User Manual

EasyPipes Plus

(Detailed dimensioning tool for air-soil heat exchangers)

EasyPipes Plus developed by
(*Dr. Pierre Hollmuller, University of Geneva*)

User Manual prepared by BEEP Team
(*Prashant Bhanware and Sonal Kumar*)

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This is the beta version of the user manual. Please provide your inputs and feedback to help Improve it.

For any queries and comments, please contact: prashant@gkspl.in

PREFACE

‘EasyPipes Plus’ is a tool developed by **Dr. Pierre Hollmuller, University of Geneva**, Switzerland for detailed dimensioning of air-soil heat exchangers. Under the **Indo-Swiss Building Energy Efficiency Project (BEEP)**, a two day training programme on Earth Air Tunnel Design was organised in which Dr. Pierre Hollmuller, University of Geneva, Switzerland was the lead trainer. He has an extensive experience of designing and monitoring earth air tunnels. He has developed two tools – EasyPipes Basic (pre-dimensioning tool) and EasyPipes Plus (detailed dimensioning tool) for designing of earth air tunnels. Participants of the training programme were demonstrated how to use these tools and they were also provided with these tools for further use.

This user manual on EasyPipes Plus, developed by the BEEP project team (Prashant Bhanware and Sonal Kumar), will help the professionals working on earth air tunnels in understanding and using this tool. In this manual all the steps involved are explained with the help of screen shots to make it user friendly.

1 General Information

The ‘EP.Plus’ folder provided in the CD contains:

- ‘EP.Plus.xlsm’ file: Excel based tool for detailed dimensioning of ‘Earth Air Tunnels’.
- ‘Doc’ folder: It contains a document on general description of the tool, mathematical model on which it works and the list of reference documents.
- ‘Meteo’ folder: It contains weather data files for 5 locations (Geneva, New Delhi, Jaipur, Bangalore and Mumbai).
- ‘Projects’ folder: This is the folder where user can make keep files for specific project.
- ‘Trnsys’ folder: It contains the specially compiled TRNSYS files to run the TRNSYS simulation for earth air tunnel.

2 Before using the tool

2.1 Estimate air flow rate

First do a calculation to estimate the volume flow rate of air required to condition the space under consideration. This can be estimated based on the volume of the space to be conditioned and the required air change rate. (Air change rate for different categories of spaces/buildings can be found at National Building Code of India, 2005.) In addition to the volume flow rate quantity, define the schedule of operation as well.

For example, if there is a building with 1000 m^2 area and 3 m height, and the air change rate recommended for this category of building is 3 ach, then the air flow rate would be 1000 x 3 x 3 = 9000 m^3/h.

2.2 Collect the weather data

Weather data is provided for few locations in the “Meteo” folder. Procedure to collect weather data for other locations is explained in **Annexure – I**.

3 Step-by-step instructions to use the tool

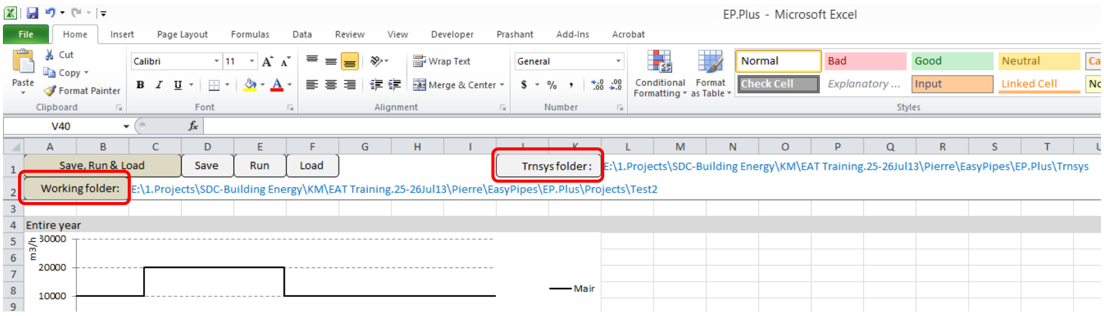
3.1 Define folder and file locations

1. Open the ‘Ep.Plus.xlsm’ file

2. In the first worksheet 'ViewYear', define the folder path for the TRNSYS files and the Project specific files.

2.1. Click on the button 'Trnsys folder' and give the path for trnsys folder e.g. "…\EasyPipes\EP.Plus\Trnsys". This needs to be defined only once until you move the entre EP.Plus folder to a new location.

Do not double click on the folder name 'Trnsys' while defining the path (just select by clicking once), else it would show error.

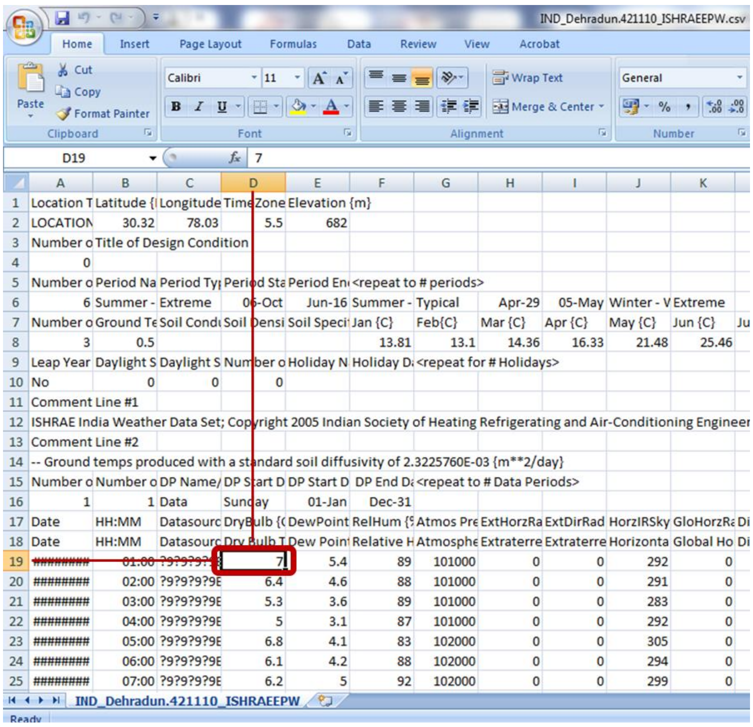


2.2. Click on the 'Working folder' button and give the path for the folder where you would like to store the files for specific project. E.g. "…\EasyPipes\EP.Plus\Projects\Test1".

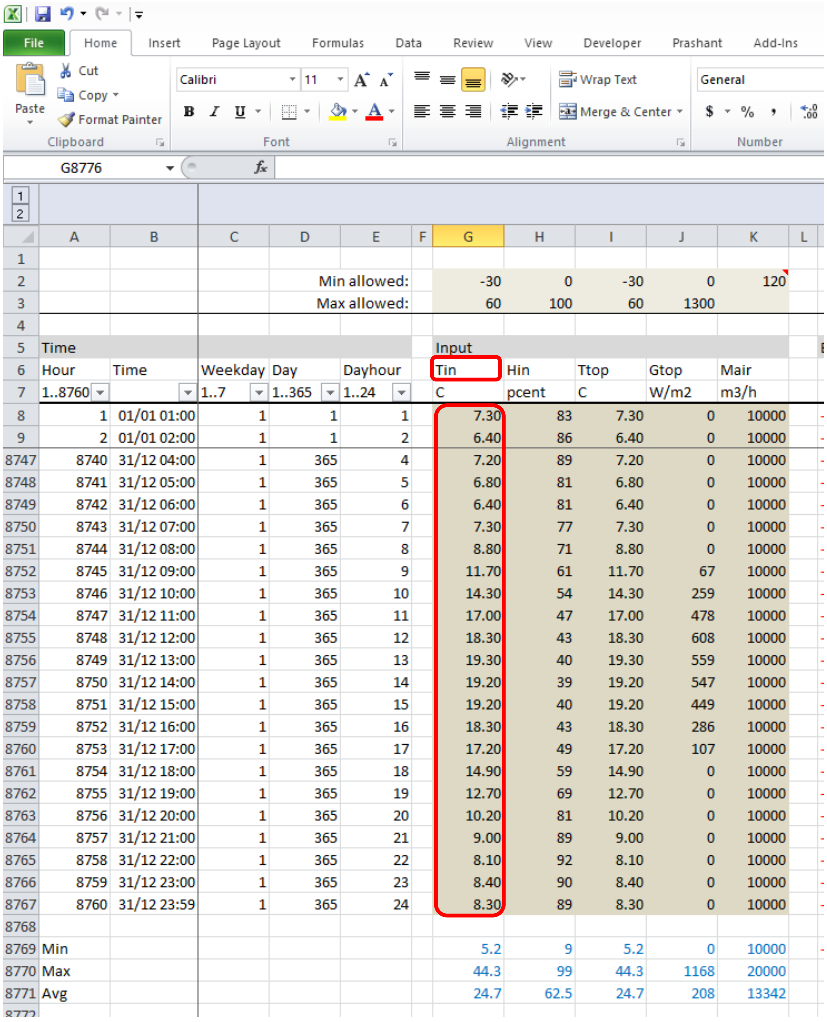
3.2 Define simulation inputs

1. Go to the worksheet 'In&Output' and input the weather data and the air flow rates.

1.1. Open the weather data file generated in *.csv format. (refer to Annexure –I for obtaining the weather data in .csv format)



1.2. Copy the ‘Dry Bulb Temperature’ data (from cells D19 – D8778) from this as shown above and paste it in the ‘In&Output’ worksheet of ‘EP.Plus.xlsm’ under the head ‘Tin’ (from cells G8 – G8767) as shown below.



	A	B	C	D	E	F	G	H	I	J	K
1											
2					Min allowed:		-30	0	-30	0	120
3					Max allowed:		60	100	60	1300	
4											
5	Time						Input				
6	Hour	Time	Weekday	Day	Dayhour		Tin	Hin	Ttop	Gtop	Mair
7	1..8760		1..7	1..365	1..24		C	pcent	C	W/m2	m3/h
8	1	01/01 01:00	1	1	1		7.30	83	7.30	0	10000
9	2	01/01 02:00	1	1	2		6.40	86	6.40	0	10000
8747	8740	31/12 04:00	1	365	4		7.20	89	7.20	0	10000
8748	8741	31/12 05:00	1	365	5		6.80	81	6.80	0	10000
8749	8742	31/12 06:00	1	365	6		6.40	81	6.40	0	10000
8750	8743	31/12 07:00	1	365	7		7.30	77	7.30	0	10000
8751	8744	31/12 08:00	1	365	8		8.80	71	8.80	0	10000
8752	8745	31/12 09:00	1	365	9		11.70	61	11.70	67	10000
8753	8746	31/12 10:00	1	365	10		14.30	54	14.30	259	10000
8754	8747	31/12 11:00	1	365	11		17.00	47	17.00	478	10000
8755	8748	31/12 12:00	1	365	12		18.30	43	18.30	608	10000
8756	8749	31/12 13:00	1	365	13		19.30	40	19.30	559	10000
8757	8750	31/12 14:00	1	365	14		19.20	39	19.20	547	10000
8758	8751	31/12 15:00	1	365	15		19.20	40	19.20	449	10000
8759	8752	31/12 16:00	1	365	16		18.30	43	18.30	286	10000
8760	8753	31/12 17:00	1	365	17		17.20	49	17.20	107	10000
8761	8754	31/12 18:00	1	365	18		14.90	59	14.90	0	10000
8762	8755	31/12 19:00	1	365	19		12.70	69	12.70	0	10000
8763	8756	31/12 20:00	1	365	20		10.20	81	10.20	0	10000
8764	8757	31/12 21:00	1	365	21		9.00	89	9.00	0	10000
8765	8758	31/12 22:00	1	365	22		8.10	92	8.10	0	10000
8766	8759	31/12 23:00	1	365	23		8.40	90	8.40	0	10000
8767	8760	31/12 23:59	1	365	24		8.30	89	8.30	0	10000
8768											
8769	Min						5.2	9	5.2	0	10000
8770	Max						44.3	99	44.3	1168	20000
8771	Avg						24.7	62.5	24.7	208	13342

1.3. Similarly, copy the ‘Relative Humidity’ data (from cells F19 – F8778) from .csv file and paste it in the ‘In&Output’ worksheet of ‘EP.Plus.xlsm’ under the head ‘Hin’ (from cells H8 – H8767).

1.4. Similarly, copy the ‘Global Horizontal Radiation’ data (from cells K19 – K8778) from .csv file and paste it in the ‘In&Output’ worksheet of ‘EP.Plus.xlsm’ under the head ‘Gtop’ (from cells J8 – J8767).

Sometimes the input values may exceed 1300 W/m2 and in that case simulation would show error. This is because the higher limit for this parameter is defined as ‘1300’ in the cell ‘J3’. To remove the error, increase this value so that it is more than the maximum value of ‘Global Horizontal Radiation’ appearing in the weather data.

1.5. Usually, ‘Ttop’ is same as ‘Tin’ if the tunnel is not below a building. If the tunnel is below a building, then the ‘Ttop’ would be the floor temperature of spaces in the building. Also, ‘Gtop’ would be zero for all hours if the entire tunnel is below a building.

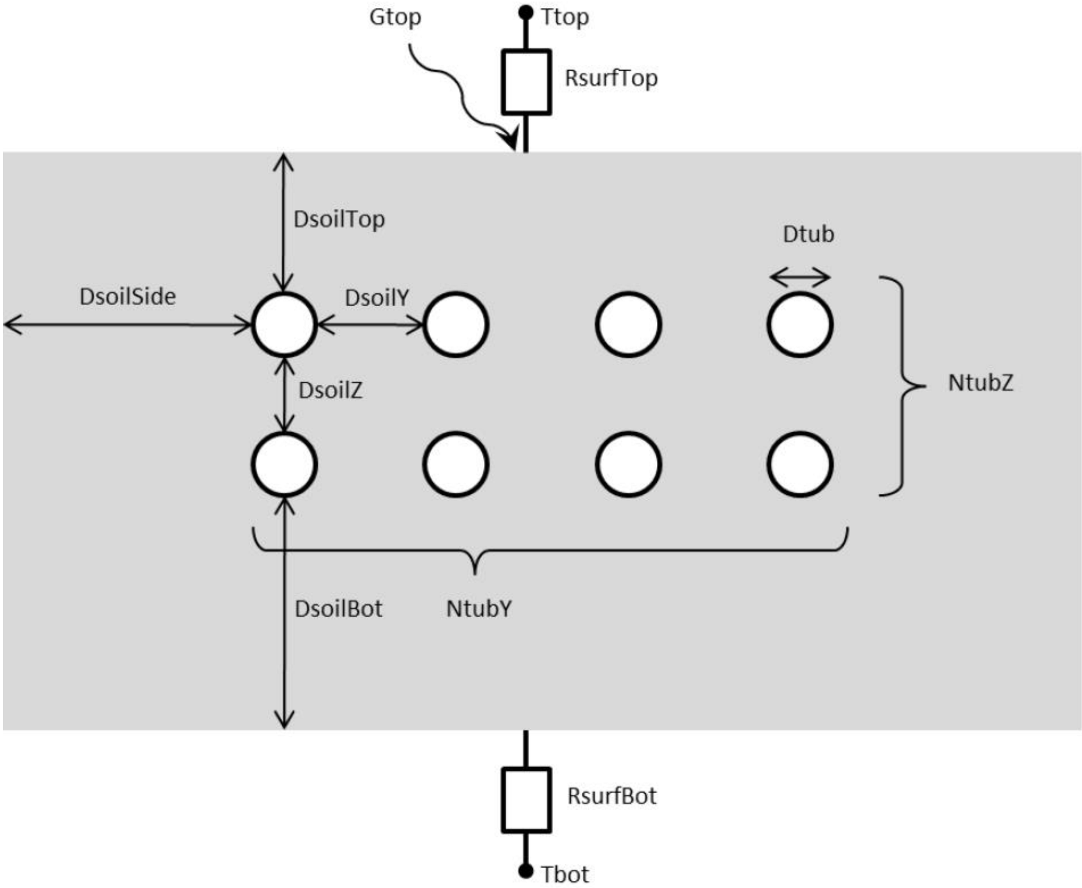
1.6. Define the air flow rate for each hour (as estimated in 2.1) in the ‘In&Output’ worksheet of ‘EP.Plus.xlsm’ under the head ‘Mair’ (from cells K8 – K8767).

2. Input the simulation parameters in the ‘Parameters’ worksheet. The inputs include earth air tunnel geometry, their arrangement, soil & pipe material properties and simulation control parameters.

2.1. Go to the ‘Parameters’ worksheet. Values for each parameter need to be defined in the column ‘C’. For your reference, the minimum and maximum values for each parameter are given in column ‘D’ & ‘E’, respectively. The description of each parameter is given in column ‘F’.

	A	B	C	D	E	F	G	H
1								
2	**Variable**	**Unit**	**Value**	**Min**	**Max**	**Description**	**Error**	**Warning**
3								
4	**Geometry**							
5	Ltub	m	120	1	200	pipe length (per pipe)	--	
6	Dtub	m	0.7	0.1	2.0	pipe diameter	--	
7	ThTub	m	0.05	0	0.1	pipe thickness	--	
8	NtubY	-	2	1	20	number of pipes y axis	--	
9	NtubZ	-	1	1	5	number of pipes z axis	--	
10	DsoilY	m	3	0.1	50	pipe - pipe distance y axis	--	
11	DsoilZ	m	2	0.1	2	pipe - pipe distance z axis	--	
12	DsoilTop	m	4	0.1	10	pipe - top surface distance	--	
13	DsoilBot	m	20	0.1	50	pipe - bottom surface distance	--	
14	DsoilSide	m	20	0.1	50	pipe - lateral surface distance	--	
15								
16	**Node size**							
17	DxIni	m	1	0.5	5	node initial size, x axis	--	
18	DxExp	-	1.2	1	1.5	node expansion factor, x axis	--	
19	DyzIni	m	0.1	0.1	0.1	node initial size, y and z axis	--	
20	DyzExp	-	1.5	1.5	1.5	node expansion factor, y and z axis	--	
21								
22	**Physical properties**							
23	LamSoil	W/K.m	1.1	0.5	3	soil conductivity	--	
24	CvSoil	kJ/K.m3	1600	500	3000	soil heat capacity	--	
25	LamTub	W/K.m	2	0.1	100	pipe conductivity	--	
26	CvTub	kJ/K.m3	2000	100	5000	pipe heat capacity	--	
27	CtubFric	-	0	0	0.1	pipe friction coefficient	--	
28	PrAir	Pa	96,000	80,000	120,000	air presuure	--	
29								
30	**Border & initial conditions**							
31	IsurfTop	-	1	0	1	border condition, top (0: adiabatic, 1: active)	--	
32	RsurfTop	K.m2/W	0.05	0	10	resistance, top	--	
33	AsurfTop	-	0.8	0	1	solar absorptivity	--	
34	IsurfBot	-	1	0	1	border condition, bottom (0: adiabatic, 1: active)	--	
35	RsurfBot	K.m2/W	0	0	10	resistance, bottom	--	
36	TsurfBot	C	25	-10	50	temperature, bottom	--	Value <> Tin average
37	TiniSoil	C	25	-10	50	initial soil temperature	--	Value <> Tin average
38								
39	**Simulation**							
40	Isim	-	2	1	2	type of simulation (1: typical section, 2: entire array)	--	Beware of run time
41	Nyear	-	1	1	10	number of years to be simulated	--	Beware of TiniSoil
42								

2.2. Define the geometry related parameters under the head 'Geometry' in the cells 'C5' to 'C15'. Description given in the worksheet & the figure given below would help in defining these parameters.



Note: For optimum performance of earth air tunnels, the velocity of air in the tunnels should be in accordance with the diameter of tunnels. The recommended range of velocity, for a diameter of 0.1-1.2 m, is 2-14 m/s (For larger pipes {0.6 m and above} the velocity should be 2-12 m/s and for smaller pipes it should be 1-4 m/s. For details, please refer to the nomographs provided with EasyPipes CD). The diameter of tunnels should be accordingly chosen. Length and the number of tunnels are constrained by the ground space available.

For example, to meet the required flow rate of 9000 m^3/h, the following combination of velocity and diameter are possible:

Diameter (m)	Calculated velocity (m/s)	Remarks
0.3	35.4	Not recommended as the velocity is beyond the recommended range. However, if ~10 pipes are used the velocity would fall within the recommended range.
0.7	6.5	Recommended.
1.0	3.2	Not recommended, as the velocity is below the recommended range given in nomograph.

2.3. The parameters listed under the ‘Node size’ are used to define the size of the minimum node used for heat transfer calculations. Smaller node size would increase the accuracy in calculations but increase the simulation time and vice-versa. Users are advised to leave these values to defaults.

2.4. The parameters listed under the ‘Physical properties’ head include properties of soil, pipe material & air. Read the description, units and min/max values for these parameters and input the values in cells ‘C23’ to ‘C28’.

Reference table for soil properties (Source: EnergyPlus Engineering Reference)

Soil condition	k_s (W/m°C)	α_s x 10^{-7} (m^2/s)
Heavy soil, saturated	2.42	9.04
Heavy soil, damp solid masonry	1.30	6.45
Heavy soil, dry	0.865	5.16
Light soil, damp	-	-
Light soil, dry	0.346	2.80

For pipe material properties the following link could be useful:

http://www.engineeringtoolbox.com/thermal-conductivity-d_429.html

If pipe friction coefficient is not known, keep that as zero.

2.5. Define the ‘Border & initial conditions’ in cells ‘C31’ to ‘C37’.

2.5.1. The value for ‘IsurfTop’ in most of the cases would be ‘1’ which means heat transfer from top surface would be calculated. In case the value is defined as ‘0’ then the top surface would be treated as adiabatic.

2.5.2. Define the surface resistance at top under the parameter ‘RsurfTop’

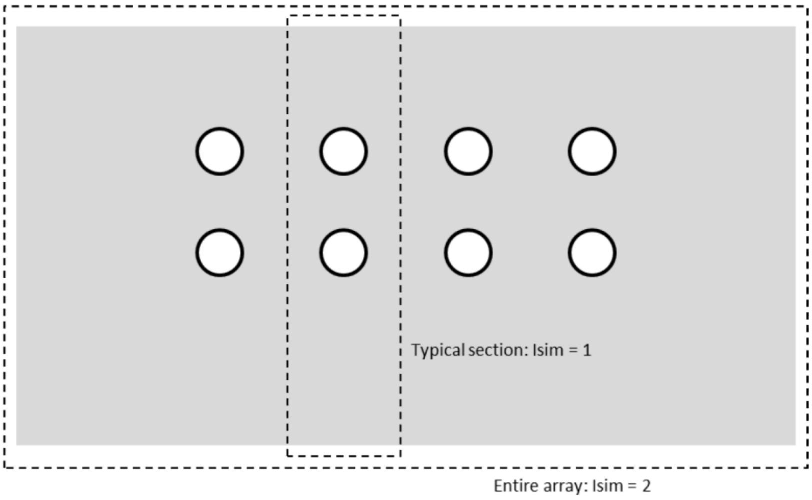
2.5.3. The parameter ‘AsurfTop’ defines the solar absorptivity of the top surface. If not known the value can be taken as ‘0.8’.

2.5.4. The parameter ‘DsoilBot’ defined under the ‘Geometry’ head defines the depth of soil which is affected by the tunnel. The value for ‘IsurfBot’ can be defined as ‘1’ which means heat transfer beyond the point ‘DsoilBot’ is calculated based on the soil temperature. In case the value is defined as ‘0’ then the point beyond ‘DsoilBot’ is treated as adiabatic for heat transfer calculations.

2.5.5. Define the surface resistance at bottom under the parameter ‘RsurfBot’

2.5.6. Value for the both parameters ‘TsurfBot’ & ‘TiniSoil’ can be defined as the annual mean air temperature for that location.

2.6. Under the head ‘Simulation’, define the ‘Isim’ for type of simulation i.e. 1 for typical section and 2 for entire array (Refer to the figure below). Define the number of years for simulation under the head ‘Nyear’.



3.3 Running the simulation, saving & loading project

Go to the worksheet ‘ViewYear’. There are four buttons for saving, simulating and loading of the project files.

1. Save: saves the parameters and inputs of the current project in their project files (EP.xpar.txt and EP.xin.txt) in the project folder defined in section 3.1. e.g. “…\EasyPipes\EP.Plus\Projects\Test1”.
2. Run: runs the Trnsys executable (i.e. simulates the project) and creates the output file (EP.xout.txt) in the project folder.
3. Load: loads the current project parameter, input and output files. The project files are stored in separate folder and this command can be used to load the previously simulated projects also.
4. Save, Run, Load: performs the above three tasks at once.

<u>Project files</u>: Following files are stored in the working directory (e.g. “…\EasyPipes\EP.Plus\Projects\Test1”):

- EP.xpar.txt: contains the information defined in the worksheet ‘Parameter’
- EP.xin.txt: contains the weather data & air flow input defined in the worksheet ‘In&Output’
- EP.xout.txt: contains the simulation results as seen in the column ‘V-Z’ of the worksheet ‘In&Output’
- EP.dck: Trnsys configuration file (created by the simulation)
- EP.log: Trnsys log file (created by the simulation)
- EP.lst: Trnsys listing file (created by the simulation)
- EP.460: Trnsys output file concerning the air-soil heat exchanger unit, Type460 (created by the simulation)

(The last four files are mainly useful for people who have prior experience with TRNSYS.)

These files should in principle not be edited outside EP.Plus.xlsx

3.4 Simulation results

The results of simulation can be seen in graphical format as well as in the numerical format.

<u>Results in 'Numerical Format'</u>

1. Hourly simulation results, for the whole period of simulation, can be seen in the column 'V-Z' of the worksheet 'In&Output'. These results include:

   1.1. Temperate of the air at the exit of the tunnel under the head 'Tout'

   1.2. Relative humidity of the air at the exit of the tunnel under the head 'Hout'

   1.3. Sensible heat transfer to the soil under the head 'Psbl'

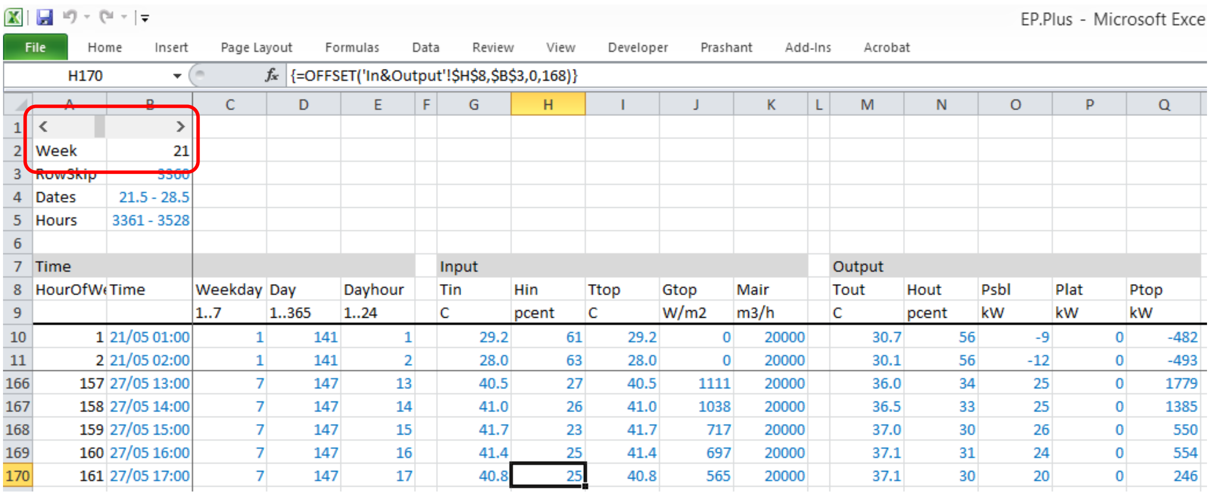
   1.4. Latent heat transfer to the soil under the head 'Plat'

   > A positive value of 'Psbl' or 'Plat' indicates that the heat is transferred from the air to the soil i.e. cooling of air and a negative value indicates that the heat is transferred from the soil to the air i.e. heating of air

   1.5. Diffusive heat transfer at the top surface under the head 'Ptop'.

   > A positive value of 'Ptop' indicates that the heat is absorbed at top surface and a negative value indicates that the heat is rejected to atmosphere from the top surface

2. Hourly simulation inputs and simulation results, for **<u>one week</u>** of simulation, can be seen in the column 'G-Q' of the worksheet 'Zoom'. This sheet essentially gives the same information which is available in the 'In&Output' worksheet, but only for one week.



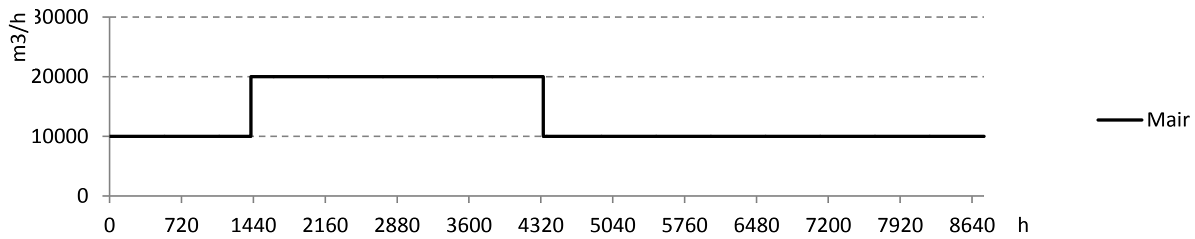
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	<	>															
2	Week	21															
3	RowSkip	3360															
4	Dates	21.5 - 28.5															
5	Hours	3361 - 3528															
6																	
7	Time						Input						Output				
8	HourOfWe	Time	Weekday	Day	Dayhour		Tin	Hin	Ttop	Gtop	Mair		Tout	Hout	Psbl	Plat	Ptop
9			1..7	1..365	1..24		C	pcent	C	W/m2	m3/h		C	pcent	kW	kW	kW
10	1	21/05 01:00	1	141	1		29.2	61	29.2	0	20000		30.7	56	-9	0	-482
11	2	21/05 02:00	1	141	2		28.0	63	28.0	0	20000		30.1	56	-12	0	-493
166	157	27/05 13:00	7	147	13		40.5	27	40.5	1111	20000		36.0	34	25	0	1779
167	158	27/05 14:00	7	147	14		41.0	26	41.0	1038	20000		36.5	33	25	0	1385
168	159	27/05 15:00	7	147	15		41.7	23	41.7	717	20000		37.0	30	26	0	550
169	160	27/05 16:00	7	147	16		41.4	25	41.4	697	20000		37.1	31	24	0	554
170	161	27/05 17:00	7	147	17		40.8	25	40.8	565	20000		37.1	30	20	0	246

The week can be selected by the slider control or can be defined in the cell 'B2'. Dates can be seen in the cell 'B4'.

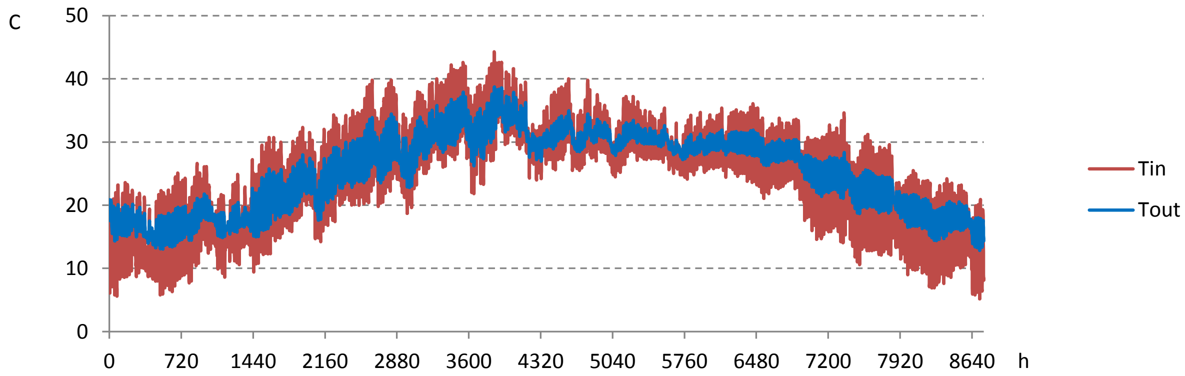
Results in 'Graphical Format'

3. Hourly simulation results, for the whole period of simulation, can be seen in the four graphs of the worksheet 'ViewYear'. These results include:

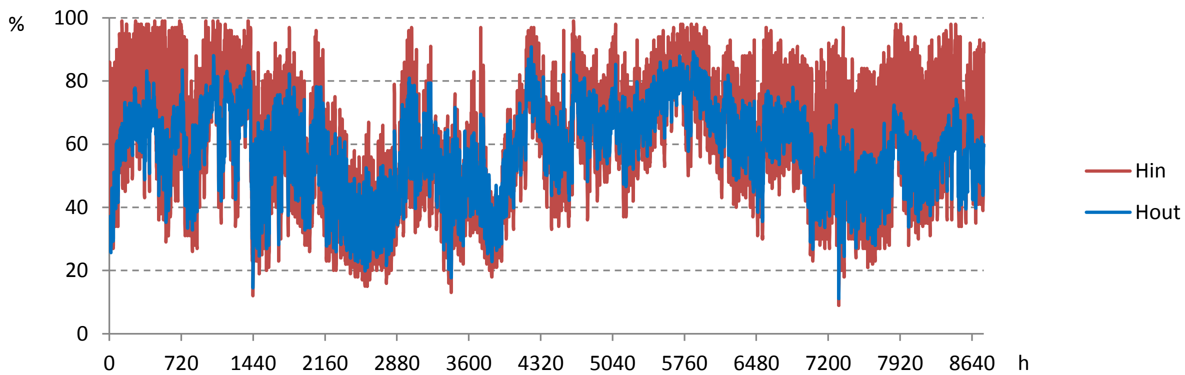
3.1. Graph 1: Mass flow rate (Mair) of the air in m3/h. This is essentially the graphical representation of the air flow defined under the head 'Mair' in the 'In&Output' worksheet.



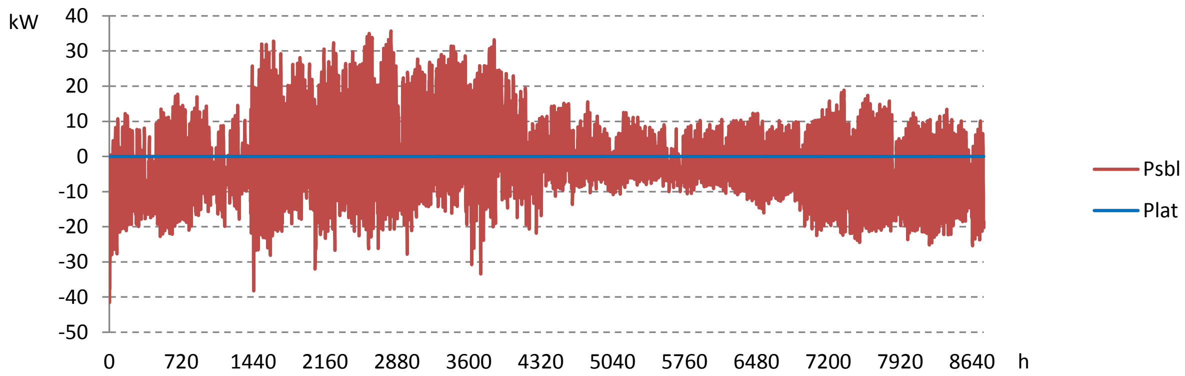
3.2. Graph 2: Air inlet (Tin) and exit temperature (Tout) in the tunnel in degree Celcius. It takes the air inlet data from the column 'G' (G7:G8767) and air exit data from column 'V' (V7:V8767) of the worksheet 'In&output'.



3.3. Graph 3: Inlet (Hin) & exit relative humidity (Hout) of the air in the tunnel in percentage. It takes the air inlet data from the column 'H' (H7:H8767) and air exit data from column 'W' (W7:W8767) of the worksheet 'In&output'.



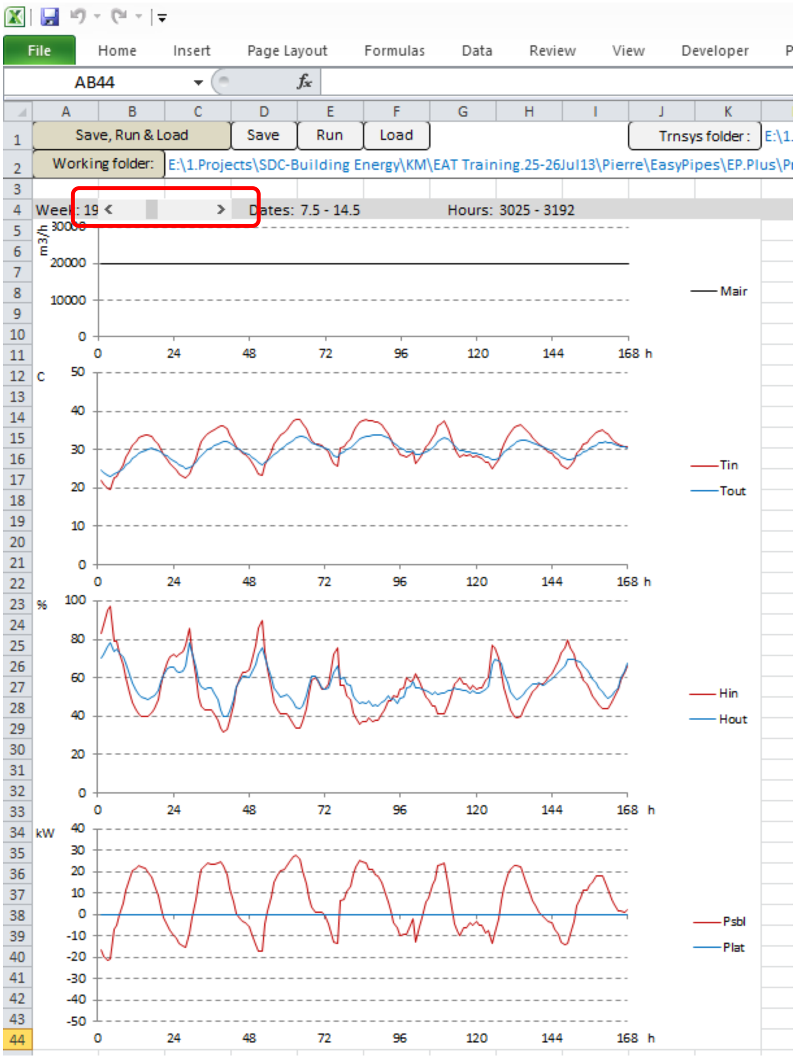
3.4. Graph 4: Sensible (Psbl) and latent heat transfer (Plat) to the soil in kW. It takes the sensible & latent heat transfer data from the column ‘Y’ (Y7:Y8767) and column ‘Z’ (Z7:Z8767), respectively. air exit data from column ‘W’ (W7:W8767) of the worksheet ‘In&output’.Sensible heat transfer to the soil under the head ‘Psbl’



4. Hourly simulation results, for **<u>one week</u>** of the simulation period, can be seen in the four graphs of the worksheet ‘ViewWeek’. This sheet essentially gives the same information which is available in the ‘ViewYear’ worksheet, but only for one week. The week can be selected by the slider control.

   The figure below gives the screenshot of the worksheet ‘ViewWeek’. The week can be seen at adjacent to the slider control. Again it gives the same four graphs for **<u>one week</u>**:

   - Graph 1: Mass flow rate (Mair) of the air in m3/h
   - Graph 2: Air inlet (Tin) and exit temperature (Tout) in the tunnel in degree Celcius
   - Graph 3: Inlet (Hin) & exit relative humidity (Hout) of the air in the tunnel in percentage
   - Graph 4: Sensible (Psbl) and latent heat transfer (Plat) to the soil in kW



5. The worksheet ‘Miscelaneous’ gives the path of the folder in which trnsys executable file & the project files are located. It also lists if there are any errors in the input parameters or occurred during the simulation.

Note: This excel based tool is protected and it will not allow making any changes in the sheet or copying the result’s graph to be used for presenting the results or any other purposes. To do this, it is first required to unprotect the sheets. Care should be taken while working with the tool in unprotected mode and it should be protected again once the purpose is served.

To unprotect/protect the tool, go to review tab of the tool and click on ‘unprotect sheet/ protect sheet’ as shown below:

Annexure – I: Procedure to collect weather data

Weather data files for some of the prominent locations of India are available on EnergyPlus website. But these files are in *.epw format which has to be converted in *.csv format before it can be used in the EP.Plus tool. The procedure has been illustrated in the following steps:

1. Download weather data for the required location from the following link (for India):

   http://apps1.eere.energy.gov/buildings/energyplus/cfm/weather_data3.cfm/region=2_asia_wmo_region_2/country=IND/cname=India

   Now extract the .zip file in a folder. Extracted folder contains the *.epw file.

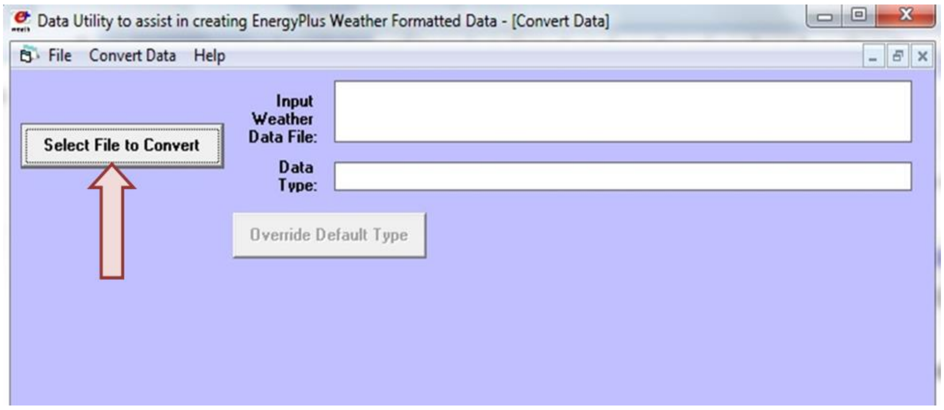
2. Now download EnergyPlus software and install it on your computer. It can be downloaded from the following link:

   http://apps1.eere.energy.gov/buildings/energyplus/register.cfm?goto=eplus

3. Now open the 'weather statistics and conversions' tool of the EnergyPlus software as shown below:

   START Menu → All Programs → EnergyPlus → Weather Statistics and Conversions

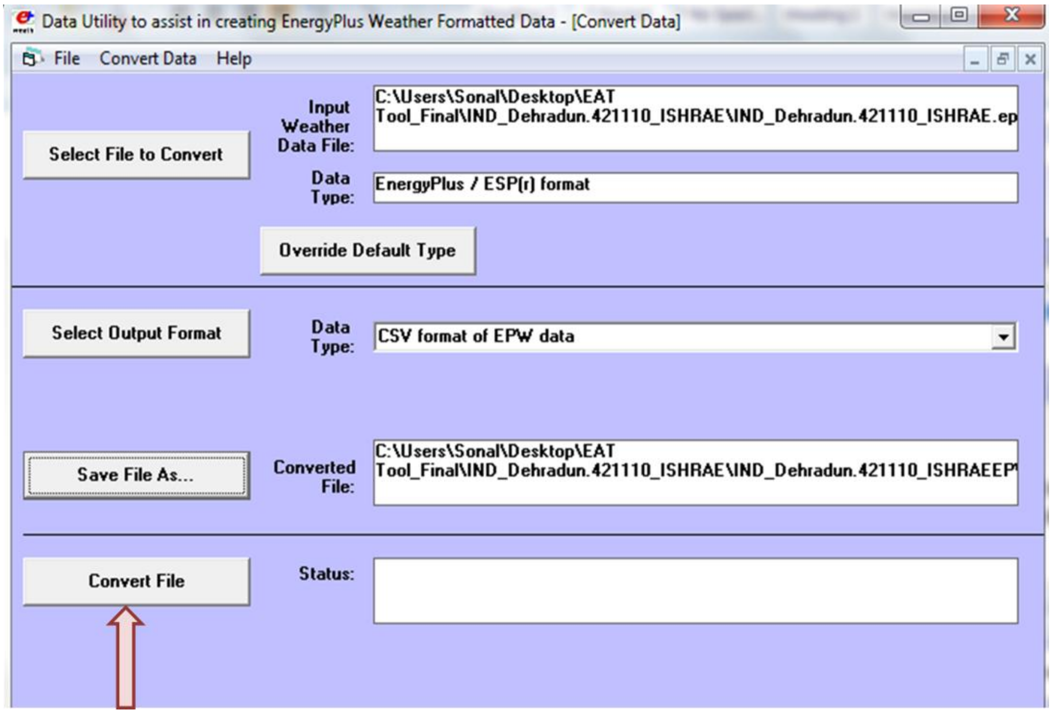
   Following window will come up:



4. Now click on the 'Select File to Convert' as shown in the above figure and specify the path to locate the *.epw file. Now select the 'CSV format of EPW data' as the output format from the drop-down menu as shown below:

5. Click on ‘Save File As...’ tab as shown and specify the path of the location where the output data in *.csv format is desired to be saved.

Now click on ‘Convert File’ tab as shown below:



Click on ‘Ok’ when the conversion is complete and close the EnergyPlus tool. With this the weather data file has been converted from *.epw format to *.csv format.

6. Save the .csv file generated in Step-5.