hi-tech photovoltaic

c o n c e n t r a t o r s

Shadow Analysis

Test Report

Horizontal E-W Trackers

Scope:

Evaluation of the energy losses due shading for different relative distances between trackers installation in Lisbon.

Prepared	Verified	Approved
Artur Borges 04-12-2009		

Objective:

The objective of this report is to supply relevant data relative to the influence of the relative distance between trackers in the losses caused by mutual shading in order to allow an installation pattern and economical feasibility decision for the usage of horizontal single axis trackers.

Shadow time limits:

The temporal boundaries were determined visually, using the shadow simulation feature of the ShadowCalc tool. This procedure allowed to acess the time limits for the energy integrations.

The times defined for the reference days (March 20th, June 21st, September 20th and December 21st), as well as the respective visual representations are presented in the tables below:

Table 1 - Time limits for March 20th

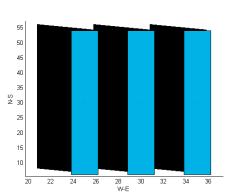
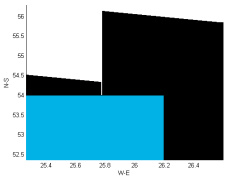
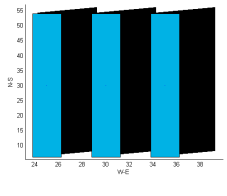
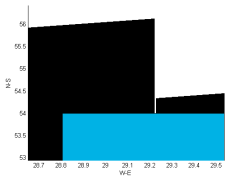
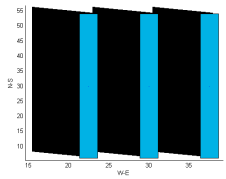
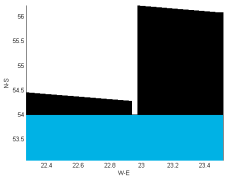
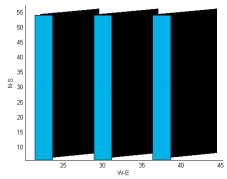
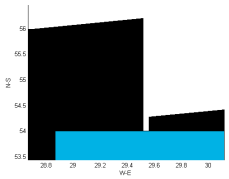
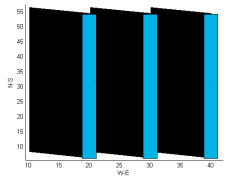
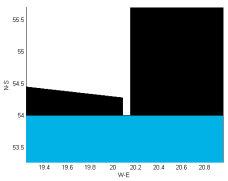
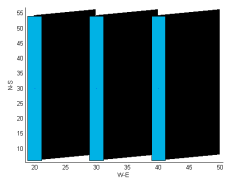
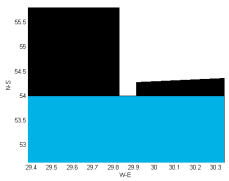
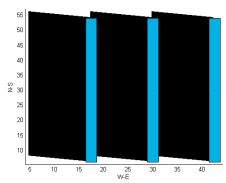
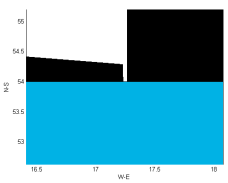
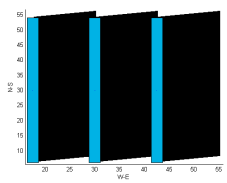
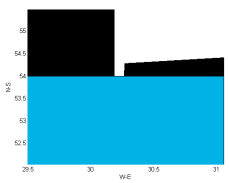
	Full view	Detail view	Full view	Detail view
5 m				
	09:59		15:32	
7.5 m				
	08:48		16:43	
10 m				
	08:13		17:18	
12.5 m				
	07:53		17:38	

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Table 2 - Time limits for June 21st

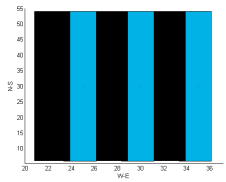
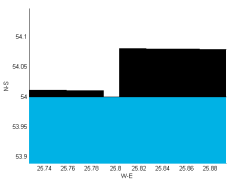
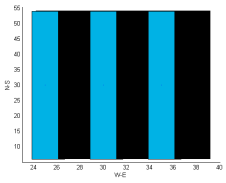
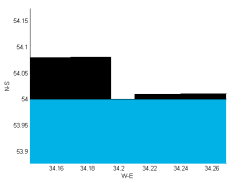
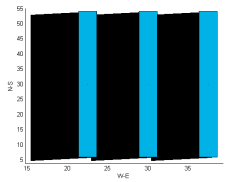
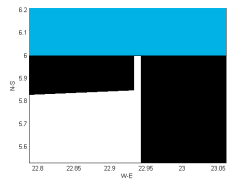
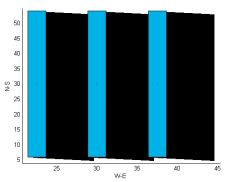
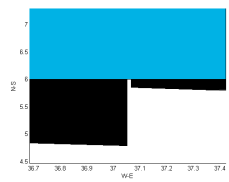
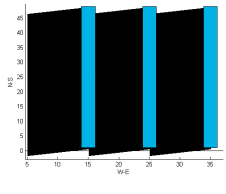
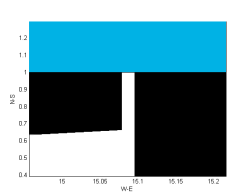
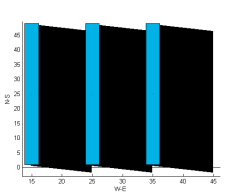
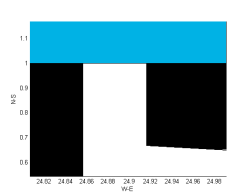
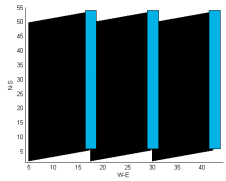
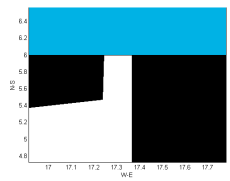
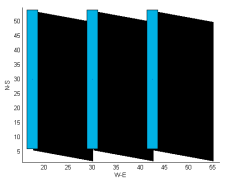
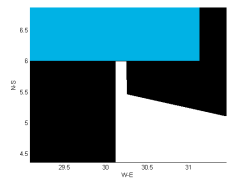
	Full view	Detail view	Full view	Detail view
5 m				
	08:59		16:18	
7.5 m				
	07:29		17:48	
10 m				
	06:56		18:46	
12.5 m				
	06:27		18:50	

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Table 3 - Time limites for September 20th

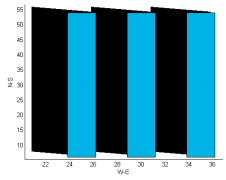
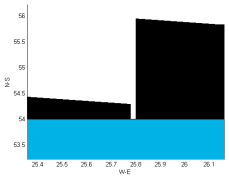
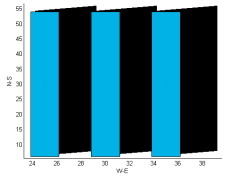
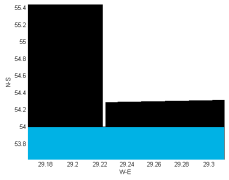
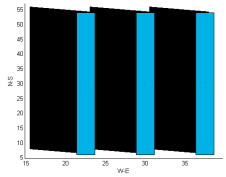
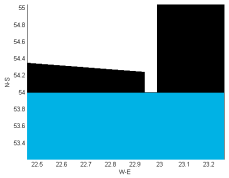
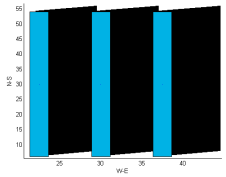
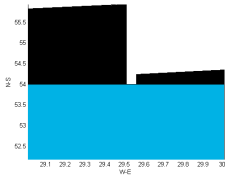
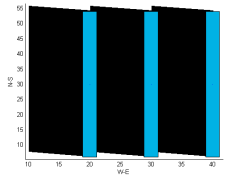
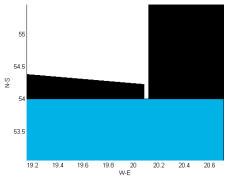
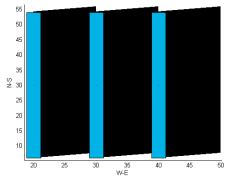
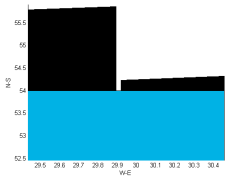
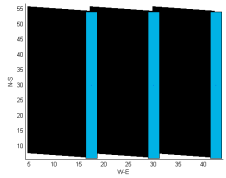
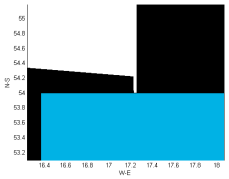
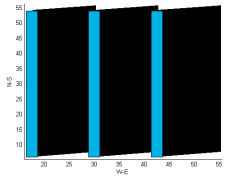
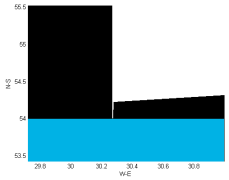
	Full view	Detail view	Full view	Detail view
5 m				
	09:41		15:24	
7.5 m				
	08:28		16:33	
10 m				
	07:52		17:09	
12.5 m				
	07:32		17:29	

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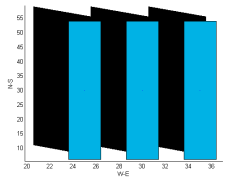
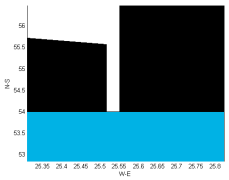
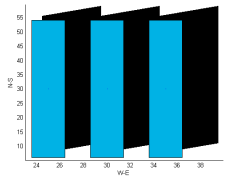
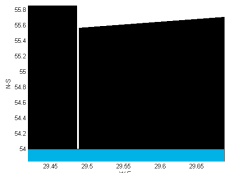
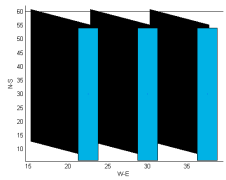
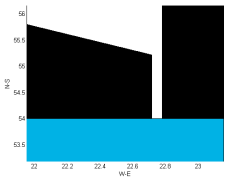
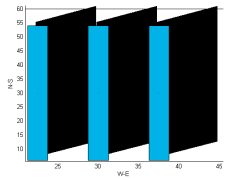
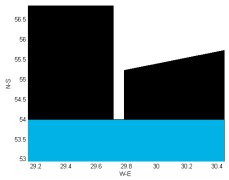
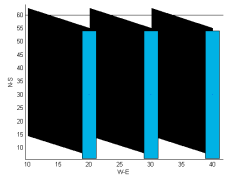
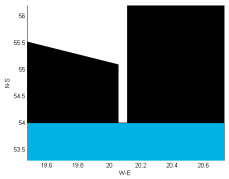
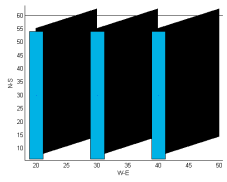
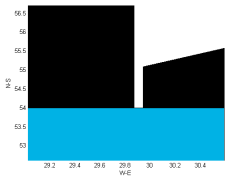
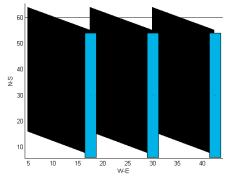
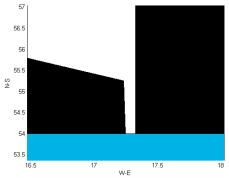
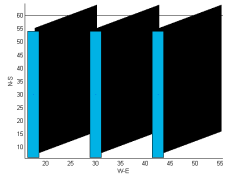
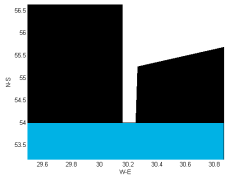
Table 4 - Time limits for December 21st

	Full view	Detail view	Full view	Detail view
5 m				
	10:30		14:41	
7.5 m				
	09:41		15:29	
10 m				
	09:16		15:54	
12.5 m				
	08:59		16:11	

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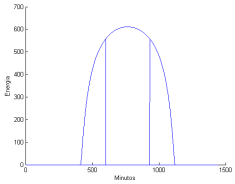
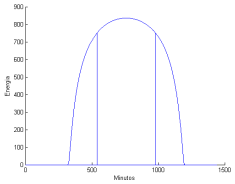
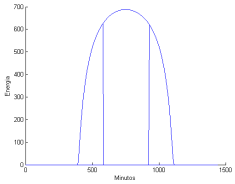
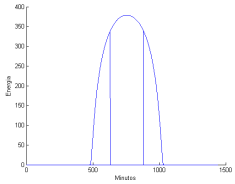
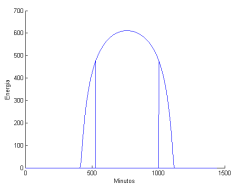
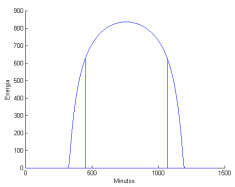
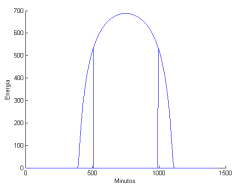
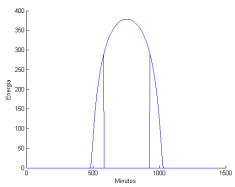
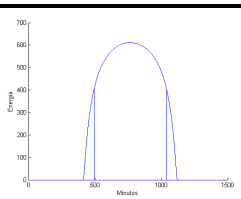
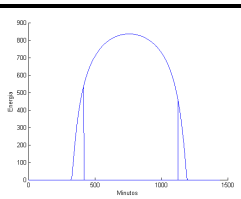
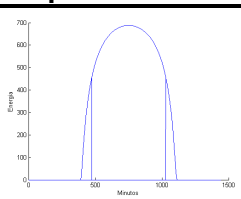
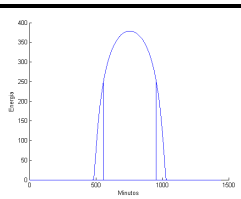
Energy Analysis:

The values presented in the tables below refer to accumulative daily energy values referring to the reference days of the year. Four different relative distances between trackers were evaluated for each of the reference days.

	March 20th	June 21st	September 20th	December 21st
5 m				
$E_{Morning}$	7,21 E4	1,12 E5	8,28 E4	3,30 E4
$E_{Afternoon}$	7,22 E4	1,12 E5	8,02 E4	3,27 E4
E_{Lost} [Wh/m^2]	1,44 E5	2,24 E5	3,91 E5	6,56 E4
E_{Lost} [%]	42,2%	38,7%	41,6%	41,7%

	March 20th	June 21st	September 20th	December 21st
7,5 m				
$E_{Morning}$	3,50 E4	4,91 E4	3,40 E4	1,74 E4
$E_{Afternoon}$	3,52 E4	4,92 E4	3,98 E4	1,60 E4
E_{Lost} [Wh/m^2]	7,02 E4	9,83 E4	7,97 E4	3,50 E4
E_{Lost} [%]	20,5%	17,0%	20,3%	22,2%

	March 20th	June 21st	September 20th	December 21st
10 m				
$E_{Morning}$	1,95 E4	2,98 E4	2,19 E4	1,10 E4
$E_{Afternoon}$	1,96 E4	2,10 E4	2,18 E4	1,02 E4
E_{Lost} [Wh/m^2]	3,91 E4	3,10 E4	4,38 E4	2,12 E4
E_{Lost} [%]	11,4%	8,15%	11,17%	13%

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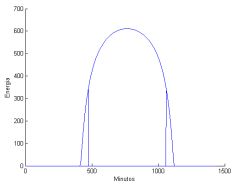
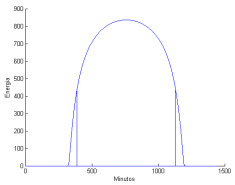
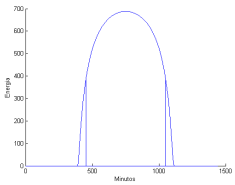
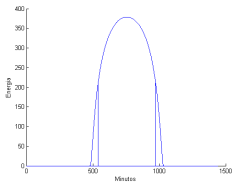
	March 20th	June 21st	September 20th	December 21st
12,5 m				
$E_{Morning}$	1,19 E4	1,55 E4	1,34 E4	6,64 E3
$E_{Afternoon}$	1,20 E4	1,56 E4	1,33 E4	6,65 E3
$E_{Lost\ [Wh/m^2]}$	2,39 E4	3,10 E4	2,68 E4	1,57 E5
$E_{Lost\ [\%]}$	7,0%	5,4%	6,84%	8,46%

Conclusions:

From the results obtain, it's possible to see that the effect of the relative distance does not progress linearly, which means that the cost of spreading the tracker more than the 12,5m maybe will not compensate the system energy gains. On the other hand, the 5m arrangement conducts to a great amount of losses due shading as it can be seen on the table below:

	March 20th	June 21st	September 20th	December 21st	Average Annual Losses[1]
5m	1,44 E5	2,24 E5	3,91 E5	3,30 E4	60,4%
7,5m	7,02 E4	9,83 E4	7,97 E4	3,50 E4	21,6%
10m	3,91 E4	3,10 E4	4,38 E4	2,12 E4	10.3%
12,5m	2,39 E4	3,10 E4	2,68 E4	1,57 E5	7.42%

So, a compromise in the middle of these two extremes (such as 7,5m or 10m) is probably the most viable solution.

[1] Average Annual Losses = $\frac{\sum Losses}{\sum Total\ Energy}$

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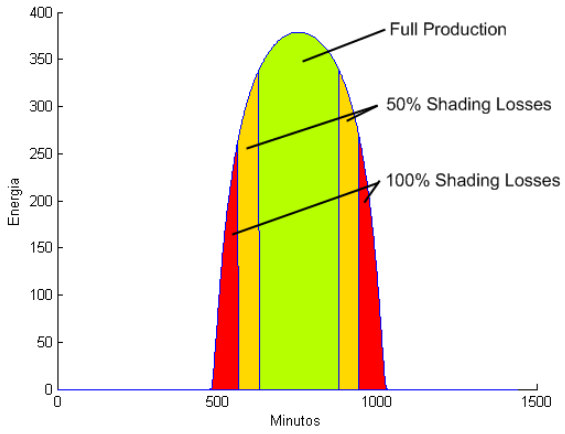
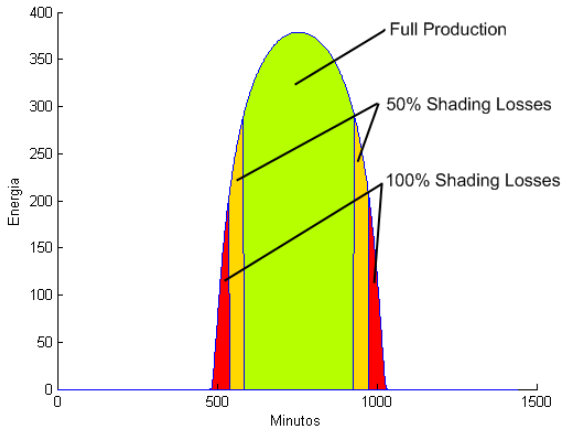
Anex I:

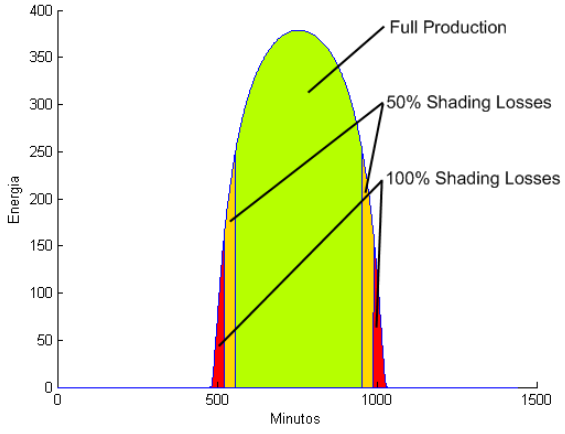
Assuming that the systems are able to produce some energy while shaded up to 50% of its area, new plots were made in order to access that scenario. The figures and the table presented below represent the comparison of the previous results with the new simulation results for the December 21st.



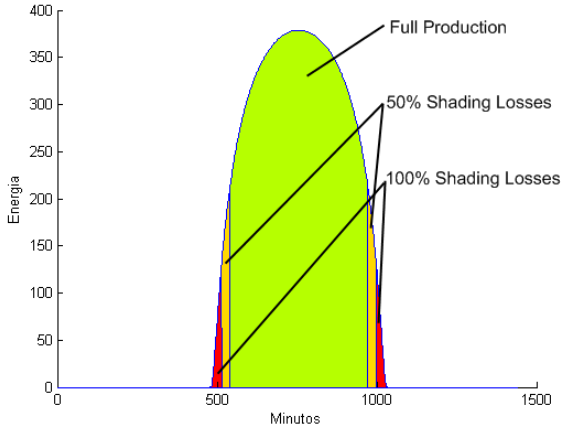
5m



7.5m



10m



12.5m

	$E_{Morning}$		$E_{Afternoon}$		E_{Lost} [Wh/m^2]		E_{Lost} [%]	
	100% S.L.	**50% S.L.**	**100% S.L.**	**50% S.L.**	**100% S.L.**	**50% S.L.**	**100% S.L.**	**50% S.L.**
5m	3,30 E4	1,27 E4	3,27 E4	1,34 E4	6,56 E4	2,61 E4	41,7%	16,6%
7.5m	1,74 E4	6,00 E3	1,60 E4	6,20 E3	3,50 E4	1,20 E4	22,2%	7,8%
10m	1,10 E4	3,10 E3	1,02 E4	3,20 E3	2,12 E4	6,30 E3	13,0%	4,0%
12.5m	6,64 E3	1,92 E3	6,65 E3	1,93 E3	1,57 E5	3,85 E3	8,5%	2,4%

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