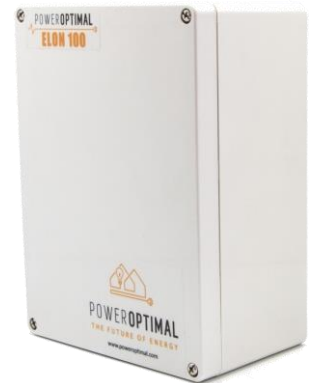


SOLAR PV ARRAY & HEATING ELEMENT SELECTION GUIDE
PowerOptimal Elon® 100

The innovative PowerOptimal Elon® 100 incorporates proprietary solar PV (photovoltaic) power management technology to allow for direct connection of solar PV arrays to electric geysers (water heaters) with optimised solar power use in a single compact unit. The system can be connected to the grid (AC mains) as well, and intelligently switches between AC and solar power supply. The system requires no inverter and no battery. It can be connected to standard AC geyser heating elements and AC thermostats, which translates into the most cost-effective solar water heating option today.



Document Version: 2.06

Note: Section A provides an easy selection guide for general users. **Section B** provides a more detailed and technical selection guide for solar PV designers and engineers.

SECTION A. EASY SELECTION GUIDE: HOW MANY SOLAR PANELS DO I NEED?

The below table shows approximately how much hot water will typically be delivered by different sizes of your solar PV array in South Africa. The most important factor is the power (in kW_p) as opposed to no. of modules.

Solar PV array size (kW _p)	Showers per day*	50%+ of daily hot water use provided for how many people?	How many people off-grid for hot water?	Typical number of solar PV modules
1 – 1.2	3 water drops	2 people icons	1 person icon	2 - 3 modules
1.2 – 1.6	4 water drops	3 people icons	2 person icons	3 - 4 modules
1.5 – 2	5 water drops	4 people icons	3 person icons	4 - 5 modules
2.4 – 3.2 (two parallel PV strings)	6 water drops	5 people icons	4 person icons	6 - 8 modules
3 – 4 (two parallel PV strings)	7 water drops	6 people icons	5 person icons	8 - 10 modules

* 6-minute showers at 40 °C with 8 litre/min (low-flow) showerheads



SECTION A. EASY SELECTION GUIDE: WHAT SIZE HEATING ELEMENT SHOULD I USE?

To get the best performance from your Elon® solar PV water heater, it is important that the geyser element is a good match for the size of your solar PV array. This table helps you match the size of the solar PV array with the size of the geyser element.

Solar PV array size (kW _p)	Matching geyser element size (kW)	Geyser (water tank) size (litres)
1 – 1.2	4 or 3	100 - 200
1.2 – 1.6	3 or 2	100 - 200
1.5 – 2	2	150 – 300
2.4 – 3.2 (two parallel PV strings)	4	150 – 300
3 – 4 (two parallel PV strings)	4	200+



SECTION B. SOLAR PV ARRAY AND HEATING ELEMENT FULL SELECTION GUIDE

It is important to match the solar PV array and heating elements for maximum power transfer efficiency.

HOW TO USE THIS GUIDE:

1. Use Tables 1 to 4 to help you select the right size solar PV array for your needs.
2. Then use Table 5 to find the recommended AC heating element power rating for your selected solar PV array (Table 6 provides alternative options with slightly lower efficiency).
3. Use Table 7 to check element & thermostat compatibility with the Elon® 100.

Contact PowerOptimal for advice on module-element matching if module properties (maximum power point current and voltage) are significantly different to the values provided in Tables 5, or **for advice on bifacial & high voltage modules**.

TABLE 1. ANNUAL AVERAGE LITRES OF WATER HEATED PER DAY

The below example table indicates the average number of litres of water per day that the system will heat from 15 to 60 °C over a year period for different solar array peak power ratings. (The amount of water heated will vary with weather conditions, by geographic location and by season. Water heated per day will be significantly lower in winter and significantly higher in summer. These numbers indicate heating capacity – i.e. if no hot water is used on a given day, there will be less water heated on that day. This is only an approximate guide.)

Location	Solar + Elon® kWh/kW _p /yr	Annual average litres of water heated per day for X kW _p installed solar capacity									
		0.8 kW _p	1 kW _p	1.2 kW _p	1.4 kW _p	1.6 kW _p	1.8 kW _p	2 kW _p	2.5 kW _p	3 kW _p	3.5 kW _p
Bloemfontein	1894	80	99	119	139	159	179	199	249	298	348
Cape Town	1624	68	85	102	119	136	154	171	213	256	299
Durban	1447	61	76	91	106	122	137	152	190	228	266
Jhb/Pretoria	1724	72	91	109	127	145	163	181	226	272	317
Mbombela	1627	68	85	103	120	137	154	171	214	256	299
Port Elizabeth	1565	66	82	99	115	132	148	164	205	247	288
Upington	1912	80	100	121	141	161	181	201	251	301	352
Saldanha	1623	68	85	102	119	136	153	170	213	256	298

Example:

For a solar PV array of **1.2 kW_p**, an installation in Johannesburg would yield about 1724 kWh/kW_p/yr, or 1724 x 1.2 kW_p = **2069 kWh/yr**. This would be sufficient to **heat on average 109 litres of water per day**. For a family of 2 each using 80 litres of hot water per day, this would provide about 109 ÷ (80 x 2) or **68% of the annual hot water requirement**.



TABLE 2. ANNUAL AVERAGE NUMBER OF SHOWERS PER DAY

The below table indicates the average number of showers per day for which the system will supply hot water over a year period for different solar array peak power ratings. (The amount of water heated will vary with weather conditions, by geographic location and by season. Water heated per day will be significantly lower in winter and significantly higher in summer. These numbers indicate heating capacity – i.e. if no hot water is used on a given day, there will be less water heated on that day. This is only an approximate guide.)

Location	Solar + Elon [®] kWh/kW _p /yr	Number of showers per day (based on annual average) for X kW _p installed solar capacity									
		0.8 kW _p	1 kW _p	1.2 kW _p	1.4 kW _p	1.6 kW _p	1.8 kW _p	2 kW _p	2.5 kW _p	3 kW _p	3.5 kW _p
Bloemfontein	1894	2.4	3.0	3.6	4.2	4.8	5.4	6.0	7.5	9.0	10.4
Cape Town	1624	2.0	2.6	3.1	3.6	4.1	4.6	5.1	6.4	7.7	9.0
Durban	1447	1.8	2.3	2.7	3.2	3.6	4.1	4.6	5.7	6.8	8.0
Jhb/Pretoria	1724	2.2	2.7	3.3	3.8	4.3	4.9	5.4	6.8	8.2	9.5
Mbombela	1627	2.1	2.6	3.1	3.6	4.1	4.6	5.1	6.4	7.7	9.0
Port Elizabeth	1565	2.0	2.5	3.0	3.5	3.9	4.4	4.9	6.2	7.4	8.6
Upington	1912	2.4	3.0	3.6	4.2	4.8	5.4	6.0	7.5	9.0	10.5
Saldanha	1623	2.0	2.6	3.1	3.6	4.1	4.6	5.1	6.4	7.7	9.0

The table is based on **6-minute** showers at **40 °C** and **8 litres/min** low flow showerheads. Old showerheads can use up to 15 litres/min and would substantially reduce the number of showers.

Example:

For a solar PV array of **2.5 kW_p**, an installation in Johannesburg would yield about 1724 kWh/kW_p/yr, or 1724 x 2.5 kW_p = **4 310 kWh/yr**. This would be sufficient for about **6 to 7 showers per day**.



TABLE 3. PERCENTAGE OF ANNUAL HOT WATER REQUIREMENT

The below example table indicates what % of the annual hot water requirement will on average be supplied by the system for **2 people each using 80 litres of hot (60 °C) water per day**. (The amount of water heated will vary with weather conditions, by geographic location and by season. Water heated per day will be significantly lower in winter and significantly higher in summer. These numbers indicate heating capacity – i.e. if no hot water is used on a given day, there will be less water heated on that day. This is only an approximate guide.)

Location	Solar + Elon [®] kWh/kW _p /yr	Annual average % of hot water requirement supplied for 2 people each using 80 litres of hot water per day for X kW _p installed solar capacity									
		0.8 kW _p	1 kW _p	1.2 kW _p	1.4 kW _p	1.6 kW _p	1.8 kW _p	2 kW _p	2.5 kW _p	3 kW _p	3.5 kW _p
Bloemfontein	1894	50%	62%	75%	87%	99%	112%	124%	155%	187%	218%
Cape Town	1624	43%	53%	64%	75%	85%	96%	107%	133%	160%	187%
Durban	1447	38%	47%	57%	66%	76%	85%	95%	119%	142%	166%
Jhb/Pretoria	1724	45%	57%	68%	79%	91%	102%	113%	142%	170%	198%
Nelspruit	1627	43%	53%	64%	75%	85%	96%	107%	134%	160%	187%
Port Elizabeth	1565	41%	51%	62%	72%	82%	92%	103%	128%	154%	180%
Upington	1912	50%	63%	75%	88%	100%	113%	126%	157%	188%	220%
Saldanha	1623	43%	53%	64%	75%	85%	96%	107%	133%	160%	186%

Examples:

An array of **1.2 kW_p** will provide approximately **64%** of the annual hot water requirement for a family of two people in Cape Town.

An array of **2 kW_p** will provide approximately $124\% \times (2 \text{ people} / 4 \text{ people}) = 62\%$ of the annual hot water requirement for a family of four people in Bloemfontein.



TABLE 4. PEAK POWER OUTPUT FOR VARIOUS SOLAR MODULES AND ARRAY SIZES

The peak power production (W_p) of the modules at STC (Standard Test Conditions: irradiance 1000 W/m², spectrum AM 1.5, module temperature 25 °C) and at NOCT (Nominal Operating Cell Temperature, irradiance 800 W/m², spectrum AM 1.5, module temperature ~43 – 45 °C) are provided by the solar PV module manufacturer. The below table indicates the peak power at STC for a range of solar module power ratings and array sizes.

No. of cells per module	Module STC power rating (W_p)	Total peak power at STC in kW _p for an array of X modules						
		3 modules	4 modules	5 modules	6 modules	8 (2 x 4) modules	10 (2 x 5) modules	12 (2 x 6) modules
60 or 120	265	0.795	1.06	1.325	1.59	2.12	2.65	3.18
60 or 120	270	0.81	1.08	1.35	1.62	2.16	2.70	3.24
60 or 120	275	0.825	1.10	1.375	1.65	2.20	2.75	3.30
60 or 120	280	0.84	1.12	1.40	1.68	2.24	2.80	3.36
60 or 120	285	0.855	1.14	1.425	1.71	2.28	2.85	3.42
60 or 120	290	0.87	1.16	1.45	1.74	2.32	2.90	3.48
60 or 120	295	0.885	1.18	1.475	1.77	2.36	2.95	3.54
60 or 120	300	0.90	1.20	1.50	1.80	2.40	3.00	3.60
60 or 120	305	0.915	1.22	1.525	1.83	2.44	3.05	3.66
60 or 120	310	0.93	1.24	1.55	1.86	2.48	3.1	3.72
60 or 120	315	0.945	1.26	1.575	1.89	2.52	3.15	3.78
60 or 120	320	0.96	1.28	1.6	1.92	2.56	3.2	3.84
60 or 120	325	0.975	1.3	1.625	1.95	2.6	3.25	3.9
60 or 120	330	0.99	1.32	1.65	1.98	2.64	3.3	3.96
72 or 144	310	0.93	1.24	1.55	1.86	2.48	3.10	3.72
72 or 144	315	0.945	1.26	1.575	1.89	2.52	3.15	3.78
72 or 144	320	0.96	1.28	1.60	1.92	2.56	3.20	3.84
72 or 144	325	0.975	1.30	1.625	1.95	2.60	3.25	3.9
72 or 144	330	0.99	1.32	1.65	1.98	2.64	3.30	3.96
72 or 144	335	1.005	1.34	1.675	2.01	2.68	3.35	4.02
72 or 144	340	1.02	1.36	1.70	2.04	2.72	3.40	4.08
72 or 144	345	1.035	1.38	1.725	2.07	2.76	3.45	4.14
72 or 144	350	1.05	1.40	1.75	2.1	2.80	3.50	4.2
72 or 144	355	1.065	1.42	1.775	2.13	2.84	3.55	4.26
72 or 144	360	1.08	1.44	1.8	2.16	2.88	3.6	4.32
72 or 144	365	1.095	1.46	1.825	2.19	2.92	3.65	4.38
72 or 144	370	1.11	1.48	1.85	2.22	2.96	3.7	4.44
72 or 144	375	1.125	1.5	1.875	2.25	3	3.75	4.5
72 or 144	380	1.14	1.52	1.9	2.28	3.04	3.8	4.56
72 or 144	385	1.155	1.54	1.925	2.31	3.08	3.85	4.62

NOT ALLOWED (exceeds maximum rated Elon®100 voltage)

NOT ALLOWED (exceeds maximum rated Elon®100 voltage)



No. of cells per module	Module STC power rating (W _p)	Total peak power at STC in kW _p for an array of X modules						
		3 modules	4 modules	5 modules	6 modules	8 (2 x 4) modules	10 (2 x 5) modules	12 (2 x 6) modules
72 or 144	390	1.17	1.56	1.95	2.34	3.12	3.9	4.68
72 or 144	395	1.185	1.58	1.975	2.37	3.16	3.95	4.74
72 or 144	400	1.2	1.6	2	2.4	3.2	4	4.8
72 or 144	405	1.215	1.62	2.025	2.43	3.24	4.05	4.86
72 or 144	410	1.23	1.64	2.05	2.46	3.28	4.1	4.92
72 or 144	415	1.245	1.66	2.075	2.49	3.32	4.15	4.98
72 or 144	420	1.26	1.68	2.1	2.52	3.36	4.2	5.04
72 or 144	425	1.275	1.7	2.125	2.55	3.4	4.25	5.1
72 or 144	430	1.29	1.72	2.15	2.58	3.44	4.3	5.16
72 or 144	435	1.305	1.74	2.175	2.61	3.48	4.35	5.22
72 or 144	440	1.32	1.76	2.2	2.64	3.52	4.4	5.28
72 or 144	445	1.335	1.78	2.225	2.67	3.56	4.45	5.34
72 or 144	450	1.35	1.8	2.25	2.7	3.6	4.5	5.4
72 or 144	455	1.365	1.82	2.275	2.73	3.64	4.55	5.46

Examples:

An array of **4 x 325 W_p modules** in series will have a total peak power (at STC) of **1.3 kW_p**.

An array of **2 parallel strings of 5 modules of 280 W_p each** (10 modules of 280 W_p in total) will have a total peak power (at STC) of **2.8 kW_p**.



TABLE 5. SOLAR PV MODULE AND AC HEATING ELEMENT MATCHING GUIDE

Contact PowerOptimal for advice on module-element matching if module properties are significantly different to the values provided in the table below or for advice on bifacial & high voltage modules.

No. of cells	Module STC power rating (W_p)	Module NOCT mpp* voltage (V)	Module NOCT mpp* current (A)	Best element size match (rated power in kW @ 230V AC) for an array of X modules									
				No. of Modules:									
				2	3	4	5	6	6 (2x3)	8 (2x4)	10 (2x5)	12 (2x6)	
60 or 120	250 – 330	28 – 32	6.5 – 8.8	NR	4 kW	3 kW	2 kW	2 kW	2 kW	NR	4 kW	4 kW	4 kW
72 or 144	295 – 455	33 – 38.5	6.5 – 8.8	4 kW	3 kW	2 kW	2 kW	NA	4 kW	4 kW	4 kW	NA	

- * mpp = maximum power point
- STC = Standard Test Conditions (irradiance 1000 W/m², spectrum AM 1.5, cell temperature 25 °C)
- NOCT = Nominal Operating Cell Temperature (800 W/m², spectrum AM 1.5, cell temperature ~ 43 – 45 °C)
- NA = Not Allowed (exceeds maximum rated Elon® 100 voltage)
- NR = Not Recommended (poor array-heating element matching efficiency)

Example:

For 4 x 390 W_p (1.56 kW_p) 72-cell solar modules, the best heating element match is a **2 kW AC element** (as rated at 230V). (However, a 2 kW element is quite slow when heating with AC, so consider a 3 kW element as per Table 6.)

Contact PowerOptimal for advice on array-element matching if module properties (V_{mpp} and I_{mpp} at NOCT) are significantly different to the values provided in the table.

DO NOT DEVIATE FROM THE RECOMMENDED MODULE-ELEMENT MATCHING CONFIGURATIONS WITHOUT CONSULTING POWEROPTIMAL.

Maximum allowed solar PV array specifications at Standard Test Conditions (STC):
 $I_{sc} < 20A$ $V_{oc} < 250V$ **Power < 4 kW_p**



TABLE 6. ALTERNATIVE MATCHING (ABOUT 5 – 10% EFFICIENCY LOSS COMPARED TO TABLE 5)

No. of cells	Module STC power rating (W _p)	Module NOCT mpp* voltage (V)	Module NOCT mpp* current (A)	Best element size match (rated power in kW @ 230V AC) for an array of X modules								
				No. of Modules:								
				2	3	4	5	6	6 (2x3)	8 (2x4)	10 (2x5)	12 (2x6)
60 or 120	250 – 330	28 – 32	6.5 – 8.8	NR	3 kW	2 or 4 kW	3 kW	NR	4 kW	NR	3 kW	3 kW
72 or 144	295 – 455	33 – 38.5	6.5 – 8.8	NR	4 kW	3 kW	3** kW	NA	NR	NR	NR	NA

- * mpp = maximum power point
- STC = Standard Test Conditions (irradiance 1000 W/m², spectrum AM 1.5, cell temperature 25 °C)
- NOCT = Nominal Operating Cell Temperature (800 W/m², spectrum AM 1.5, cell temperature ~ 43 – 45 °C)
- NA = Not Allowed (exceeds maximum rated Elon® 100 voltage)
- NR = Not Recommended (poor array-heating element matching efficiency)
- ** Marginal (10%+ loss)

Example:

For 4 x 325 W_p (1.3 kW_p) 72-cell solar modules, the best heating element match is a 2 kW AC element (as rated at 230V), but a 3 kW element can also be used. It will have about 5 - 10% efficiency loss compared to a 2 kW element.


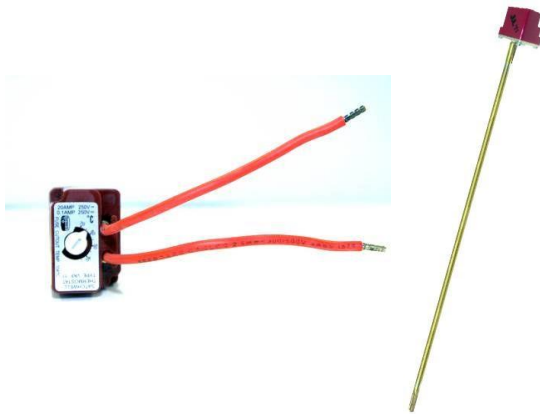
Contact PowerOptimal for advice on array-element matching if module properties (V_{mpp} and I_{mpp} at NOCT) are significantly different to the values provided in the table.

DO NOT DEVIATE FROM THE RECOMMENDED MODULE-ELEMENT MATCHING CONFIGURATIONS WITHOUT CONSULTING POWEROPTIMAL.

Maximum allowed solar PV array specifications at Standard Test Conditions (STC):
 $I_{sc} < 20A$ $V_{oc} < 250V$ Power < 4 kW_p



TABLE 7. GEYSER ELEMENT & THERMOSTAT COMPATIBILITY GUIDE

Element type	Compatible thermostat type	Comments
<p>Screw-in element:</p> 	<p>VKF-11 thermostat:</p> 	<p>Element & thermostat have separate electrical connections, so each can be connected (wired) separately to the Elon®. Thus, this element-thermostat combination is directly compatible with the Elon®. (No need to use the bridging wire or element adapter supplied with the Elon® unit.)</p> <p>The thermostat pocket in the element is the right size for the VKF-11 thermostat.</p>



Element type	Compatible thermostat type	Comments
<p>Spiral element (flange type) with smaller diameter thermostat pocket:</p> 	<p>TSE thermostat: Thermowatt (RTS) thermostat:</p> 	<p>The spiral element generally has a smaller thermostat pocket than the screw-in element. The TSE and Thermowatt (RTS) thermostats fit into this smaller pocket. The VKF-11 thermostat requires a larger pocket and does not fit into standard spiral element pockets.</p> <p>The TSE and Thermowatt thermostats normally clip directly into the element, but this won't be the case when the Elon® is connected.</p> <p>Use the bridging wire and element adapter supplied with the Elon® (see the Installation Guide) to connect the Elon® to these thermostats and elements.</p>

