Design of Solar Thermal Systems – Calculation Methods

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Dimensioning - Example

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Hotel

80 rooms (120 beds in single/double rooms) **B = 120**

80 % occupation (**O**) – 96 persons on average

Hot water demand per person (**DHW**): medium demand (see table for hotels)

Hot water demand kitchen: 160 litre/day (**HWD_K**):

Cold water:	20°C
Hot water (storage)	55°C
Hot water at shower:	50°C

Average Solar Radiation: May - July (for high solar fractions: 75 – 80%)

Storage Volume "V_{ST}"

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$$V_{St} = [(B * O * DHW) + HWD_K] * 1.2$$

$$= [(120 * 0.8 * 40) + 160] \times 1.2 = \underline{4{,}800 \text{ liter}}$$

Not all sizes are available: **5,000 liter**

→ **m = 5 m³**

Energy Demand "Q"

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$$Q_s = (m\ C_p)\ \Delta T$$

Q_s	total heat capacity of the storage tank	[kWh]
m	volume of the storage tank	[m³]
C_p	heat capacity of water	[1.16 kWh/m³K]
ΔT	temperature difference - hot water temperature and cold water temperature	[K]

$$Q_S = 5 \bullet 1.16 \bullet 35 = \underline{203\ kWh}$$

SOLAR RADIATION - 3

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Average monthly and yearly values of global solar radiation on a horizontal surface in kWh/m²

Cape Town – Global radiation in kWh/m²

Jan	Feb	March	April	May	June	July	Aug	Sept	Oct		Dec	Year
124	186	163	108	81	67	75	95	124		198	231	1624

Compare with Johannesburg!

S_R = (81 + 67 + 75) kWh / 92 days = 2.42 kWh/day.m²

SOLAR RADIATION - 3

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Average monthly and yearly values of global solar radiation on a horizontal surface in kWh/m²

Johannesburg – Global radiation in kWh/m²

Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
197	169	165	142	128	112	121	146	162	186	188	201	1917

S_R = (128 +112+121) kWh / 92 days = 3.92 kWh/m². day

Collector Yield "C_Y"

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$C_Y = S_R \bullet \eta_K \bullet \eta_{SYS}$

η_K... efficiency of the collector (500 W)

η_{SYS} ... efficiency of the system (piping, storage...)

$C_Y = 2.42 \bullet 0{,}61 \bullet 0{,}85 = \underline{1.25\ kWh/m^2}$

Collector efficiency curve

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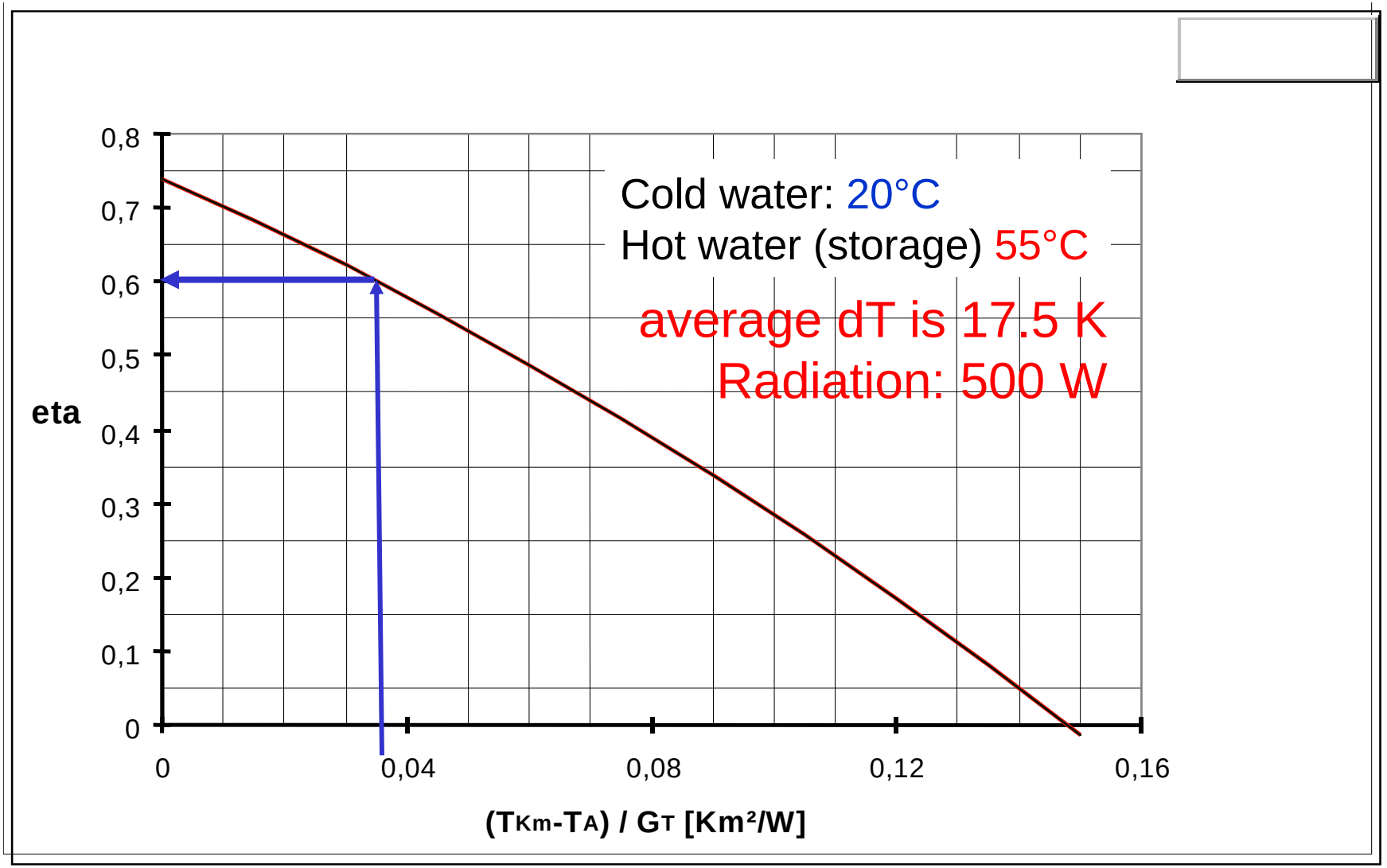

Collector Array "C_A"

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$C_A = Q / C_Y$

C_A = 203 / 1.25 = 162 m²

100% solar fraction!

80% Solar fraction ~ 130 m² (91 kW)

Orientation of collectors

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Collector orientation

As a general rule, the collector should be facing the equator. That means in the southern hemisphere **facing north** and in the northern hemisphere facing south.

Tilt of collectors

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Latitude [degree]	Best collector tilt in:					
	June	Orientation	**Sept./M**	Orientation	**December**	Orientation
50 N	26.5	S		S	73.5	S
40 N	16.5		40	S	63.5	S
30 N	6.5		30	S	53.5	S
20 N		N	20	S	43.5	S
15 N	8.	N	15	S	38.5	S
10 N	13.5	N	10	S	33.5	S
Equator = 0	**23.5**	**N**	**0**	**-**	**23.5**	**S**
10 S	33.5	N	10	N	13.5	S
15 S	38.5	N	15	N	8.5	S
20 S	43.5	N	20	N	3.5	S
30 S	53.5	N	30	N	6.5	N
40 S	63.5	N	40	N	16.5	N
50 S	73.5	N	50	N	26.5	N

Latitude Cape Town: - 34

Tilt and orientation of collectors (Cape Town)

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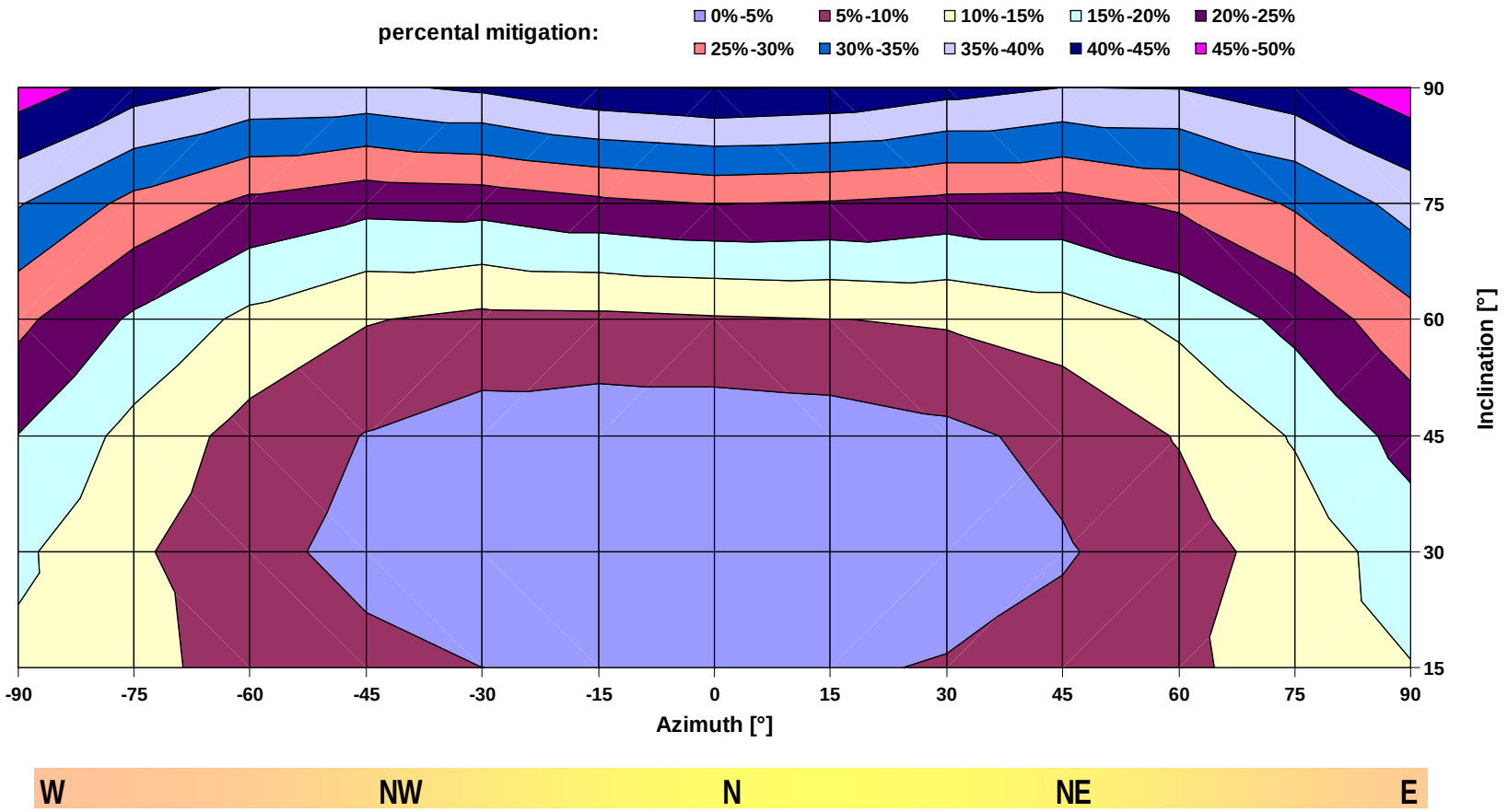

Tilt and orientation of collectors

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Variations of the annual solar yield in [kWh/m²·a] in Cape Town related to different orientations and azimuth angles. The calculations are based on a solar hot water system with 3m² collector area and a daily hot water consumption of 150 litre. Calculated solar fraction ~ 97%

Azimuth [°]		Inclination [°]					
		15	30	45	60	75	90
W	-90	820.8	802.0	763.6	703.4	616.1	499.5
	-75	848.2	850.7	825.7	770.0	681.5	550.9
	-60	872.1	891.0	875.0	822.0	726.3	579.0
NW	-45	891.6	921.5	907.8	855.2	748.3	582.5
	-30	905.8	941.3	928.5	869.7	744.7	563.7
	-15	913.8	951.6	936.3	869.1	726.0	535.1
N	0	916.5	953.5	936.4	863.5	714.0	521.2
	15	912.3	947.5	930.3	859.3	718.5	528.4
	30	902.0	933.7	916.5	852.7	730.1	553.2
NE	45	886.4	910.6	893.0	834.8	730.4	572.8
	60	865.9	878.8	855.2	799.8	707.4	570.7
	75	840.9	837.0	806.5	748.5	661.7	544.4
E	90	812.4	788.3	745.1	681.9	601.2	496.9

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Dimensioning – Example 1

Small hot water system

Hot water demand: 500 l/day

Cold water: 20°C

Hot water (storage) 60°C

Dimensioning for 100% solar fraction

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Dimensioning – Example 2

Industry – Bottle Washing

Hot water demand: 10.000 l/day

Cold water: 25°C

Hot water (storage) 80°C

Dimensioning for 70% solar fraction

Tilt and orientation of collectors (Joburg)

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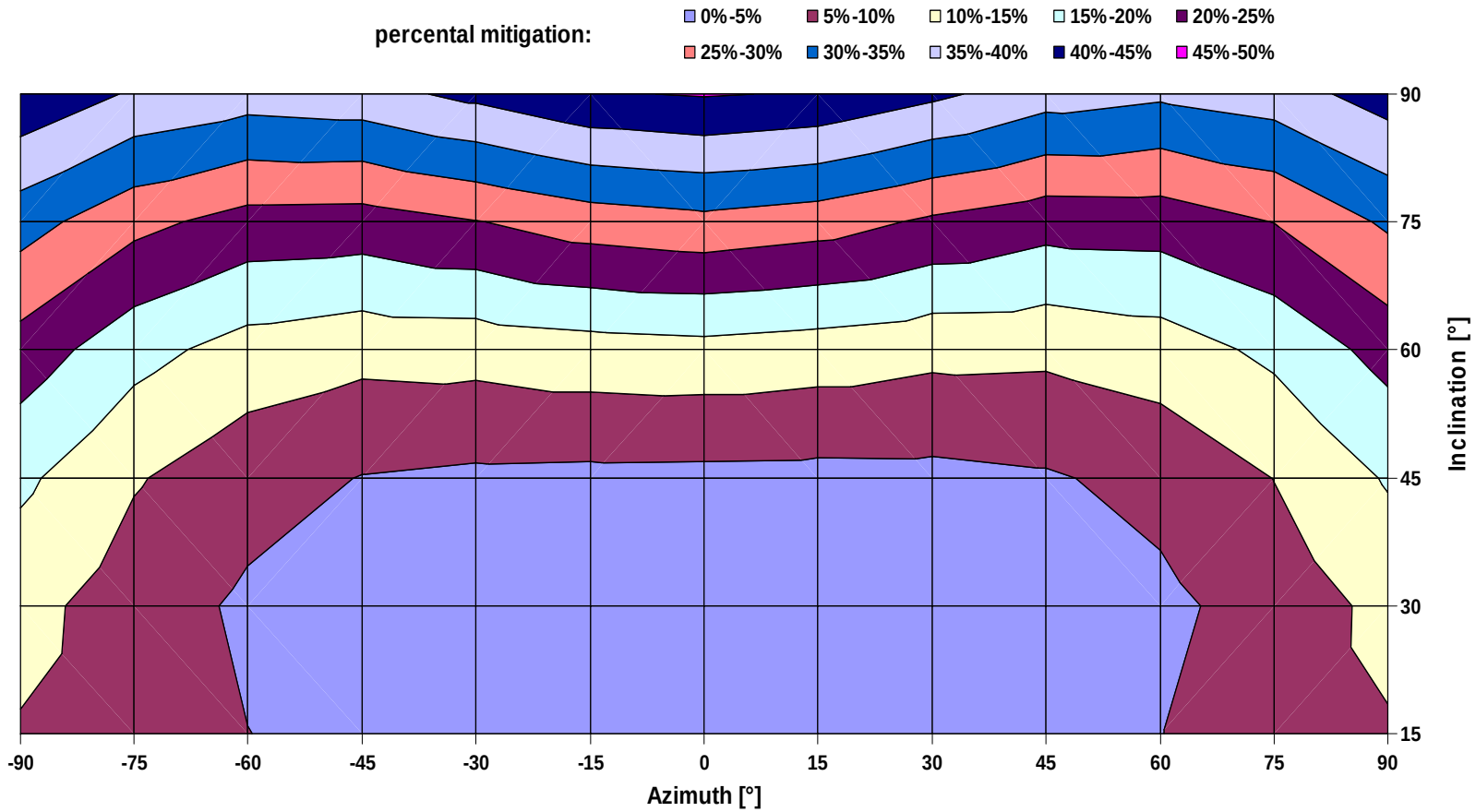

Tilt and orientation of collectors (Windhoek)

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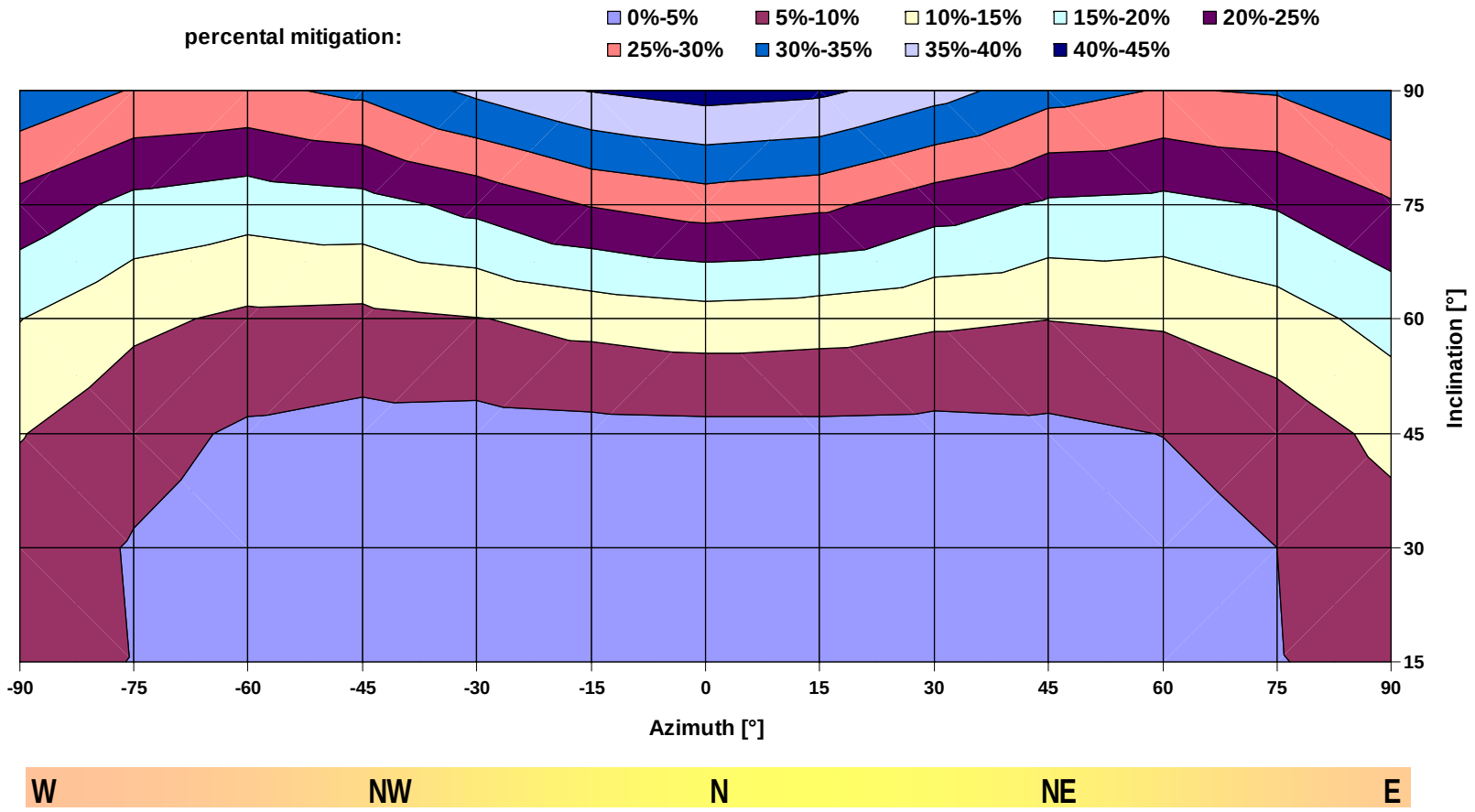

Tilt and orientation of collectors (Maputo)

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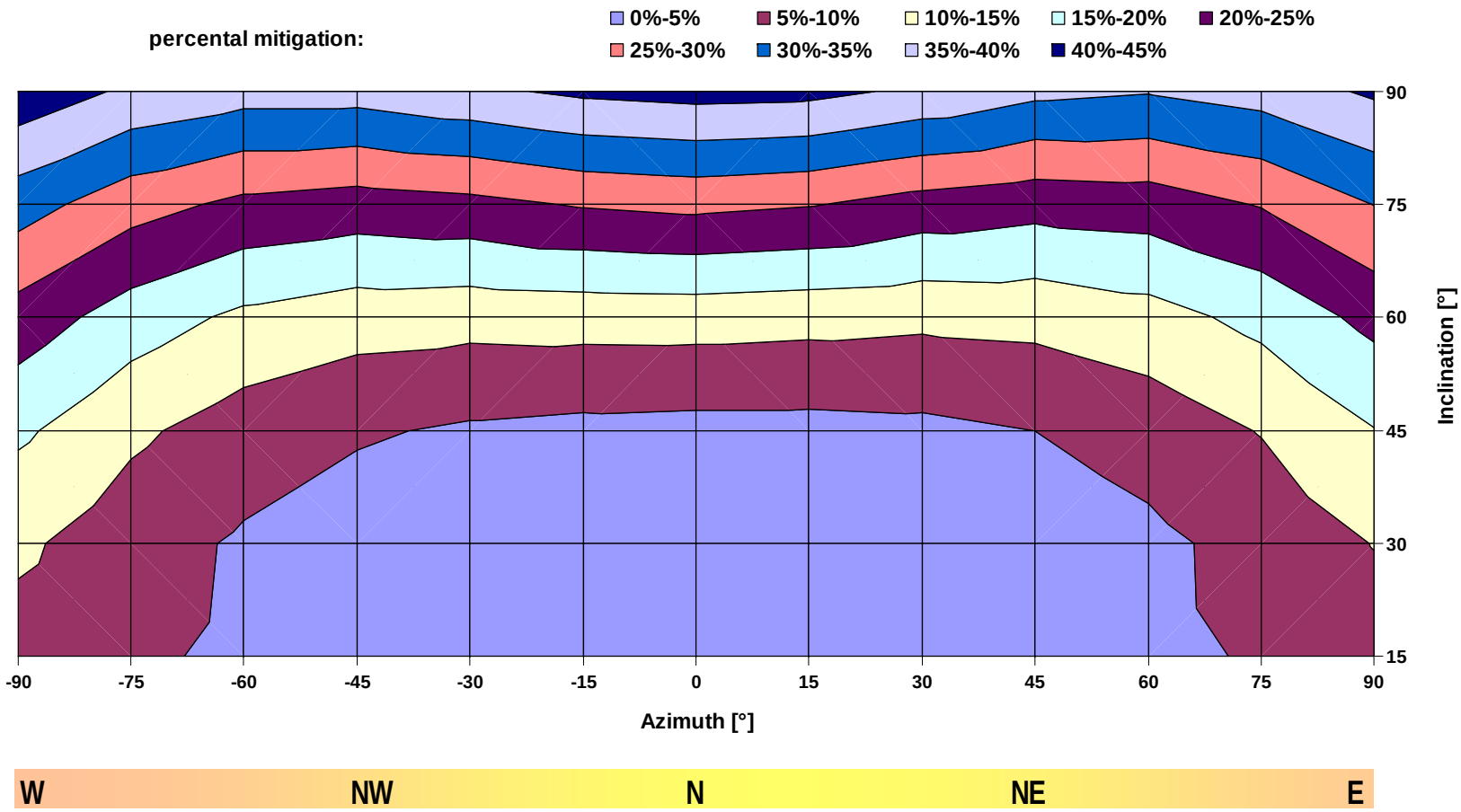

Tilt and orientation of collectors

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Variations of the annual solar yield in [kWh/m²·a] in Maputo related to different orientations and azimuth angles. The calculations are based on a solar hot water system with 3m² collector area and a daily hot water consumption of 150 litre. Calculated solar fraction ~ 97%

Azimuth [°]		Inclination [°]					
		15	30	45	60	75	90
W	-90	826.3	799.2	754.8	691.3	608.4	508.0
	-75	845.1	833.8	798.8	739.2	654.9	546.4
	-60	860.7	858.2	829.5	772.1	683.4	565.2
NW	-45	872.9	876.0	847.4	788.2	693.1	565.2
	-30	881.8	887.3	858.4	792.2	685.3	548.0
	-15	887.0	894.6	863.7	790.2	669.4	529.9
N	0	889.4	897.30	866.3	789.1	661.8	523.0
	15	888.3	895.9	865.8	793.1	670.0	525.9
	30	883.0	890.8	862.4	798.1	690.5	547.3
NE	45	874.9	879.8	852.5	794.5	701.7	572.6
	60	863.2	862.5	833.8	779.4	695.8	580.1
	75	847.9	837.9	805.5	749.8	670.1	565.3
E	90	829.6	806.2	764.2	704.6	627.3	531.2

Tilt and orientation of collectors

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Variations of the annual solar yield in [kWh/m²·a] in Johannesburg related to different orientations and azimuth angles. The calculations are based on a solar hot water system with 3m² collector area and a daily hot water consumption of 150 litre. Calculated solar fraction ~ 97%

Azimuth [°]		Inclination [°]					
		15	30	45	60	75	90
W	-90	887.9	867.0	824.5	757.1	665.9	549.7
	-75	912.3	909.6	879.6	817.0	722.3	595.1
	-60	932.3	940.9	914.7	854.0	754.9	614.7
NW	-45	947.6	961.3	934.5	868.4	758.1	607.2
	-30	957.9	973.4	942.2	865.1	738.5	576.4
	-15	964.2	979.0	944.1	854.6	711.5	545.8
N	0	966.1	**982.0**	944.8	850.4	701.0	535.9
	15	964.8	981.0	946.4	858.2	714.6	545.6
	30	959.3	975.8	945.8	870.0	744.0	579.1
NE	45	948.6	964.4	937.8	873.0	766.2	615.8
	60	933.6	943.7	918.6	858.7	764.0	629.1
	75	913.1	913.3	882.9	823.1	735.2	613.0
E	90	888.1	869.8	830.4	767.0	679.5	566.2

Tilt and orientation of collectors

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Variations of the annual solar yield in [kWh/m²·a] in Windhoek related to different orientations and azimuth angles. The calculations are based on a solar hot water system with 3m² collector area and a daily hot water consumption of 150 litre. Calculated solar fraction ~ 97%

Azimuth [°]		Inclination [°]					
		15	30	45	60	75	90
W	-90	982.6	972.3	943.6	891.7	808.2	694.9
	-75	999.7	1002.0	981.4	934.7	855.8	739.7
	-60	1013.2	1023.3	1005.9	955.4	870.9	748.9
NW	-45	1024.0	1038.6	1017.3	958.9	859.9	723.7
	-30	1031.5	1045.2	1019.5	948.0	826.5	671.8
	-15	1036.1	1049.8	1014.8	928.8	785.2	628.3
N	0	1037.9	**1051.0**	1012.1	917.5	764.0	609.8
	15	1036.9	1049.2	1012.0	923.3	777.5	619.5
	30	1033.2	1045.0	1013.7	938.1	817.2	661.9
NE	45	1026.3	1036.8	1010.2	945.3	848.2	714.6
	60	1015.8	1022.2	997.6	939.4	854.9	739.7
	75	1000.5	998.5	973.2	916.2	836.9	731.2
E	90	982.3	967.4	932.7	874.3	793.7	691.1