Identification of Standard System Configurations

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Identification of most promising markets and promotion of standardised system configurations for the market entry of small scale combined solar heating & cooling applications
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1 Introduction

The present report deals with the methodological approach for the definition of standard Solar Combi+ configurations. In WP3 energetic, economical and ecological performance of a broad range of system configurations were evaluated for different applications, different climatic situations and different chillers (see deliverables D3.2 and D3.3).

The aim of the WP4 - Task 1 is twofold: on the one hand to define the best performing configurations, on the other hand to identify mostly technology independent solutions. In such a way, a reduced number of standard system configurations has been defined.

The goal is to promote a reduced number of "standard system configurations" which are independent of specific products and work best under different circumstances, similarly to the standard systems for DHW. The simulations performed are based on simplified models of the buildings, the chillers and the other mentioned components. Therefore they provide approximate estimations of the real behaviour of the system, meant to give a view of the facts and sizes.

Targets of the outcome of the present task could be on the one hand engineers, HVAC planners and installers looking for an easy way for sizing SC+ systems, on the other hand engineers and HVAC planners interested in a deeper comprehension of SC+ technology. This is of utmost importance as recently demonstrated from the IEA-SHC Task38 program [1]: the design and sizing of solar cooling installations (big and small sizes were analyzed) do not follow shared, well established rules, leading to a wide variety of systems' performance.

2 Methodological Approach

The results of simulations run have been collected from all partners involved in WP3 and organized in a suitable way, by means of an Excel Macro implemented by EURAC.

A challenge of the present methodological approach is to give a synthetic (as much as possible) representation of the standardized configurations and to give a complete (as much as possible) information about all the investigated cases. In WP3 a wide number of simulations were carried out. Every investigated virtual case was defined by a specific set of parameters:

- chiller manufacturer
- location (climatic zone)
- application (office, highly insulated residential building, poorly insulated residential building)
- distribution system (fan coil, chilled ceiling)
- solar collector type (flat plate, evacuated tube)
- heat rejection system (dry air cooler, wet cooling tower, hybrid system)
- collector area
- storage volume.

"Configuration" is a combination of all the previous parameters. Every configuration is identified by a conventional code, reporting the values of each parameter. For instance, the following code identifies a SolarCombi+ plant based on the chiller of the manufacturer XXX with dry air cooler (DC), located in Toulouse (TOU), in a residential building with annual heating demand of 100 kWh/m^2/year in Zurich (R100), with heating and cooling distribution system based on chilled ceilings (CC) and evacuated tube collectors (ET):

XXX-TOU-CC-ET-HC-R100

The complete set of possible variables is:

- Locations: Toulouse (TOU), Naples (NAP), Strasbourg (STR)
- Distribution system: chilled ceilings (CC), fan coils (FC)
- Solar collectors type: evacuated tubes (ET), flat plates (FP)
- Heat rejection system type: wet cooling towers (WCT), dry cooler (DC), hybrid cooler (HC, dry cooler + sprinkled water).
- Application: residential low energy consumption (R60), residential high energy consumption (R100), office (OFF).

The buildings definitions are taken from the work of the IEA Task 32 [2] with regard to the residential buildings and of the IEA Task 38 [3] with regard to the office building (see deliverables D3.2 "Report on the methodology of the virtual case study" and D3.3 "General results of the virtual case study"). In particular, within Task32, residential buildings were simulated in Zurich leading to yearly hetaing loads of 100 and 60 kWh/m^2/year (from which the definition R60 and R100 originate). The buildings, with the same thermal characteristics, were in this study simulated for the three locations considered and the heating, cooling and DHW loads re-computed.

Table 1 - Building demands simulated [kWh/m^2/year]

	Office		Typical House			Low consumption House		
kWh/m^2/year	Heating	Cooling	Heating	Cooling	DHW	Heating	Cooling	DHW
Strasbourg	69.74	34.19	-	-	-	-	-	-
Toulouse	34.13	50.28	46.05	5.69	12.66	24.58	6.12	12.66
Naples	9.22	80.75	21.11	18.45	11.43	9.37	17.45	11.43

Additionally, two numbers specify the collectors' area (square meter per cooling reference power unit, see D3.2) and the storage volume (cubic meters per collectors' aperture area).

As the objective of the present task is to select standard system configurations, a way for comparing energetic and environmental performance of different configurations was implemented. All the parameters defining the configurations were classified in three categories:

- "fixed" parameters
- "semi-fixed" parameters
- "free" parameters.

The idea is to distinguish the options that are substantially imposed when a SolarCombi+ plant is designed (*fixed parameters*), the items that - depending on every specific case - could be imposed or not (*semi-fixed parameters*), and the variable that planners and designers can arbitrarily determine (*free parameters*). In Figure 1 the classification is shown.

Location, application and chiller are considered fixed parameters. When a SolarCombi+ system is designed, the location of the plant is typically pre-determined: it is not a choice of the planner. Similarly, the building typology where the SolarCombi+ plant will be located is not an option of the

SC+ system design, but it is an independent variable. This is true both in the case of a new building and an existing building. The specific chiller would not actually be a fixed parameter, because every planner can freely choose a specific manufacturer; nevertheless, the comparison of the chillers performance is not an objective of the SolarCombi+ project. So the use of a specific chiller is here considered a pre-selection and the chiller is included between the fixed parameters. The heating/cooling distribution systems are considered *semi-fixed parameters*. That is because, when the building and its plants are already pre-existing to the planned SC+ system, the distribution system usually cannot be modified. On the contrary, if the building is under construction or it has to be planned, the choice of the distribution system could be an option. The choice of solar collector type (evacuated tube or flat plate collectors) is almost always an option of the designer; nevertheless, sometimes some architectural constraints and the location (see deliverable D4.7) could limit or deny the use of some types of solar collectors (for instance, evacuated tube collectors are often not suitable for an architectural full integration in the roof, or heat pipe solar collectors cannot be installed in an horizontal plane). For this reason, they are included among the *semi-fixed parameters*. The heat rejection system is typically selected by the plant designer, depending on the chiller which is installed. Nevertheless, in some urban contexts some constraints could limit the use of a specific heat rejection system (it is not always possible, for instance, the installation of wet cooling towers in residential buildings, due to strict Legionella prevention laws). So the selection of the heat rejection system is again considered *semi-fixed*.

Collectors' area is classified as a *free parameter*. It is assumed that in the considered building the necessary area is available for solar collector installations. Storage volume is classified as a *free parameter* as well. It is assumed that in the considered building enough place is available.

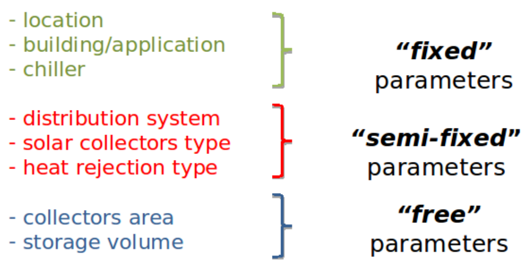

Figure 1 - Classification of the configuration parameters

In order to compare all investigated cases and extrapolate the standard configurations, two methods were used:

- optimization function to select suitable configurations
- sensitivity analysis (also through graphical representation) of chillers' performance.

2.1 Best Configurations

The first step of the analysis was the choice of suitable configurations through optimization functions that account for energetic and environmental performance of the system. The following two parameters were taken into consideration:

- total solar fraction
- total electrical efficiency
- yearly relative primary energy saved

The total solar fraction accounts for the percentage of the total DHW, heating and cooling needs covered through the solar energy utilization. The total electric efficiency is the average ratio of the total thermal loads (for heating, cooling and domestic hot water) and the electrical consumption of the system (comprising chiller and solar circuits pumps, heat rejection system fans, etc). The primary energy saved is an environmental figure comparing energy needs of the conventional and the renewable solution, in terms of primary energy employed, during a year period. In the study presented, a relative figure is used:

$$PES_{rel} = \frac{PE_{trad} - PE_{SC+}}{PE_{trad}}$$

Depending on the location of the solar combi+ system investigated, and therefore on the solar energy availability, different optimization functions were identified. For Naples applications, it requested that more than 60% of the load are covered through solar energy, the electrical COP is higher than 10, and the primary energy used in the solar combi+ system is lower than the one employed in the traditional system (PES_{rel}>0):

$$Suitable\ solutions = \{solutions \mid SF_{tot} > 60\%, COP_{el} > 10, PES_{rel} > 0\}$$

For Toulouse and Strasbourg applications, it is accepted a lower total solar fraction (SF_{tot}>40) as a consequence of the lower available solar irradiation and the irradiation and the reduced correlation between supply and demand. On the other hand, it requires a higher electrical COP, since the heat rejection system electrical consumption is lower, as a consequence of lower summer temperatures:

$$Suitable\ solutions = \{solutions \mid SF_{tot} > 40\%, COP_{el} > 15, PES_{rel} > 0\}$$

Once suitable configurations are assessed, the following step was the selection of the "best" configurations with regard to the three figures mentioned earlier. For every combination of *fixed parameters* (location,

application and chiller) three best configurations can, in general, be identified:

- configuration with the highest total solar fraction (the energetic "best" case)
- configuration with the highest total solar fraction (the electrical consumption "best" case)
- configuration with the highest primary energy saved (the environmental "best" case)

In order to give a synthetic representation of the optimal configurations, the table shown in Figure 2 is proposed. Such a table allows evaluating which parameters' combination gives the maximum of the considered selection parameter.

location	building	chiller

	WC		DC		HC	
FC	ET	FP	ET	FP	ET	FP
CC	ET	FP	ET	FP	ET	FP

Figure 2 - Table reporting the optimal configurations

In such a table, the *fixed parameters* are indicated in the first row (see Figure 3). A table for every possible combination of *fixed parameters* has to be drawn.

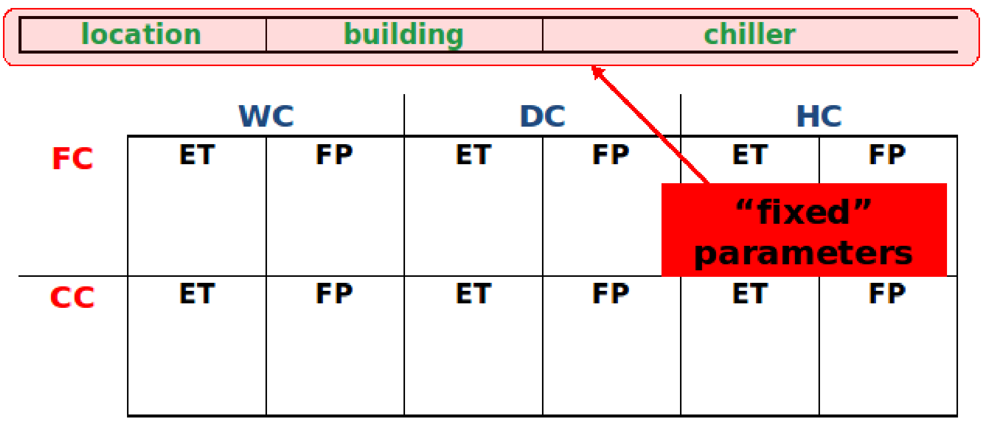

Figure 3 - Table reporting the optimal configuration: *the fixed parameters*

Figure 4 shows the location of the *semi-fixed parameters* within the table. The three heat rejection systems are reported in the columns, the two distribution systems are reported in the rows: for each combination of that two parameters, two solar collector types are possible (evacuated tubes and flat plate).

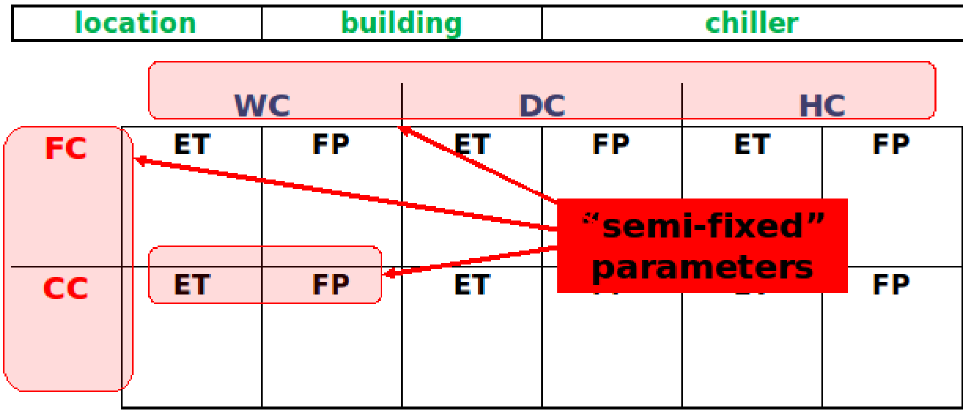

Figure 4 - Table reporting the optimal configuration: *the semi-fixed parameters*

The values of the *free parameters* (collector area and storage volume) are placed within the twelve cells corresponding to all the possible combinations of the *semi-fixed parameters* (see Figure 5). Every cell reports the values of the *free parameters* corresponding to the maximum of the considered selection parameter. Among all these values, the absolute maximum (“best” configuration) is identified.

location	building	chiller

	WC		DC		HC	
	ET	FP	ET	FP	ET	FP
FC	_ m^2/kW _ l/m^2	_ m^2/kW _ l/m^2	_ m^2/kW _ l/m^2	_ m^2/kW _ l/m^2	_ m^2/kW _ l/m^2	_ m^2/kW _ l/m^2
	ET	FP	ET	FP	ET	FP
CC	_ m^2/kW _ l/m^2	_ m^2/kW _ l/m^2	_ m^2/kW _ l/m^2	_ m^2/kW _ l/m^2	_ m^2/kW _ l/m^2	_ m^2/kW _ l/m^2

Figure 5 - Table reporting the optimal configuration: *the free parameters*

Since the purpose of the project is not to compare technologies and manufacturers, on the contrary it is meant to provide information about solar heating and cooling applications, the analysis was in the end carried out and presented, mixing data from the five chillers considered. A codified reference to the chillers (A to E) is however maintained, since the variability of the results as a function of the machine considered would hide their dependency on the technical solutions adopted.

2.2 Standard Configurations

The final goal of the project is the identification of a reduced number of "standard system configurations", which can be promoted with reasonably good results in typical/average cases, and which are mostly technology independent. The idea is to move from the best configurations (found out chiller by chiller) to good configurations (not dependent on the specific chillers). This approach was adopted since the best energetic-environmental solution might not be the most effective from the point of view of marketing-cost aspects.

A sensitivity analysis was carried out for this purpose, showing the effect of varying technologies employed and sizing of the components on the solar combi+ system performance for different applications and locations. An extended set of performance figures was selected for this exercise; besides the ones already mentioned, two other were considered:

- Cooling Solar Fraction
- Gross Solar Yield

The cooling solar fraction accounts for the percentage of cooling load covered through the solar energy utilization. The gross solar yield measures the solar energy yearly harvested by the system per unit of collectors' area.

Due to the wide variability of the results detected in D3.3, it was decided to take into account only the three best performing configurations for each set of simulated fixed/semi fixed parameters. Nevertheless, the range of results is still quite large (see Figure 6, Figure 7) as a consequence of the different conditions, technologies and chillers adopted; therefore each set of fixed/semi fixed parameters was discussed separately.

It has to be stated here that not all chillers' manufacturers wanted to simulated the whole set of configurations, since they decided not sell such a configuration, knowing from the beginning the modest performance of their machine for given configuration, or because they do not market that technology. Table 2 shows all the simulated cases for each considered chiller. As it can be seen, only one manufacturer (chiller C) wanted to take

into consideration the dry cooler for this analysis on a voluntary basis, due to ambient conditions that complicate the heat rejecting in the two southern locations investigated; therefore, this solution is not discussed in the following. Chiller D was not considered in combination with fan coils and chiller E do not sell solar combi+ systems with evacuated tubes. It is also remembered that only fan coils are considered as a distribution system suitable for office applications.

Two configurations were taken as the reference configurations for the discussion in Chapter 3, i.e. CC-FP-WCT for residential and FC-FP-WCT for office buildings.

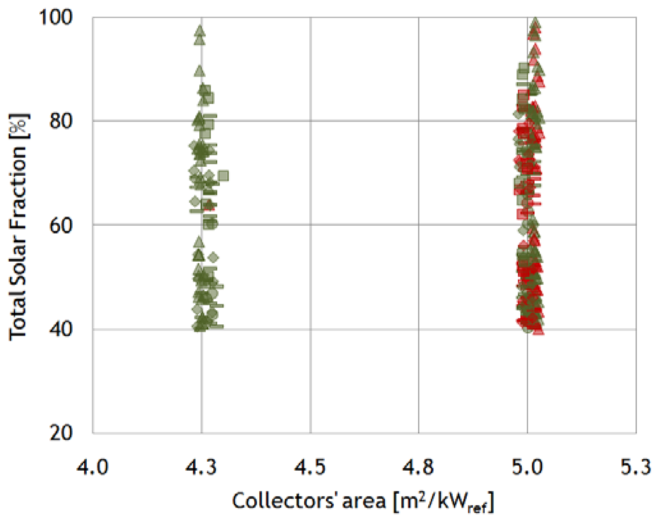

Figure 6 - Total Solar Fraction for all the configurations selected

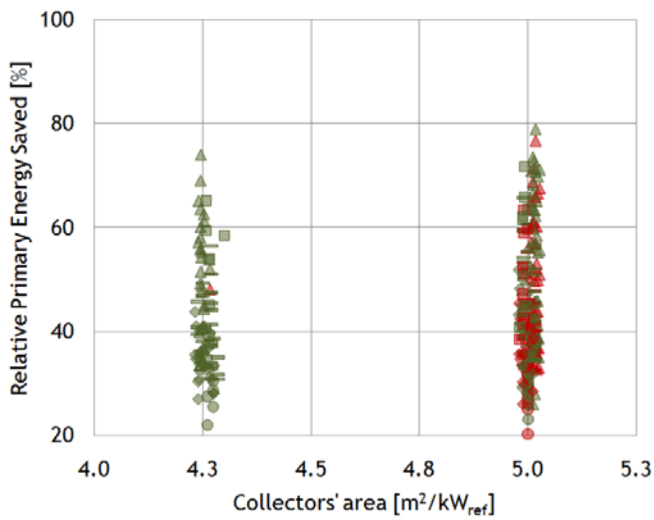

Figure 7 - Relative Primary Energy Saved for all the configurations selected

Table 2 - Simulated configurations for the chillers named from "A" to "E"

	WCT				HC				DC			
	ET		FP		ET		FP		ET		FP	
CC	A	X	A	X	A	X	A	X	A		A	
	B	X	B	X	B	X	B	X	B		B	
	C	X	C	X	C	X	C	X	C	X	C	X
	D	X	D	X	D	X	D	X	D		D	
	E		E	X	E		E	X	E		E	
	ET		FP		ET		FP		ET		FP	
FC	A	X	A	X	A	X	A	X	A		A	
	B	X	B	X	B	X	B	X	B		B	
	C	X	C	X	C	X	C	X	C	X	C	X
	D		D		D		D		D		D	
	E		E	X	E		E	X	E		E	

3 Results

In this chapter the results of the analysis described are reported. The best configuration are addressed first; results from the selection of best configurations are reported in Annex I. Then the standard configurations are discussed for each set of simulated parameters. The values discussed are reported in graphs (see Annex II) and in an overall table (see Annex III).

Results are reported as a function of specific collectors' area and storage tank volume: the first figure, reported in m^2/kW_{ref}, relates the collectors' area to the reference chiller power for given heat rejection technology and distribution system used (see D3.3 "General results of virtual case studies" for more information). The second, reported in l/m2, relates the storage volume size to the collectors' area. In this way, components performance, cooling and heating loads are sized in an integrated process.

3.1 Best Configurations

The first outcome that can easily be noted is that all the best configurations are related to the largest collectors' area (5 m^2/kW_{ref}) and storage volume (75 l/m^2) simulated. Even though it might seem trivial, it shows values that differ to quite some extent from the ones usually encountered when pure solar cooling systems are considered. Collectors' areas for such plants range in fact between 3.5 and 4.5 m^2/kW_{ref} [4]. This difference is due to the operation of solar combi+ operation also during winters: in fact, even though smaller areas allow to cover rated heat fluxes at the generator of the sorption chillers to cover most of the cooling load at summer time, in winters, larger areas are required if heating and DHW preparation are needed, due to the significantly reduced radiation available; as can be seen in deliverable D4.7 ("Description and Visual Representation of Most Promising Markets"), about the same energy is delivered during 4 months in summer than in the remaining 8 months. A few simulations run, show that an inversion of the trend is obtained at around 7 m^2/kW_{ref}; such big areas were not taken into account in this study, since they hardly could find place on the roof of residential buildings, being far beyond feasibility.

Looking at the performance figures used for the selection of the best configurations, total solar fraction and relative primary energy saved are analyzed first. From the tables in Annex I, it can be seen that the best results are obtained with regard to Naples installations; Toulouse and Strasbourg systems follow. Without going into many details –since this is done for Standard Configurations discussion- the residential applications in Naples feature values of total solar fraction that vary between 67% and 87% for the low consumption building (R60) and 60% - 78% for the average consumption building (R100). Toulouse applications range between 46% and

55% in the case of low consumption building and between 40% and 46% for the average consumption building. Such a large difference, is due on the one side to the higher available radiation in Naples, on the other to the better temporal match between solar energy supplied and heat demand: in Toulouse winter loads are by far prevailing on the cooling ones. The differences between the two houses' types is also due to heating loads since cooling loads are about the same for given location (see Table 1).

The same trends are detected when primary energy saved is considered. Naples values vary between 30%-70% and 25%-60% for the R60 and the R100 building. In Toulouse, values vary between 23%-45% and 25%-40% for the R60 and the R100 building respectively. In this case a much larger variation of the performance is noticed mainly in Naples. This behavior is largely related to the heat rejection operation: in Naples, due to high summer temperatures and latent loads (the city is placed on the see), the heat rejection system is used at high regimes for large periods. The electrical loads related to this component can grow to be a relevant percentage of the saved energy, unless a well designed strategy is adopted for its control. Some of the chillers' manufacturers involved in the project already adopted heat rejection control strategies for all the technologies employed (dry cooler, hybrid cooler, wet cooling tower) at the time of the simulations, leading to better results. The control design is in progress for the other companies.

This aspect can be seen also looking at the total electrical efficiency. With regard to this performance parameter, higher values are obtained in Toulouse: between 12 and 24 for the low consumption building (R60), 12 and 30 for the average consumption building (R100) in Naples, between 24 and 50 for the R60 building and 30 and 55 for the R100 in Toulouse. As can be seen higher values are also obtained with respect to the R100 buildings, due to the higher ratio between heating and cooling loads. The total electrical efficiency becomes an issue, when fan coils are considered as the distribution system: in this case lower temperatures have to be delivered (chillers inlet temperatures are 12°C for fan coils and 18°C for chilled ceilings); therefore, higher heat fluxes are conveyed to the heat rejection system. That leads to only few cases which total electrical efficiency passes the selection through the optimization functions.

This issue becomes even more severe, if office applications are considered (see Table 5, Table 8 and Table 9). Total electrical efficiencies vary from about 11 in Naples and 15 in Toulouse (i.e. the lower limits of the optimization functions) to around 25 in Strasbourg. Moreover, only the performance of chiller "A" were selected (just one case was taken for chiller "E" in Strasbourg).

For chiller "A" in office applications, the relative PES ranges between 63% and 78% in Naples, 55% and 71% in Toulouse and 26% and 40% in Strasbourg.

The total solar fraction approaches the unity in Naples, varies between 80% and 90% in Toulouse and ranges between 50% and 60% in Strasbourg. If compared to residential building applications, due to negligible DHW loads, the ratio between winter and summer loads increases. Therefore, the total solar fraction is significantly higher, while the primary energy saved is fully comparable. The discussion above shows that in office applications a higher percentage of the loads is covered, to the price of an higher electrical energy consumption (i.e. heating and DHW preparation require very low electrical energy, mostly related to the recirculation pumps, no heat rejection system is needed).

3.2 Standard Configurations

In this section, the results of the sensitivity analysis carried out is presented, to show the effect of varying technologies employed and sizing of the components on the system operation. In this way standard configurations, with performance comparable to the best ones, were individuated. The performance figures used for the discussion were:

- total solar fraction
- cooling solar fraction
- relative primary energy saved
- total electrical efficiency
- gross solar yield

The values discussed are reported in graphs (see Annex II) and in an overall table (see Anne III). The graphs discussed in the following paragraphs are setup like in Figure 8: on the y-axis the performance figure is reported versus the specific collectors' area.

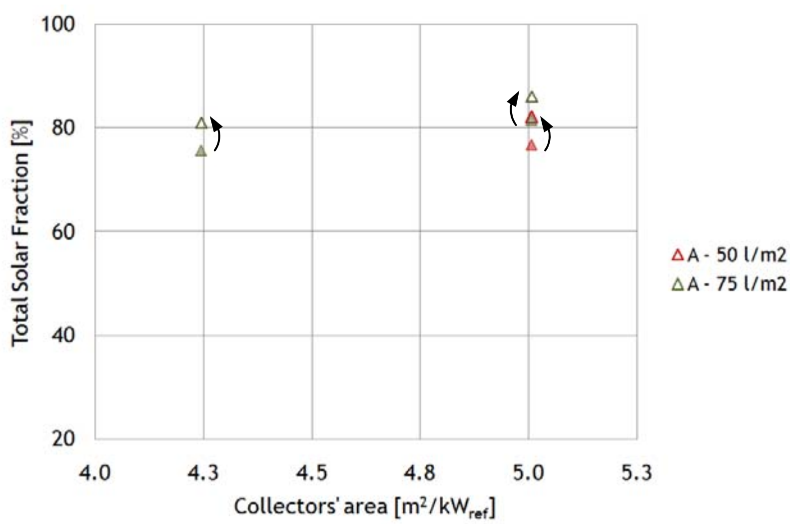

Figure 8 - Example of comparison chart shown in Annex II

Storage tank specific volume is stated through red (50 l/m^2) and green (75 l/m^2) colors. A different symbol is used for each chiller: chiller A = triangle, B = circle, C = line, D = diamond, E = square. Finally, since the graphs serve to comparing technologies, a reference configuration -i.e CC-FP-WCT for residential and FC-FP-WCT for office buildings- is always shown with a solid symbol, while "compared" technologies are specified with a void one. Therefore, in Figure 8, the solid and the void green triangles at 4.3 m^2/kW_{ref} have to be considered if comparison between technologies is sought. The effect of sizing is illustrated through x-axis and colors.

3.2.1 Residential Buildings

Solar combi+ systems performance in residential buildings are investigated first. Figure 9 and Figure 10 show total solar fraction figures for Naples and Toulouse respectively. Again, the performance for all chillers considered range between around 60% and 85% in Naples and between 40% and 60% in Toulouse.

Analyzing the effect of the sizing procedure, it is shown (see blue arrows) that the result of reducing the storage tank volume of 33% (from 75 l/m^2 to 50 l/m^2) is a slight reduction of total solar fraction in between 3% and 5%. The effect of additionally reducing the collectors area (14% from 5m^2/kW_{ref} to 4.3m^2/kW_{ref}) is an extra drop of about 4% of the performance. Therefore, from this point of view, a moderate decrease of the solar utilization efficacy is reached. On the other hand, a significant reduction of the investment costs might be obtained depending on the technologies adopted.

Figure 9a) and Figure 10a) display the effect of the solar collector type. The black arrows show the performance change for some considered configurations. In Naples the evacuated tubes allow increasing the performance of 5 to 7%, while in Toulouse the gain is higher, but still limited to around 10%. As can be seen in Figures b) and c), the consequence of changing heat rejection system or distribution system is more or less no variation in operation. The impact of the building efficiency (Figure d)) is a reduction of 7 to 10% when going from R60 to R100. In absolute terms the variations are about the same in Naples and in Toulouse, resulting in higher impacts (in relative terms) in Toulouse.

The same discussion holds if cooling solar fraction is considered. In general, these values are higher than the corresponding total solar fraction ones: in Naples, except for one point, they are in the range 70%-95%, whereas in Toulouse they vary from 50% to 95%. However, while in Naples the points are grouped together, a large variability of the values is detected in Toulouse: in the first case in fact high temperatures can be reached with both collectors technologies and all chillers can reach their rated conditions for most of the time. In the latter, on the contrary, being lower the

radiation levels, only machines working at lower temperatures can reach nominal operating conditions for large periods of time. This aspect is also proved by figures a): Figure 11a) shows a variability of about 5% between flat plate and evacuated tubes collectors; in Figure 12a) a rise of cooling solar fraction of about 10-15% is noticed when passing to evacuated tubes collectors, which guaranty higher temperature levels.

For the same reason, chilled ceilings give slightly better results than fan coils when only cooling is considered (see figures c)): while in winter the two distribution systems work at similar temperature levels, in summer, fan coils work at significantly lower temperatures with respect to chilled ceilings, leading to lower heat fluxes available at the evaporator of the chillers. This is clearly visible if cooling solar fraction is taken into account; the effect is mostly mitigated by winter operation if total solar fraction is contemplated. With respect to this figure, higher variations are encountered in Naples (5-7%) since higher latent loads are experienced.

Again, the effect of the heat rejection system (figures b)) and buildings' efficiency are not significant. The latter result is due to the fact that roughly the same cooling loads are assessed in the two constructions' categories.

If relative primary energy saved is regarded (Figure 13 and Figure 14), the effect of reducing the storage volume from 75 l/m^2 to 50 l/m^2 is a quite significant reduction of about 9-10%. The outcome of additionally reducing the collectors area is a drop of the values calculated of around 12-17%. Thus, in this case, the sizing of the components produces major consequences on the system performance; since the primary energy saved is linearly related to the "money spared" through the utilization of the system, the reduction of the investment costs has to be critically weighted with the increase of running costs.

Relative primary energy saved was assessed between 30% and 70% in Naples and between 20% and 50% in Toulouse. With regard to this figure, a much larger spread of data is obtained in Naples than in Toulouse, depending on the chiller considered. As already noticed in chapter 3.1, in fact, in Naples the heat rejection system is used for longer periods at higher rates, resulting in large electrical energy consumption in case of unwise heat rejection system use. Nevertheless, for given chiller and configuration, better performance is obtained in Naples: it might be argued therefore, that the ratio between solar energy harvested and electrical energy consumption for the operation of the solar combi+ plant is anyhow more favorable in Naples than in Toulouse.

Figure 13a) and Figure 14a) show a difference in relative primary energy saved of about 10% in Naples and 5% in Toulouse, depending on the

collectors technology used. This corresponds to total variations in a range of 15-30%.

Once again, the effect of the heat rejection technology employed, is slightly relevant. Deviations of about 2-3% are noticed both in Naples and in Toulouse (i.e. Hybrid cooler less efficient than the wet cooling tower). As already observed, fan coils utilization (figures c)) requires a higher heat rejection, producing larger electrical energy consumption; the effect is still very limited in Toulouse (apart for chiller B), while it might result in a quite large reduction of the system performance (5-10%) in Naples. The primary energy saved is lower for buildings with larger loads (R100,see Table 1). Cuts of about 3-7% from R60 to R100 are evaluated. In absolute terms the variations are about the same in Naples and in Toulouse, yet resulting in higher impacts in Toulouse.

The latter analysis holds also regarding the total electric efficiency (Figure 15 and Figure 16): higher summer electrical energy consumption brings to much lower data in Naples (i.e. range 10-25%) than in Toulouse (range 25-40%).

Finally, Figure 17 and Figure 18 show the results relative to the gross solar yield. This figure, accounting for the solar energy harvested per unit collectors' area, is reported to compare performance of solar combi+ system with a simple plant for the preparation of DHW, which generally allows for a yearly capture of 300-400 kWh/m^2/year depending on the location. The simulated configurations perform all better than the reported values; nonetheless, a strong dependence on the collectors area is evident: smaller areas work better since the ratio between the energy gathered and the loads is lower; the energy is therefore better used in the system and the return temperature to the collectors is lower. This produces lower thermal losses toward the environment. For the same reason much lower stagnation is encountered.

Once again, better absolute performance are evaluated in Naples (400-600 kWh/m^2/year) than in Toulouse (300-500 kWh/m^2/year), due to higher radiation and average ambient temperatures in southern countries. The effect of varying the collectors area between 4.3 to 5.0 m^2/kW$_{ref}$ is a reduction of gross solar yield of 40-50 kWh/m^2/year; the outcome of using smaller storage tanks is more limited (i.e. around 10 kWh/m^2/year). This reduction can be recovered by using evacuated tubes rather than flat plate collectors (figures a)).

With regard to this figure, better working conditions are obtained with hybrid cooler, fan coils and R100 house, since in all those cases a lower ratio between solar gain and loads is encountered.

3.2.2 Office Buildings

As can be seen in Table 1, whereas the heating loads of the office applications are completely comparable with those of the residential buildings, the cooling loads are much higher: values ranging from 34 to 81 kWh/m^2/year are used for the simulations. Therefore, the operation in cooling conditions overtakes the performance of the solar combi+ system.

The massive cooling loads, together with the use of fan coils as distribution system, lead to very high electrical energy consumption, resulting in very low total electric efficiency values: in Naples and Toulouse only chiller "A" performance exceed the lower limits of 10 and 15 respectively. In Strasbourg, also chiller "E" slightly tops the limit (see Figure 28 to Figure 30). Chillers "B" and "C" did not provide any suitable result; chiller "D" was not simulated with fan coils. In any case, data very close to the lower limit were detected, apart for chiller "A" operated with evacuated tubes in Strasbourg: for this configurations values up to 25 were obtained.

Total solar fraction varies between 90% and 95% in Naples, 75% and 90% in Toulouse and 50-70% in Strasbourg (Figure 19 to Figure 21). Figures a) show that the use of evacuated tubes collectors do not produce any performance increase. The better technology becomes increasingly beneficial as far as the application is moved to Toulouse (+2% - 3%) and to Strasbourg (+10% in the only comparable configuration).

Cooling solar fraction data (Figure 22 to Figure 24) range again between 90 and 95% in Naples, since heating loads are negligible with respect to cooling ones. In Toulouse and Strasbourg they also approach the unity. The effect of heat rejection technology is yet negligible for all configurations presented.

Relative primary energy saved varies in the range 55-75% in Naples and 45-70% in Toulouse; much lower values are seen in Strasbourg, where simulations run range between 25% and 40% (see Figure 25 to Figure 27). This figure is strongly affected by the collectors technology employed: differences between 10% and 15% were evaluated depending on the location.

Finally, Figure 31 to Figure 33 show the performance of the solar combi+ system in terms of gross solar yield. The figure is clearly dependent on the collectors area, the variation being less and less significant the application moving to north, from Naples to Strasbourg. Moreover, moving northern the gross solar yield decreases toward the lower limit of 300 kWh/m^2/year: in Strasbourg the applications analyzed slightly exceed such a limit.

3.2.3 Simulations without Backup Heater

The performance of the best configurations assessed were also evaluated in a configuration where the backup heater was not used for driving the sorption chiller. In particular, results from the simulations relating to the residential applications are here discussed: wet cooling tower configurations are presented both for R60 and R100 applications, and for fan coils and chilled ceiling distribution systems. Office applications are not discussed due to the already extremely high solar fractions reported in the previous paragraph. Collectors' area of 5 m^2/kW_{ref} and storage volume of 75 l/m^2 were considered.

Solar coverage of cooling load -which in this case replaces the cooling solar fraction figure since no comparison with fossil fuel operation is applicable- decreases if the backup heater is not used. This is due to the fact that the heater allows higher temperatures at chillers inlet (and also at the outlet); therefore, also higher temperatures at the collectors are temporarily produced and thus higher solar fractions. Chillers working at average lower temperatures feature cooling solar fractions that drop of around 3%-10% with respect to the reference cases in which backup heater is considered. In Naples the decrease is around 3%-5%, while higher values are encountered in Toulouse, i.e. around 5%-10%: again the better matching between solar energy availability and heat demand in Naples, allows for higher average temperatures at the chillers (and at the DHW tank), consequently mitigating the lack of backup heater.

The lower temperatures at the collectors produce a slightly enhanced gross solar yield in the range of 1%-2%.

The largest effects are however encountered if yearly relative primary energy is considered. The saving of fossil fuel results in a relative increase of this figure in a range of 10%-30%. For the same reasons reported above, the best effects are encountered in Naples where 20%-30% higher savings are obtained, while in Toulouse more moderate increases are achieved around 10%.

4 Conclusions

The standard configurations analysis shows that the sizing of a solar combi+ system independently of the chiller technology can be obtained: sizes of 5 m^2/kW_{ref} and 75 l/m^2 provide best loads' coverage under all considered conditions. Due to heating requirements, larger collectors areas could be more suitable in residential applications; however, the additional gain, paid through a larger and expensive system, would be negligible. The best working technologies are in any considered case chilled ceiling as a distribution system, evacuated tubes collectors and wet cooling tower. Sizing of the components with an integrated process is also of utmost importance. Even though standard components' sizing can be individuated, a large variability of the results was detected as a consequence of the location, application technologies and chiller employed.

In general, best performing plants are encountered where high radiation is coupled with high cooling loads and modest needs for heating and DHW preparation (i.e. high ration between suitable solar energy and heat demand), as residential applications. In fact, even though office applications present the highest cooling and total solar fractions, they also show limited performance in terms of total electric efficiency (large electrical energy consumption at heat rejection) and gross solar yield (low solar energy capture at lower temperatures for DHW preparation and during mid seasons when cooling or heating is not needed).

The technologies affecting mostly the operation of the solar combi+ system are the solar collectors and the heat rejection. Evacuated tubes collectors allow (obviously) better performance, being much more expensive than flat plate ones (around double price on average); consequently, the use of one or the other type has to be weighted carefully. Two types of heat rejection system were discussed in the document: a technology clearly prevailing on the other could not be assessed. However, it was shown how electrical consumption for heat rejection can be a large part of the total "fossil" energy consumption, in some cases affecting primary energy savings to a large extent. With regard to the latter figure, office and residential application present about the same maximum values. More cases were presented regarding residential applications: here minimum primary energy savings can easily be half (25-30%) of maximum values computed (60-70%). Much work has to be carried out therefore to reduce gas usage for heating and driving the chiller, and to minimize electrical energy consumption for heat rejection and fluids pumping through the system, through energy efficiency of buildings and wise control strategies of the plants. Primary energy saved is also the most affected by system sizing; reducing collectors' areas below the values analyzed brings to highly reduced performance: around 15% drop in yearly primary energy saved is evaluated going from 5 to 4.3 m^2/kW_{ref} area.

The simulations performed are based on simplified models of the buildings, the chillers and the other mentioned components. Therefore they provide approximate estimations of the real behaviour of the system, meant to give a view of the facts and sizes. Moreover, the standard configurations are selected from a purely technical point of view; manufacturers and suppliers take into consideration also cost and marketing figures for the setup of their solutions. The latter are discussed in the reports on the manufacturers package solutions.

5 Reference

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5. Annex I – Best configurations

Table 3 - Naples, residential R60 configurations

		WCT				HC				DC			
		ET		FP		ET		FP		ET		FP	
Total Solar Fraction [%]	CC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	86.1	A	81.4	A	86.2	A	81.4	A	0.0	A	0.0
		B	73.3	B	67.1	B	0.0	B	73.1	B	0.0	B	0.0
		C	87.0	C	83.0	C	82.5	C	77.1	C	80.2	C	74.2
		D	82.5	D	77.8	D	81.5	D	76.6	D	0.0	D	0.0
		E	0.0	E	90.3	E	0.0	E	0.0	E	0.0	E	0.0
		ET		FP		ET		FP		ET		FP	
	FC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	87.1	A	81.8	A	86.4	A	81.0	A	0.0	A	0.0
		B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0
		C	0.0	C	0.0	C	0.0	C	0.0	C	0.0	C	0.0
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	89.1	E	0.0	E	0.0	E	0.0	E	0.0

		WCT				HC				DC			
		ET		FP		ET		FP		ET		FP	
Relative Primary Energy Saved [%]	CC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	70.9	A	64.1	A	73.5	A	66.5	A	0.0	A	0.0
		B	40.6	B	29.2	B	0.0	B	35.4	B	0.0	B	0.0
		C	65.7	C	59.4	C	60.5	C	52.3	C	56.7	C	47.7
		D	55.9	D	47.6	D	51.9	D	43.3	D	0.0	D	0.0
		E	0.0	E	71.7	E	0.0	E	0.0	E	0.0	E	0.0
		ET		FP		ET		FP		ET		FP	
	FC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	68.3	A	59.8	A	70.7	A	62.2	A	0.0	A	0.0
		B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0
		C	0.0	C	0.0	C	0.0	C	0.0	C	0.0	C	0.0
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	62.2	E	0.0	E	0.0	E	0.0	E	0.0

		WCT				HC				DC			
		ET		FP		ET		FP		ET		FP	
Total Electric Efficiency [-]	CC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	24.2	A	24.1	A	29.1	A	28.2	A	0.0	A	0.0
		B	18.4	B	18.4	B	0.0	B	14.6	B	0.0	B	0.0
		C	13.4	C	13.2	C	14.5	C	14.3	C	13.9	C	13.7
		D	19.9	D	19.4	D	16.9	D	16.4	D	0.0	D	0.0
		E	0.0	E	16.7	E	0.0	E	0.0	E	0.0	E	0.0
		ET		FP		ET		FP		ET		FP	
	FC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	17.7	A	17.2	A	21.6	A	20.5	A	0.0	A	0.0
		B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0
		C	0.0	C	0.0	C	0.0	C	0.0	C	0.0	C	0.0
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	12.0	E	0.0	E	0.0	E	0.0	E	0.0

Table 4 - Naples, residential R100 configurations

		WCT				HC				DC			
		ET		FP		ET		FP		ET		FP	
Total Solar Fraction [%]	CC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	76.2	A	72.7	A	76.7	A	67.2	A	0.0	A	0.0
		B	67.9	B	62.7	B	65.9	B	60.3	B	0.0	B	0.0
		C	78.4	C	74.5	C	74.5	C	69.9	C	72.2	C	67.6
		D	76.5	D	71.7	D	75.7	D	71.3	D	0.0	D	0.0
		E	0.0	E	82.4	E	0.0	E	0.0	E	0.0	E	0.0
		ET		FP		ET		FP		ET		FP	
	FC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	80.4	A	75.9	A	79.7	A	75.0	A	0.0	A	0.0
		B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0
		C	82.0	C	78.1	C	75.2	C	69.8	C	71.7	C	66.2
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	84.3	E	0.0	E	0.0	E	0.0	E	0.0

		WCT				HC				DC			
		ET		FP		ET		FP		ET		FP	
Relative Primary Energy Saved [%]	CC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	62.1	A	57.4	A	64.5	A	52.1	A	0.0	A	0.0
		B	40.8	B	32.5	B	35.1	B	25.9	B	0.0	B	0.0
		C	59.7	C	54.2	C	55.4	C	49.1	C	52.0	C	45.6
		D	51.9	D	44.8	D	48.3	D	41.7	D	0.0	D	0.0
		E	0.0	E	65.8	E	0.0	E	0.0	E	0.0	E	0.0
		ET		FP		ET		FP		ET		FP	
	FC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	63.3	A	56.8	A	65.1	A	58.5	A	0.0	A	0.0
		B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0
		C	59.1	C	53.1	C	50.9	C	43.1	C	45.3	C	37.5
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	61.6	E	0.0	E	0.0	E	0.0	E	0.0

		WCT				HC				DC			
		ET		FP		ET		FP		ET		FP	
Total Electric Efficiency [-]	CC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	30.6	A	28.9	A	34.8	A	34.2	A	0.0	A	0.0
		B	22.6	B	22.5	B	19.6	B	19.7	B	0.0	B	0.0
		C	17.0	C	16.7	C	17.9	C	17.3	C	17.0	C	16.5
		D	24.0	D	23.4	D	20.0	D	19.5	D	0.0	D	0.0
		E	0.0	E	20.9	E	0.0	E	0.0	E	0.0	E	0.0
		ET		FP		ET		FP		ET		FP	
	FC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	21.9	A	21.3	A	25.6	A	24.3	A	0.0	A	0.0
		B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0
		C	12.3	C	11.9	C	12.9	C	12.4	C	11.7	C	11.5
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	14.6	E	0.0	E	0.0	E	0.0	E	0.0

Table 5 - Naples, office configurations

		WCT				HC				DC			
		ET		FP		ET		FP		ET		FP	
Total Solar Fraction [%]	CC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	0.0	A	0.0	A	0.0	A	0.0	A	0.0	A	0.0
		B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0
		C	0.0	C	0.0	C	0.0	C	0.0	C	0.0	C	0.0
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	0.0	E	0.0	E	0.0	E	0.0	E	0.0
		ET		FP		ET		FP		ET		FP	
	FC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	97.5	A	93.3	A	99.0	A	96.6	A	0.0	A	0.0
		B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0
		C	0.0	C	0.0	C	0.0	C	0.0	C	0.0	C	0.0
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	0.0	E	0.0	E	0.0	E	0.0	E	0.0

		WCT				HC				DC			
		ET		FP		ET		FP		ET		FP	
Relative Primary Energy Saved [%]	CC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	0.0	A	0.0	A	0.0	A	0.0	A	0.0	A	0.0
		B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0
		C	0.0	C	0.0	C	0.0	C	0.0	C	0.0	C	0.0
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	0.0	E	0.0	E	0.0	E	0.0	E	0.0
		ET		FP		ET		FP		ET		FP	
	FC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	72.8	A	63.5	A	78.9	A	71.4	A	0.0	A	0.0
		B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0
		C	0.0	C	0.0	C	0.0	C	0.0	C	0.0	C	0.0
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	0.0	E	0.0	E	0.0	E	0.0	E	0.0

		WCT				HC				DC			
		ET		FP		ET		FP		ET		FP	
Total Electric Efficiency [-]	CC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	0.0	A	0.0	A	0.0	A	0.0	A	0.0	A	0.0
		B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0
		C	0.0	C	0.0	C	0.0	C	0.0	C	0.0	C	0.0
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	0.0	E	0.0	E	0.0	E	0.0	E	0.0
		ET		FP		ET		FP		ET		FP	
	FC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	11.2	A	11.1	A	12.9	A	11.5	A	0.0	A	0.0
		B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0
		C	0.0	C	0.0	C	0.0	C	0.0	C	0.0	C	0.0
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	0.0	E	0.0	E	0.0	E	0.0	E	0.0

Table 6 - Toulouse, residential R60 configurations

		WCT				HC				DC			
		ET		FP		ET		FP		ET		FP	
Total Solar Fraction [%]	CC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	55.0	SF	50.8	SF	54.1	SF	49.9	SF	0.0	SF	0.0
		B	51.9	SF	47.0	SF	50.9	SF	46.1	SF	0.0	SF	0.0
		C	54.4	SF	51.3	SF	53.9	SF	49.9	SF	53.1	SF	48.9
		D	60.1	SF	54.9	SF	59.1	SF	54.0	SF	0.0	SF	0.0
		E	0.0	SF	63.5	SF	0.0	SF	0.0	SF	0.0	SF	0.0
		ET		FP		ET		FP		ET		FP	
	FC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	56.4	SF	51.9	SF	55.1	SF	50.7	A	0.0	A	0.0
		B	50.9	SF	45.8	SF	0.0	SF	0.0	B	0.0	B	0.0
		C	55.8	SF	52.1	SF	54.2	SF	50.2	SF	52.3	SF	48.2
		D	0.0	SF	0.0	SF	0.0	SF	0.0	SF	0.0	SF	0.0
		E	0.0	SF	64.9	E	0.0	E	0.0	E	0.0	E	0.0
		WCT				HC				DC			
		ET		FP		ET		FP		ET		FP	
Relative Primary Energy Saved [%]	CC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	45.9	A	41.1	A	45.9	A	41.2	A	0.0	A	0.0
		B	36.7	B	30.6	B	33.8	B	27.8	B	0.0	B	0.0
		C	45.1	C	39.0	C	43.1	C	38.5	C	42.0	C	37.2
		D	42.3	D	36.5	D	39.4	D	33.6	D	0.0	D	0.0
		E	0.0	E	52.1	E	0.0	E	0.0	E	0.0	E	0.0
		ET		FP		ET		FP		ET		FP	
	FC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	45.3	A	40.0	A	45.7	A	40.6	A	0.0	A	0.0
		B	29.5	B	23.2	B	0.0	B	0.0	B	0.0	B	0.0
		C	46.0	C	38.7	C	42.1	C	37.5	C	39.7	C	35.0
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	50.6	E	0.0	E	0.0	E	0.0	E	0.0
		WCT				HC				DC			
		ET		FP		ET		FP		ET		FP	
Total Electric Efficiency [-]	CC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	50.4	A	49.2	A	53.3	A	51.7	A	0.0	A	0.0
		B	35.1	B	34.7	B	30.6	B	30.2	B	0.0	B	0.0
		C	36.7	C	29.6	C	30.6	C	30.0	C	28.7	C	28.2
		D	35.5	D	34.2	D	29.5	D	28.2	D	0.0	D	0.0
		E	0.0	E	34.1	E	0.0	E	0.0	E	0.0	E	0.0
		ET		FP		ET		FP		ET		FP	
	FC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	39.8	A	38.8	A	41.0	A	39.7	A	0.0	A	0.0
		B	25.8	B	25.9	B	0.0	B	0.0	B	0.0	B	0.0
		C	30.3	C	24.2	C	24.3	C	23.9	C	21.8	C	21.6
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	25.9	E	0.0	E	0.0	E	0.0	E	0.0

Table 7 - Toulouse, residential R100 configurations

		WCT				HC				DC			
		ET		FP		ET		FP		ET		FP	
Total Solar Fraction [%]	CC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	46.5	A	43.3	A	44.7	A	41.6	A	0.0	A	0.0
		B	43.7	B	40.4	B	43.3	B	0.0	B	0.0	B	0.0
		C	46.2	C	44.0	C	45.9	C	43.0	C	45.2	C	42.3
		D	48.9	D	45.3	D	48.3	D	44.4	D	0.0	D	0.0
		E	0.0	E	53.2	E	0.0	E	0.0	E	0.0	E	0.0
		ET		FP		ET		FP		ET		FP	
	FC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	46.6	A	43.1	A	45.3	A	42.0	A	0.0	A	0.0
		B	43.1	B	0.0	B	41.8	B	0.0	B	0.0	B	0.0
		C	46.7	C	44.4	C	45.4	C	42.7	C	44.1	C	41.3
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	54.5	E	0.0	E	0.0	E	0.0	E	0.0

		WCT				HC				DC			
		ET		FP		ET		FP		ET		FP	
Relative Primary Energy Saved [%]	CC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	40.4	A	36.9	A	39.2	A	35.7	A	0.0	A	0.0
		B	33.2	B	29.5	B	31.6	B	0.0	B	0.0	B	0.0
		C	40.0	C	36.0	C	38.7	C	35.5	C	37.8	C	34.6
		D	35.7	D	31.8	D	33.4	D	29.3	D	0.0	D	0.0
		E	0.0	E	45.0	E	0.0	E	0.0	E	0.0	E	0.0
		ET		FP		ET		FP		ET		FP	
	FC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	38.8	A	35.0	A	38.7	A	35.1	A	0.0	A	0.0
		B	28.1	B	0.0	B	24.2	B	0.0	B	0.0	B	0.0
		C	40.1	C	35.6	C	37.3	C	34.3	C	35.5	C	32.5
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	44.0	E	0.0	E	0.0	E	0.0	E	0.0

		WCT				HC				DC			
		ET		FP		ET		FP		ET		FP	
Total Electric Efficiency [-]	CC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	51.7	A	50.6	A	54.7	A	53.0	A		A	0.0
		B	47.1	B	46.8	B	41.1	B	0.0	B	0.0	B	0.0
		C	51.8	C	42.9	C	42.8	C	42.0	C	39.5	C	38.8
		D	47.3	D	45.5	D	38.3	D	36.9	D	0.0	D	0.0
		E	0.0	E	46.5	E	0.0	E	0.0	E	0.0	E	0.0
		ET		FP		ET		FP		ET		FP	
	FC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	41.2	A	40.2	A	42.3	A	41.1	A	0.0	A	0.0
		B	35.0	B	0.0	B	28.6	B	0.0	B	0.0	B	0.0
		C	43.2	C	35.4	C	34.1	C	33.6	C	30.1	C	29.9
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	36.2	E	0.0	E	0.0	E	0.0	E	0.0

Table 8 - Toulouse, office configurations

		WCT				HC				DC			
		ET		FP		ET		FP		ET		FP	
Total Solar Fraction [%]	CC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	0.0	A	0.0	A	0.0	A	0.0	A	0.0	A	0.0
		B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0
		C	0.0	C	0.0	C	0.0	C	0.0	C	0.0	C	0.0
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	0.0	E	0.0	E	0.0	E	0.0	E	0.0
		ET		FP		ET		FP		ET		FP	
	FC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	90.6	A	82.0	A	89.9	A	80.7	A	0.0	A	0.0
		B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0
		C	0.0	C	0.0	C	0.0	C	0.0	C	0.0	C	0.0
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	0.0	E	0.0	E	0.0	E	0.0	E	0.0

		WCT				HC				DC			
		ET		FP		ET		FP		ET		FP	
Relative Primary Energy Saved [%]	CC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	0.0	A	0.0	A	0.0	A	0.0	A	0.0	A	0.0
		B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0
		C	0.0	C	0.0	C	0.0	C	0.0	C	0.0	C	0.0
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	0.0	E	0.0	E	0.0	E	0.0	E	0.0
		ET		FP		ET		FP		ET		FP	
	FC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	69.8	A	55.2	A	71.1	A	55.6	A	0.0	A	0.0
		B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0
		C	0.0	C	0.0	C	0.0	C	0.0	C	0.0	C	0.0
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	0.0	E	0.0	E	0.0	E	0.0	E	0.0

		WCT				HC				DC			
		ET		FP		ET		FP		ET		FP	
Total Electric Efficiency [-]	CC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	0.0	A	0.0	A	0.0	A	0.0	A	0.0	A	0.0
		B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0
		C	0.0	C	0.0	C	0.0	C	0.0	C	0.0	C	0.0
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	0.0	E	0.0	E	0.0	E	0.0	E	0.0
		ET		FP		ET		FP		ET		FP	
	FC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	15.3	A	15.2	A	17.1	A	16.2	A	0.0	A	0.0
		B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0
		C	0.0	C	0.0	C	0.0	C	0.0	C	0.0	C	0.0
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	0.0	E	0.0	E	0.0	E	0.0	E	0.0

Table 9 - Strasbourg, office configurations

		WCT				HC				DC			
		ET		FP		ET		FP		ET		FP	
Total Solar Fraction [%]	CC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	0.0	A	0.0	A	0.0	A	0.0	A	0.0	A	0.0
		B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0
		C	0.0	C	0.0	C	0.0	C	0.0	C	0.0	C	0.0
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	0.0	E	0.0	E	0.0	E	0.0	E	0.0
		ET		FP		ET		FP		ET		FP	
	FC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	61.3	A	51.0	A	58.8	A	50.2	A	0.0	A	0.0
		B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0
		C	0.0	C	0.0	C	0.0	C	0.0	C	0.0	C	0.0
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	68.2	E	0.0	E	0.0	E	0.0	E	0.0

		WCT				HC				DC			
		ET		FP		ET		FP		ET		FP	
Relative Primary Energy Saved [%]	CC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	0.0	A	0.0	A	0.0	A	0.0	A	0.0	A	0.0
		B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0
		C	0.0	C	0.0	C	0.0	C	0.0	C	0.0	C	0.0
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	0.0	E	0.0	E	0.0	E	0.0	E	0.0
		ET		FP		ET		FP		ET		FP	
	FC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	39.4	A	26.0	A	39.5	A	27.9	A	0.0	A	0.0
		B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0
		C	0.0	C	0.0	C	0.0	C	0.0	C	0.0	C	0.0
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	40.8	E	0.0	E	0.0	E	0.0	E	0.0

		WCT				HC				DC			
		ET		FP		ET		FP		ET		FP	
Total Electric Efficiency [-]	CC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	0.0	A	0.0	A	0.0	A	0.0	A	0.0	A	0.0
		B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0
		C	0.0	C	0.0	C	0.0	C	0.0	C	0.0	C	0.0
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	0.0	E	0.0	E	0.0	E	0.0	E	0.0
		ET		FP		ET		FP		ET		FP	
	FC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	24.3	A	24.1	A	27.8	A	25.0	A	0.0	A	0.0
		B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0
		C	0.0	C	0.0	C	0.0	C	0.0	C	0.0	C	0.0
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	16.4	E	0.0	E	0.0	E	0.0	E	0.0

6 Standard Configurations Charts

In the following figures, performance figure is reported on the y-axis the versus the specific collectors' area on te x-axis.

Storage tank specific volume is stated through red (50 l/m^2) and green (75 l/m^2) colors.

A different symbol is used for each chiller: chiller A = triangle, B = circle, C = line, D = diamond, E = square.

Since the graphs serve to comparing technologies, a reference configuration - i.e CC-FP-WCT for residential and FC-FP-WCT for office buildings - is always shown with a solid symbol, while "compared" technologies are specified with a void one.

6.1 Total Solar Fraction - Residential

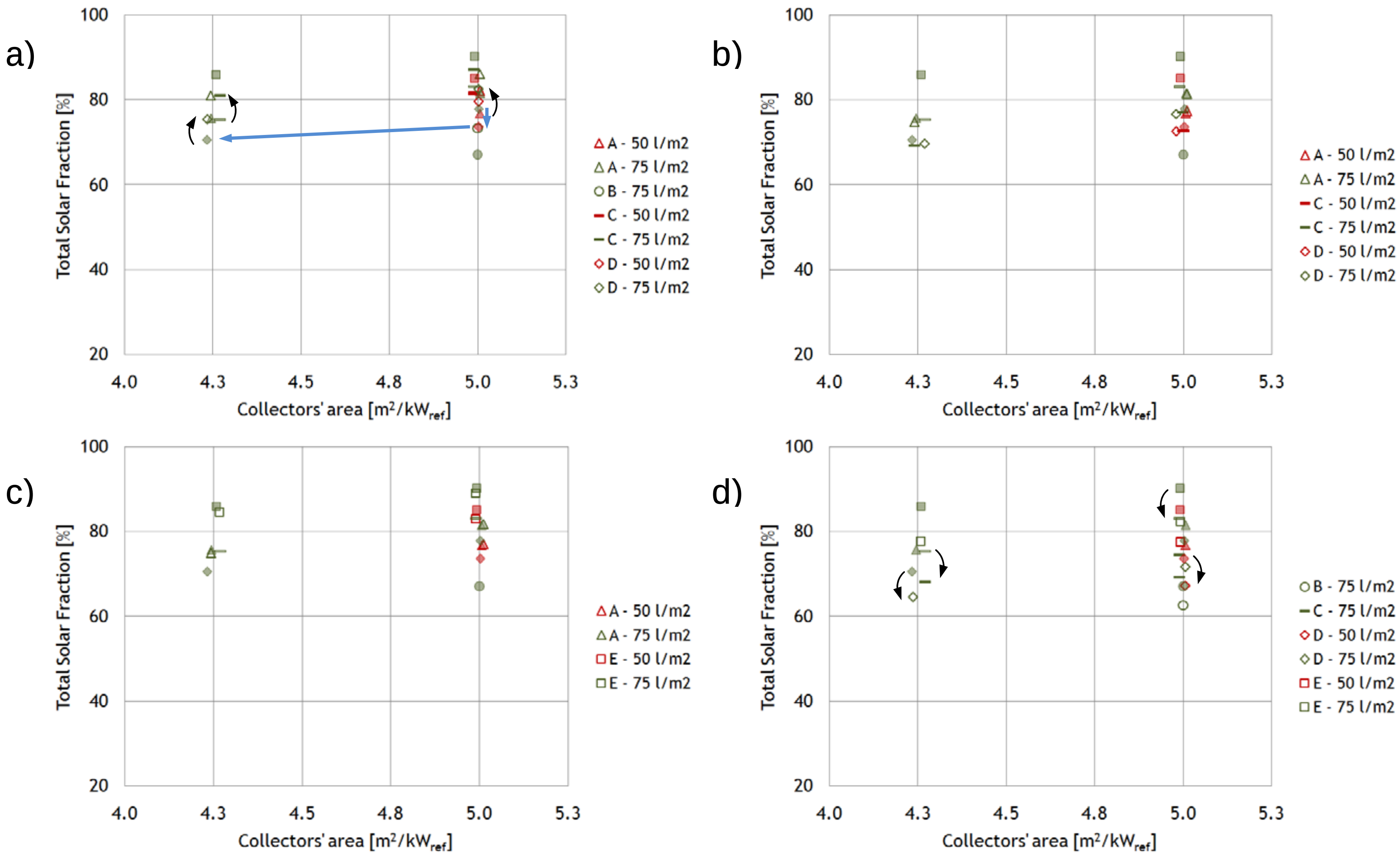

Figure 9 - Naples, a) FP vs ET collectors, b) WCT vs HC rejection system, c) CC vs FC distribution system, d) R60 vs R100 building

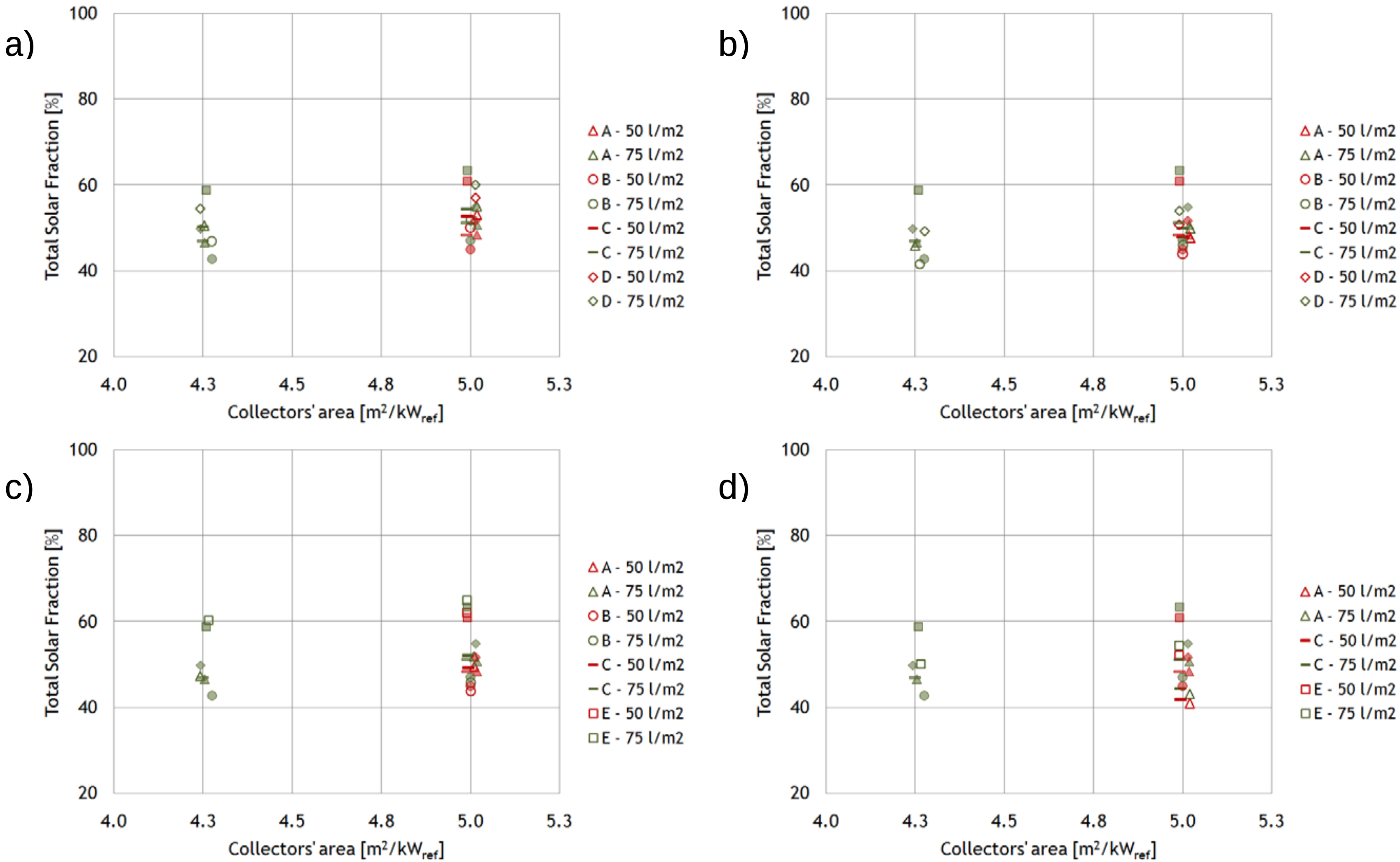

Figure 10 - Toulouse, a) FP vs ET collectors, b) WCT vs HC rejection system, c) CC vs FC distribution system, d) R60 vs R100 building

6.2 Cooling Solar Fraction - Residential

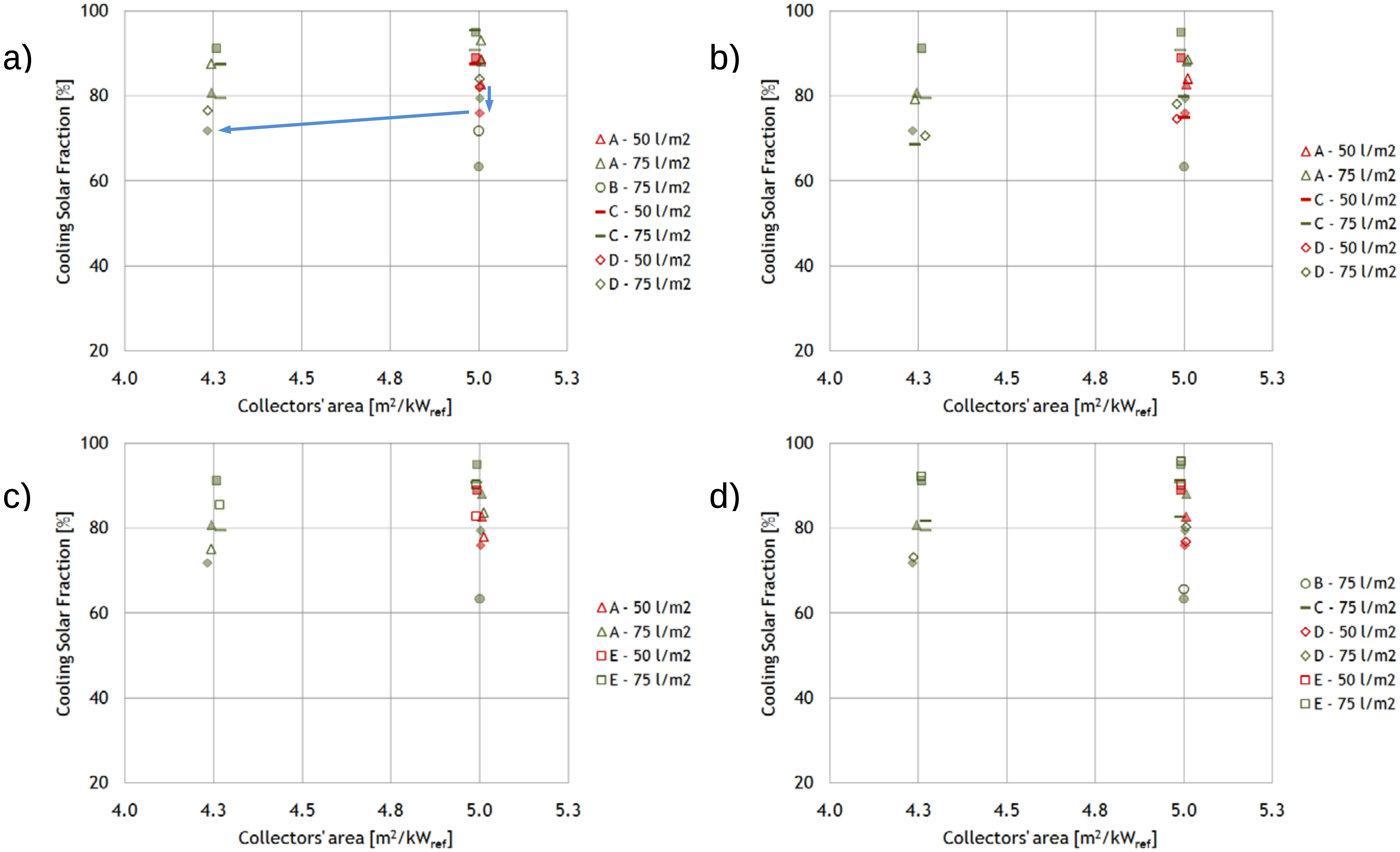

Figure 11 - Naples, a) FP vs ET collectors, b) WCT vs HC rejection system, c) CC vs FC distribution system, d) R60 vs R100 building

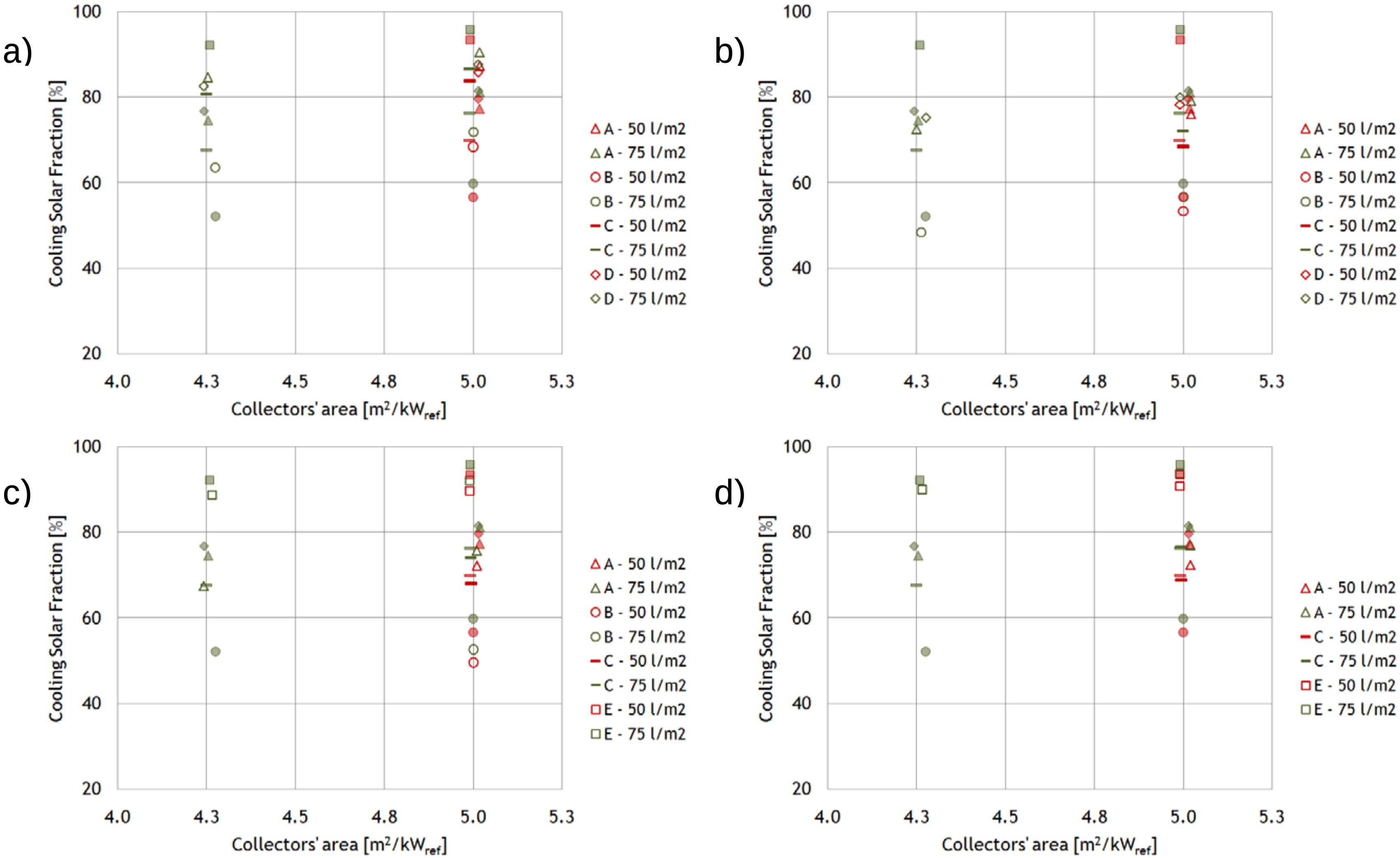

Figure 12 - Toulouse, a) FP vs ET collectors, b) WCT vs HC rejection system, c) CC vs FC distribution system, d) R60 vs R100 building

6.3 Relative Primary Energy Saved - Residential

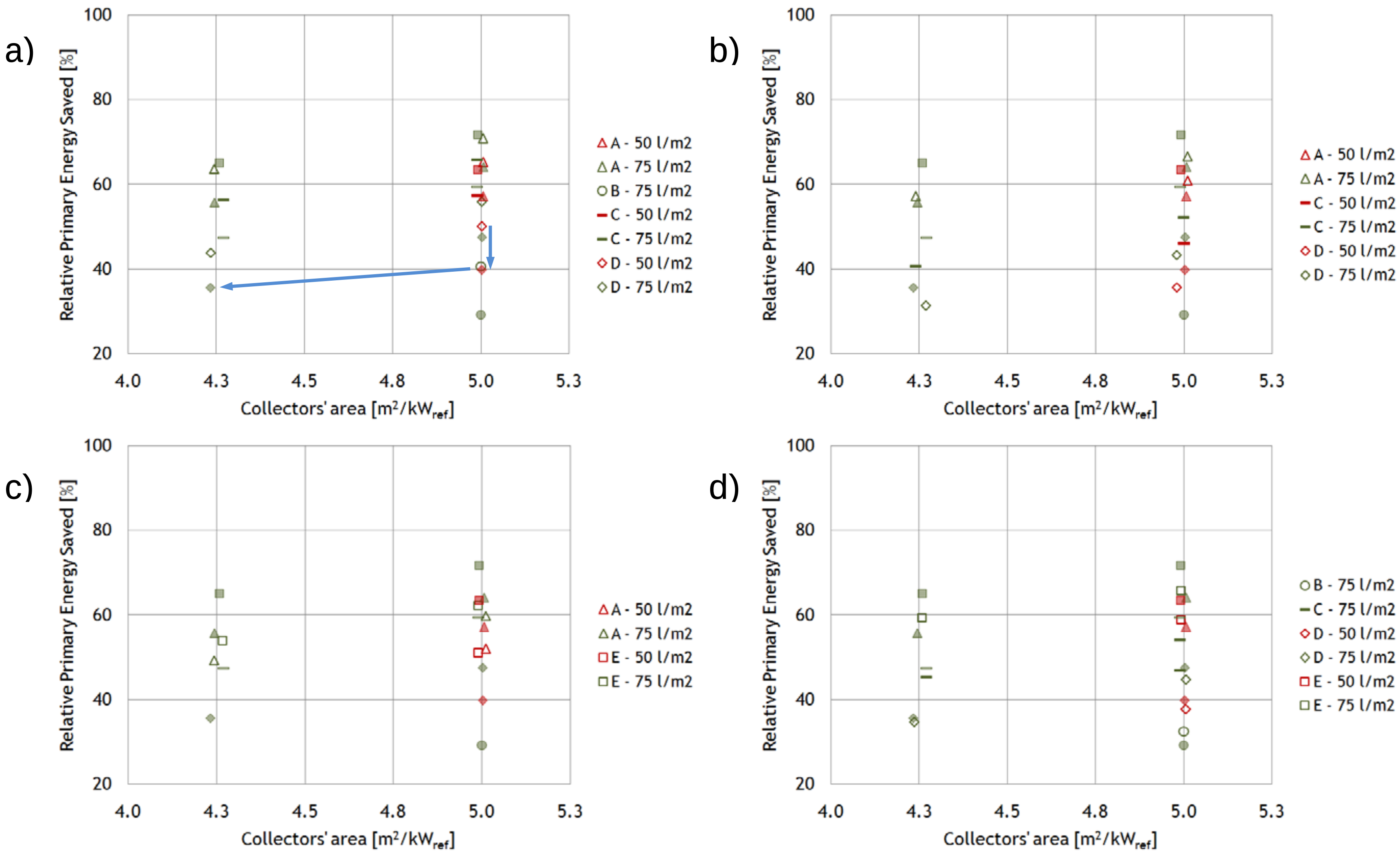

Figure 13 - Naples, a) FP vs ET collectors, b) WCT vs HC rejection system, c) CC vs FC distribution system, d) R60 vs R100 building

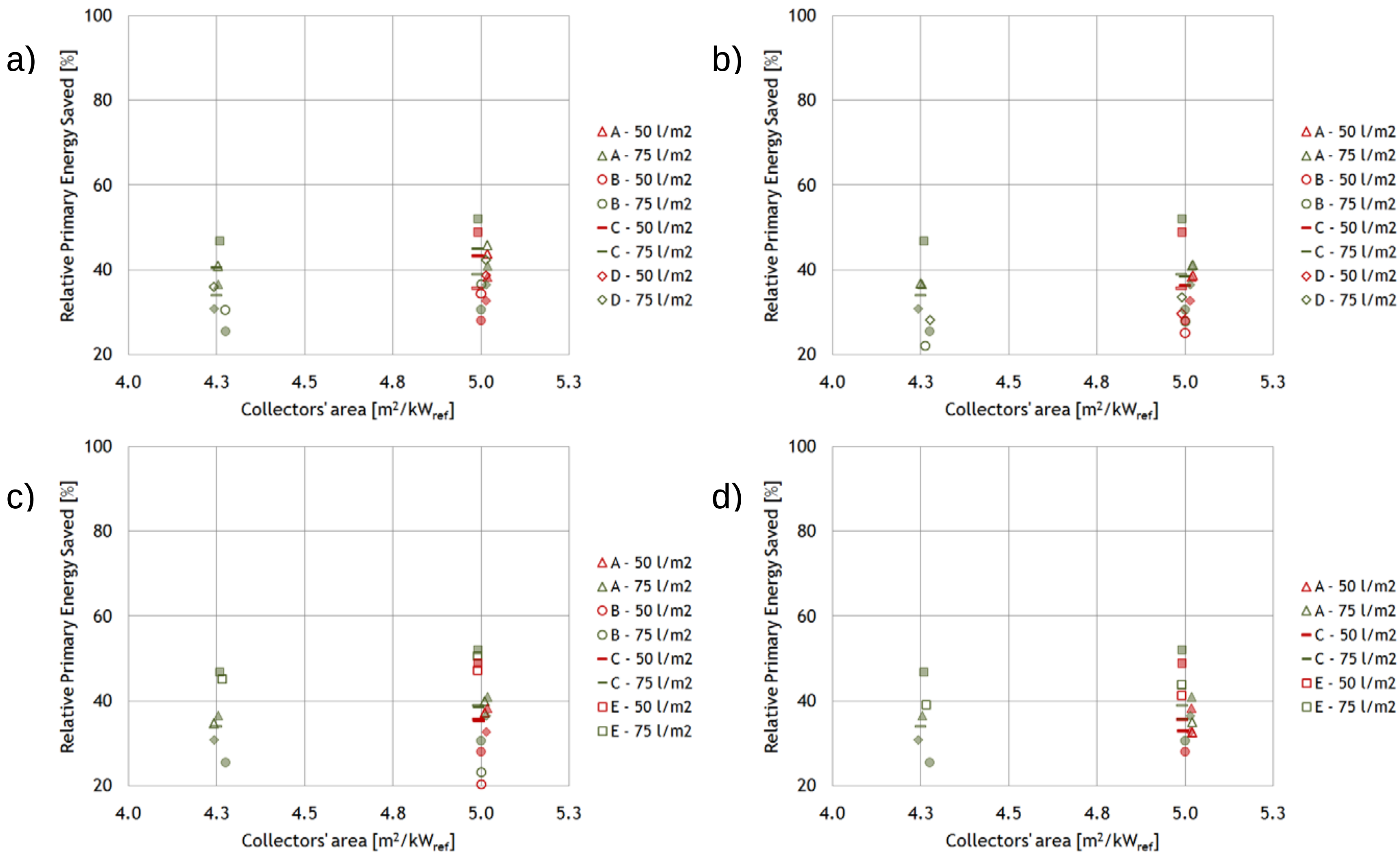

Figure 14 - Toulouse, a) FP vs ET collectors, b) WCT vs HC rejection system, c) CC vs FC distribution system, d) R60 vs R100 building

6.4 Total Electric Efficiency - Residential

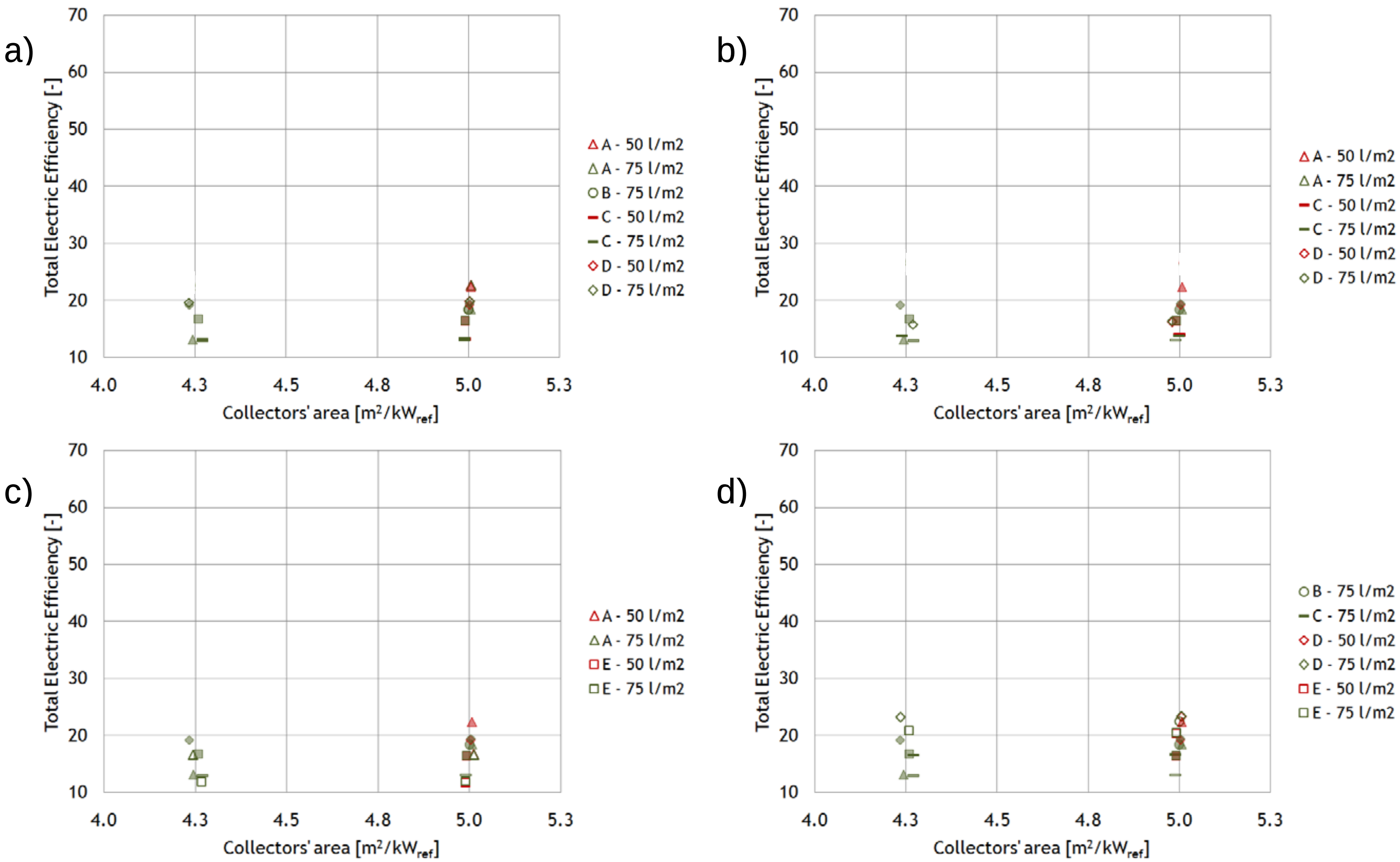

Figure 15 - Naples, a) FP vs ET collectors, b) WCT vs HC rejection system, c) CC vs FC distribution system, d) R60 vs R100 building

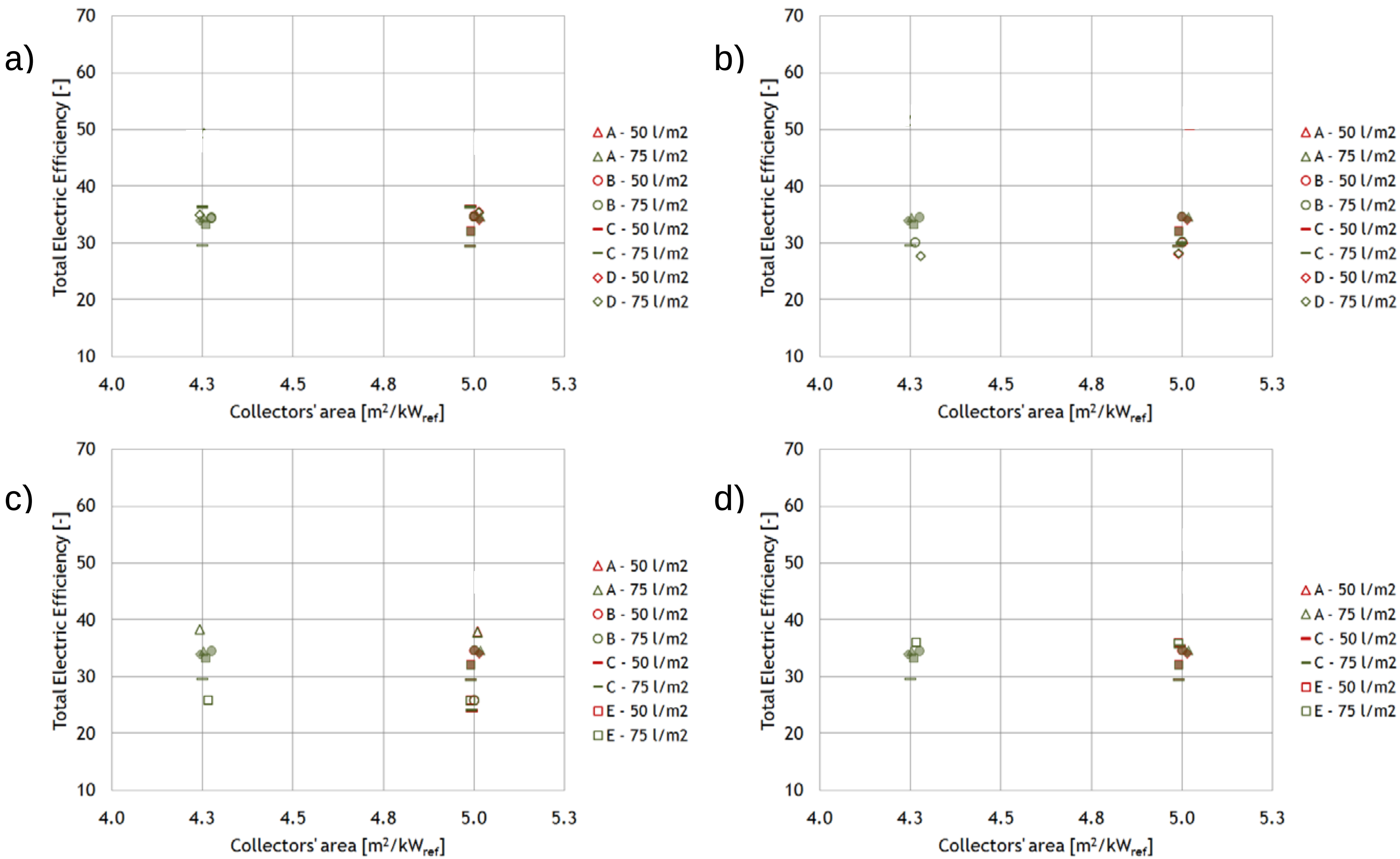

Figure 16 - Toulouse, a) FP vs ET collectors, b) WCT vs HC rejection system, c) CC vs FC distribution system, d) R60 vs R100 building

6.5 Gross Solar Yield - Residential

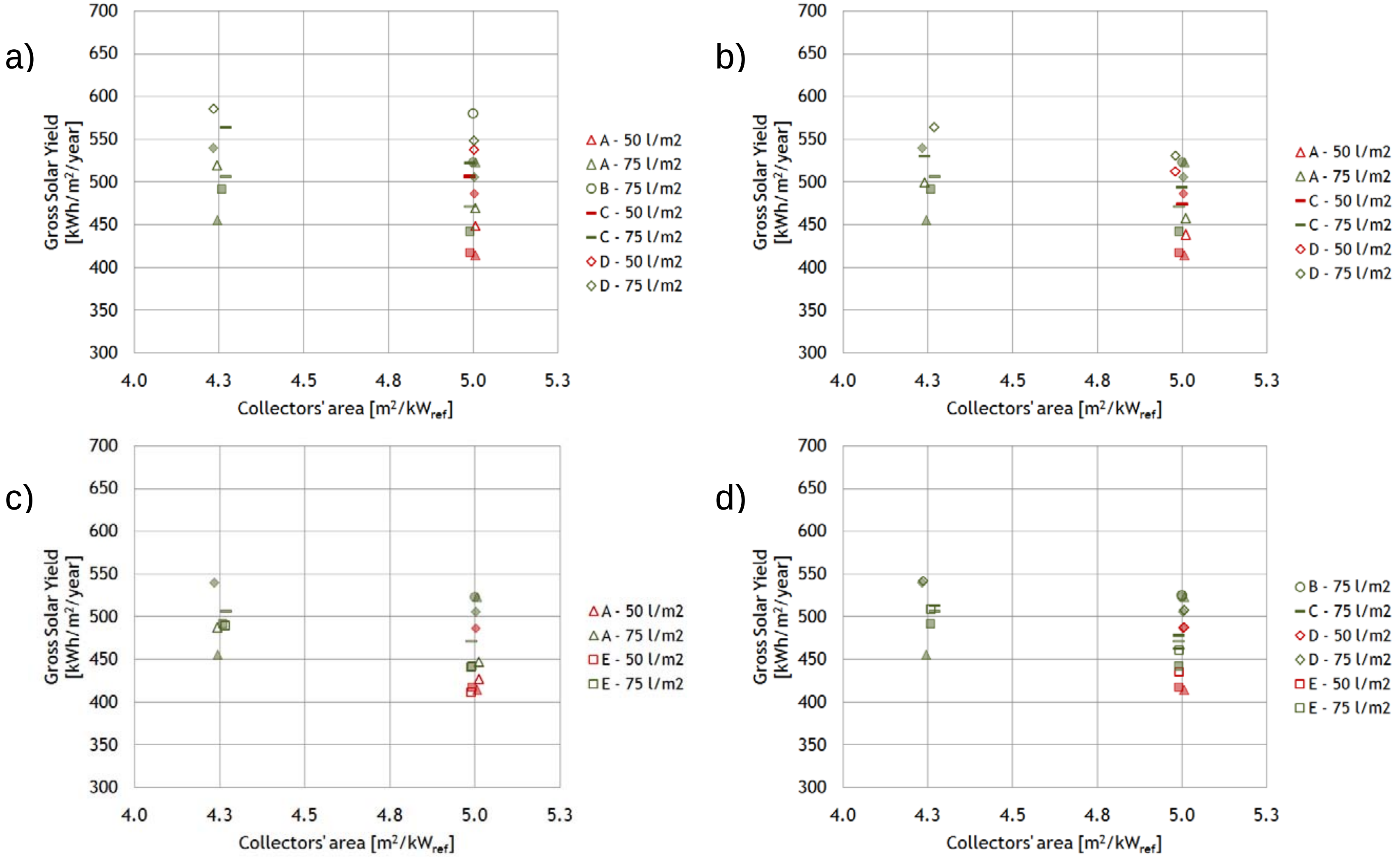

Figure 17- Naples, a) FP vs ET collectors, b) WCT vs HC rejection system, c) CC vs FC distribution system, d) R60 vs R100 building

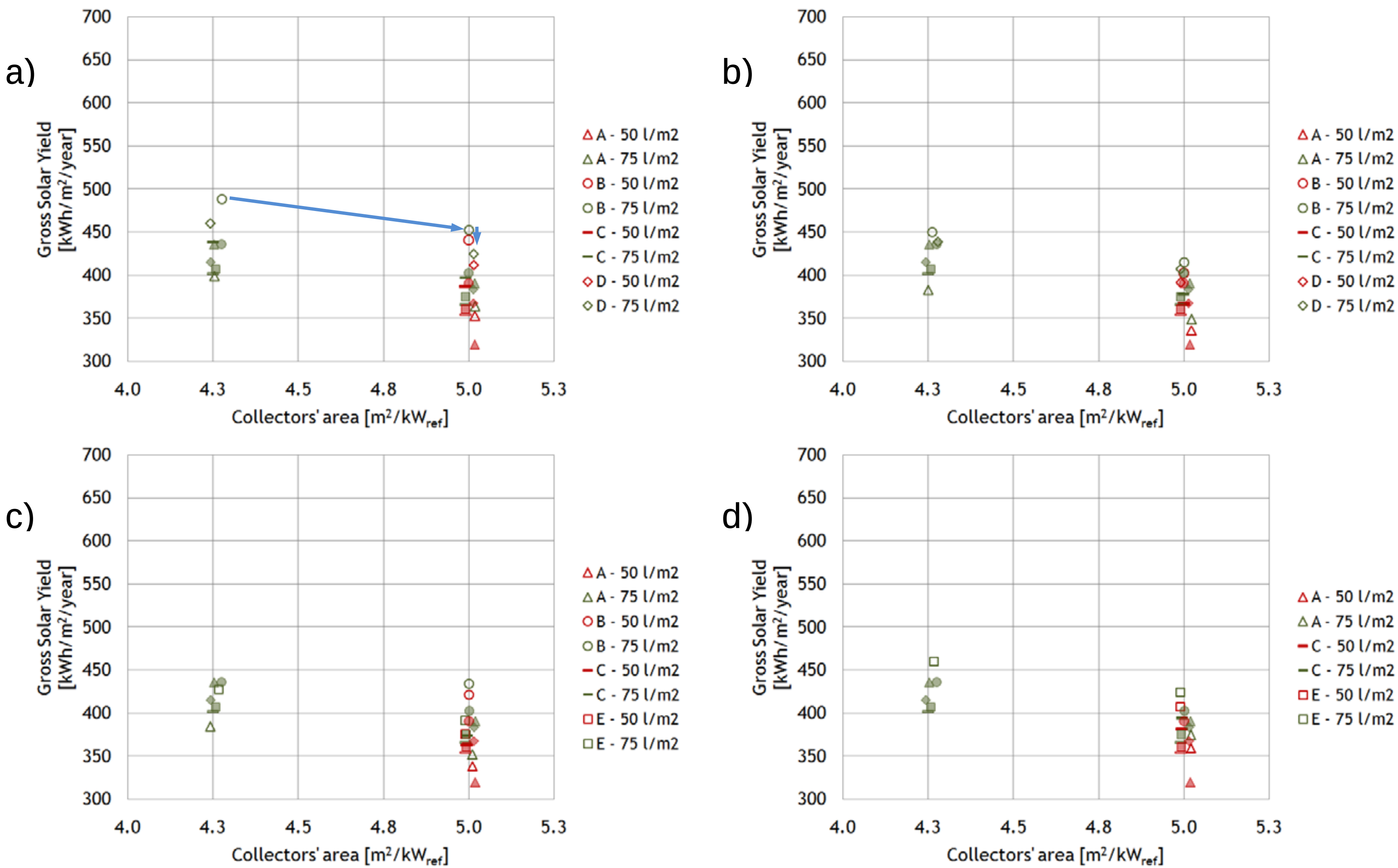

Figure 18 - Toulouse, a) FP vs ET collectors, b) WCT vs HC rejection system, c) CC vs FC distribution system, d) R60 vs R100 building

6.6 Total Solar Fraction – Office

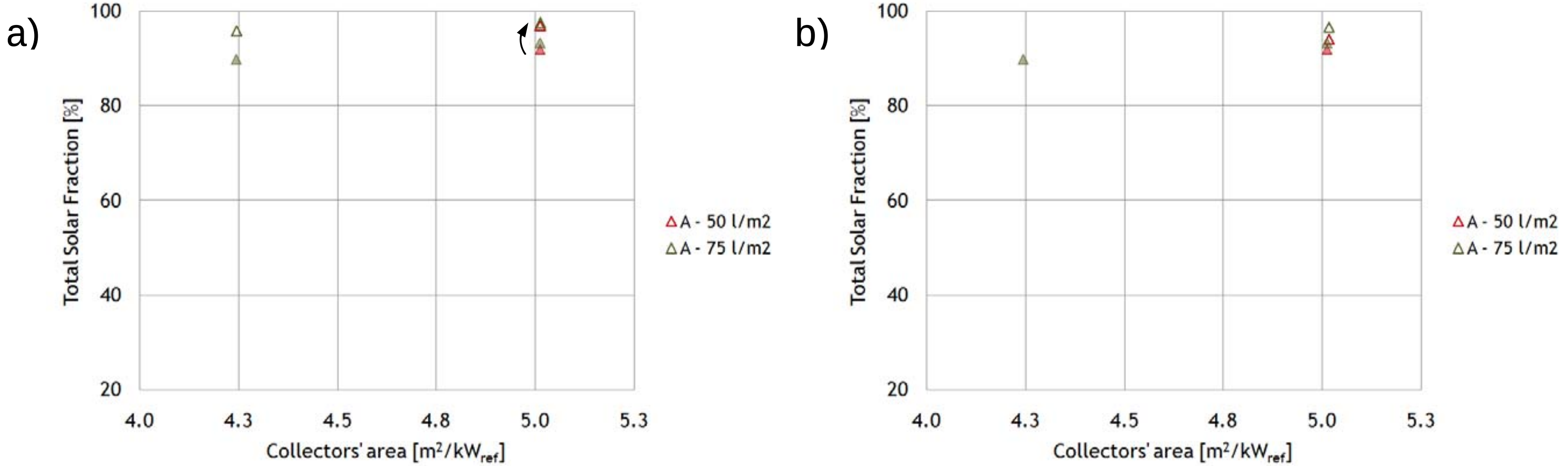

Figure 19 - Naples, a) FP vs ET collectors, b) WCT vs HC rejection system

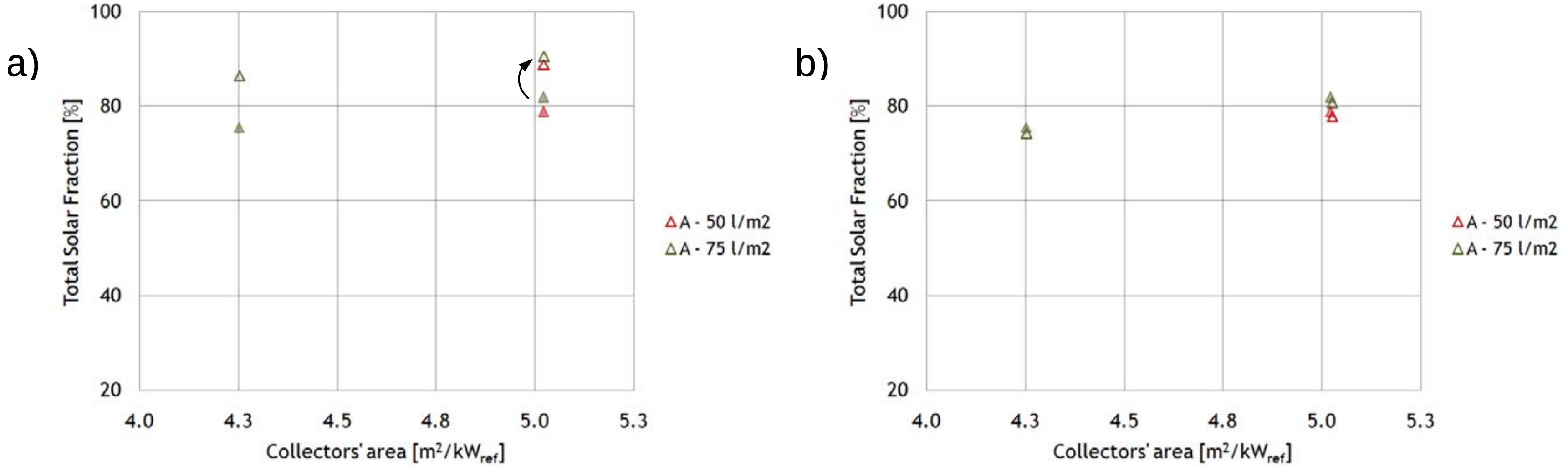

Figure 20 - Toulouse, a) FP vs ET collectors, b) WCT vs HC rejection system

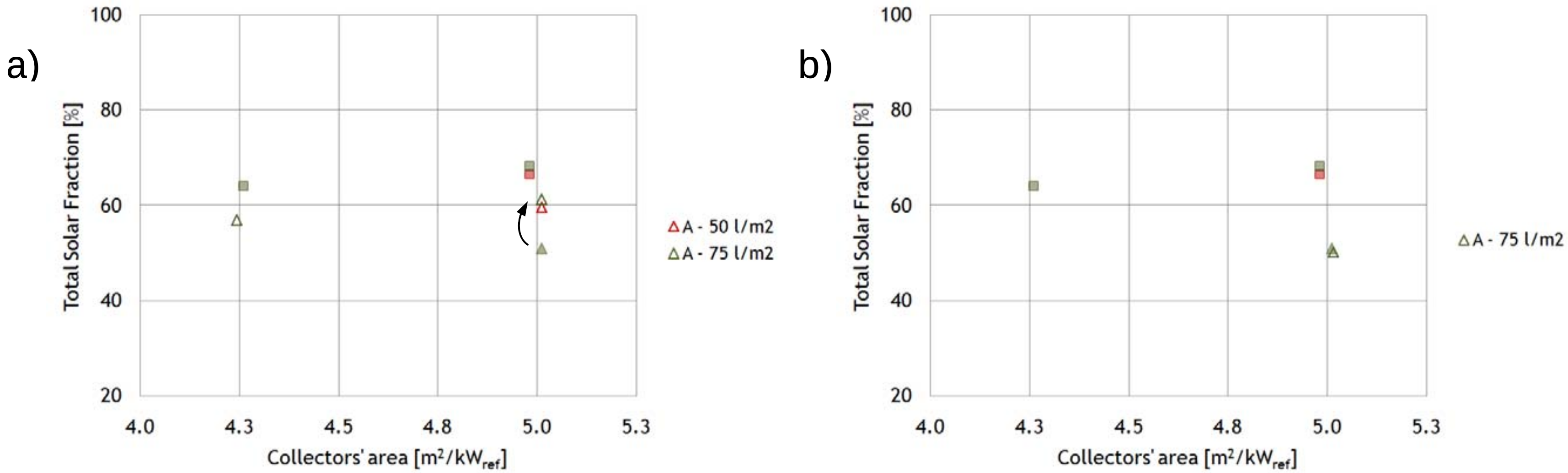

Figure 21 - Strasbourg, a) FP vs ET collectors, b) WCT vs HC rejection system

6.7 Cooling Solar Fraction - Office

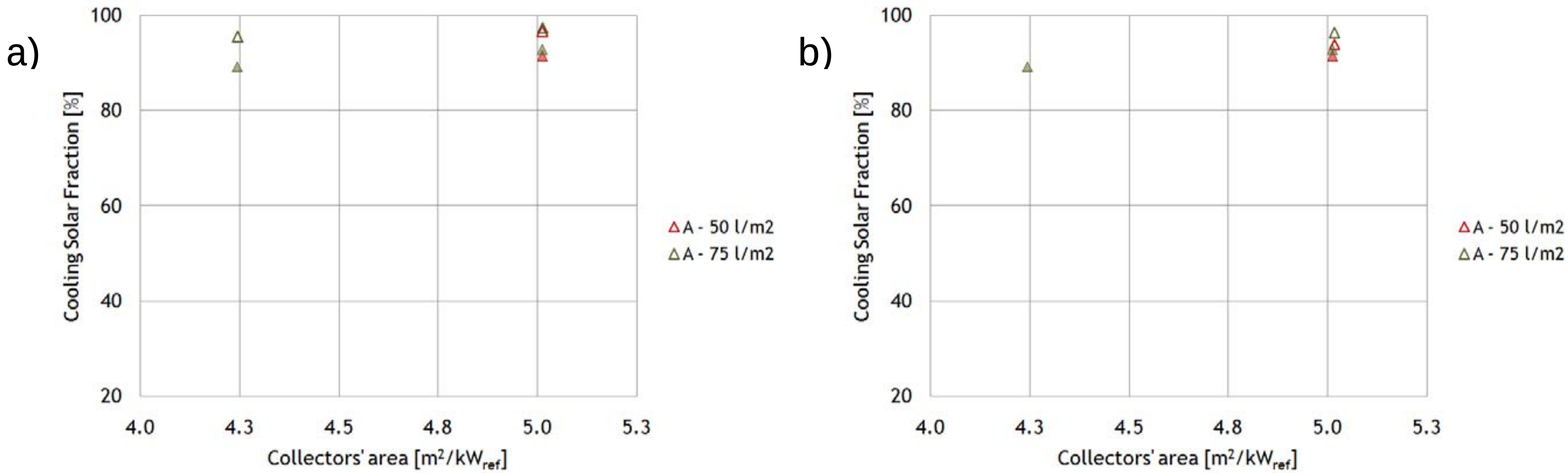

Figure 22 - Naples, a) FP vs ET collectors, b) WCT vs HC rejection system

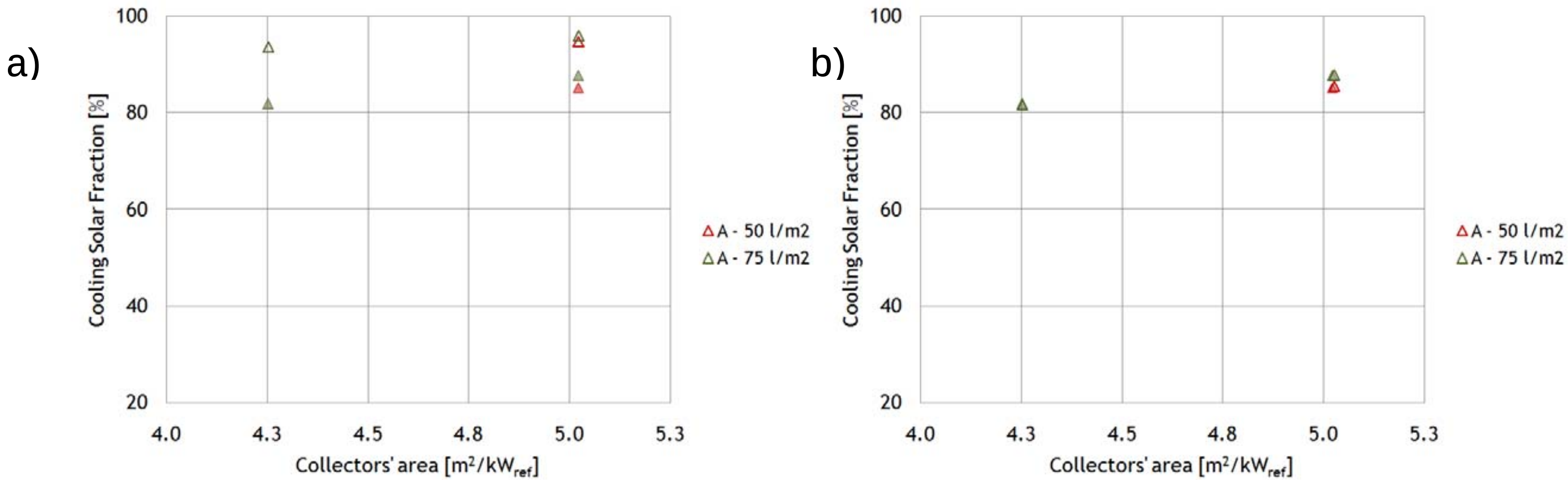

Figure 23 - Toulouse, a) FP vs ET collectors, b) WCT vs HC rejection system

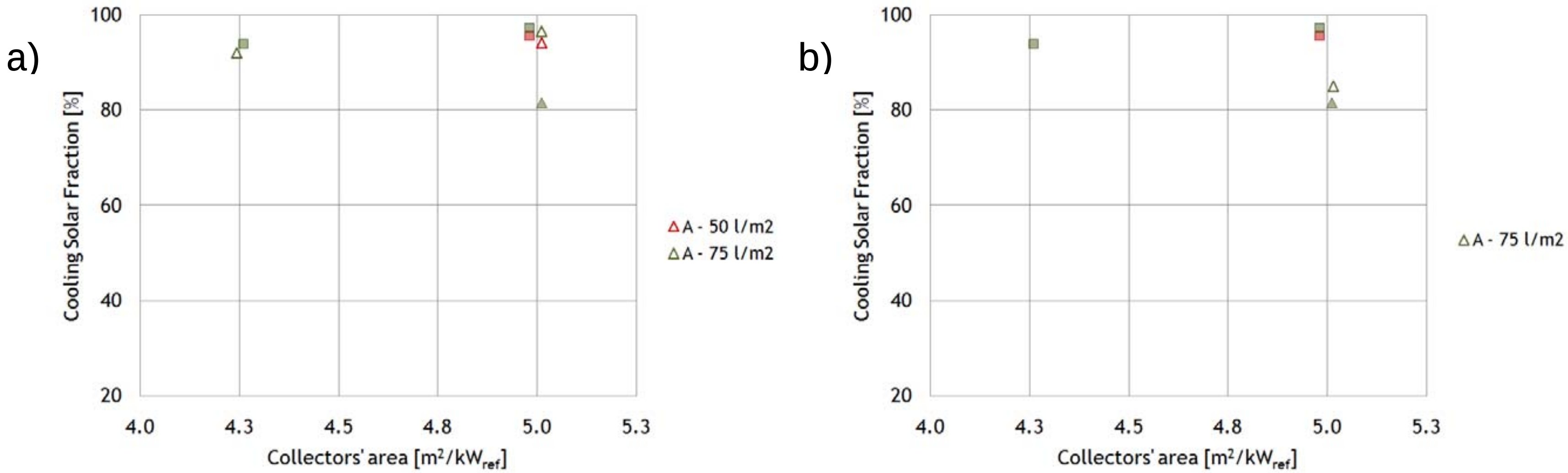

Figure 24 - Strasbourg, a) FP vs ET collectors, b) WCT vs HC rejection

6.8 Relative Primary Energy Saved - Office

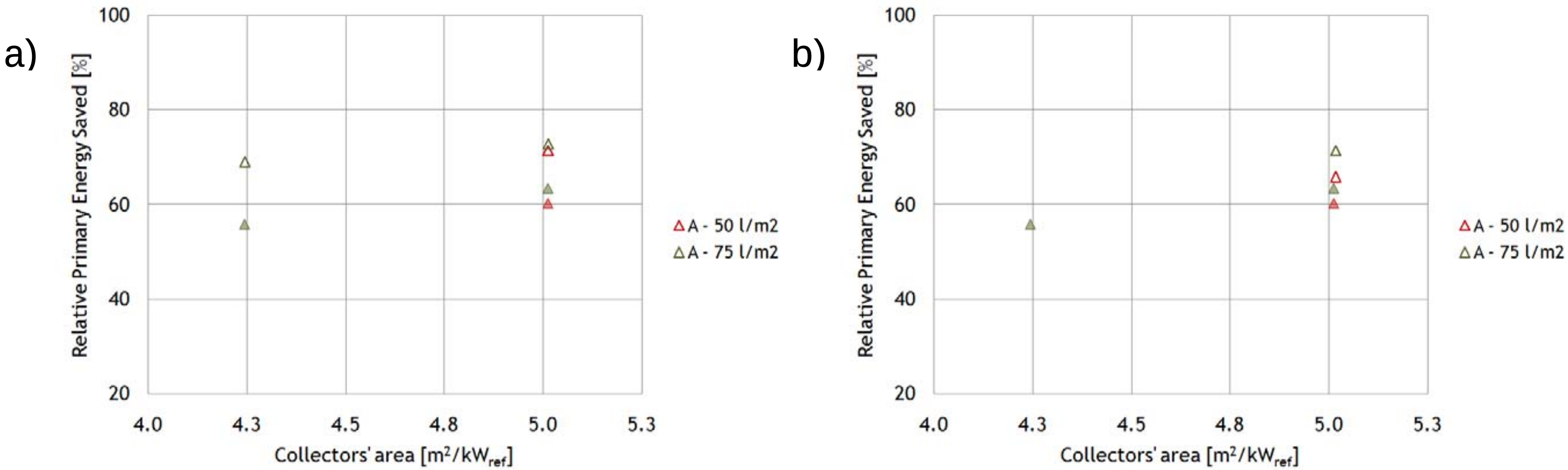

Figure 25 - Naples, a) FP vs ET collectors, b) WCT vs HC rejection system

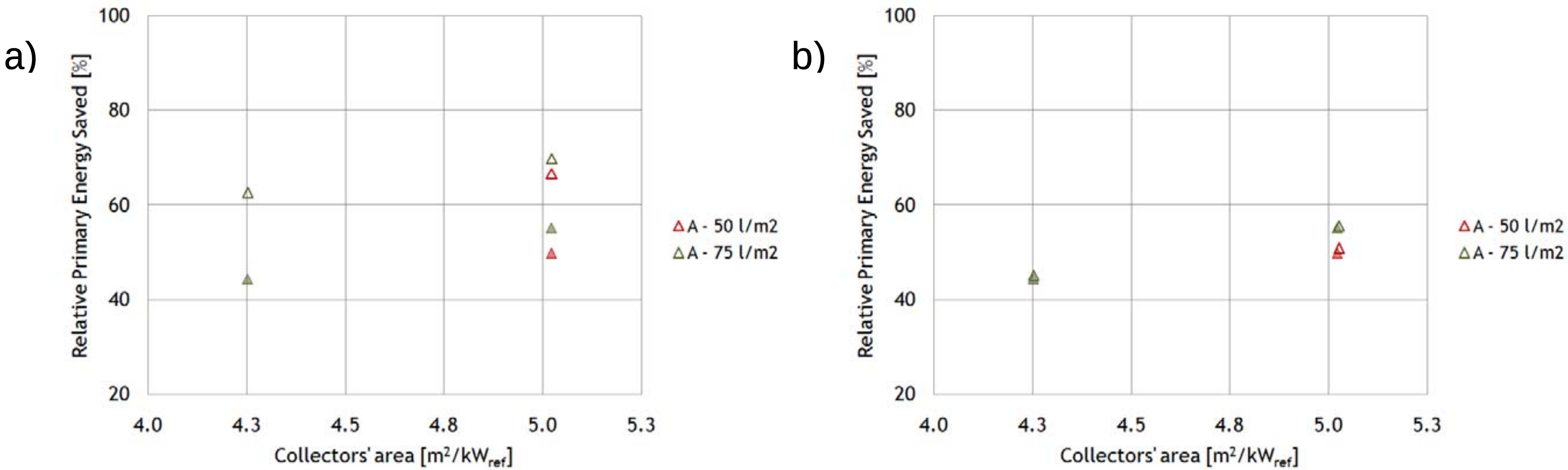

Figure 26 - Toulouse, a) FP vs ET collectors, b) WCT vs HC rejection system

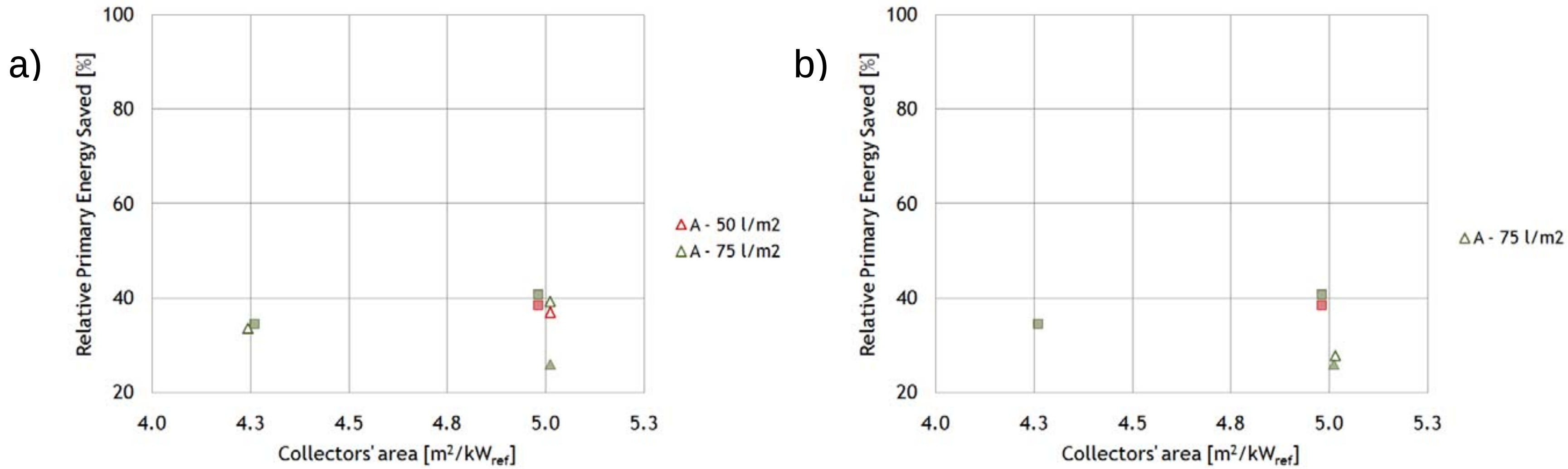

Figure 27 - Strasbourg, a) FP vs ET collectors, b) WCT vs HC rejection

6.9 Total Electric Efficiency - Office

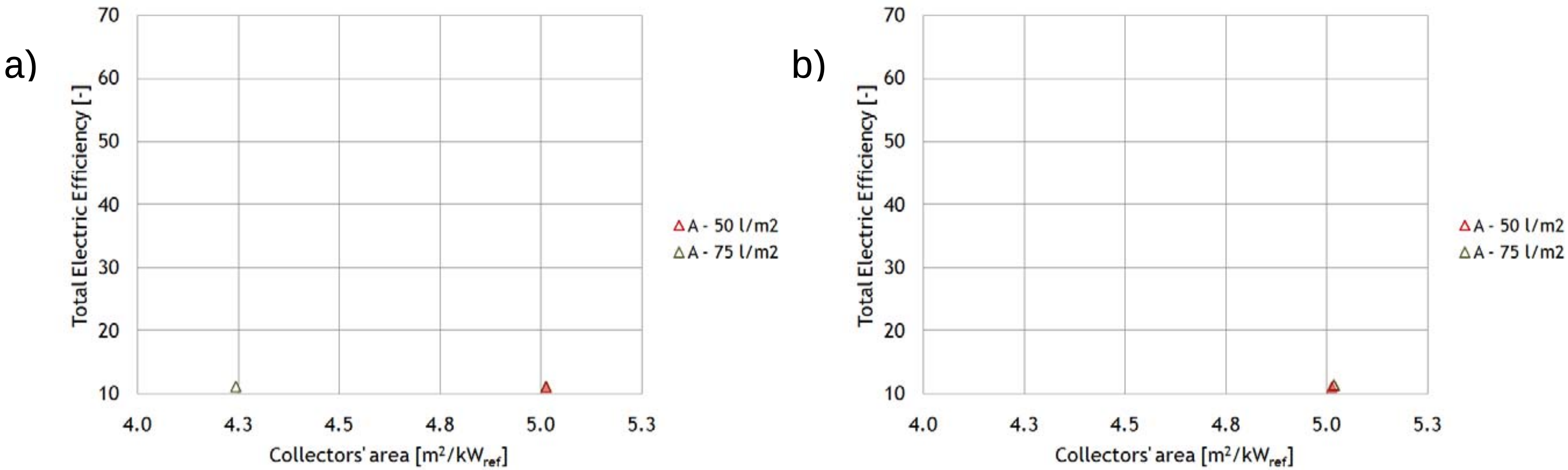

Figure 28 - Naples, a) FP vs ET collectors, b) WCT vs HC rejection system

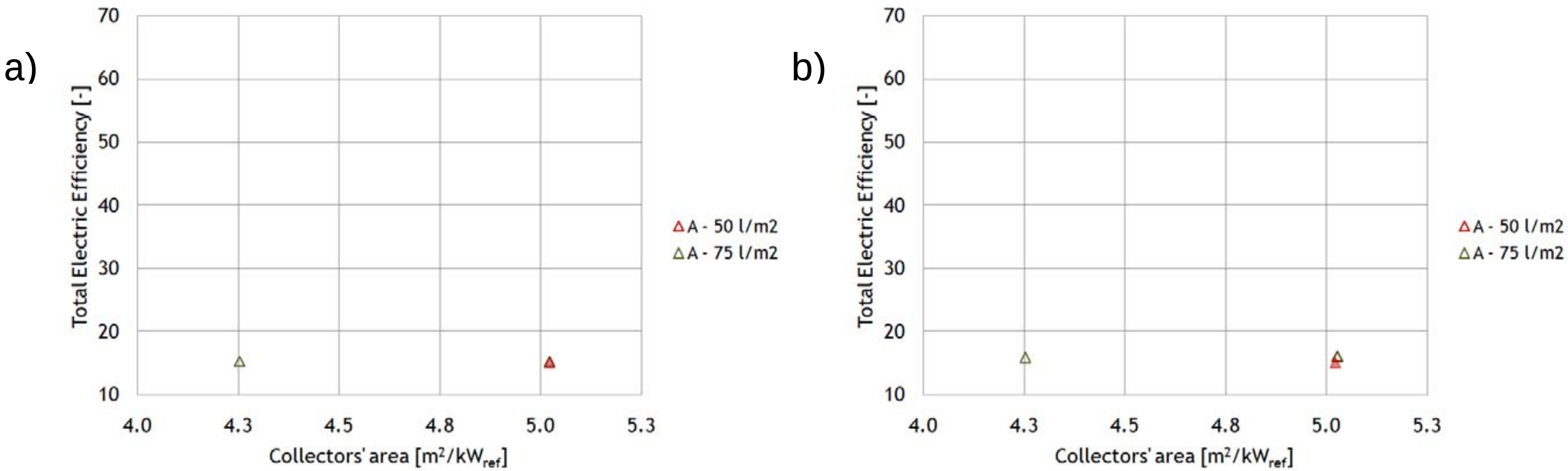

Figure 29 - Toulouse, a) FP vs ET collectors, b) WCT vs HC rejection system

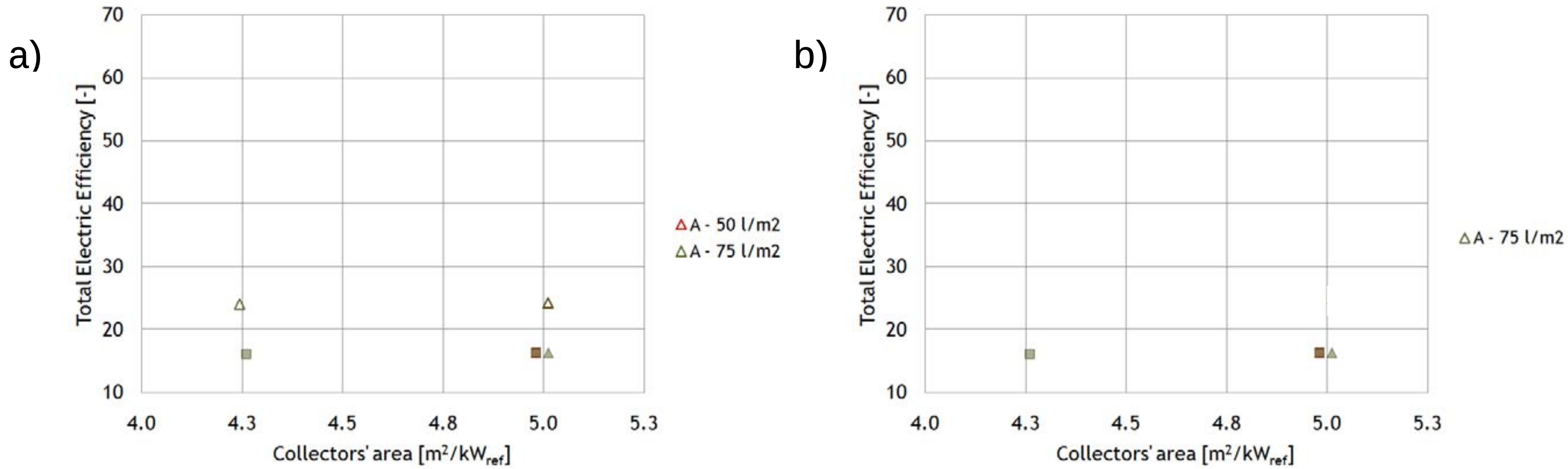

Figure 30 - Strasbourg, a) FP vs ET collectors, b) WCT vs HC rejection

6.10 Gross Solar Yield – Office

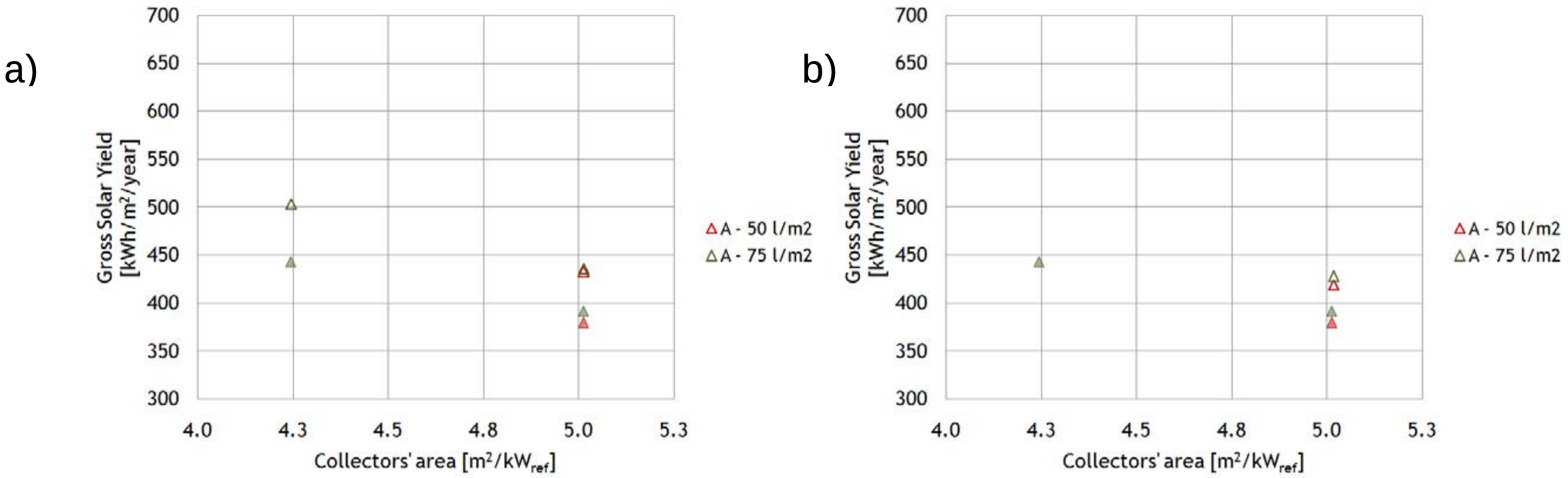

Figure 31 - Naples, a) FP vs ET collectors, b) WCT vs HC rejection system

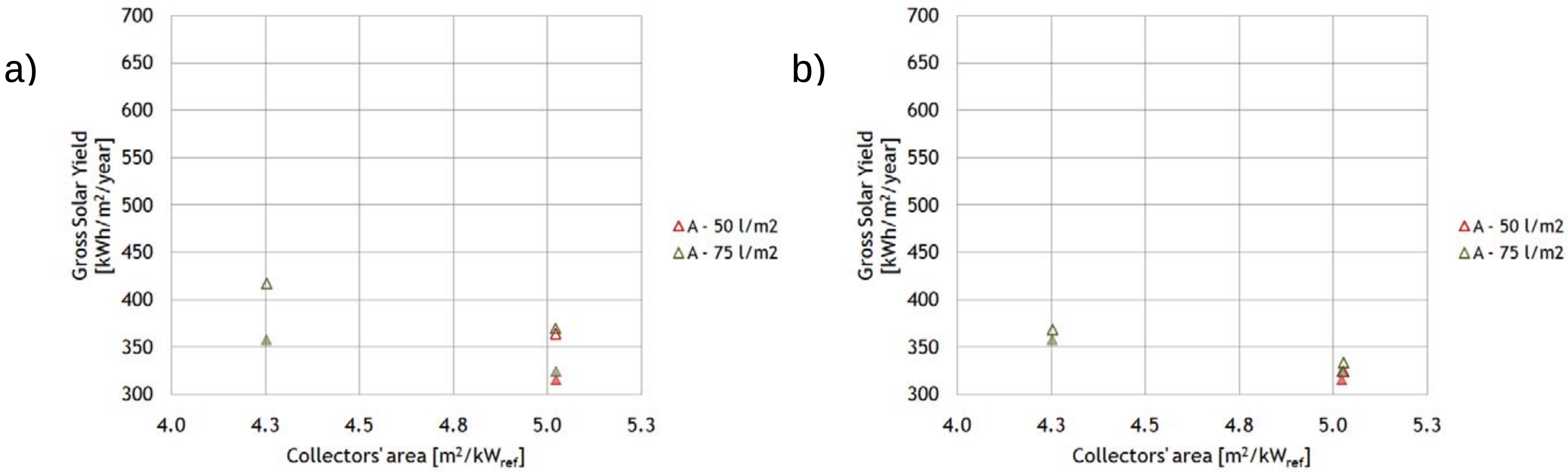

Figure 32 - Toulouse, a) FP vs ET collectors, b) WCT vs HC rejection system

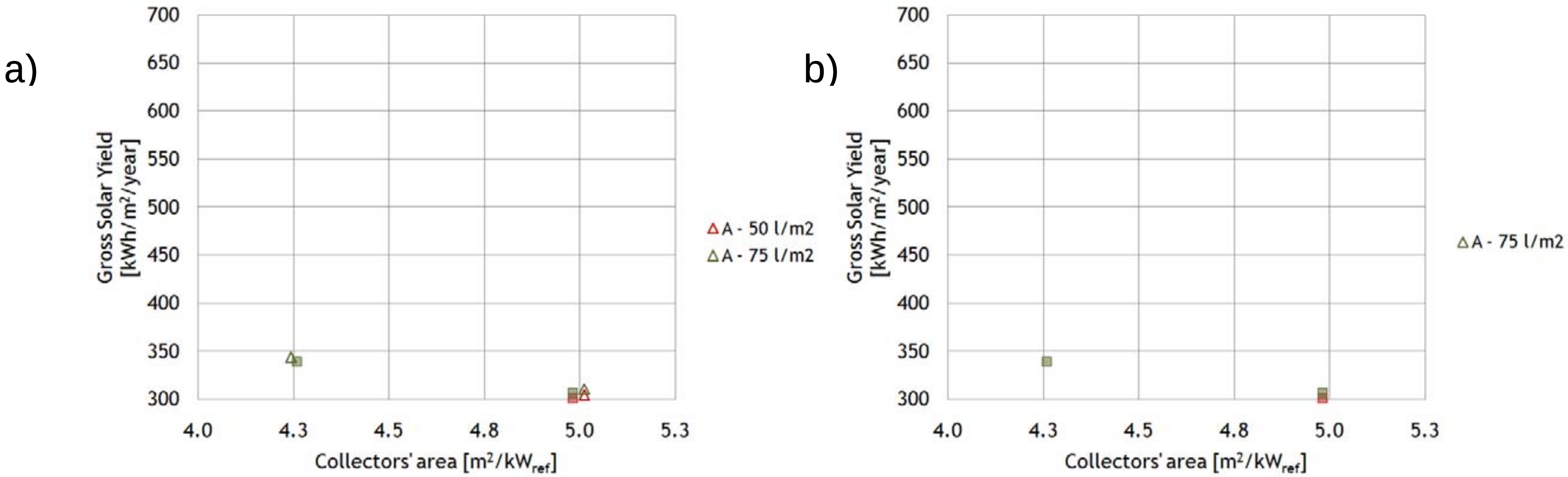

Figure 33 - Strasbourg, a) FP vs ET collectors, b) WCT vs HC rejection

7 Annex III - Standard Configurations Table

Location	Distribution	Collector	Heat Rejection	Building	Chiller	Collectors' Area [m^2/kW_{ref}]	Storage Volume [l/m^2]	Total Solar Fraction [%]	Cooling Solar Fraction [%]	Relative Primary Energy Saved [%]	Electric COP [-]
NAP	FC	ET	HC	R60	A	5.0	49	83	86	66	21
NAP	FC	FP	HC	R60	A	5.0	49	77	79	57	20
NAP	FC	ET	HC	R100	A	5.0	49	76	87	60	25
NAP	FC	FP	HC	R100	A	5.0	49	71	81	53	24
NAP	FC	ET	HC	OFF	A	5.0	49	98	98	77	13
NAP	FC	FP	HC	OFF	A	5.0	49	94	94	66	11
TOU	FC	ET	HC	R60	A	5.0	49	53	81	43	41
TOU	FC	FP	HC	R60	A	5.0	49	48	71	38	39
TOU	FC	ET	HC	R100	A	5.0	49	44	82	37	55
TOU	FC	FP	HC	R100	A	5.0	49	40	72	33	53
TOU	FC	ET	HC	OFF	A	5.0	49	88	95	68	17
TOU	FC	FP	HC	OFF	A	5.0	49	78	85	51	16
STR	FC	ET	HC	OFF	A	5.0	49	57	95	38	28
NAP	CC	ET	HC	R60	A	5.0	50	83	91	69	28
NAP	CC	FP	HC	R60	A	5.0	50	77	84	61	27
NAP	CC	FP	HC	R100	A	4.3	50	64	78	48	34
TOU	CC	ET	HC	R60	A	5.0	50	52	86	44	52
TOU	CC	FP	HC	R60	A	5.0	50	48	76	39	51
NAP	CC	ET	WC	R60	A	5.0	50	82	89	65	23
NAP	CC	FP	WC	R60	A	5.0	50	77	83	57	22
TOU	CC	ET	WC	R60	A	5.0	50	53	87	44	48
TOU	CC	FP	WC	R60	A	5.0	50	48	77	38	47
NAP	FC	ET	WC	R60	A	5.0	50	83	84	61	17
NAP	FC	FP	WC	R60	A	5.0	50	77	78	52	17
NAP	FC	ET	WC	R100	A	5.0	50	76	85	57	21
NAP	FC	FP	WC	R100	A	5.0	50	71	79	50	21
NAP	FC	ET	WC	OFF	A	5.0	50	97	97	71	11
NAP	FC	FP	WC	OFF	A	5.0	50	92	91	60	11
TOU	FC	ET	WC	R60	A	5.0	50	54	82	43	39
TOU	FC	FP	WC	R60	A	5.0	50	50	72	37	38
TOU	FC	ET	WC	R100	A	5.0	50	45	83	37	55
TOU	FC	FP	WC	R100	A	5.0	50	41	72	33	54
TOU	FC	ET	WC	OFF	A	5.0	50	89	95	67	15
TOU	FC	FP	WC	OFF	A	5.0	50	79	85	50	15
STR	FC	ET	WC	OFF	A	5.0	50	60	94	37	24
NAP	CC	ET	HC	R60	A	5.0	74	86	95	74	28
NAP	CC	FP	HC	R60	A	5.0	74	81	89	67	27
NAP	CC	FP	HC	R100	A	4.3	74	67	82	52	34
TOU	CC	ET	HC	R60	A	5.0	74	54	89	46	52
TOU	CC	FP	HC	R60	A	5.0	74	50	79	41	51
TOU	CC	ET	HC	R100	A	5.0	74	45	92	39	55
TOU	CC	FP	HC	R100	A	5.0	74	42	81	36	53
NAP	FC	ET	HC	R60	A	5.0	75	86	90	71	20
NAP	FC	FP	HC	R60	A	5.0	75	81	83	62	19
NAP	FC	ET	HC	R100	A	5.0	75	80	91	65	24
NAP	FC	FP	HC	R100	A	5.0	75	75	85	58	23
NAP	FC	ET	HC	OFF	A	5.0	75	99	99	79	13
NAP	FC	FP	HC	OFF	A	5.0	75	97	96	71	11
TOU	FC	ET	HC	R60	A	5.0	75	55	85	46	41
TOU	FC	FP	HC	R60	A	5.0	75	51	75	41	39
TOU	FC	ET	HC	R100	A	5.0	75	45	86	39	42
TOU	FC	FP	HC	R100	A	5.0	75	42	76	35	41
TOU	FC	ET	HC	OFF	A	5.0	75	90	97	71	17
TOU	FC	FP	HC	OFF	A	5.0	75	81	88	56	16
STR	FC	ET	HC	OFF	A	5.0	75	59	97	40	28
STR	FC	FP	HC	OFF	A	5.0	75	50	85	28	25
NAP	CC	ET	HC	R60	A	4.2	75	80	87	65	28
NAP	CC	FP	HC	R60	A	4.2	75	75	79	57	27
TOU	CC	ET	HC	R60	A	4.2	75	50	83	41	53
TOU	CC	FP	HC	R60	A	4.2	75	46	73	37	52
NAP	CC	ET	WC	R60	A	5.0	75	86	93	71	23
NAP	CC	FP	WC	R60	A	5.0	75	81	88	64	22
TOU	CC	ET	WC	R60	A	5.0	75	55	91	46	48

TOU	CC	FP	WC	R60	A	5.0	75	51	81	41	47
TOU	CC	ET	WC	R100	A	5.0	75	46	93	40	52
TOU	CC	FP	WC	R100	A	5.0	75	43	83	37	51
NAP	CC	ET	WC	R60	A	4.2	75	81	88	64	23
NAP	CC	FP	WC	R60	A	4.2	75	76	81	56	22
NAP	FC	ET	WC	R60	A	5.0	75	87	90	68	17
NAP	FC	FP	WC	R60	A	5.0	75	82	84	60	17
NAP	FC	ET	WC	R100	A	5.0	75	80	90	63	21
NAP	FC	FP	WC	R100	A	5.0	75	76	85	57	21
NAP	FC	ET	WC	OFF	A	5.0	75	97	97	73	11
NAP	FC	FP	WC	OFF	A	5.0	75	93	93	64	11
TOU	CC	ET	WC	R60	A	4.3	75	51	85	41	49
TOU	CC	FP	WC	R60	A	4.3	75	47	75	37	49
TOU	FC	ET	WC	R60	A	5.0	75	56	85	45	39
TOU	FC	FP	WC	R60	A	5.0	75	52	76	40	38
TOU	FC	ET	WC	R100	A	5.0	75	47	87	39	41
TOU	FC	FP	WC	R100	A	5.0	75	43	77	35	40
TOU	FC	ET	WC	OFF	A	5.0	75	91	96	70	15
TOU	FC	FP	WC	OFF	A	5.0	75	82	88	55	15
STR	FC	ET	WC	OFF	A	5.0	75	61	97	39	24
STR	FC	FP	WC	OFF	A	5.0	75	51	82	26	24
NAP	FC	ET	WC	R60	A	4.2	75	81	82	58	17
NAP	FC	FP	WC	R60	A	4.2	75	75	75	49	17
NAP	FC	ET	WC	R100	A	4.2	75	74	83	54	21
NAP	FC	FP	WC	R100	A	4.2	75	69	77	48	21
NAP	FC	ET	WC	OFF	A	4.2	75	96	96	69	11
NAP	FC	FP	WC	OFF	A	4.2	75	90	89	56	11
TOU	FC	ET	WC	R60	A	4.2	75	52	79	40	39
TOU	FC	FP	WC	R60	A	4.2	75	47	67	35	38
TOU	FC	ET	WC	R100	A	4.3	75	42	80	34	56
TOU	FC	ET	WC	OFF	A	4.3	75	86	94	63	15
TOU	FC	FP	WC	OFF	A	4.3	75	75	82	44	15
STR	FC	ET	WC	OFF	A	4.2	75	57	92	34	24
NAP	FC	ET	HC	R60	A	4.2	75	79	81	60	20
NAP	FC	FP	HC	R60	A	4.2	75	74	73	51	19
NAP	FC	ET	HC	R100	A	4.2	75	73	82	55	24
NAP	FC	FP	HC	R100	A	4.2	75	68	75	49	23
NAP	FC	ET	HC	OFF	A	4.2	75	97	97	74	12
TOU	FC	ET	HC	R60	A	4.2	75	50	78	40	40
TOU	FC	FP	HC	R60	A	4.2	75	46	68	36	40
TOU	FC	ET	HC	R100	A	4.3	75	41	79	34	55
TOU	FC	ET	HC	OFF	A	4.3	75	84	92	61	17
TOU	FC	FP	HC	OFF	A	4.3	75	74	82	45	16
STR	FC	ET	HC	OFF	A	4.2	75	54	92	34	26
TOU	FC	ET	WC	R60	B	5.0	50	49	61	27	26
TOU	FC	FP	WC	R60	B	5.0	50	44	50	20	26
TOU	FC	ET	WC	R100	B	5.0	50	42	63	26	35
NAP	CC	ET	WC	R100	B	5.0	51	64	69	35	23
TOU	CC	ET	WC	R60	B	5.0	51	50	68	34	35
TOU	CC	FP	WC	R60	B	5.0	51	45	57	28	35
TOU	CC	ET	WC	R100	B	5.0	51	42	71	32	47
TOU	CC	ET	HC	R60	B	5.0	51	49	66	32	30
TOU	CC	FP	HC	R60	B	5.0	51	44	53	25	30
TOU	CC	ET	HC	R100	B	5.0	51	42	69	30	41
NAP	CC	ET	WC	R100	B	4.3	75	60	63	29	22
TOU	CC	ET	WC	R60	B	4.3	75	47	64	31	35
TOU	CC	FP	WC	R60	B	4.3	75	43	52	26	35
TOU	CC	ET	HC	R60	B	4.3	75	46	61	28	30
TOU	CC	FP	HC	R60	B	4.3	75	42	48	22	30
TOU	FC	ET	WC	R60	B	5.0	75	51	64	30	26
TOU	FC	FP	WC	R60	B	5.0	75	46	53	23	26
TOU	FC	ET	WC	R100	B	5.0	75	43	66	28	35
NAP	CC	ET	WC	R60	B	5.0	75	73	72	41	18
NAP	CC	FP	WC	R60	B	5.0	75	67	63	29	18
NAP	CC	ET	WC	R100	B	5.0	75	68	74	41	22
NAP	CC	FP	WC	R100	B	5.0	75	63	66	33	22
TOU	CC	ET	WC	R60	B	5.0	75	52	72	37	35
TOU	CC	FP	WC	R60	B	5.0	75	47	60	31	35
TOU	CC	ET	WC	R100	B	5.0	75	44	74	33	47
TOU	CC	ET	WC	R100	B	5.0	75	44	74	33	47
TOU	CC	FP	WC	R100	B	5.0	75	40	63	30	47
NAP	CC	ET	HC	R100	B	5.0	75	66	70	35	20

NAP	CC	FP	HC	R100	B	5.0	75	60	62	26	20
TOU	CC	ET	HC	R60	B	5.0	75	51	69	34	30
TOU	CC	FP	HC	R60	B	5.0	75	46	57	28	30
TOU	CC	ET	HC	R100	B	5.0	75	43	72	32	41
TOU	CC	ET	WC	R60	C	5.0	49	53	84	43	36
TOU	CC	FP	WC	R60	C	5.0	49	48	70	36	29
TOU	CC	ET	WC	R100	C	5.0	49	45	86	38	51
TOU	CC	FP	WC	R100	C	5.0	49	42	72	34	43
NAP	FC	ET	DC	R100	C	5.0	49	68	73	41	12
NAP	FC	FP	DC	R100	C	5.0	49	62	64	33	12
TOU	FC	ET	DC	R60	C	5.0	49	51	74	38	22
TOU	FC	FP	DC	R60	C	5.0	49	46	61	33	22
TOU	FC	ET	DC	R100	C	5.0	49	43	73	34	30
NAP	CC	ET	DC	R60	C	5.0	49	76	79	51	14
NAP	CC	FP	DC	R60	C	5.0	49	70	71	42	13
NAP	CC	ET	DC	R100	C	5.0	49	69	81	48	17
NAP	CC	FP	DC	R100	C	5.0	49	64	73	41	17
TOU	CC	ET	DC	R60	C	5.0	49	51	77	40	28
TOU	CC	FP	DC	R60	C	5.0	49	47	66	35	28
TOU	CC	ET	DC	R100	C	5.0	49	44	79	36	39
TOU	CC	FP	DC	R100	C	5.0	49	40	67	33	39
TOU	FC	ET	WC	R60	C	5.0	50	54	83	44	30
TOU	FC	FP	WC	R60	C	5.0	50	49	68	35	24
TOU	FC	ET	WC	R100	C	5.0	50	45	84	39	43
TOU	FC	FP	WC	R100	C	5.0	50	42	69	33	35
NAP	FC	ET	WC	R100	C	5.0	50	76	85	50	12
NAP	FC	FP	WC	R100	C	5.0	50	71	79	43	12
NAP	FC	ET	HC	R100	C	5.0	50	71	78	46	13
NAP	FC	FP	HC	R100	C	5.0	50	66	70	38	12
TOU	FC	ET	HC	R60	C	5.0	50	52	77	40	24
TOU	FC	FP	HC	R60	C	5.0	50	48	66	35	24
TOU	FC	ET	HC	R100	C	5.0	50	44	77	36	34
TOU	FC	FP	HC	R100	C	5.0	50	41	67	32	34
TOU	CC	ET	HC	R60	C	5.0	51	52	79	41	30
TOU	CC	FP	HC	R60	C	5.0	51	48	68	36	30
TOU	CC	ET	HC	R100	C	5.0	51	44	81	37	42
TOU	CC	FP	HC	R100	C	5.0	51	41	71	34	42
NAP	CC	ET	HC	R60	C	5.0	51	79	83	55	14
NAP	CC	FP	HC	R60	C	5.0	51	73	75	46	14
NAP	CC	ET	HC	R100	C	5.0	51	71	85	51	18
NAP	CC	FP	HC	R100	C	5.0	51	66	77	45	17
NAP	CC	ET	WC	R60	C	5.0	51	82	87	57	13
NAP	CC	FP	WC	R60	C	5.0	51	75	78	47	13
NAP	CC	ET	WC	R100	C	5.0	51	74	90	53	17
NAP	CC	FP	WC	R100	C	5.0	51	69	83	47	17
TOU	CC	ET	WC	R60	C	5.0	73	54	87	45	36
TOU	CC	FP	WC	R60	C	5.0	73	51	76	39	30
TOU	CC	ET	WC	R100	C	5.0	73	46	89	40	51
TOU	CC	FP	WC	R100	C	5.0	73	44	80	36	43
NAP	FC	ET	HC	R100	C	5.0	73	75	83	51	12
NAP	FC	FP	HC	R100	C	5.0	73	70	75	43	12
NAP	FC	ET	DC	R100	C	5.0	73	72	77	45	12
NAP	FC	FP	DC	R100	C	5.0	73	66	69	37	11
TOU	FC	ET	DC	R60	C	5.0	73	52	76	40	22
TOU	FC	FP	DC	R60	C	5.0	73	48	64	35	22
TOU	FC	ET	DC	R100	C	5.0	73	44	77	35	30
TOU	FC	FP	DC	R100	C	5.0	73	41	65	32	30
TOU	CC	ET	WC	R60	C	4.3	74	50	81	41	36
TOU	CC	FP	WC	R60	C	4.3	74	47	68	34	30
TOU	CC	ET	WC	R100	C	4.3	74	42	82	36	51
TOU	CC	FP	WC	R100	C	4.3	74	40	71	32	43
NAP	CC	ET	DC	R60	C	5.0	74	80	84	57	13
NAP	CC	FP	DC	R60	C	5.0	74	74	76	48	13
NAP	CC	ET	DC	R100	C	5.0	74	72	86	52	17
NAP	CC	FP	DC	R100	C	5.0	74	68	78	46	16
TOU	CC	ET	DC	R60	C	5.0	74	53	80	42	28
TOU	CC	FP	DC	R60	C	5.0	74	49	68	37	28
TOU	CC	ET	DC	R100	C	5.0	74	45	83	38	39
TOU	CC	FP	DC	R100	C	5.0	74	42	72	35	39
NAP	CC	ET	WC	R60	C	4.3	74	81	87	56	13
NAP	CC	FP	WC	R60	C	4.3	74	75	79	48	13
NAP	CC	ET	WC	R100	C	4.3	74	72	88	51	17
NAP	CC	FP	WC	R100	C	4.3	74	68	82	45	17

TOU	FC	ET	HC	R60	C	4.3	75	50	73	37	24
TOU	FC	FP	HC	R60	C	4.3	75	46	60	32	24
TOU	FC	ET	HC	R100	C	4.3	75	42	73	33	34
NAP	CC	ET	HC	R60	C	5.0	75	82	88	61	14
NAP	CC	FP	HC	R60	C	5.0	75	77	80	52	14
NAP	CC	ET	HC	R100	C	5.0	75	74	89	55	17
NAP	CC	FP	HC	R100	C	5.0	75	70	82	49	17
TOU	CC	ET	HC	R60	C	5.0	75	54	82	43	30
TOU	CC	FP	HC	R60	C	5.0	75	50	72	39	30
TOU	CC	ET	HC	R100	C	5.0	75	46	85	39	42
TOU	CC	FP	HC	R100	C	5.0	75	43	75	36	42
NAP	FC	ET	WC	R100	C	4.3	75	74	84	47	12
NAP	FC	FP	WC	R100	C	4.3	75	68	74	38	12
TOU	FC	ET	HC	R60	C	5.0	75	54	80	42	24
TOU	FC	FP	HC	R60	C	5.0	75	50	69	37	24
TOU	FC	ET	DC	R60	C	4.3	75	48	70	35	21
TOU	FC	FP	DC	R60	C	4.3	75	45	58	31	21
TOU	FC	ET	HC	R100	C	5.0	75	45	80	37	34
TOU	FC	FP	HC	R100	C	5.0	75	43	70	34	34
TOU	FC	ET	DC	R100	C	4.3	75	41	70	32	30
NAP	CC	ET	HC	R60	C	4.3	75	75	77	49	14
NAP	CC	FP	HC	R60	C	4.2	75	69	69	41	14
NAP	CC	ET	HC	R100	C	4.2	75	67	79	46	17
NAP	CC	FP	HC	R100	C	4.2	75	63	70	39	17
NAP	CC	ET	WC	R60	C	5.0	76	87	95	66	13
NAP	CC	FP	WC	R60	C	5.0	76	83	91	59	13
NAP	CC	ET	WC	R100	C	5.0	76	78	97	60	17
NAP	CC	FP	WC	R100	C	5.0	76	75	91	54	17
NAP	FC	ET	HC	R100	C	4.3	76	66	70	38	12
NAP	FC	FP	HC	R100	C	4.3	76	61	62	31	12
NAP	FC	ET	WC	R100	C	5.0	76	82	94	59	12
NAP	FC	FP	WC	R100	C	5.0	76	78	89	53	12
TOU	FC	ET	WC	R60	C	5.0	76	56	86	46	30
TOU	FC	FP	WC	R60	C	5.0	76	52	74	39	24
TOU	FC	ET	WC	R100	C	5.0	76	47	88	40	43
TOU	FC	FP	WC	R100	C	5.0	76	44	77	36	35
NAP	CC	ET	DC	R60	C	4.3	76	74	75	47	13
NAP	CC	FP	DC	R60	C	4.3	76	68	67	39	13
NAP	CC	ET	DC	R100	C	4.3	76	66	77	44	16
NAP	CC	FP	DC	R100	C	4.3	76	62	69	38	16
TOU	CC	ET	DC	R60	C	4.3	76	49	74	37	28
TOU	CC	FP	DC	R60	C	4.3	76	45	61	33	28
TOU	CC	ET	DC	R100	C	4.3	76	41	75	33	39
NAP	FC	ET	DC	R100	C	4.3	77	64	67	34	11
TOU	FC	ET	WC	R60	C	4.3	77	52	80	41	30
TOU	FC	FP	WC	R60	C	4.3	77	48	66	34	24
TOU	FC	ET	WC	R100	C	4.3	77	43	81	36	43
TOU	CC	ET	HC	R60	C	4.3	78	50	77	39	30
TOU	CC	FP	HC	R60	C	4.3	78	46	65	34	30
TOU	CC	ET	HC	R100	C	4.3	78	42	79	35	42
NAP	CC	ET	WC	R60	D	5.0	50	80	82	50	20
NAP	CC	FP	WC	R60	D	5.0	50	74	76	40	19
NAP	CC	ET	WC	R100	D	5.0	50	73	83	46	24
NAP	CC	FP	WC	R100	D	5.0	50	67	77	38	23
TOU	CC	ET	WC	R60	D	5.0	50	57	86	39	36
TOU	CC	FP	WC	R60	D	5.0	50	52	80	33	34
TOU	CC	ET	WC	R100	D	5.0	50	46	87	33	47
TOU	CC	FP	WC	R100	D	5.0	50	42	82	29	46
NAP	CC	ET	HC	R60	D	5.0	51	78	80	46	17
NAP	CC	FP	HC	R60	D	5.0	51	73	75	36	16
NAP	CC	ET	HC	R100	D	5.0	51	72	82	42	20
NAP	CC	FP	HC	R100	D	5.0	51	67	76	35	19
TOU	CC	ET	HC	R60	D	5.0	51	56	84	36	29
TOU	CC	FP	HC	R60	D	5.0	51	51	78	30	28
TOU	CC	ET	HC	R100	D	5.0	51	45	85	30	38
TOU	CC	FP	HC	R100	D	5.0	51	41	80	26	37
NAP	CC	ET	WC	R60	D	4.2	75	75	77	44	20
NAP	CC	FP	WC	R60	D	4.2	75	71	72	36	19
NAP	CC	ET	WC	R100	D	4.2	75	69	78	41	24
NAP	CC	FP	WC	R100	D	4.2	75	65	73	35	23
TOU	CC	ET	WC	R60	D	4.2	75	54	83	36	35
TOU	CC	FP	WC	R60	D	4.2	75	50	77	31	34

TOU	CC	ET	WC	R100	D	4.2	75	44	85	30	47
TOU	CC	FP	WC	R100	D	4.2	75	41	80	27	45
NAP	CC	ET	WC	R60	D	5.0	75	82	84	56	20
NAP	CC	FP	WC	R60	D	5.0	75	78	80	48	19
NAP	CC	ET	WC	R100	D	5.0	75	77	85	52	24
NAP	CC	FP	WC	R100	D	5.0	75	72	80	45	23
TOU	CC	ET	WC	R60	D	5.0	75	60	88	42	35
TOU	CC	FP	WC	R60	D	5.0	75	55	82	36	34
TOU	CC	ET	WC	R100	D	5.0	75	49	89	36	47
TOU	CC	FP	WC	R100	D	5.0	75	45	84	32	45
NAP	CC	ET	HC	R60	D	5.0	75	81	83	52	17
NAP	CC	FP	HC	R60	D	5.0	75	77	78	43	16
NAP	CC	ET	HC	R100	D	5.0	75	76	84	48	20
NAP	CC	FP	HC	R100	D	5.0	75	71	80	42	19
TOU	CC	ET	HC	R60	D	5.0	75	59	86	39	29
TOU	CC	FP	HC	R60	D	5.0	75	54	80	34	28
TOU	CC	ET	HC	R100	D	5.0	75	48	89	33	38
TOU	CC	FP	HC	R100	D	5.0	75	44	82	29	37
NAP	CC	ET	HC	R60	D	4.3	76	74	75	40	16
NAP	CC	FP	HC	R60	D	4.3	76	70	71	31	16
NAP	CC	ET	HC	R100	D	4.3	76	68	76	37	19
NAP	CC	FP	HC	R100	D	4.3	76	64	72	31	19
TOU	CC	ET	HC	R60	D	4.3	76	54	81	33	29
TOU	CC	FP	HC	R60	D	4.3	76	49	75	28	28
TOU	CC	ET	HC	R100	D	4.3	76	43	84	28	37
NAP	FC	FP	WC	R60	E	5.0	50	83	83	51	12
NAP	FC	FP	WC	R100	E	5.0	50	79	84	52	14
TOU	FC	FP	WC	R60	E	5.0	50	62	90	47	26
TOU	FC	FP	WC	R100	E	5.0	50	52	91	41	36
STR	FC	FP	WC	OFF	E	5.0	50	67	96	39	16
NAP	CC	FP	WC	R60	E	5.0	50	85	89	63	16
NAP	CC	FP	WC	R100	E	5.0	50	78	90	59	20
TOU	CC	FP	WC	R60	E	5.0	50	61	93	49	32
TOU	CC	FP	WC	R100	E	5.0	50	51	95	43	44
NAP	CC	FP	WC	R60	E	4.3	75	86	91	65	17
NAP	CC	FP	WC	R100	E	4.3	75	78	92	59	21
TOU	CC	FP	WC	R60	E	4.3	75	59	92	47	33
TOU	CC	FP	WC	R100	E	4.3	75	49	94	41	46
NAP	CC	FP	WC	R60	E	5.0	75	90	95	72	17
NAP	CC	FP	WC	R100	E	5.0	75	82	96	66	21
TOU	CC	FP	WC	R60	E	5.0	75	64	96	52	32
TOU	CC	FP	WC	R100	E	5.0	75	53	97	45	44
NAP	FC	FP	WC	R60	E	5.0	75	89	90	62	12
NAP	FC	FP	WC	R100	E	5.0	75	84	91	62	15
TOU	FC	FP	WC	R60	E	5.0	75	65	92	51	26
TOU	FC	FP	WC	R100	E	5.0	75	54	94	44	36
STR	FC	FP	WC	OFF	E	5.0	75	68	97	41	16
NAP	FC	FP	WC	R60	E	4.3	75	85	86	54	12
NAP	FC	FP	WC	R100	E	4.3	75	79	86	54	14
TOU	FC	FP	WC	R60	E	4.3	75	60	89	45	26
TOU	FC	FP	WC	R100	E	4.3	75	50	90	39	36
STR	FC	FP	WC	OFF	E	4.3	75	64	94	35	16