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# Documentation Report for the TRNSED PV/Thermal System Simulation tool for IEA Task 35

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**A Report of IEA SHC - Task 35**

**PV/Thermal Solar Systems**

**Report DB3-2**

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## IEA Solar Heating and Cooling Programme

The *International Energy Agency* (IEA) is an autonomous body within the framework of the Organization for Economic Co-operation and Development (OECD) based in Paris. Established in 1974 after the first “oil shock,” the IEA is committed to carrying out a comprehensive program of energy cooperation among its members and the Commission of the European Communities.

The IEA provides a legal framework, through IEA Implementing Agreements such as the *Solar Heating and Cooling Agreement*, for international collaboration in energy technology research and development (R&D) and deployment. This IEA experience has proved that such collaboration contributes significantly to faster technological progress, while reducing costs; to eliminating technological risks and duplication of efforts; and to creating numerous other benefits, such as swifter expansion of the knowledge base and easier harmonization of standards.

The *Solar Heating and Cooling Programme* was one of the first IEA Implementing Agreements to be established. Since 1977, its members have been collaborating to advance active solar and passive solar and their application in buildings and other areas, such as agriculture and industry. Current members are:

Australia	Finland	Portugal
Austria	France	Spain
Belgium	Italy	Sweden
Canada	Mexico	Switzerland
Denmark	Netherlands	United States
European Commission	New Zealand	
Germany	Norway	

A total of 44 Tasks have been initiated, 33 of which have been completed. Each Task is managed by an Operating Agent from one of the participating countries. Overall control of the program rests with an Executive Committee comprised of one representative from each contracting party to the Implementing Agreement. In addition to the Task work, a number of special activities—Memorandum of Understanding with solar thermal trade organizations, statistics collection and analysis, conferences and workshops—have been undertaken.

To find Solar Heating and Cooling Programme publications and learn more about the Programme visit [www.iea-shc.org](http://www.iea-shc.org) or contact the SHC Executive Secretary, Pamela Murphy, e-mail: [pmurphy@kmgrp.net](mailto:pmurphy@kmgrp.net).

The Tasks of the IEA Solar Heating and Cooling Programme, both underway and completed are as follows:

### *Current Tasks & Working Group:*

Task 35	<i>PV/Thermal Solar Systems</i>
Task 36	<i>Solar Resource Knowledge Management</i>
Task 37	<i>Advanced Housing Renovation with Solar &amp; Conservation</i>
Task 38	<i>Solar Thermal Cooling and Air Conditioning</i>
Task 39	<i>Polymeric Materials for Solar Thermal Applications</i>
Task 40	<i>Net Zero Energy Solar Buildings</i>
Task 42	<i>Compact Solar Thermal Energy Storage</i>
Working Group	<i>Daylight Research Group</i>

### **C**ompleted Tasks:

Task 1	<i>Investigation of the Performance of Solar Heating and Cooling Systems</i>
Task 2	<i>Coordination of Solar Heating and Cooling R&amp;D</i>
Task 3	<i>Performance Testing of Solar Collectors</i>
Task 4	<i>Development of an Insolation Handbook and Instrument Package</i>
Task 5	<i>Use of Existing Meteorological Information for Solar Energy Application</i>
Task 6	<i>Performance of Solar Systems Using Evacuated Collectors</i>
Task 7	<i>Central Solar Heating Plants with Seasonal Storage</i>
Task 8	<i>Passive and Hybrid Solar Low Energy Buildings</i>
Task 9	<i>Solar Radiation and Pyranometry Studies</i>
Task 10	<i>Solar Materials R&amp;D</i>
Task 11	<i>Passive and Hybrid Solar Commercial Buildings</i>
Task 12	<i>Building Energy Analysis and Design Tools for Solar Applications</i>
Task 13	<i>Advance Solar Low Energy Buildings</i>
Task 14	<i>Advance Active Solar Energy Systems</i>
Task 16	<i>Photovoltaics in Buildings</i>
Task 17	<i>Measuring and Modeling Spectral Radiation</i>
Task 18	<i>Advanced Glazing and Associated Materials for Solar and Building Applications</i>
Task 19	<i>Solar Air Systems</i>
Task 20	<i>Solar Energy in Building Renovation</i>
Task 21	<i>Daylight in Buildings</i>
Task 23	<i>Optimization of Solar Energy Use in Large Buildings</i>
Task 22	<i>Building Energy Analysis Tools</i>
Task 24	<i>Solar Procurement</i>
Task 25	<i>Solar Assisted Air Conditioning of Buildings</i>
Task 26	<i>Solar Combisystems</i>
Task 28	<i>Solar Sustainable Housing</i>
Task 27	<i>Performance of Solar Facade Components</i>
Task 29	<i>Solar Crop Drying</i>
Task 31	<i>Daylighting Buildings in the 21<sup>st</sup> Century</i>
Task 32	<i>Advanced Storage Concepts for Solar and Low Energy Buildings</i>
Task 33	<i>Solar Heat for Industrial Processes</i>
Task 34	<i>Testing and Validation of Building Energy Simulation Tools</i>

### **C**ompleted Working Groups:

*CSHPSS, ISOLDE, Materials in Solar Thermal Collectors, and the Evaluation of Task 13 Houses*

## IEA SHC Task 35 PV/Thermal Solar Systems

### Objective

The objectives of the Task are to catalyze the development and market introduction of high quality and commercial competitive PV/Thermal Solar Systems and to increase general understanding and contribute to internationally accepted standards on performance, testing, monitoring and commercial characteristics of PV/Thermal Solar Systems in the building sector.

The Task is organized in 5 subtasks:

- Subtask A: Market and Commercialization of PV/T
- Subtask B: Energy Analysis and Modeling
- Subtask C: Product and System Development, Tests and Evaluation
- Subtask D: Demonstration Projects
- Subtask E: Dissemination

### Organisation

IEA SHC Task 35 "PV/Thermal Solar Systems" is a three year Task initiated by the International Energy Agency (IEA) Solar Heating and Cooling (SHC) Programme in January 2005.

The Danish Energy Authority, acting through Mr. Henrik Sørensen, Esbensen Consulting Engineers A/S, Denmark, is designated as Operating Agent for the Task.

Task 35 is a so-called "minimum-level" collaboration task with IEA PVPS (Photovoltaic Power Systems Programme). At this level, experts selected by the PVPS Executive Committee participate in experts meetings of the Task managed by the SHC Executive Committee. The Task is fully defined and managed by the SHC Executive Committee with appropriate input from the PVPS Executive Committee. In this project Israel participated as a PVPS country member.

The official participants in the Task are listed in the table below:

Country	Organization	Person
Canada	Dept. of Mechanical Engineering, University of Waterloo, Waterloo, Ontario, Canada	Mike Collins
Denmark	Esbensen Consulting Engineers A/S	Henrik Sørensen
	Solar Energy Center, Danish Technological Institute	Ivan Katic
Israel	Millennium Electric	Ami Elazari
Sweden	Lund Technical University	Björn Karlsson Johan Nilsson Bengt Perers
The Netherlands	ECN (Energy Research Centre of the Netherlands)	Wim van Helden Herbert Zondag Marco Bakker

Apart from the above mentioned a number of manufacturers, universities, and research institutes from the countries Germany, Greece, Hong Kong, Italy, South Korea, Thailand, and Spain have been involved in the work.

Visit the Task 35 website: <http://www.iea-shc.org/task35> for more details on activities and results.

# **Documentation Report for the TRNSED PV/Thermal System Simulation tool for IEA Task 35**

by

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A technical report of Subtask B  
Report DB3-2

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## Introduction

**The PVT system simulation tool** is based on a well tested TRNSYS/TRNSED model for a solar heating and hot water system including simplified simulation of the house load for each climate chosen. Heat losses from the system components are added to the internal heat in the building to give a more realistic heating load.

**The basic system model** has been used for education at Lund and Uppsala University for a number of years with good results. The students can often produce results within 15 minutes, after a short software introduction and at the end of a solar thermal course.

**The thermal part** of the PV/T dynamic collector model follows the collector model in the European test standard EN12975. The parameters from such a test can be used directly in the tool. Parameters for thermal collectors are published on the ESTIF Solar Keymark homepage <http://www.estif.org/solarkeymark/>

**The photovoltaic part** of the PVT collector model simulates the output on electrical energy level and assumes a maximum power point tracking device for extraction of electricity. Therefore no complicated IV curve input has to be supplied to the software for each collector model. Still the first order dependencies of fluid temperature, incidence angle and heat transfer coefficient cell-absorber are taken into account in the simplified PVT model in the tool. This is close to the simplified level of modelling in TRNSYS type 50. No irradiation dependence is taken into account at the present stage. For concentrating collectors the irradiation dependency is assumed to be compensated for in the measured  $W_p$  value already. An efficiency at 25C cell temperature is the main PV performance input. This is given in a separate text file also specifying the detailed thermal collector parameters.

When operating the PVT collector in the simulation, the thermal output is reduced by the electrical energy extraction from the PV module.

In the TRNSYS environment much more advanced TRNSED tools can be made if needed. This tool is a compromise based on available man-hours and a goal of short simulations time for each run.

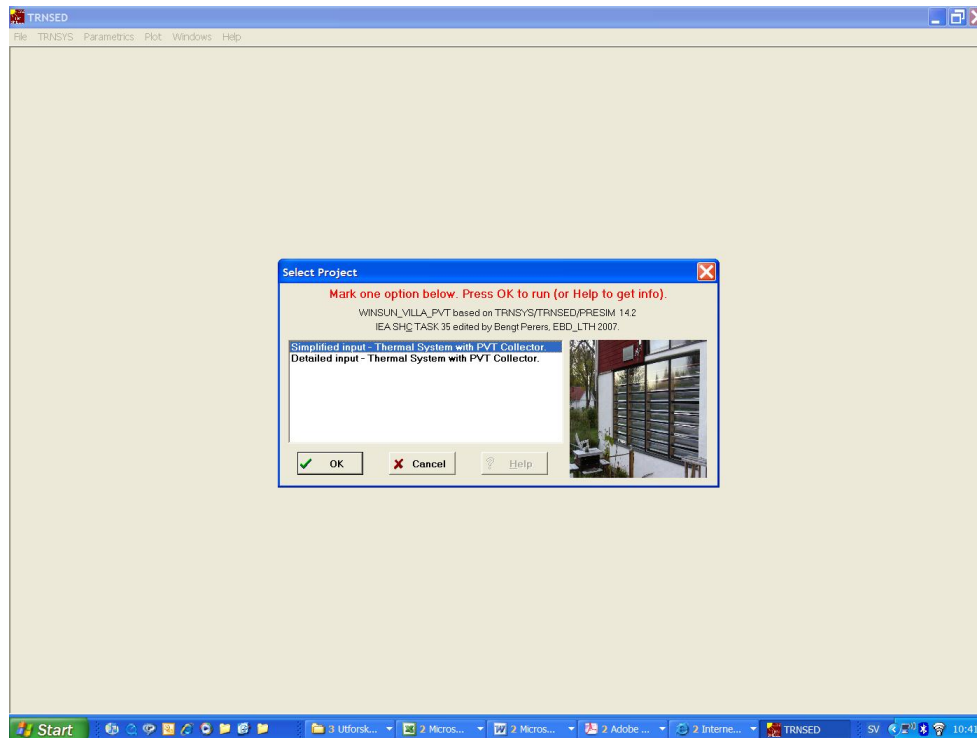
## Installation of the software

**The software is supplied as a setup file** that installs the programme and produces an icon on the desktop during installation. Un-installation information is available in the control panel.

## How to run the PV/T program

Presently **two levels of system simulation** and input details can be chosen during start-up of the software:

- 1) **Simplified level** opening just a few basic collector- and system parameters.
- 2) **Advanced level** enabling more detailed input for the PVT collector and system..



Choice of **simple** or **advanced** simulation level during start up.

The next software step is the **input page** where all parameters are presented. In each parameter field an **online help** is given by pressing the **F1** button. See the example below.



Upper part of the **input parameter page** with an online help window shown (press F1 Key).  
**Basic Help** on how to use the software is also given below the input fields in **green text**.

A **simplified thermal system diagram** is also given on the input page to help the user:

The screenshot displays the TRNSYS software window titled "TRNSEED - [WINSUN\_VILLA\_PVT\_1A.trd]". The main area shows a schematic diagram of a thermal system. The diagram includes a PVT Solar Collector at the top left, connected via red and blue pipes to a central Storage tank. An Auxiliary heater is also connected to the Storage tank. The Storage tank is connected to a Radiator Heating unit, which is shown with a temperature gradient from blue (Cold Water) at the bottom to red (Hot Water) at the top. The diagram also shows a pump and various control valves.

Below the diagram, the input parameters are listed:

```

***** INPUT DATA FOR THE HOUSE LOADS, Relative numbers and Deg C ***
Relative Hot Water Load (relative to 210 l/d)      1.00  relative value
Relative Heating Load (relative to an old house, 250W/K) 1.00  relative value
*** INPUT DATA FOR THE THERMAL STORAGE TANK ***
Tank Volume (typ 0.3-1.5 m3)                       0.75  m3
  
```

At the bottom of the window, there is a small photograph of a house with a large window and a solar collector mounted on the roof.

**Simplified system diagram** for the thermal system on the input parameter page.

The PV system is assumed to be a **grid connected system** with an inverter equipped with a maximum power point tracker. This is standard today in most grid connected PV systems. Stand alone PVT systems can not be simulated with the tool at the present development level.

**Edit all input parameters** as desired and choose Climate and Collector Type.

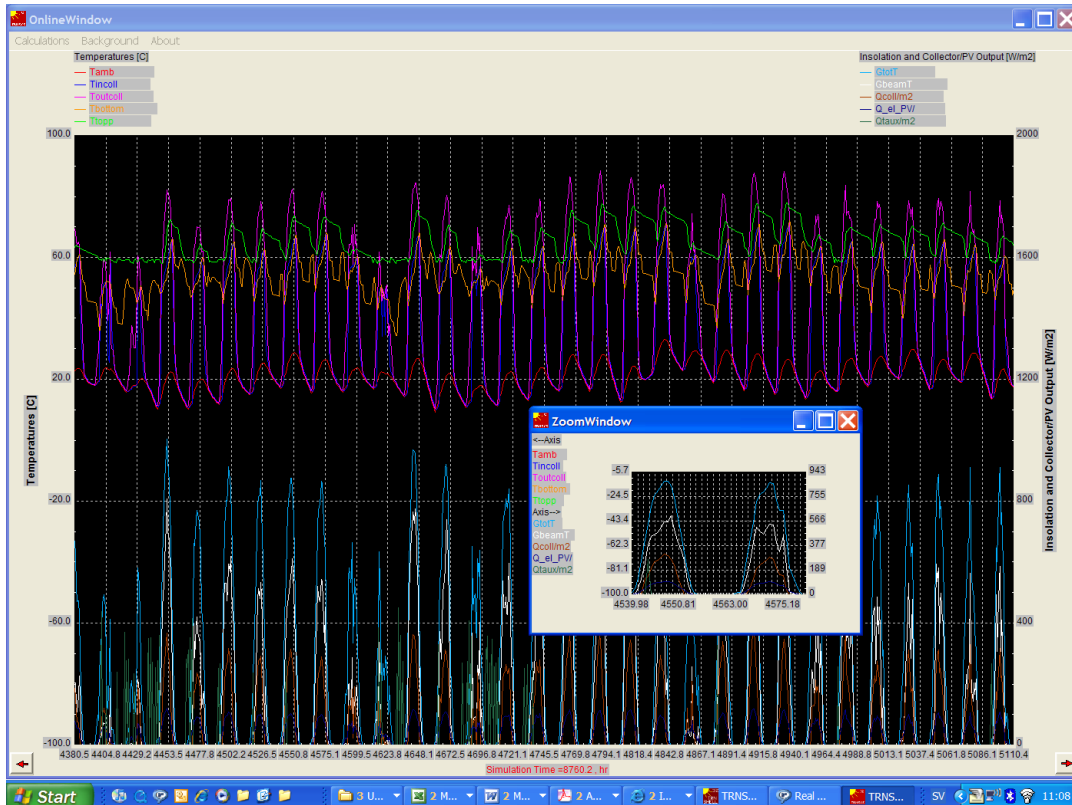
## Press F8 to start a Simulation Run

A System Simulation Run is started by **pressing F8** or via the top menu => TRNSYS => Calculate.

## Output from the software

**On-line diagrams**, one for each month, are shown during the simulation to present short-term values. A small part of the diagram can also be magnified by marking an area with the mouse as shown.





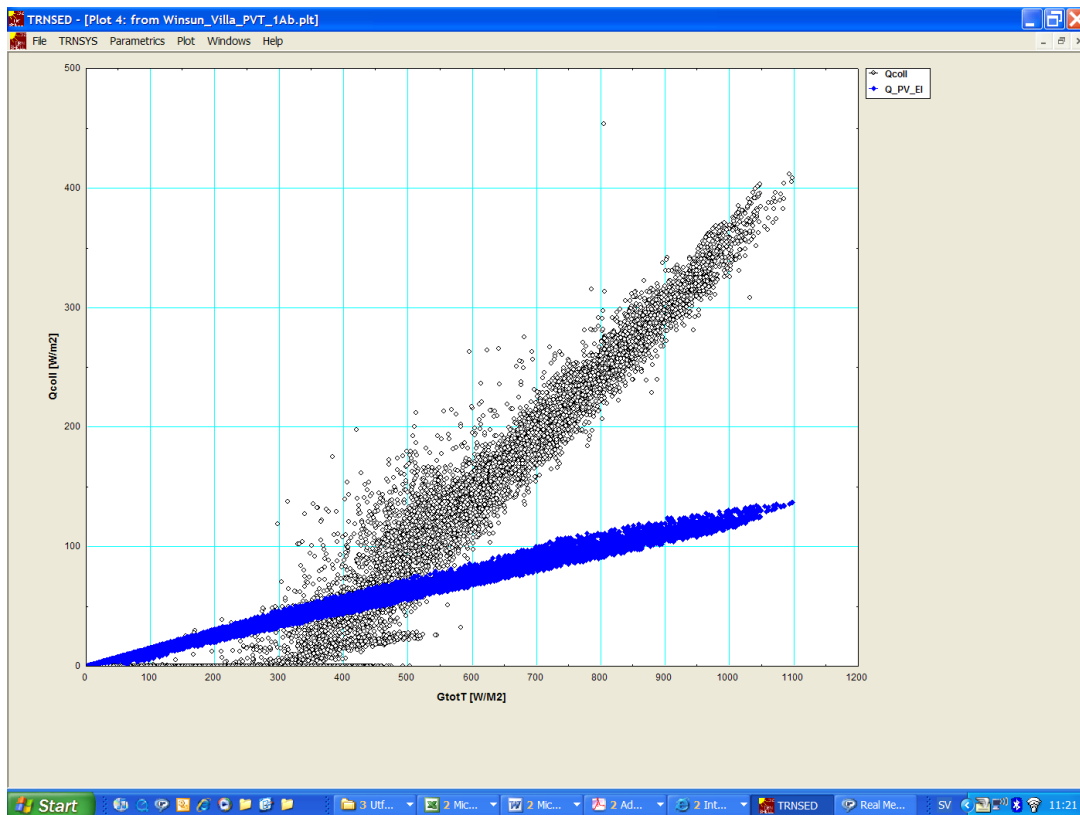
**On-line diagram** from a simulation run showing temperatures and energies.

After the simulation a **summary results table** can be opened and imported to Excel. The file can be accessed via the top menu under => Windows => Output => Winsun\_villa\_PVT\_\*\*.out. The output values are presented in E-format to cover a large range of system sizes without exploding the table format.

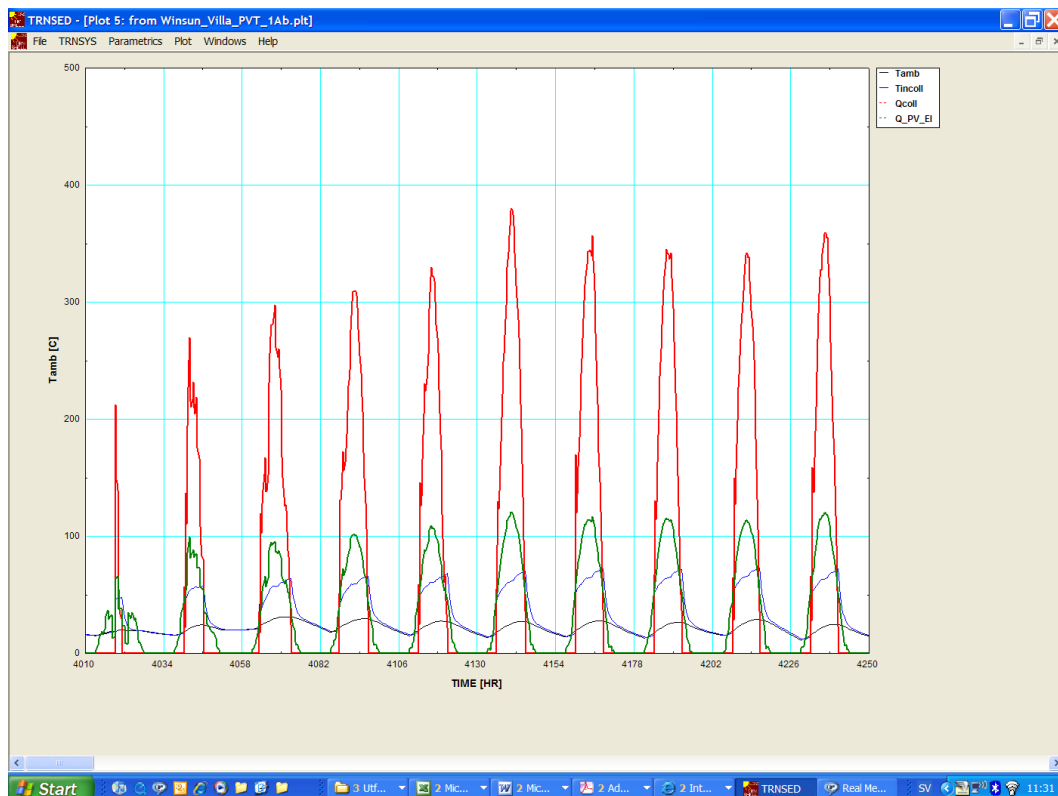
MONTH	TIME	Hsuntot	Qprv	Qcoll	Qt_coll	Qt_load	Qt_aux	Qt_loss	top_coll	QeI_PV
JAN	744.000	7.989E+02	0.000E+00	1.326E+02	1.174E+02	4.563E+03	4.493E+03	5.329E+01	9.650E+01	1.102E+
FEB	1416.000	1.047E+03	0.000E+00	2.017E+02	1.802E+02	3.942E+03	3.816E+03	4.958E+01	1.293E+02	1.421E+
MAR	2160.000	1.403E+03	0.000E+00	2.711E+02	2.395E+02	3.311E+03	3.147E+03	6.395E+01	1.643E+02	1.842E+
APR	2880.000	1.537E+03	0.000E+00	3.035E+02	2.659E+02	2.044E+03	1.850E+03	7.236E+01	1.700E+02	1.949E+
MAY	3624.000	1.820E+03	0.000E+00	3.832E+02	3.329E+02	1.137E+03	9.012E+02	8.512E+01	2.130E+02	2.230E+
JUN	4344.000	1.834E+03	0.000E+00	4.140E+02	3.593E+02	6.274E+02	3.668E+02	8.978E+01	2.153E+02	2.204E+
JUL	5088.000	1.953E+03	0.000E+00	4.653E+02	4.031E+02	4.243E+02	1.123E+02	9.622E+01	2.503E+02	2.324E+
AUG	5832.000	1.803E+03	0.000E+00	4.283E+02	3.723E+02	4.760E+02	2.019E+02	9.419E+01	2.260E+02	2.165E+
SEP	6552.000	1.461E+03	0.000E+00	3.216E+02	2.778E+02	8.232E+02	6.187E+02	8.218E+01	1.980E+02	1.799E+
OCT	7296.000	1.116E+03	0.000E+00	2.070E+02	1.797E+02	1.717E+03	1.610E+03	7.795E+01	1.253E+02	1.423E+
NOV	8016.000	5.973E+02	0.000E+00	7.089E+01	5.873E+01	2.719E+03	2.721E+03	6.650E+01	6.100E+01	7.978E+
DEC	8760.000	5.455E+02	0.000E+00	5.483E+01	4.484E+01	4.070E+03	4.089E+03	5.764E+01	6.175E+01	7.537E+
SUM	8760.000	1.592E+04	0.000E+00	3.254E+03	2.832E+03	2.586E+04	2.393E+04	8.888E+02	1.911E+03	2.001E+

**Output table** with monthly values for solar radiation and energy flows in the system.

More detailed studies of the simulation results can be done with the **Plot option** on the main menu, like the input output diagram for thermal and electrical output shown below.



**Input output-diagram for Thermal and electrical output vs. incident solar radiation**



**Time diagram showing thermal and electrical power plus ambient and inlet temperature.**

## Quick help in the TRNSED PV/T programme

At each input parameter field you can use the **F1 Key** to get help on that parameter. **Quick Help/Advice** is also available in the software, in **green text** below the input data field in the TRNSED tool. A copy of that text is given below:

\*\*\*\*\* SOME ADVICE HOW TO USE WINSUN\_VILLA\_PVT \*\*\*\*\*

- Change the input data in the fields above, as desired. F1 for help.
- Use the Tab key or Mouse to move between items. Not the arrow keys.
- Always use decimal point not comma (as in Swedish) in the input fields.
- A run is started with "TRNSYS/Calculate" from the TRNSED menu above.
- Help is available at each input field below. Just press the F1 key.
- To get Summary Output choose "Windows / Output> and WINSUN\_VILLA\_PVT.OUT"
- To Plot detailed results choose "Plot / New plot"
- To make Multiple Runs choose "Parametrics/New Table" then "TRNSYS/Run Table"

\*\*\*\*\* RESULTS SHOWN AS DATA FILES \*\*\*\*\*

Results can be found as a table in WINSUN\_VILLA\_PVT.OUT or as a plot file WINSUN\_VILLA\_PVT.PLT  
The WINSUN\_VILLA\_PVT.OUT file can be viewed from the "Windows" option  
The WINSUN\_VILLA\_PVT.PLT file can be plotted with the Plot option.

\*\*\*\*\* Columns shown in the output file WINSUN\_VILLA\_PVT\_\*.OUT\*\*\*\*\*

TIME = Simulation Time in Hours from Jan 1 at 00.00  
Hsuntot = Total Solar Radiation onto the Collector plane [kWh]  
Qprv = Energy leaving the system due to collector over sizing or storage under sizing [kWh]  
Qcoll = Energy from collector loop [kWh]  
Qt\_coll = Solar Thermal from Collector to the tank [kWh]  
Qt\_load = Load drawn from the tank [kWh]  
Qt\_aux = Auxiliary energy needed to the tank [kWh]  
Qt\_loss = Tank losses [kWh]  
top\_coll = Collector Loop Operating Time [Hours]  
Qel\_PV = PV Electrical Output [kWh]

\*\*\*\*\* RESULTS ARE ALSO SHOWN AS AN ONLINE PLOT \*\*\*\*\*

The on line plot can be analysed on screen. An example of output parameters are shown there.

A line in the plot is removed and shown again with one mouse click on the legend.

A part of the image can be magnified by marking that area on screen with the mouse. See also Help.

\*\*\*\*\* DEVELOPMENT STATUS OF WINSUN\_VILLA\_PVT \*\*\*\*\*

This is a simplified tool that can be further developed according to user needs.

WINSUN\_VILLA\_PVT is developed for the highest standards for quality but the user has to check and take full responsibility for the use of the results from WINSUN\_VILLA\_PVT.

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Grateful for Corrections and Error reporting to Email: [bengt-perers@telia.com](mailto:bengt-perers@telia.com)

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