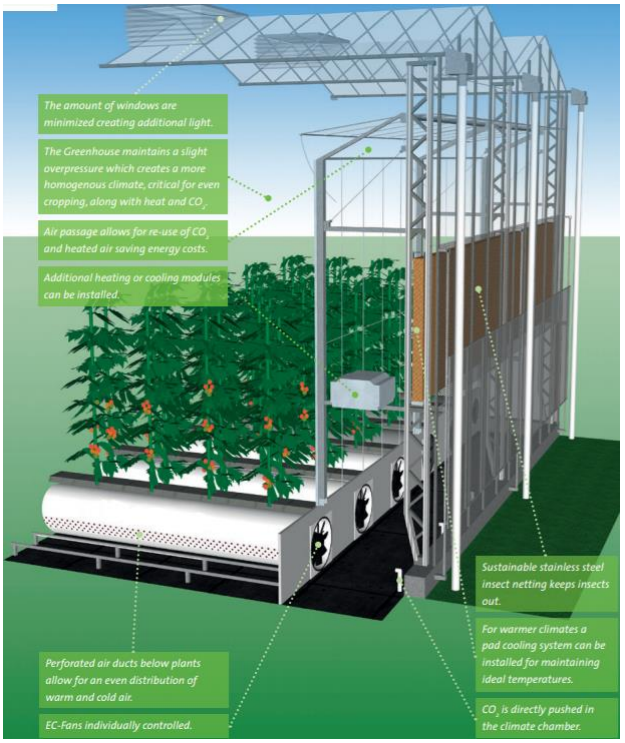
V Climate control equipments

Hortinergy's parameters include heating and cooling systems. Besides, it lets you compare the best solution of lighting, if needed.

1 Semi-closed greenhouse :

How does it work ?

The corridor, located on the outer gable of the greenhouse, uses outside air for dehumidification and cooling. Thus, the corridor is used to mix inner air with external air. This phenomenon represents the air treatment of semi-closed greenhouses, mostly used for Venlo glass (Kubo, Van der Hoeven, Richel…) and plastic (CMF, Richel…) ones.



This system aims to :

-dehumidify the atmosphere of the greenhouse by renewing and drying out the air inside, due to outdoor air (during the night and in the morning)
-cool dry inner temperature with pad cooling system, on external side of the corridor
-reduce the amount of harmful insects, thanks to overpressure
-control the climate of the greenhouse avoiding the gap of temperatures
-optimize the use of energy and CO2

Heating system is composed of :

-air ducts below crops' gutters for the diffusion of warm/cold air
-low temperature network (30-40°C) placed in in vegetation
-high temperature network (70-80°C) placed on the ground to ensure heating

Cooling system could be composed of :

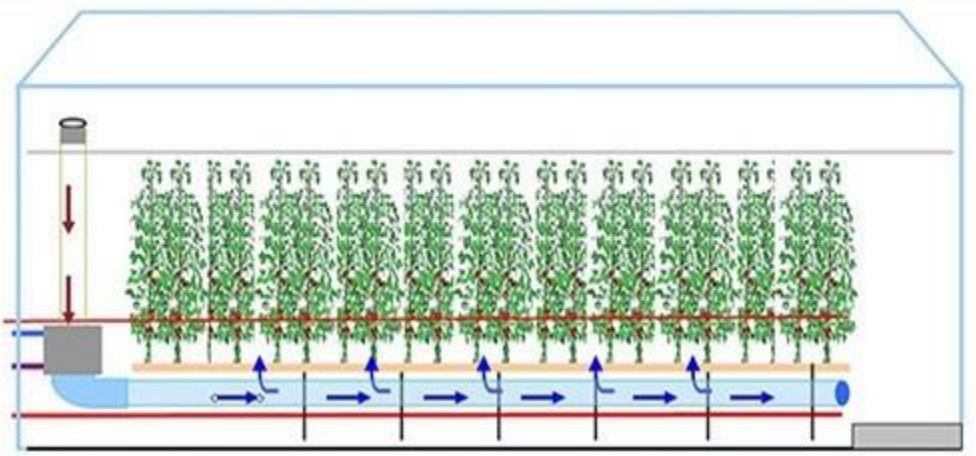
-pad and fan system using evaporative cooling

-fog system using evaporative cooling

2 Closed greenhouse

Principle

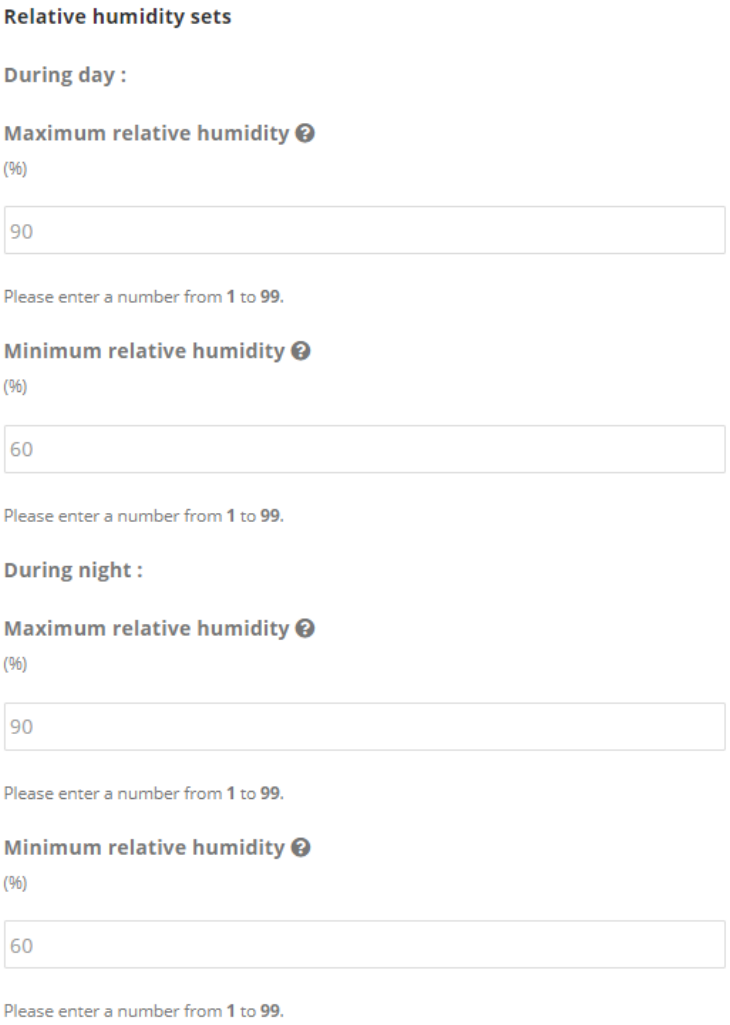
A greenhouse is « sealed » or « closed » when there is not any air exchange with outdoor air.
In order to maintain inner temperature and relative humidity of a closed greenhouse, heating, cooling and dehumidification systems have to be implemented, so that crop production can be realized in good conditions.



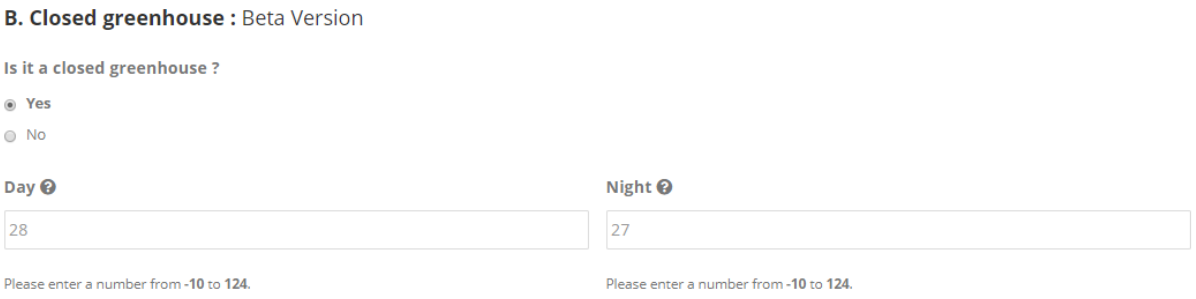
Cooling and dehumidification are usually done via heat-exchangers in the greenhouse. This enables higher CO_2 concentrations in the greenhouse and consequently a higher crop production rate.
In some cases, a sealed greenhouse is linked to underground aquifer or very large buffer. During sunny or hot days, the surplus heat is stored in the short term (diurnal) buffers or long term (seasonal) storage in underground aquifers. During nightime or cloudy days, warm water from the aquifer or buffer heats the greenhouse.

What are the Hortinergy parameters ?

The maximum temperature and humidity settings, such as relative humidity and humidity deficit, have to be filled.



Once inner relative humidity is exceeded by relative humidity sets, latent cooling is engaged.



Cooling system will be activated so that inner temperature will not go above this set.
For instance, even though solar radiation is expected to rise the inside temperature significantly, the cooling temperature, set at 28°C during the day will prevent from exceeding this temperature.

Results

In turn, Hortinergy calculates the sensible and latent cooling needs to control the greenhouse inner climate (temperature and relative humidity).

Sensible cooling : it is the process in which only the sensible heat of the air is removed so as to reduce its temperature, without any change in the moisture content of the air.

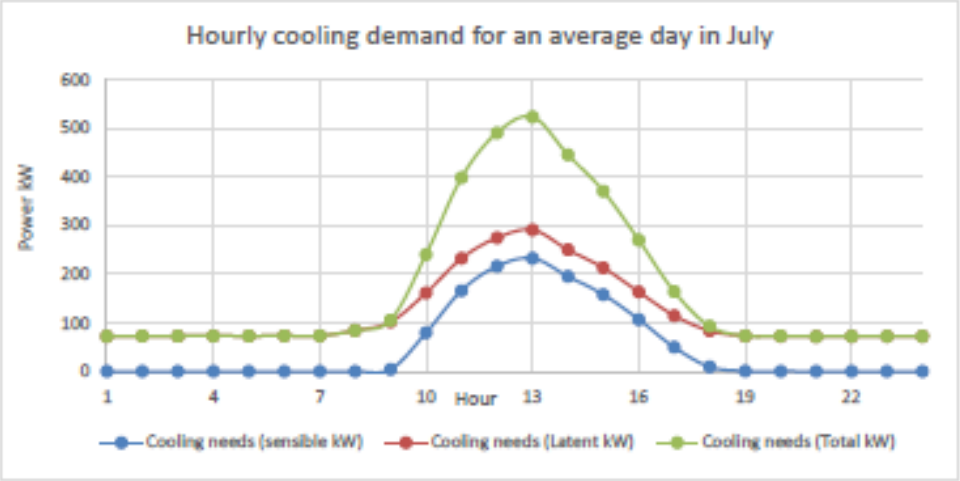
Latent cooling : it is the capacity to remove the moisture from the air, without any change in the temperature of the air.

Based on the results, the engineer can design the best HVAC system and calculate energy consumption.
Hereunder a typical example from a report. Results are shown in three different ways.
First, as a monthly synthesis.

5.2 **Closed greenhouse:** estimation for sensible and latent needs

	Cooling needs (sensible)	Cooling needs (Latent)	Cooling needs (Total)	
	MWh	MWh	MWh	kWh/m²
Jan	0.0	163.3	163.3	14.5
Feb	4.2	156.2	160.3	14.2
Mar	25.6	237.1	262.7	23.3
Apr	88.5	363.5	452.0	40.1
May	215.6	570.8	786.4	69.8
Jun	322.2	661.7	983.9	87.3
Jul	385.5	701.4	1 086.9	96.4
Aug	319.6	603.0	922.7	81.8
Sept	164.1	440.0	604.0	53.6
Oct	44.2	314.2	358.4	31.8
Nov	3.7	206.7	210.4	18.7
Dec	0.0	189.5	189.5	16.8
Total	**1 573.3**	**4 607.3**	**6 180.6**	**548.3**

Then, as an hourly synthesis of a typical month.



Finally, hourly values during a typical year are referenced as OX-24h.

Sensible heat : it is the amount of heat exchanged, without any physical stage transition, between several bodies forming an isolated system.

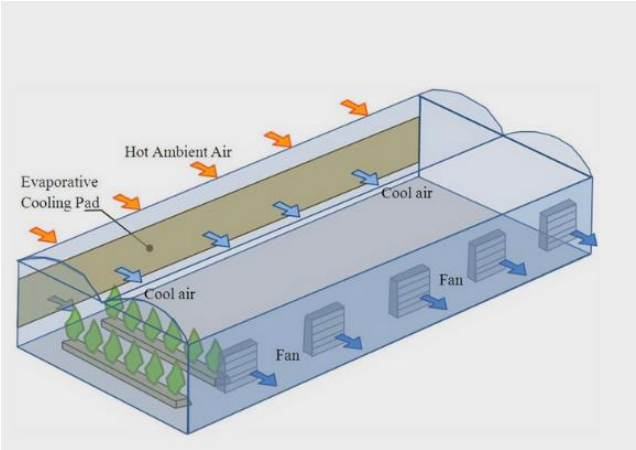
Latent heat : it is the amount of energy exchanged between an object and its environment during a change of state, i.e. during solidification, fusion or boiling.

3 Pad and Fan in classic greenhouse

Pad and fan system :

How does it work ?

Pad and fan system cools down greenhouse temperature, using evaporative cooling, which absorption of a large amount of latent heat, by the water, in order to evaporate. During hot summer days, it is an effective way, for small greenhouses, to cool, putting plants in the best climate conditions. Besides, this system uses exhaust fans to absorb air from outdoors into the greenhouse. Firstly, the air is blown through the pad, which constantly evaporates water, creating a cooling effect. Then, the fans blow the cool air into the greenhouse, leading to an overall drop in temperature.
Some greenhouses do require cooling at night, mostly in tropical regions. However, wet pad and fan system may not provide the desired results in tropical regions, where absolute humidity is often high during the night.
When conditions outside are humid, pad and fan system loses effectivity and provides a much lower cooling capacity. This is because evaporative cooling relies on the difference between outdoor and indoor conditions.



Hortinergy parameters

1 Maximum ventilation

Air renewal maximum rate

2 Pad

Pad thickness:

Pad height:

Pad length:

Flush rate:

Maximum water flow for the whole greenhouse:

3 Fan

Number fans for the whole greenhouse?Max

air flow for a fan:

Electrical power at 100% air flow:

Electrical power at 75% air flow:

Electrical power at 50% air flow:

Electrical power at 25% air flow:

4Temperature regulation

Cooling temperature:

Priority for ventilation of humidification?

Distance between pad and fan:

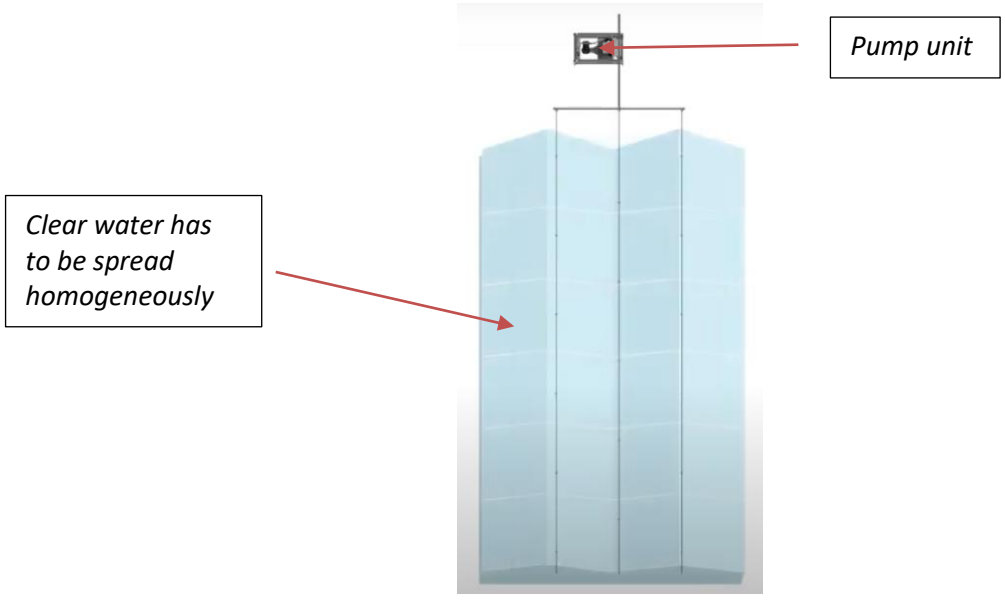
4 Fog in classic greenhouse

Fog system :

As the pad and fan system, it uses evaporative cooling method to cool down greenhouse temperature.

How does it work ?

Clear water is pushed through a stainless steel nozzle. Then, the particles of this water are evaporated before they reach the crops. This system works with a pump unit fitted with a high pressure pump. Nevertheless, it has to be mounted at the right height, according to climate conditions. Lastly, nozzles should be mounted alternately for a homogeneous coverage.



Hortinergy parameters

Maximum water flow for the whole greenhouse:

Cooling temperature:

VI Supplementary light

Principle :

Supplementary lighting is used to increase the total daily light. Light intensity, spectrum and duration affect several plant growth and processes. There are several reasons for providing supplementary lighting:

- When natural light is scarce, it helps to increase yield and production quality such as tomato …
- Supplementary lighting is also applied for day length control in ornamental crops.

With Hortinergy, you have two types of lighting systems : the first one is called “High Pressure Sodium” (HPS) and the second one “Light Emitting Diode” (LED).

LED light :

Pros :

-long life expectancy
-almost no excess heat, which allows it to be placed very close to plants
-low operating/maintenance cost
-high yield per Watt

Cons :

-high initial cost

HPS light :

Pros :

-low initial cost

Cons :

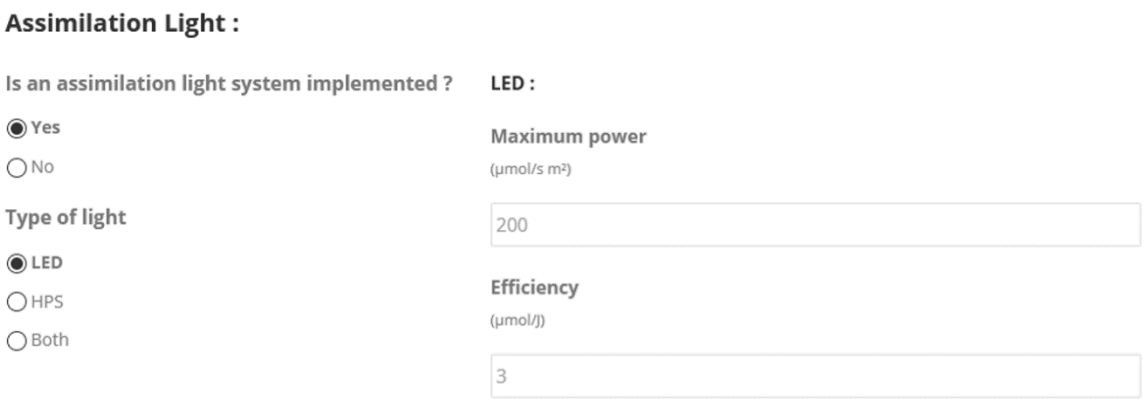
-the high intensity of light from this lighting system generates a lot of heat
-additional cooling system is needed
-high operating cost

Imput parameters with Hortinergy

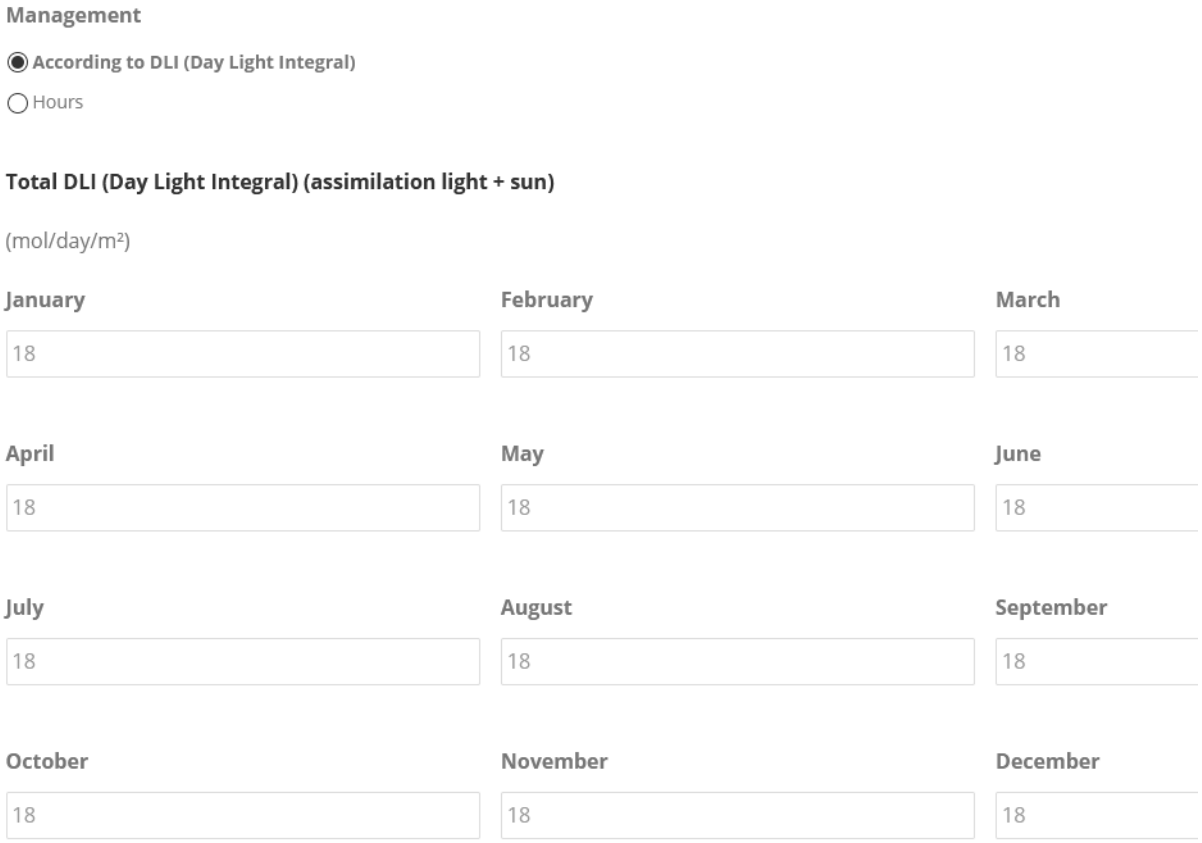
Input parameters are:

- LED and HPS specification: lighting intensity, efficiency…
- Regulation setpoints:
    - Day Light Integral (DLI) and minimum hours of ‘’night’’ per day,
    - or fixed monthly schedule above which solar radiation intensity lighting is switched off.

You first define you lighting system:



Then you define the regulation settings:



3. Results

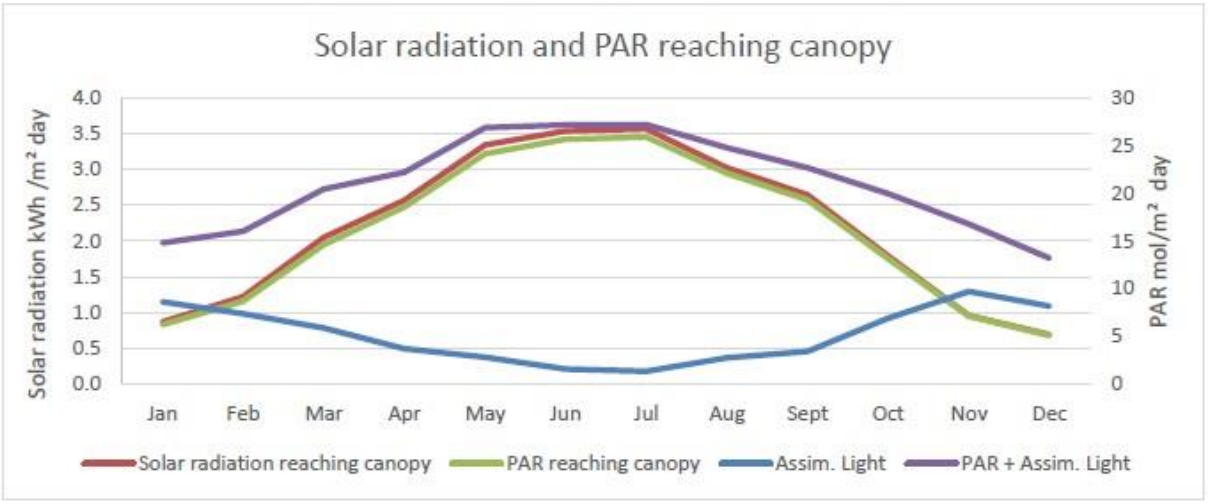
Hortinergy simulates your project during one year like a virtual greenhouse. Outputs are :

- Solar radiation transmitted by the transparent cover and reaching canopy,
- Assimilation lighting required according to regulation setpoints (mol/m²/day):
- Electricity consumption,
- Impact on the inner climate and energy consumption: heating, cooling, dehumidification.

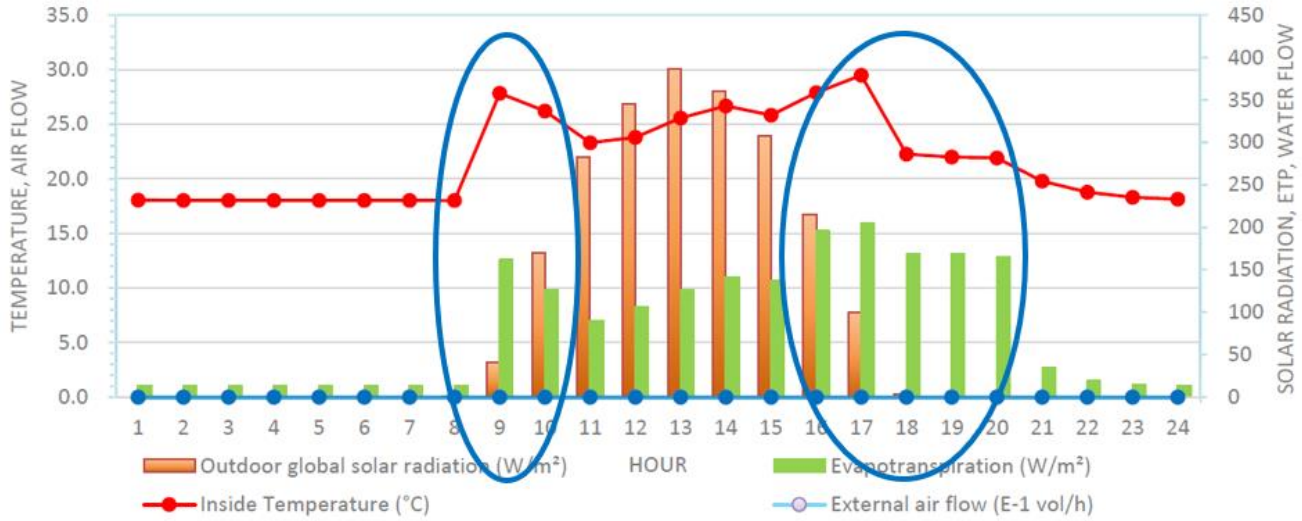
The reports are:

- a pdf document with typical days and monthly summary tables
- an Excel file with hourly data for deeper analysis.

<u>Solar radiation reaching canopy and additional assimilation lighting required</u>
Hortinergy simulates on hourly basis the solar radiation reaching canopy and the additional assimilation lighting required to reach the DLI.
The example below shows a monthly summary.



<u>Impact on the inner climate and energy consumption (heating, cooling, dehumidification)</u>
Hortinergy models the impact of assimilation lighting on the inner climate and energy consumption (heating, cooling, dehumidification).
The example below shows the crop transpiration and a higher inner temperature when HPS assimilation lighting is switched on from to 9 to 11 AM and 4 to 9 PM to reach DLI.



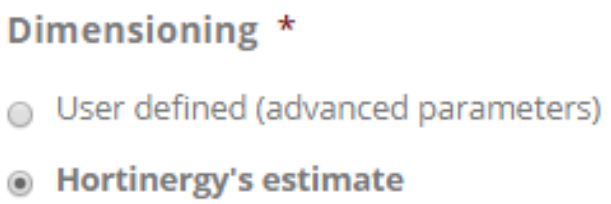
<u>Electricity consumption and expenditures</u>
Hortinergy shows also the electricity consumption and expenditures.

	Electricity consumption		Expenditure	
	MWh	kWh/m²	€	€/m²
Jan	241.3	25.1	24 128.0	2.5
Feb	185.6	19.3	18 560.0	1.9
Mar	179.2	18.7	17 920.0	1.9
Apr	68.5	7.1	6 848.0	0.7
May	53.1	5.5	5 312.0	0.6
Jun	56.3	5.9	5 632.0	0.6
Jul	25.0	2.6	2 496.0	0.3
Aug	62.1	6.5	6 208.0	0.6
Sept	53.1	5.5	5 312.0	0.6
Oct	144.0	15.0	14 400.0	1.5
Nov	208.6	21.7	20 864.0	2.2
Dec	259.8	27.1	25 984.0	2.7
Total	**1 536.6**	**160.1**	**153 664.0**	**16.0**

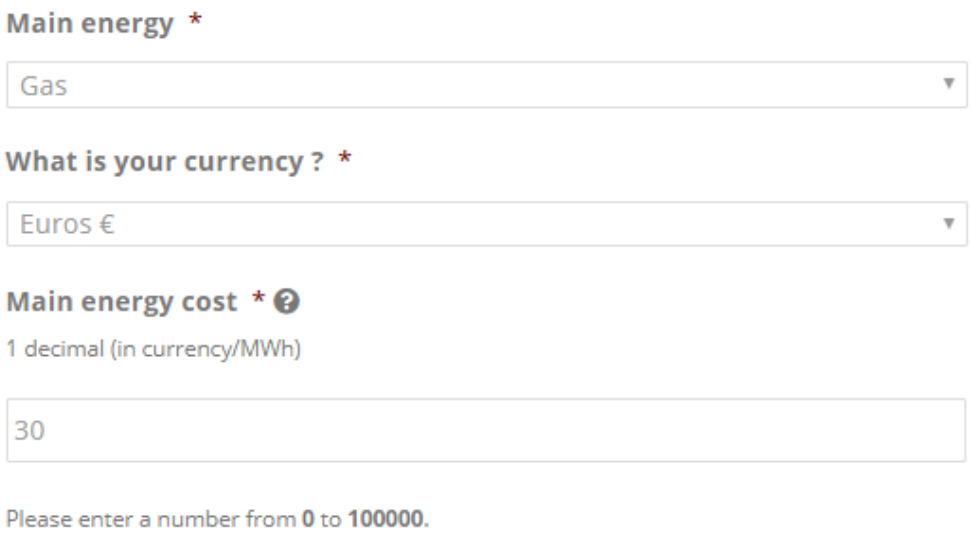
VII Heating system

1 Heat production:

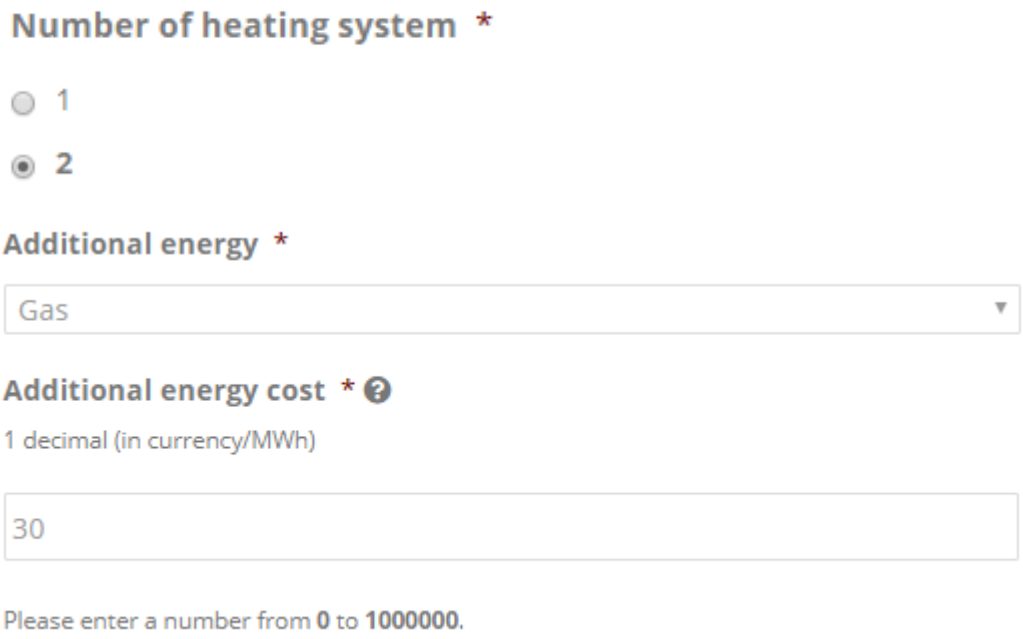
Hortinergy offers two heat production settings :
- Hortinergy's estimate
- User defined (advanced parameters)



On the one hand, **Hortinergy's estimate** takes into account one energy system, accompanied by its type and cost, considering also an efficiency of 95% of the boiler. Max power of the boiler is also calculated by the software. With it, you might choose one main energy and its cost, followed by its currency.



On the other hand, the option **user defined** puts forward two energy systems. Each of them can have different types of energy and advanced parameters : heating period, the maximum power that will be used, the presence of a condenser or not and the boiler efficiency.



Additional boiler

Max power *

Integer (in kW)

3000

Please enter a number from **1** to **50000**.

Condenser *

- Yes
- **No**

Boiler efficiency max *

(in %)

95

Please enter a number from **1** to **1000**.

As said before, for each system, you have the choice between several types of energy. The most common ones are gas and biomass.

Main heating production

Heating period - Beginning *

05/12/2020

Heating period - End *

15/11/2021

Max power *

Integer (in kW)

3000

Please enter a number from **1** to **50000**.

Condenser *

- **Yes**
- No

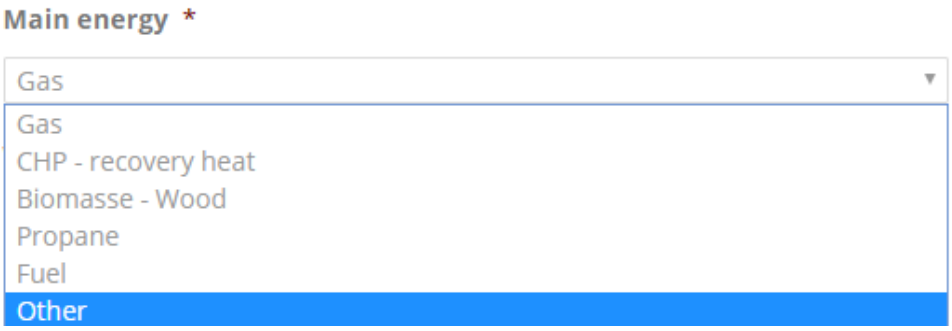
Boiler efficiency max *

(In %)

95

Please enter a number from **1** to **1000**.

Device that enables to pass from the state of gas/vapor to liquid one.



If there is not any open buffer and the demand is superior than the maximum energy power of the main system, the second type of energy is turned on. In case there is an open buffer, if the request is superior than the maximum energy power of the main system, then it will unload. Once it is void, the second energy is engaged to replace it.

Heat pump enters COP as an efficiency and chooses electricity. For instance, a COP that is equal to 4 represents an efficiency of 400%.

CHP is based on heat production efficiency, generally set at 44%. Besides, it also calculates overall gas consumption.

Regarding water buffer tank, there are two utilisations : the first one with gas boiler and the second one with biomass/waste heat boiler.

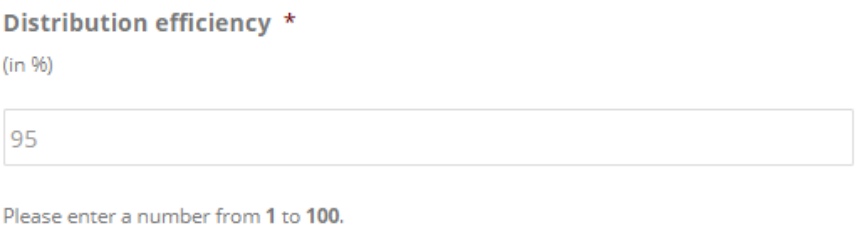
Gas boiler : the container stores the heat energy generated in the gas boiler during daytime CO_2 supply, when heating demand is the lowest.

Waste heat boiler : it uses the heat in flue gases from combustion processes or hot waste air flows from industrial processes to generate hot water.

For more information about water buffer tank, you can have a look at our support documentation.

Distribution efficiency :

It represents the heat losses in the transport between the boiler and the greenhouse. By default value, these losses amount to 5%, which represents a distribution efficiency of 95%.



2 Water buffer tank :

Imagine a battery of energy that's ready to be distributed at any time.

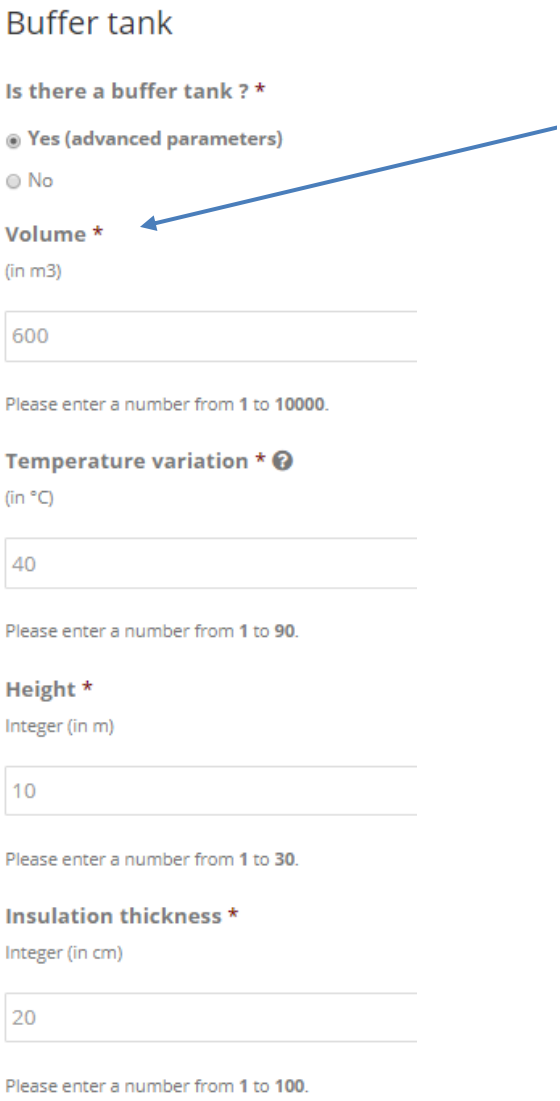
There are two utilisations of a water buffer tank : the first one with gas boiler and the second one with biomass/waste heat boiler.

How does it work ?

Gas boiler : the container stores the heat energy generated in the gas boiler during daytime CO2 supply, when heating demand is the lowest.

Waste heat boiler : it uses the heat in flue gases from combustion processes or hot waste air flows from industrial processes to generate hot water.

What are the Hortinergy parameters ?



The volume in which the heating energy needed for your installation is stored.

The volume of a buffer tank is generally around 300 m³ per hectare.
As regards temperature variation, it is calculated according to the difference between the heat production temperature and the heat emission temperature of the boiler.

$$\Delta T = heat\ production\ temperature - heat\ emission\ temperature$$

For instance, if the heat production of the boiler is 85°C and the heat emission temperature is 60°C, the temperature variation equals 85-20=65°C.

VIII Greenhouse gas (GHG) emission estimation

Nutriments

Type of first N fertilizer:
Quantity of first N fertilizer:

Type of 2nd N fertilizer:
Quantity of 2nd N fertilizer:

Type of 3rd N fertilizer:
Quantity of 3rd N fertilizer:

Substrate

Do you re-used growing substrate? "yes"

Injection of CO2: "liquid co2 injection" or "combination of both"

Quantity of CO2:

Crop yield:

Transport:

Truck <3.5T:
Truck 7.5T:
Truck 12T:
Truck 40T:

Medium-haul aircraft:

Long-haul aircraft:

Container ship:

All data are easy to enter in the form, and we give you indications of usual values for each datayou have to fill.

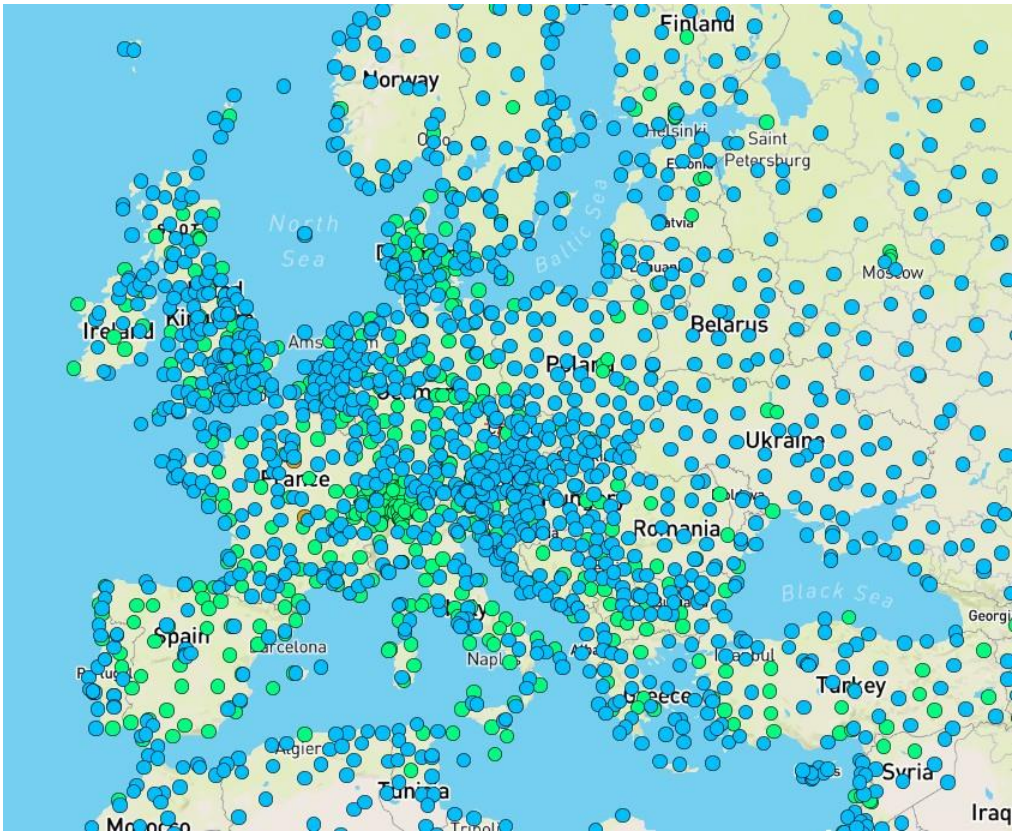
Keep in touch with us either by e-mail or phone!

Contact:
contact@hortinergy.com
+33 6 301 778 94
+33 479 72 40 59

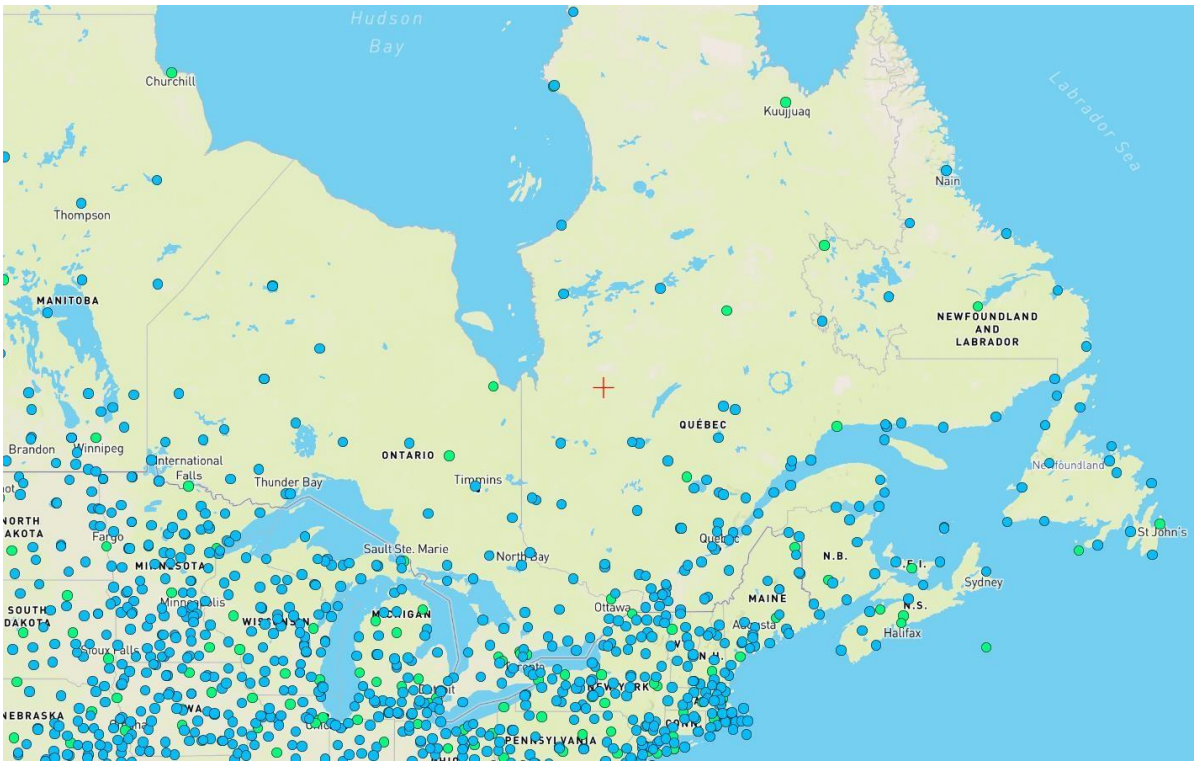
IX Appendix

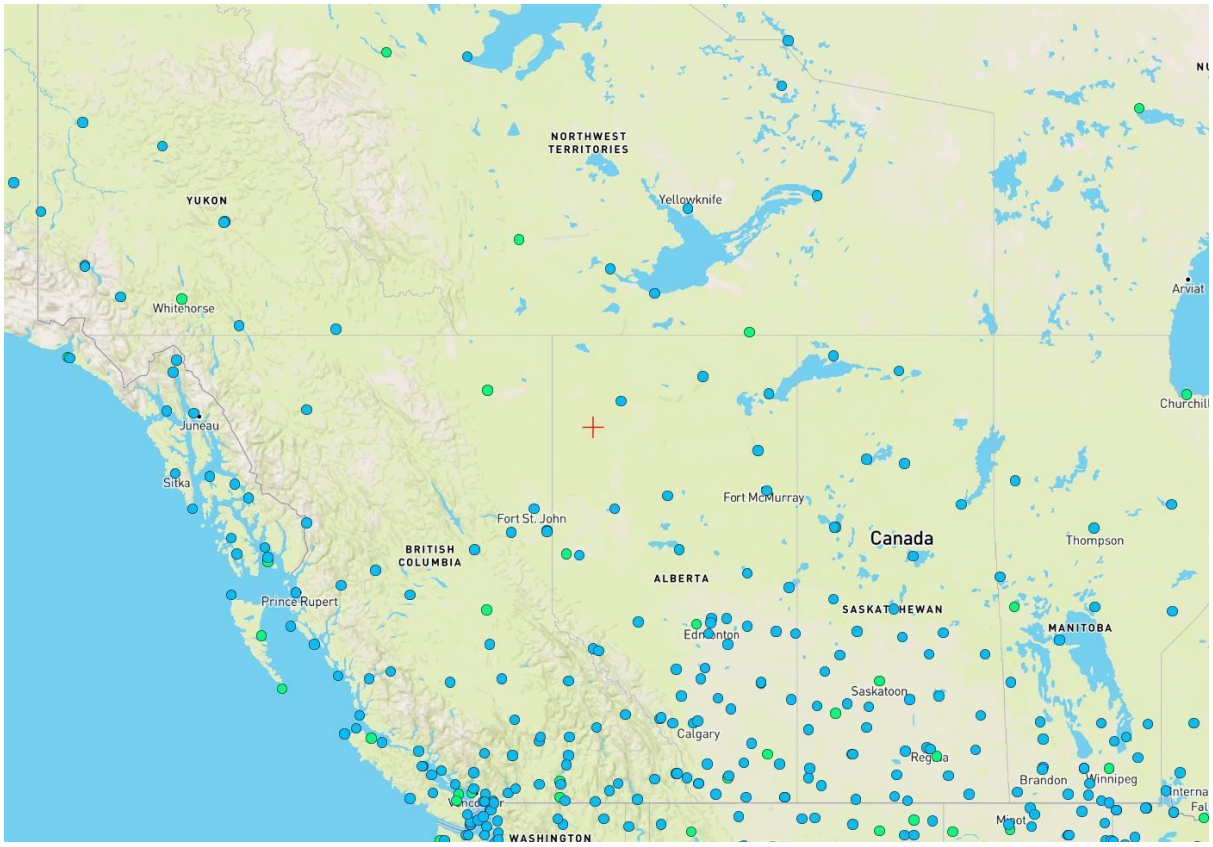
1 Meteonorm sites

Europe



Canada

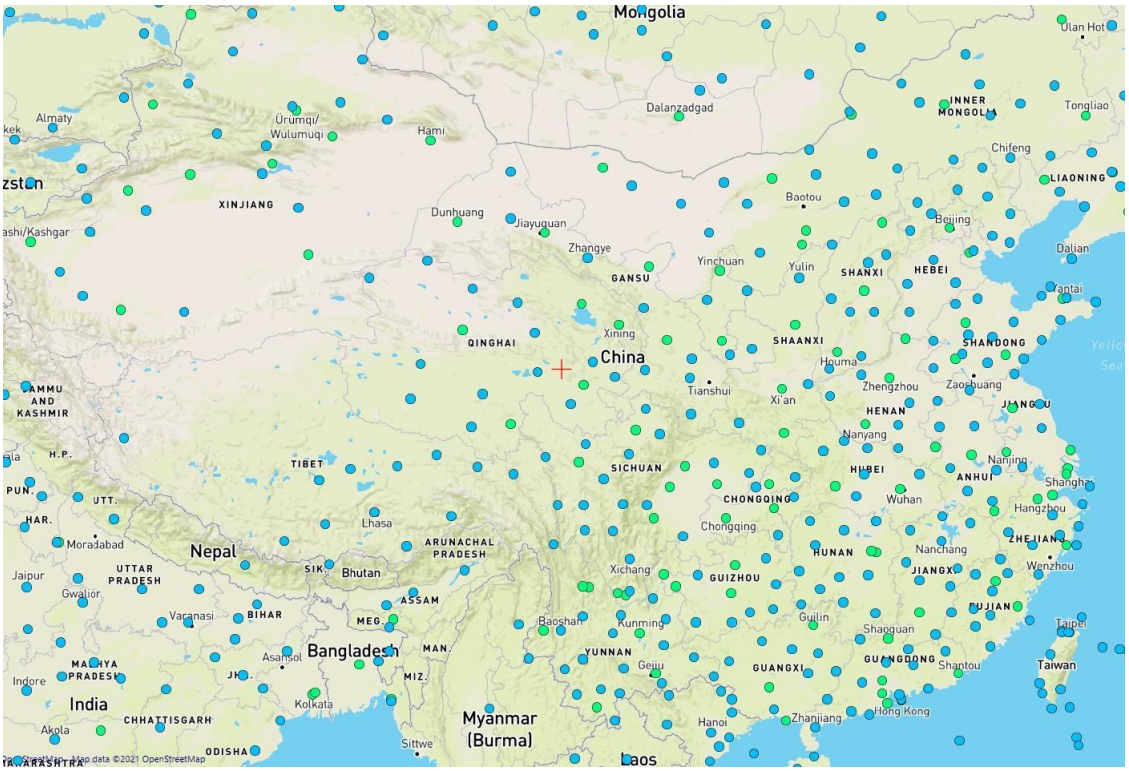

Hudson Bay
Churchill
Kuujjuaq
Labrador Sea
Nain
Thompson
MANITOBA
NEWFOUNDLAND AND LABRADOR
QUÉBEC
Brandon
Winnipeg
ONTARIO
International Falls
Thunder Bay
Timmins
Fargo
Sault Ste. Marie
North Bay
Quebec
St John's
N.B.
P.E.I.
Sydney
MAINE
Ottawa
N.S.
Halifax
Augusta
Sioux Falls
Detroit
PENNSYLVANIA


NORTHWEST TERRITORIES
YUKON
Yellowknife
Whitehorse
Juneau
Sitka
Fort McMurray
Fort St. John
Canada
BRITISH COLUMBIA
ALBERTA
SASKATCHEWAN
MANITOBA
Prince Rupert
Edmonton
Thompson
Saskatoon
Calgary
Regina
Brandon
Winnipeg
WASHINGTON

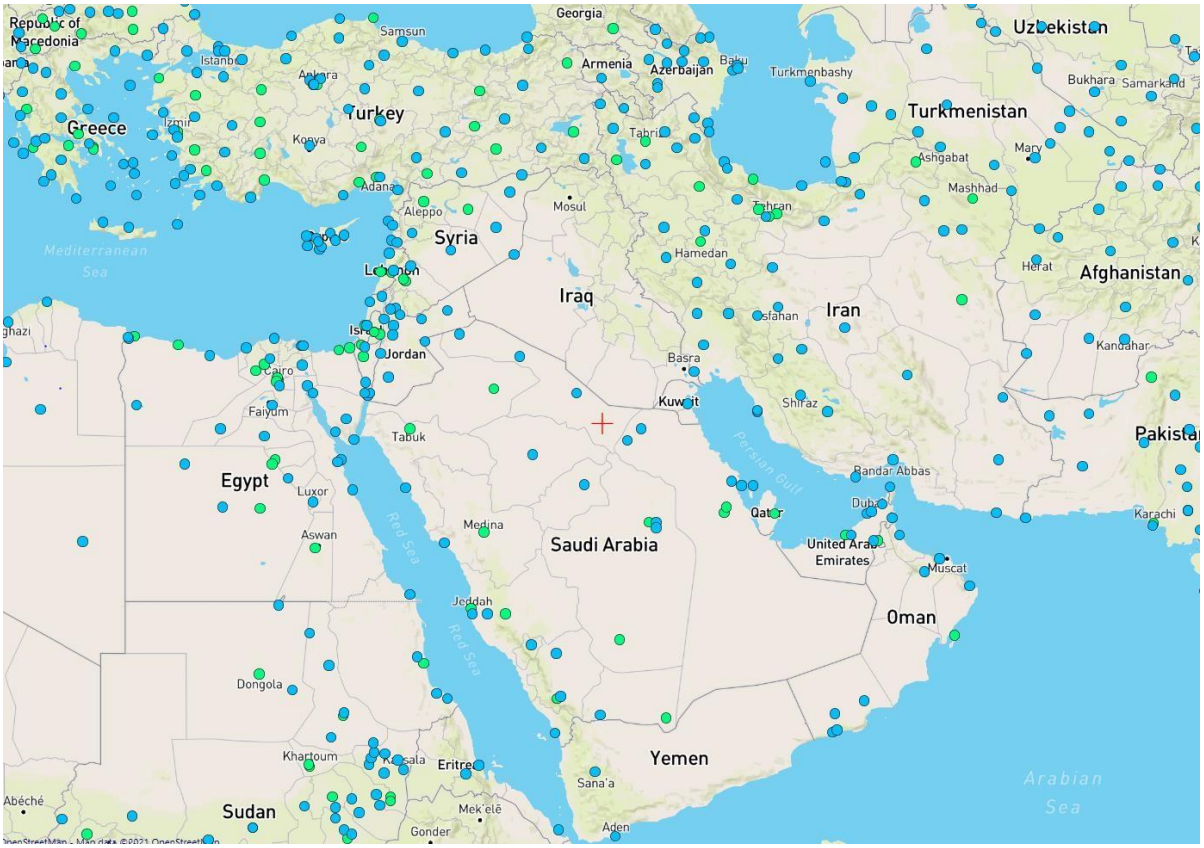
Mexico :


El Paso
TEXAS
Dallas
Shreveport
LOUISIANA
New Orleans
Houston
San Antonio
Corpus Christi
Matamoros
Gulf of Mexico
SONORA
Hermosillo
CHIHUAHUA
Chihuahua
COAHUILA
B.C.
B.C.S.
La Paz
Torreón
DURANGO
SIN.
Mexico
TAMAULIPAS
S.L.P.
Tampico
NAY.
AGS.
JAL.
HID.
MICH.
Colima
GUE.
Acapulco
OAXACA
VER.
TAB.
CAMP.
YUC.
Q.R.
CAH.
CHI.
Guatemala
Honduras

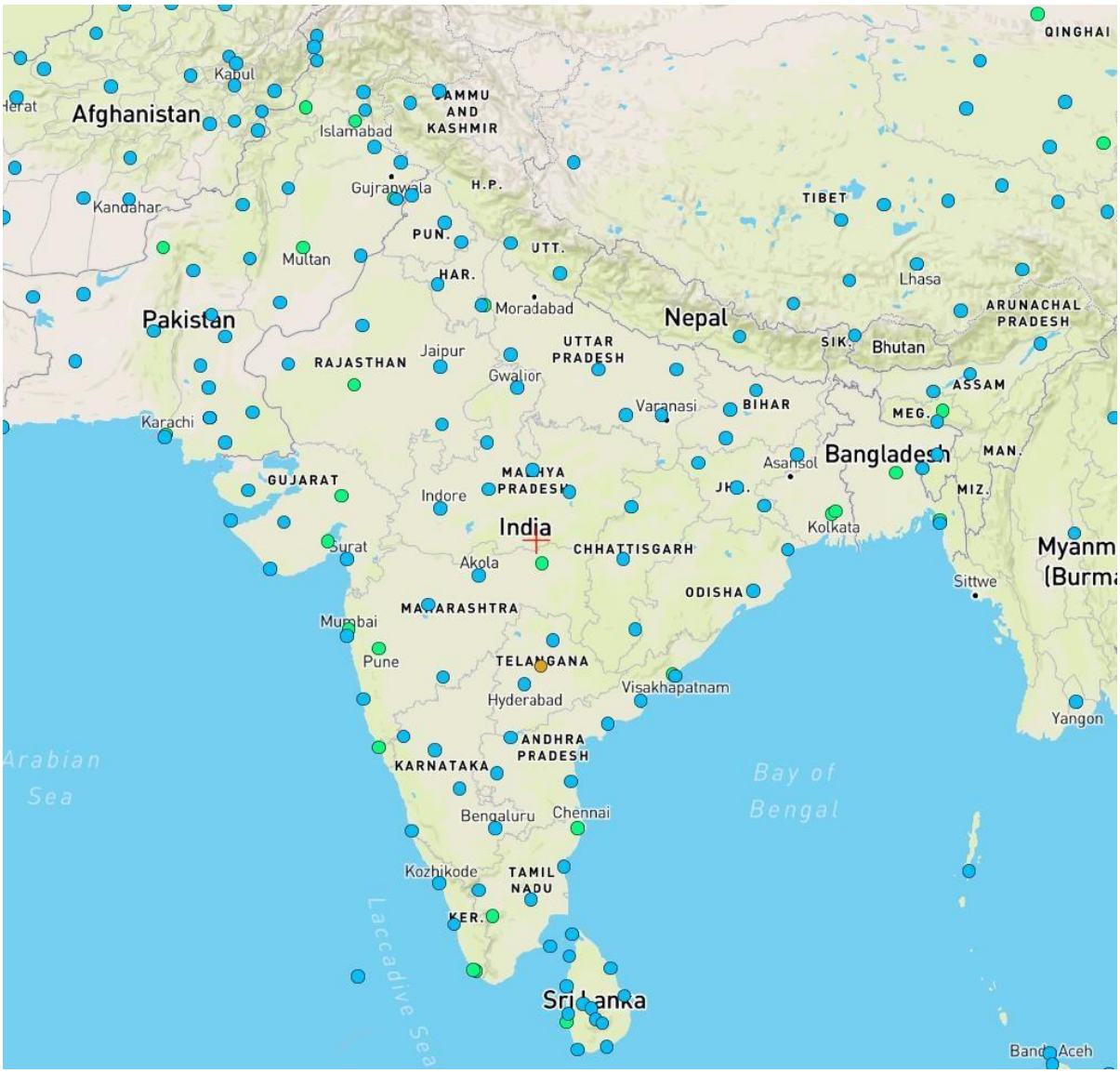
China



Turkey and MENA Countries

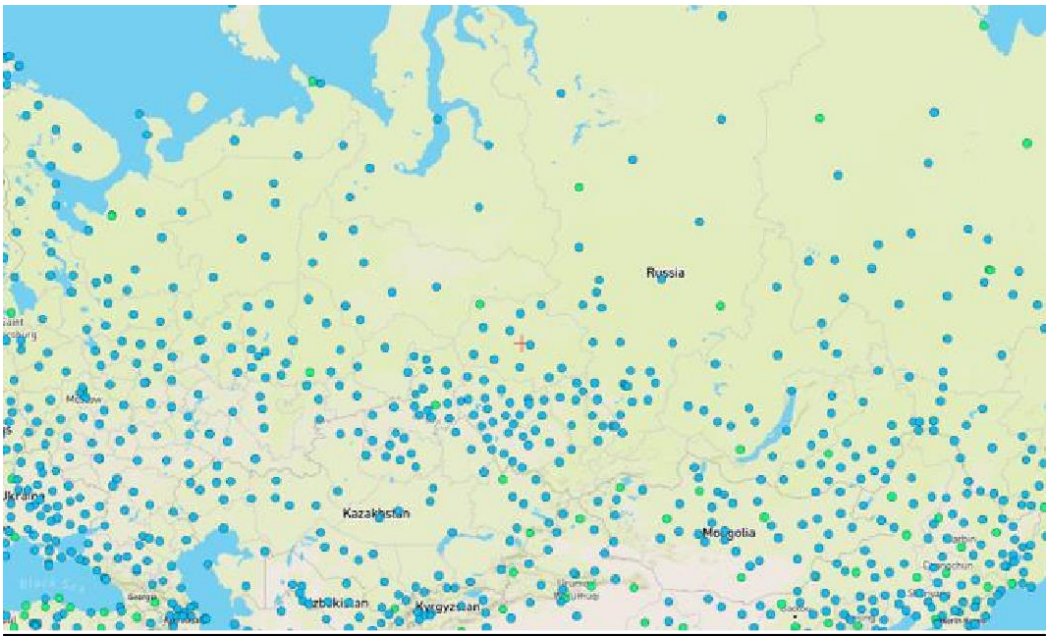


India


QINGHAI
Kabul
Afghanistan
AMMU AND KASHMIR
Islamabad
Gujranwala
H.P.
Kandahar
TIBET
PUN.
UTT.
Multan
HAR.
Lhasa
Moradabad
Pakistan
Nepal
ARUNACHAL PRADESH
SIK.
Bhutan
UTTAR PRADESH
Jaipur
RAJASTHAN
Gwalior
ASSAM
Varanasi
BIHAR
MEG.
Karachi
Bangladesh
MAN.
Asansol
MADHYA PRADESH
GUJARAT
Indore
JH.
MIZ.
India
Kolkata
Surat
CHHATTISGARH
Akola
Myanm
(Burma
Sittwe
ODISHA
MAHARASHTRA
Mumbai
Pune
TELANGANA
Visakhapatnam
Hyderabad
Yangon
ANDHRA PRADESH
Arabian Sea
KARNATAKA
Bay of Bengal
Bengaluru
Chennai
Kozhikode
TAMIL NADU
KER.
Laccadive Sea
Sri Lanka
Banda Aceh

South East Asia

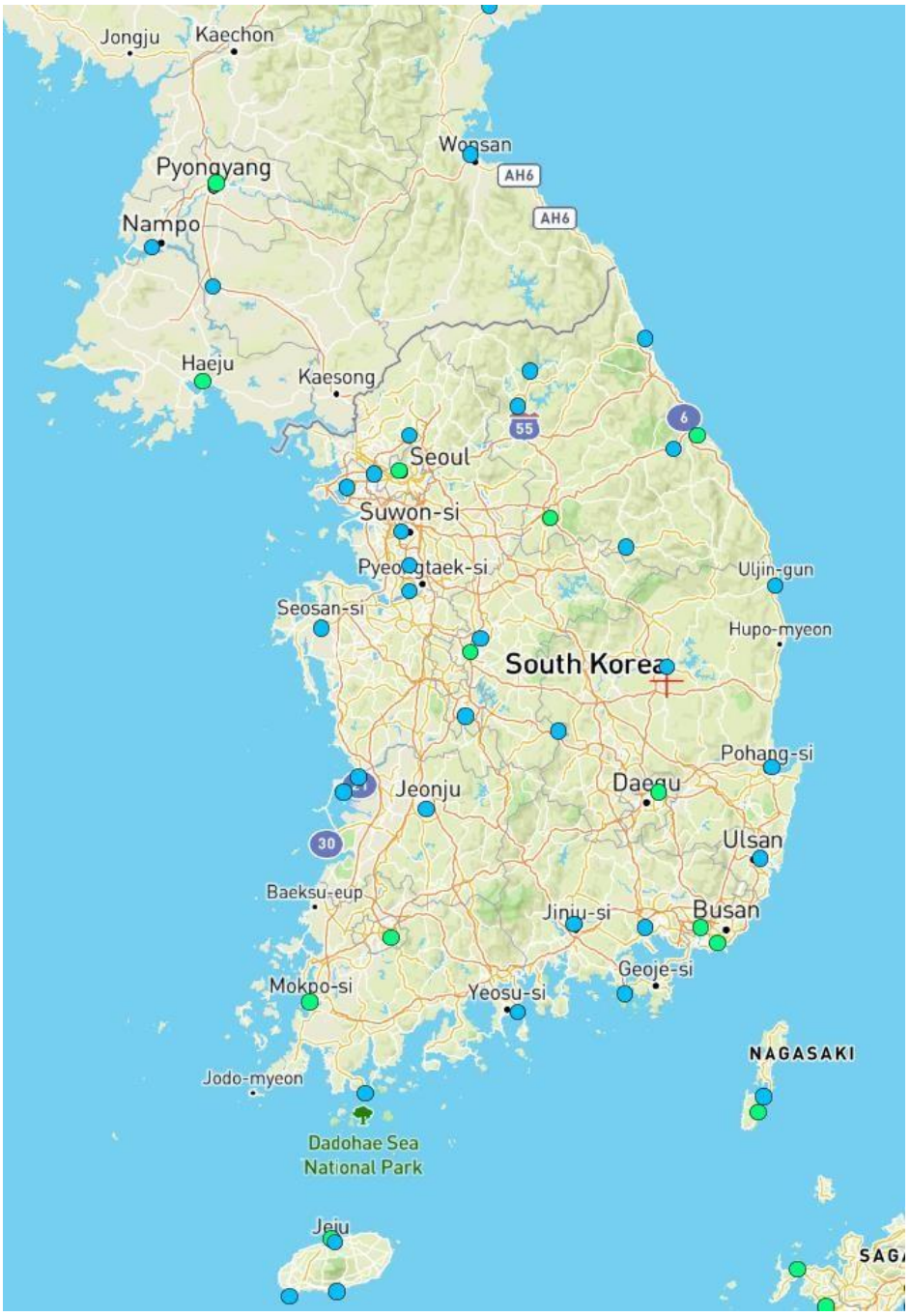
Russia :



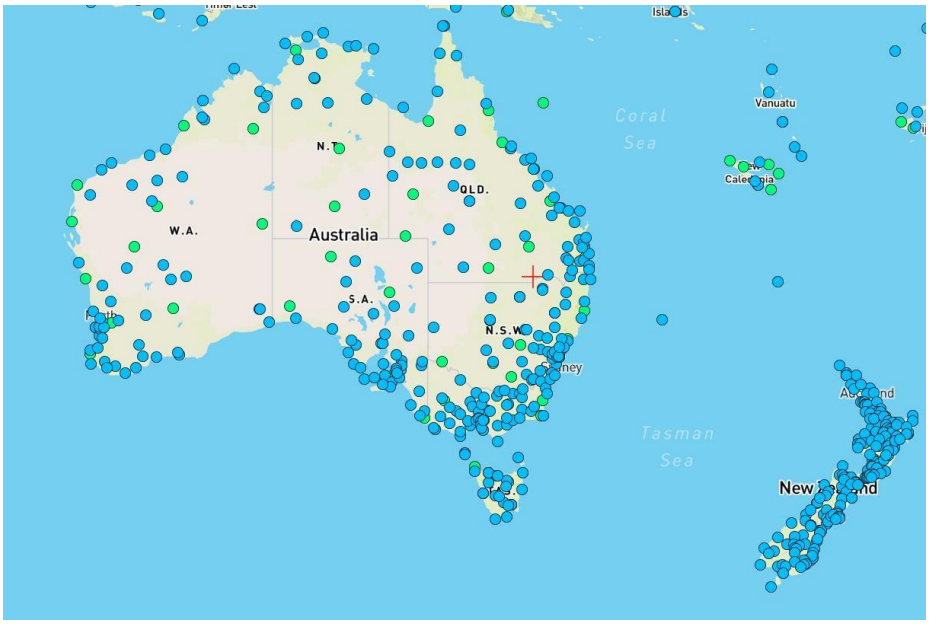
Japan :


Jixi
Vladivostok
Sapporo
Kushiro
East Sea
Sea of
Japan
Sakata
Sendai
Japan

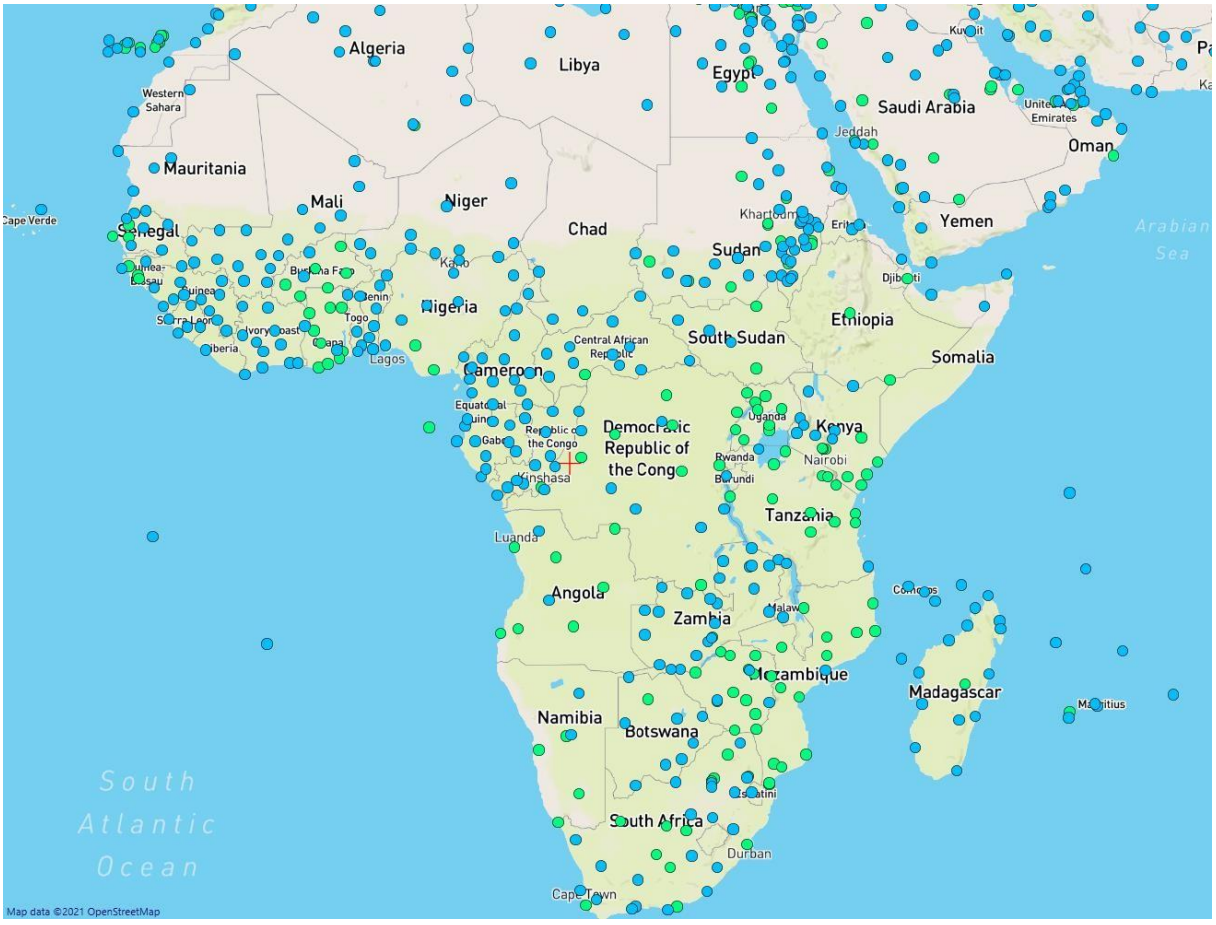
Korea


Jongju
Kaechon
Wonsan
Pyongyang
AH6
AH6
Nampo
Haeju
Kaesong
55
6
Seoul
Suwon-si
Pyeongtaek-si
Uljin-gun
Seosan-si
Hupo-myeon
South Korea
Pohang-si
Jeonju
Daegu
30
Ulsan
Baeksu-eup
Jinju-si
Busan
Geoje-si
Mokpo-si
Yeosu-si
NAGASAKI
Jodo-myeon
Dadohae Sea
National Park
Jeju

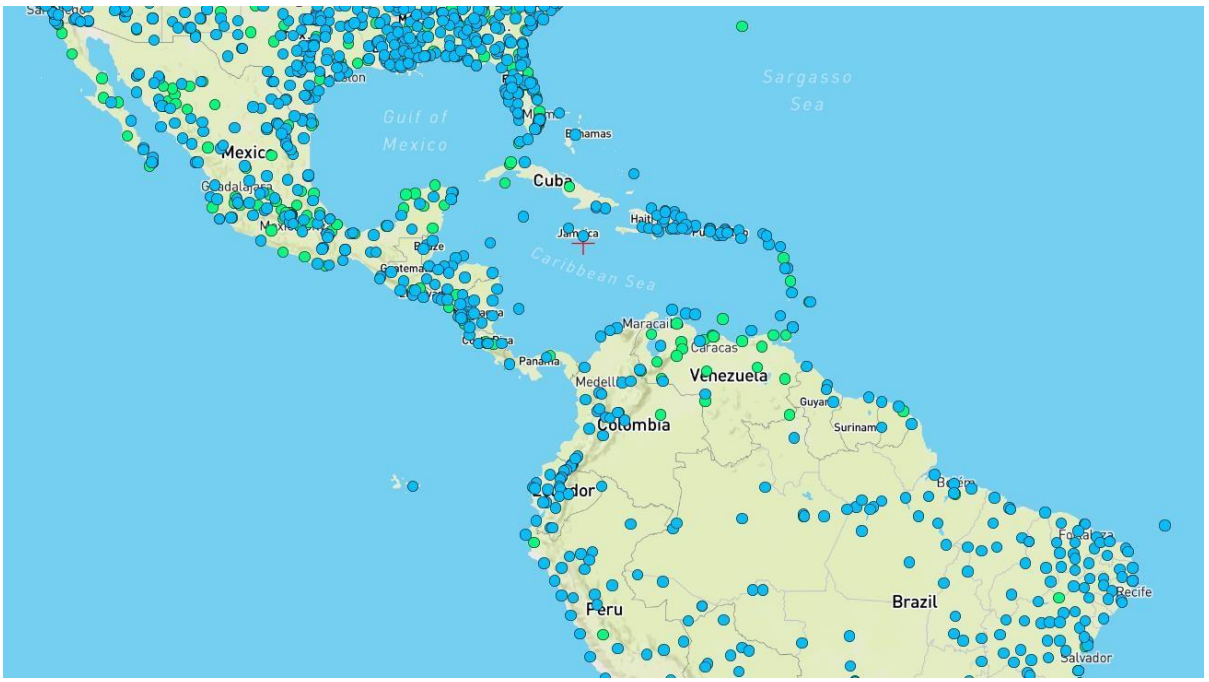
Australia and New Zealand:



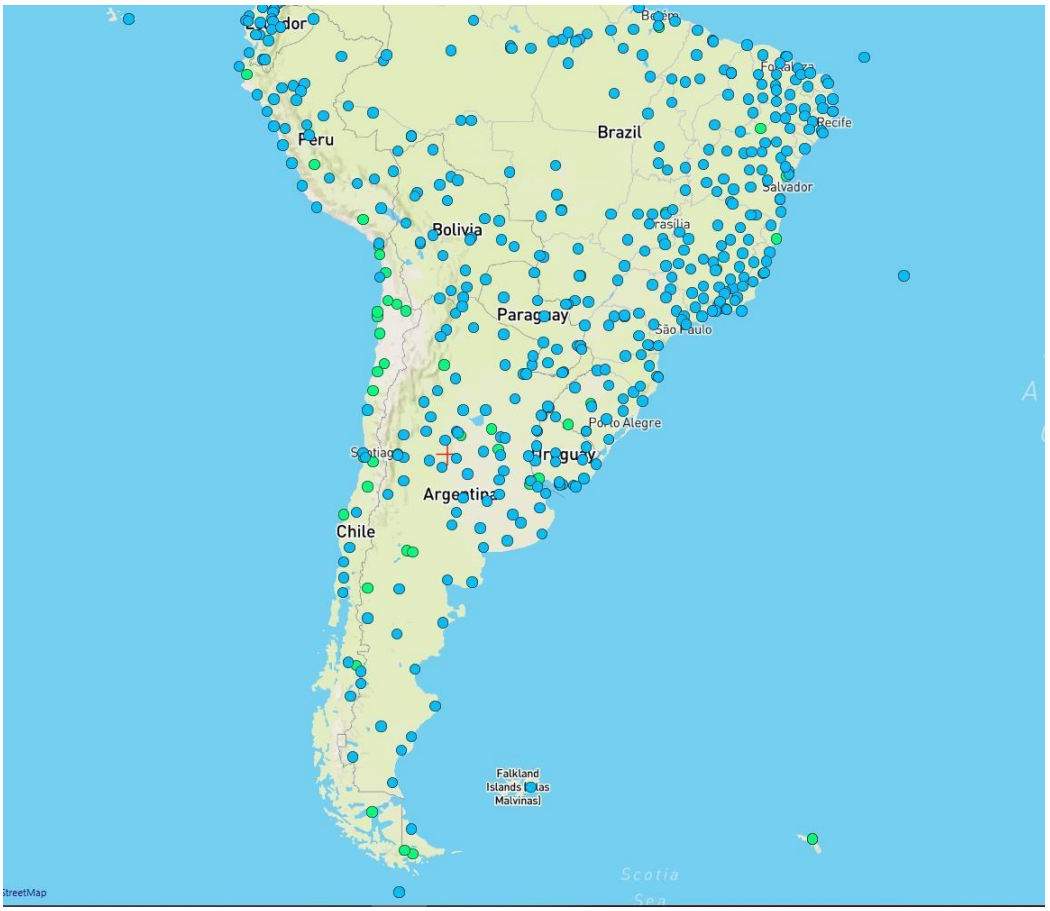
Africa



Central America



South America



2 Glossary

Hereunder a pair of words that will certainly help you to better understand Hortinergy's parameters.

Absolute humidity : actual water vapour content of air. Units are either in g/kg, g/m³ or kPa.

Absolute humidity difference inside/outside = AH inside – AH outside → in g/kg or g/m³, determines the amount of moisture expelled by ventilation.

Adiabatic cooling : process of cooling down air wit h very fine droplets of water. The variation of enthalpy is void, because of the same amount of latent heat created and energy withdrawn from the air.

Assimilation lighting : used to adjust the light intensity of a greenhouse to the desired level during the darkest days of the year.

Black out screen : under hot conditions, shading prevents the plants from heat to 99%, thus letting just 1% of incoming solar radiation reach them. It is mostly used for the control of photoperiod and the growth of cannabis crops and ornamental plants.

Crop transpiration : mutation of the water from the crop to the air, in the vapour phase.

Distribution efficiency : heat losses in the transport between the boiler and the greenhouse.

Enthalpy : energy content of dry air expressed in kJ / kg. Based on two components : sensible heat (energy required to raise the temperature of a substance) and latent heat (energy required to evaporate the present water content).

ETFE : a plastic film that is clearer and lighter than glass. Even though the lifespan of this product is higher, it stays noisy while dealing with wind and rain.

Evaporation : conversion of liquid water to water vapour, due to the removal of water from evaporating area.

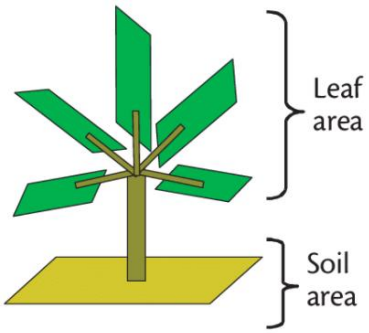
Fog system : As the pad and fan system, it uses evaporative cooling method to cool down greenhouse temperature. Clear water is pushed through a stainless steel nozzle. Then, the particles of this water are evaporated before they reach the crops. This system works with a pump unit fitted with a high pressure pump.

Humidity deficit : difference between the maximum water vapour content at the actual temperature and the actual water vapour content. Unit in g.kg or g/m³.

Latent heat : it is the amount of energy exchanged between an object and its environment during a change of state, i.e. during solidification, fusion or boiling.

Latent cooling : it is the capacity to remove the moisture from the air.

Leaf Area Index (LAI) :
It characterizes plant canopies (aboveground portion of a crop or plant)



$$LAI = \frac{\text{Leaf area}}{\text{Soil area}}$$

Pad and fan system : Pad and fan system cools down greenhouse temperature, using evaporative cooling. The pads are installed on one side of the greenhouse, with the fans on the other side. These fans blow air from inside to outside, absorbing outdoor air through the pad. Thanks to the wet pads, dry outdoor air becomes colder and more humid, ideal for the growth of plants.

PAR light : radiation with a wavelength in the range from 400 to 700 nm that is used by photosynthetic organisms in the process of photosynthesis.

Polycarbonate : plastic film presenting in two forms : a single layer and a multi layer. Here are the different features of polycarbonate in multi layer :
-for 8 or 10mm of polycarbonate thickness, 1 air gap with a double layer are used
-for 16mm of polycarbonate width, 2 air gaps with a triple layer are used
-for 32mm of polycarbonate width, 3 air gaps with a fourfold layer are used

Relative humidity : percentage of the saturated/maximum water vapour content at the actual temperature. RH = (actual water vapour content) / (maximum water vapour content) x 100.

Semi-closed system : a corridor, located on the outer gable of the greenhouse, uses outside air for dehumidification and cooling. Thus, the corridor is used to mix inner air with external air. This system uses also air tubes below gutters bringing air from the corridor to the crop.

Sensible cooling : it is the process in which only the sensible heat of the air is removed so as to reduce its temperature, without any change in the moisture content of the air.

Sensible heat : it is the amount of heat exchanged, without any physical stage transition, between several bodies forming an isolated system.

Shade and open screen : with its highly reflective quality and open structure ideal for ventilation, shade and open screen shelters plants from sunlight, which makes it suitable for shading in hot climates or to manage more sensitive plants.

Solar radiation : radiation coming from the sun on an area in the range from 1 and 1400 W/m², depending on location and season.

Thermal screen : its main goal is to regulate inner temperature and humidity, thereby reducing plant stress and ensuring healthy growth of crops. On the one hand, it keeps heat and radiation into the greenhouse during cold periods, such as night time. On the other hand, it prevents radiation and heat entering during hot periods, such as summer days.

Thermal and shade screen : as indicated, it has two features. On the one hand, aluminum strips are used in a closed structure to bring the greatest energy savings of all. On the other hand, it has an effective shading level when needed.

Ventilation capacity : maximum volume of air exchanged by a fan in m^3/h or $m^3/m^2.h$.

Ventilation - natural/forced : used to exhaust heat and moisture in order to refresh the air within the greenhouse. Therefore, it is the exchange of inner air and external air of the greenhouse. Natural ventilation depends on wind, temperature differences and vents dimensions, while forced ventilation refers to technical methods such as fans and vents opening characteristics.

Ventilation rate : volume of exchanged air in $m^3/m^2.h$ or m^3/h.

Vents : ventilation windows located in the roof or the side walls of the greenhouse.