SOLAR HEATING SYSTEMS:
SOFTWARE ANALYSIS FOR A SIMPLER DESIGN

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Summary

The European Directive 2002/91/EC on the energy performance of buildings considers the positive influence of the active solar systems and other heating and electric systems based on renewable energy sources.
The energy performance of buildings should be calculated on the basis of a methodology that includes, in addition to thermal insulation other factors that play an increasingly important role such as heating and air-conditioning installations, application of renewable energy sources and design of the building.
In addition, in the 2007 Italian government financial plan, economic advantages are considered for restoration aimed at energy consumption reduction and for solar heating systems design.
Some computer programs dedicated to the energy project analyses can be used to evaluate the energy production, life-cycle costs and greenhouse gas emission reductions for various types of efficient and renewable energy technologies.
The different calculation methodologies offer a simplified or a more complicated way to reach the surface dimensioning and evaluation. Some calculation instruments can reach more accurate results than others. Deep attention must be given to the input radiation data suitable for the building location. Some software make calculations on the basis of mean solar radiation data taken by national standards. These data are not corresponding as well with more recent measurements and therefore standards should be revised.
In the present work the analysis of some software is developed, by comparing their capability of solar heating system determination. The results highlight the features that must be verified in the choice of software and freeware tools and can give good results if properly used.

1. Tools for solar heating systems dimensioning

Nowadays, wide possibilities for the solar energy exploitation are offered by the new technologies; however the availability of many solutions for the realisation of the systems implies accurate calculations for their dimensioning.

Technicians and sellers propose their solutions but often it is not so evident which one is the best.

Software tools can aid in highlighting the main features of the system, even if sometimes are based on conventional data and give largely approximate results.

Simplified analysis methods have the advantages of computational speed, low cost, rapid turnaround and simplicity of use by persons with little technical experience.

The availability of trustworthy calculation tools has indeed a great importance, as the efficiency and the cost saving of each solution weighs on the choice. On the contrary, limited flexibility for design optimization, lack of control over assumptions, and a limited selection of systems that can be analyzed represent the main disadvantages.

The use of standardised and affordable decision-making tools can reduce the costs of pre-feasibility studies and can give better results in the realisation of the system. As the solar energy utilisation becomes widespread, also at basic levels (solar kits are available for self-constructing his own solar system), means to help people make better decisions can be very important. Even training people to better analyse the technical and financial viability of possible projects allows making them aware of the convenience and the need of modernising the existing technologies.

In this analysis some programs have been compared (Retscreen, Trasol, PuntoEnergia, Elioinox, Rotex/Heliant) by examining their user-friendly access, databases, calculation data, flexibility to consider various conditions and materials, results.

Some of them are demo-software and therefore have limits on the application. One of the most complete is produced by the RETScreen International Clean Energy Decision Support Centre that seeks to build the capacity of planners, decision-makers and industry to implement renewable energy and energy efficiency projects. It is managed under the leadership and ongoing financial support of Natural Resources Canada's (NRCan) CANMET Energy Technology Centre - Varennes (CETC-Varennes) [1].

Retscreen Analysis Software is a decision support tool developed with the contribution of numerous experts from government, industry, and academia. The software, provided free-of-charge, can be used worldwide to evaluate the energy production and savings, life-cycle costs, emission reductions, financial viability and risk for various types of energy efficient and Renewable Energy Technologies (RETs). The software also includes product, cost and climate databases, and a detailed online user manual. All the tools are available free-of-charge in English and French, with many of the tools available in other languages.

RETScreen® Energy Model - Solar Water Heating Project

Project name		**domestic hot water**	
Project location		**Genoa**	
Nearest location for weather data		Genova/Sestri	*Complete SR&HLC sheet*
Annual solar radiation (tilted surface)	MWh/m²	1.24	
Annual average temperature	°C	15.6	
Annual average wind speed	m/s	4.9	
Desired load temperature	°C	45	
Hot water use	L/d	5,000	
Number of months analysed	month	3.5	
Energy demand for months analysed	MWh	17.32	
Application type		Service hot water (with storage)	
Base Case Water Heating System			
Heating fuel type	-	**Natural gas**	
Heating system seasonal efficiency	%	250%	60% to 300%
Solar Collector			
Collector type	-	Glazed	*See Technical Note 1*
Solar water heating collector manufacturer		ABC	*See Product Database*
Solar water heating collector model		XYZ	
Area per collector	m²	4.00	1.00 to 5.00
Fr (tau alpha) coefficient	-	0.85	0.50 to 0.90
Fr UL coefficient	(W/m²)/°C	11.56	3.50 to 6.00
Suggested number of collectors		12	
Number of collectors		7	
Total collector area	m²	28.0	
Storage			
Ratio of storage capacity to coll. area	L/m²	45.9	37.5 to 100.0
Storage capacity	L	1,285	
Balance of System			
Heat exchanger/antifreeze protection	yes/no	No	
Suggested pipe diameter	mm	19	8 to 25 or PVC 30 to 38
Pipe diameter	mm	38	8 to 25 or PVC 30 to 38
Pumping power per collector area	W/m²	0	3 to 22, or 0
Piping and solar tank losses	%	1%	1% to 10%
Losses due to snow and/or dirt	%	3%	2% to 10%
Horz. dist. from mech. room to collector	m	5	5 to 20
# of floors from mech. room to collector	-	2	0 to 20

Figure 1 – Retscreen data sheet

The RETScreen International Solar Water Heating Model, based on ASHRAE Applications Handbook calculations, can be used world-wide to easily evaluate the energy production, life-cycle costs and greenhouse gas emissions reduction for three basic applications: domestic hot water, industrial process heat and swimming pools (indoor and outdoor), ranging in size from small residential systems to large scale commercial, institutional and industrial systems.

TRASOL represents training software material in the field of solar thermal systems realised in the program "Leonardo da Vinci" (1996) financed by the European Commission. The attention is focused on design and sizing methodologies, production technologies, installation techniques, economics of installing solar water heating systems. The TRASOL CD-Rom, developed by CRES in cooperation with EBHE and SELETE, can represent useful multimedia training tool for the on-the-job training of engineers and technicians (manufacturers employees and free lancers) in the solar thermal systems issues of interest [2]

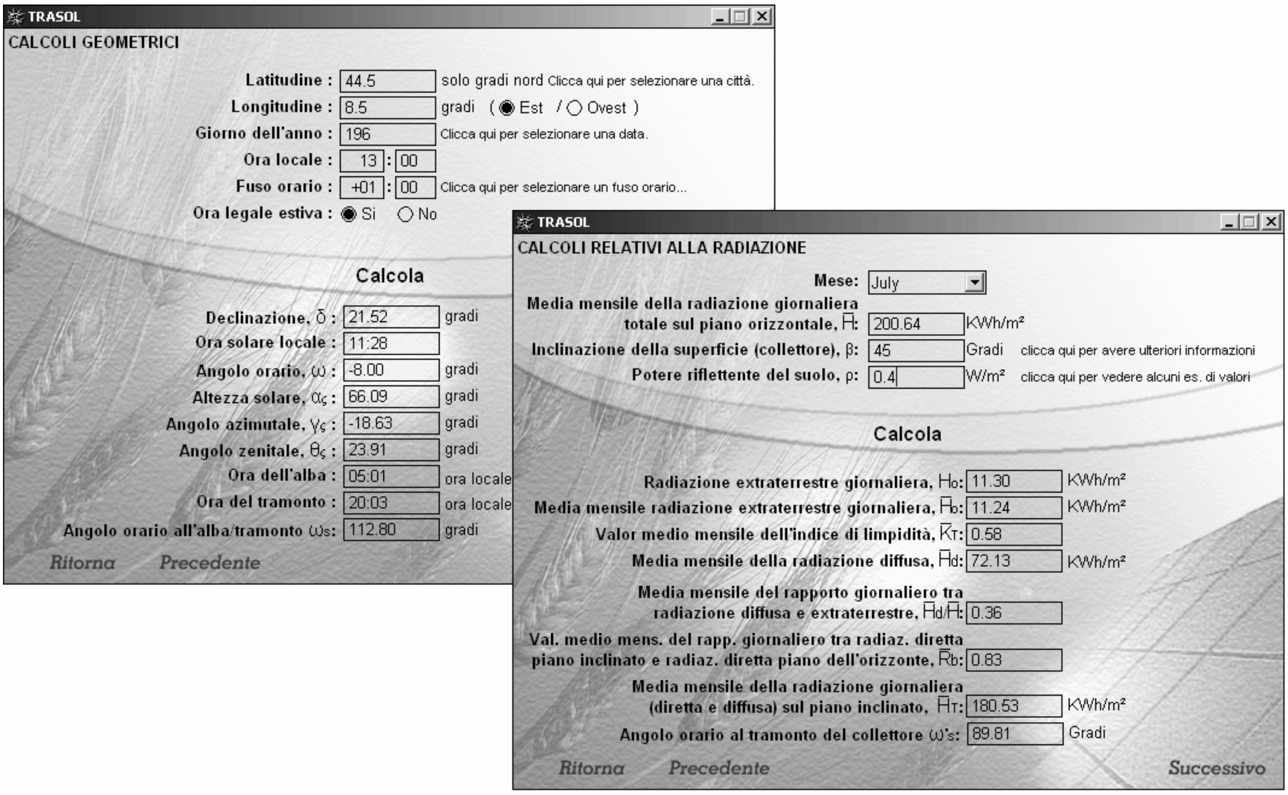


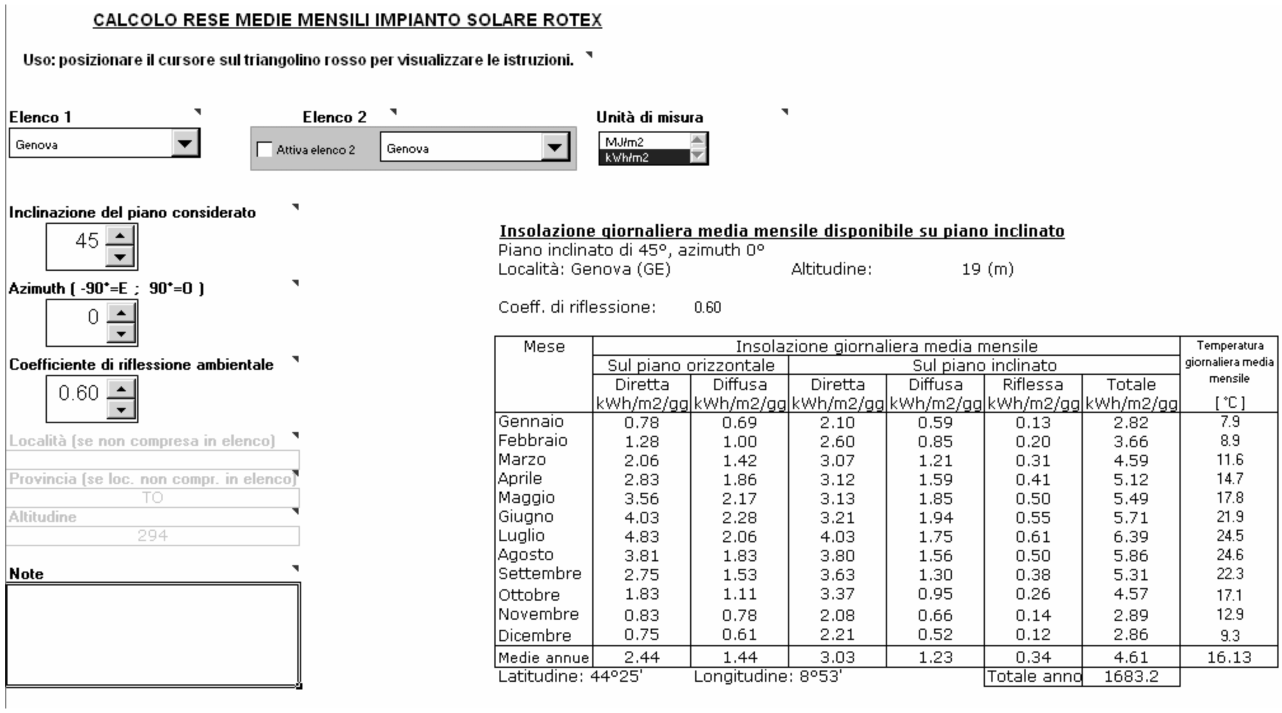
Figure 2 – Trasol data collection

Other tools - For the comparison also a freeware tool taken by Punti Energia S.c.a.r.l.., the Central Co-ordination Unit of a non-profit Association founded in 1996 by the Lombardy Region and its Provinces and supported by the EU SAVE programme. This Network of Local Agencies promotes the rational use of energy and the exploitation of renewable energy within a framework of sustainable development in the Lombardy Region [3].

FEA srl PROGRAMMA PER IL DIMENSIONAMENTO PRELIMINARE DEGLI IMPIANTI SOLARI PER PRODUZ. DI ACQUA CALDA SANITARIA			
In quale regione devo installare l'impianto?	LIGURIA	Inclinazione collettori sull'orizzontale (°)	45
In quale periodo dell'anno intendo sfruttare prevalentemente l'impianto?	TUTTO L'ANNO	Temperatura utilizzo acqua sanitaria (°C)	50
Che tipo di utilizzo farò dell'acqua calda?	GENERICO	Produzione di acqua calda richiesta all'impianto solare (lt/giorno)	200
Quante persone utilizzeranno mediamente l'impianto?	4	Energia captata dai collettori a LUGLIO (kcal/mq/giorno)	5,144
In quale mese voglio il 100% dell'acqua calda dall'impianto solare?	LUGLIO	Energia richiesta all'impianto (kcal/giorno)	8,360
A quale temperatura iniziale si trova l'acqua? (°C)	12	Numero di collettori ELIOINOX da installare	1

Figure 3 – Elioinox solar calculation tool (FEA srl)

In addition two data sheet available in the WebPages of Italian traders in the solar energy market were considered [4,5].



Mese	Insolazione giornaliera media mensile						Temperatura giornaliera media mensile
	Sul piano orizzontale		Sul piano inclinato				
	Diretta kWh/m2/gg	Diffusa kWh/m2/gg	Diretta kWh/m2/gg	Diffusa kWh/m2/gg	Riflessa kWh/m2/gg	Totale kWh/m2/gg	[°C]
Gennaio	0.78	0.69	2.10	0.59	0.13	2.82	7.9
Febbraio	1.28	1.00	2.60	0.85	0.20	3.66	8.9
Marzo	2.06	1.42	3.07	1.21	0.31	4.59	11.6
Aprile	2.83	1.86	3.12	1.59	0.41	5.12	14.7
Maggio	3.56	2.17	3.13	1.85	0.50	5.49	17.8
Giugno	4.03	2.28	3.21	1.94	0.55	5.71	21.9
Luglio	4.83	2.06	4.03	1.75	0.61	6.39	24.5
Agosto	3.81	1.83	3.80	1.56	0.50	5.86	24.6
Settembre	2.75	1.53	3.63	1.30	0.38	5.31	22.3
Ottobre	1.83	1.11	3.37	0.95	0.26	4.57	17.1
Novembre	0.83	0.78	2.08	0.66	0.14	2.89	12.9
Dicembre	0.75	0.61	2.21	0.52	0.12	2.86	9.3
Medie annue	2.44	1.44	3.03	1.23	0.34	4.61	16.13
Latitudine: 44°25'	Longitudine: 8°53'				Totale anno	1683.2	

Figure 4 – Heliant solar calculations tool

2. Calculations for solar heating systems dimensioning

A number of environmental variables have to be defined, starting from the weather data. The values to compute are:

- Monthly average daily irradiance in the plane of the solar collector, used to calculate collector efficiency and solar energy collected;
- Sky temperature, used to calculate energy collected by unglazed collectors and radiative losses of swimming pools to the environment;
- Cold water temperature, used to determine the heating load the system has to meet;
- Collectors positioning, depending on the flat or sloped surface (or roof) where they must be located;
- Loads (service hot water amount and its temperature)

The performance of service hot water systems with storage is estimated with the f-Chart method. The purpose of the method is to calculate f , the fraction of the hot water load that is provided by the solar heating system (solar fraction). Once f is calculated, the amount of renewable energy that displaces conventional energy for water heating can be determined.

The method enables the calculation of the monthly amount of energy delivered by hot water systems with storage, given monthly values of incident solar radiation, ambient temperature and loads.

The data must be accurate as dimensioning errors can be made, influencing costs and reducing the energy and money saving potentials.

Two approaches to the solar energy heating system design have been analysed on the basis of the considered tools, to evaluate their capabilities and the results concordance.

In the first case the available collectors surface is defined on the basis of the widest available space for the positioning. In this case the heating energy production can be calculated together with the corresponding needs covering of each month.

In the second situation the domestic hot water needs are the starting point and the calculations aim at determining the collectors surface.

The analysis was performed by comparing the efficiency of various collectors, as there are several types of solar collectors to heat liquids. Selection of a solar collector type will depend on the temperature of the application being considered and the intended season of use (or climate). The most common solar collector types are: unglazed liquid flat-plate collectors; glazed liquid flat-plate collectors; and evacuated tube solar collectors.

Unglazed liquid flat-plate collectors (made of a black polymer) do not have a selective coating neither a frame nor insulation at the back; therefore they are low-cost and usually simply laid on a roof or on a wooden support. Their thermal losses to the environment increase rapidly with water temperature particularly in windy locations. Therefore they are commonly used for applications requiring energy delivery at low temperatures (pool heating, process heating applications, etc.)

Glazed liquid flat-plate collectors present a flat-plate absorber (with often a selective coating) fixed in a frame between a single or double layer of glass and an insulation panel at the back. They are commonly used in moderate temperature applications (e.g. domestic hot water, space heating, year-round indoor pools and process heating applications).

Evacuated tube solar collectors are characterised by an absorber with a selective coating enclosed in a sealed glass vacuum tube. Their thermal losses to the environment are extremely low. A sealed heat-pipe on each tube extracts heat from the absorber (liquid is vaporised while touching the heated absorber, heat is recovered at the top of the tube by the condensing vapour, and condensate returns by gravity to the absorber). Evacuated collectors are good for applications requiring energy delivery from moderate to high temperatures (domestic hot water, space heating and process heating applications typically at 60°C to 80°C depending on outside temperature), particularly in cold climates.

2.1 Application example

In the first application the reference surface was 10 m^2. For each collector configuration the obtained thermal energy is calculated by means of Retscreen and Puntoenergia tools that allow this kind of analysis. Trasol tool cannot be utilised for a complete comparison as collectors data must fall in a defined field and the tool doesn't work otherwise. Maybe the field is limited, as the software was created in 1996 and nowadays different data intervals are available.

Fixed collectors surface

Retscreen and Puntoenergia allow dimensioning the thermal needs starting from a fixes area of the collectors. Analysing the results, some problems can be highlighted, as Puntoenergia over-estimates the energy production. This could be addicted to the gross area that Retscreen considers in the calculations, while in the Puntoenergia tool the useful surface is required (figure 5).

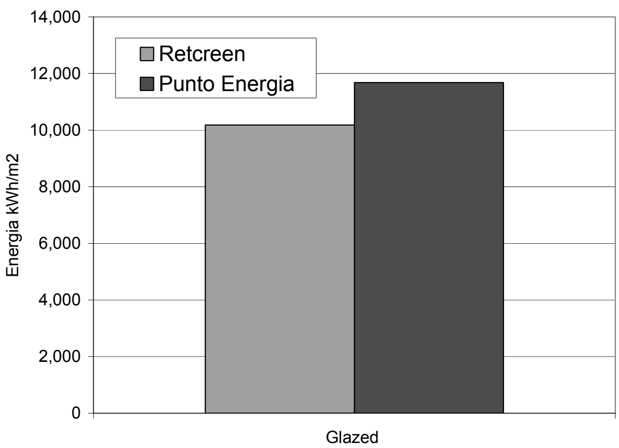


Figure 5 - – Comparison between energy production results

Fixed energy requirements

The available solar radiation amount is calculated by Heliant and Retscreen software, as the other tools don't leave the choice of the position. Trasol make calculations only for collectors positioned in the South direction. Puntoenergia requires data already referred to the specific position. In figure 6 the results show that the two tools have not problems to describe the real situation.

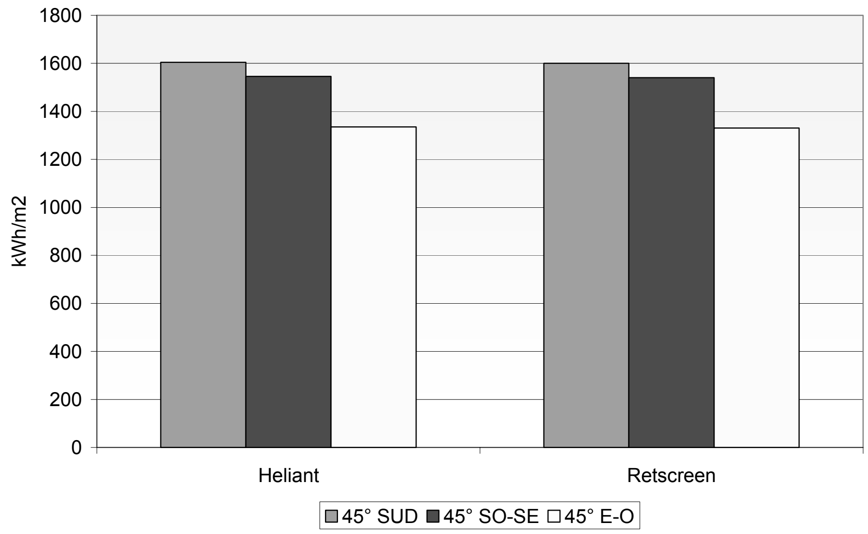


Figure 6 – Available solar radiation

With these tools the analysis of the energy performance depending on the inclination can be performed (all the other conditions fixed). The results can support the designer to highlight the most valuable position and which is the performance reduction of the other inclinations (figure 7 for glazed panels, by Retscreen software).

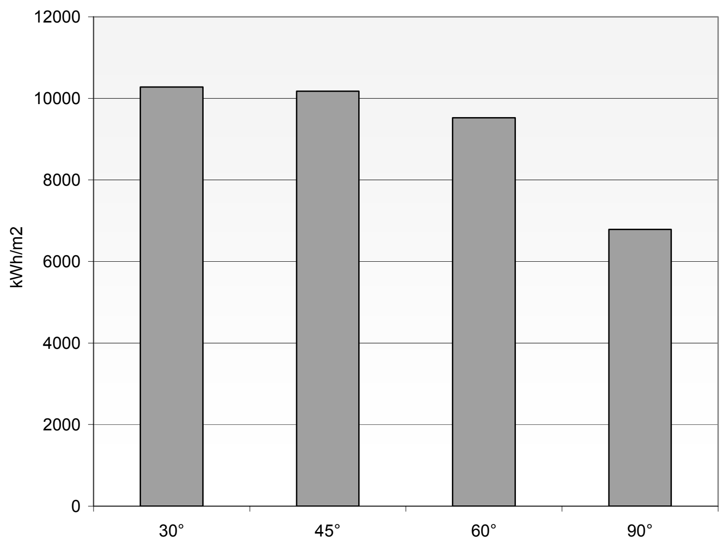


Figure 7 - Energy utilisation as function of the collector inclination

The analysis can give obviously information about the advantages to utilise solar collectors in the various parts of Italy: all the tools can perform this analysis, even if some of them have a wide database already available (Retscreen) and the others require a more complex elaboration and data input.
The loads covering for each month is shown by all the tools except Retscreen.
The costs-benefits optimisation, performed on the basis of the hot water utilisation (for domestic use or also for heating system integration) can be performed quite with all the software, even if Retscreen remains the best and the most complicated one, as requires a wider number of input data, but also a better definition of the results, not strictly connected to a particular collector manufacturer.

3 Observations and conclusions

With all the considered tools some useful information can be obtained, i.e. the solar radiation utilisation as function of the inclination and orientation of the collectors, as often the roof inclination and orientation put limits to the best collector performance.

3.1 Weather data availability

Input weather data must be considered carefully. Retscreen works with its own database, even if more information can be obtained by connecting with the NASA website.

The user may obtain weather data from ground monitoring stations and/or from NASA's satellite data. Ground monitoring stations data is obtained by making a selection for a specific location from the online weather database dialogue box. NASA's satellite data is obtained via a link to NASA's Website from the dialogue box. NASA and CETC - Varennes are co-operating to facilitate the use of NASA's global satellite solar data with RETScreen and to develop a new global weather database (see Surface meteorology and Solar Energy Data Set for the tool). This collaboration provides RETScreen users access (free-of-charge) to satellite data (e.g. the amount of solar energy striking the surface of the earth, global temperatures and wind speeds), simply by clicking on links in either the RETScreen software or the NASA Website. These data had previously only been available from a limited number of ground monitoring stations and are critical for assessing the amount of energy a project is expected to produce. The use of these data results in substantial cost savings for users and increased market opportunities for industry while allowing governments and industry to evaluate regional energy resource potential.

Climatic data by Retscreen database, NASA and UNI 10349 (National Standard about national monthly climatic data, used by the other tools) give different results. The corresponding mean monthly temperatures don't differ significantly each other.

A local investigation developed in Genoa, Italy, regarding the solar radiation data, gave the monthly mean values averaged in the last 10 years. The comparison among the values is shown in figure 8.The available solar radiation differs highly in the summer months and could produce significant differences in the solar collector dimensioning.

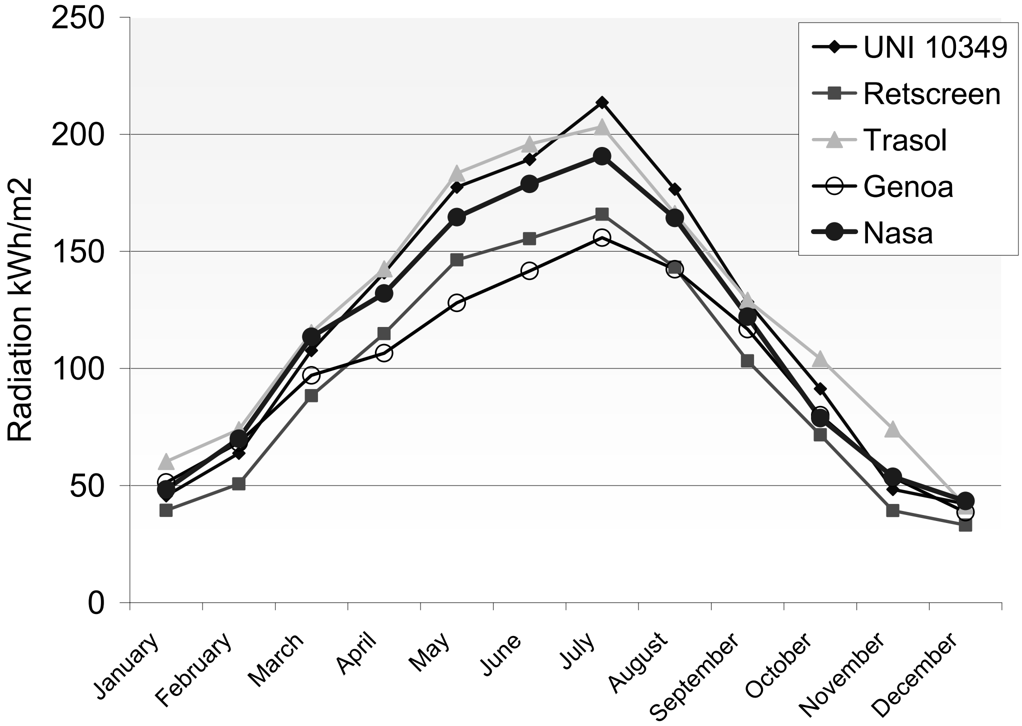


Figure 8 - Climatic data comparison

3.2 Sensitivity and risk analysis

As part of the RETScreen Clean Energy Project Analysis Software, a Sensitivity and Risk Analysis worksheet is provided to help the user estimate the sensitivity of important financial indicators in relation to key technical and financial parameters. This standard sensitivity and risk analysis worksheet provides information on the relationship between the key parameters and the important financial indicators, showing the parameters which have the greatest impact on the financial indicators. The Risk Analysis section performs a Monte Carlo simulation. The impact of each input parameter on a financial indicator is obtained by applying a standardised multiple linear regression on the financial indicator.

The risk analysis allows the user to assess if the variability of the financial indicator is acceptable, or not, by looking at the distribution of the possible outcomes. An unacceptable variability will be an indication of a need to put more effort into reducing the uncertainty associated with the input parameters that were identified as having the greatest impact on the financial indicator.

The GreenHouse Gas (GHG) mitigation potential of the proposed project is also considered

3.3 Better performances

Even if the examined tools give all useful information, an accurate design should be performed by means of more complete software like Retscreen, which is a download free and therefore doesn't imply commercial indications and promotions. The PuntoEnergia excel sheet seems good enough but it must be modified to take into account different location data as it don't offer a wide database. It seems not more available in the web site [3]. Calculations can be controlled easily in both the data-sheets (Retscreen and Puntoenergia).

References

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