SolarPeak®

SolarPeak® 2 kW Thermal System

Example of SolarPeak residential installation

Energy report

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1 What is this about?

This document shows the expected energy and expected monetary savings for a SolarPeak 2 kWp (30 tube SP system). The displayed charts and data are valid for an average radiation in New Zealand, but can be adjusted to any specific location, by using a correction factor. This means you can take the shown results and –if you want more precision- simply multiply it by a number you can look up for your location at Table 4.

This document is divided in following parts:

- Input parameters and assumptions (of the model used to calculate the expected savings)
- Savings
- Energy calculation steps

2 Input parameters and assumptions

The input parameters and assumptions for modeling the energy savings are organized by topics and listed as follows:

- ✓ **Energy demand**

  The energy demand is determined as the necessary energy to heat up 250 liters from the cold water inlet temperature until 45ºC. The used cold water inlet temperatures are shown in the next table.

Table 1: Cold water inlet temperatures [ºC]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Cold water	11	10	9	8	7	6	5	6	7	8	9	10

- ✓ **Meteorological data**

  The energy production depends on the climate of the region. The considered solar radiation and ambient temperatures are shown in the next table. The solar radiation was obtained from the "National Institute of Water and Atmospheric Research (NIWA)" and the temperature from NASA's database.

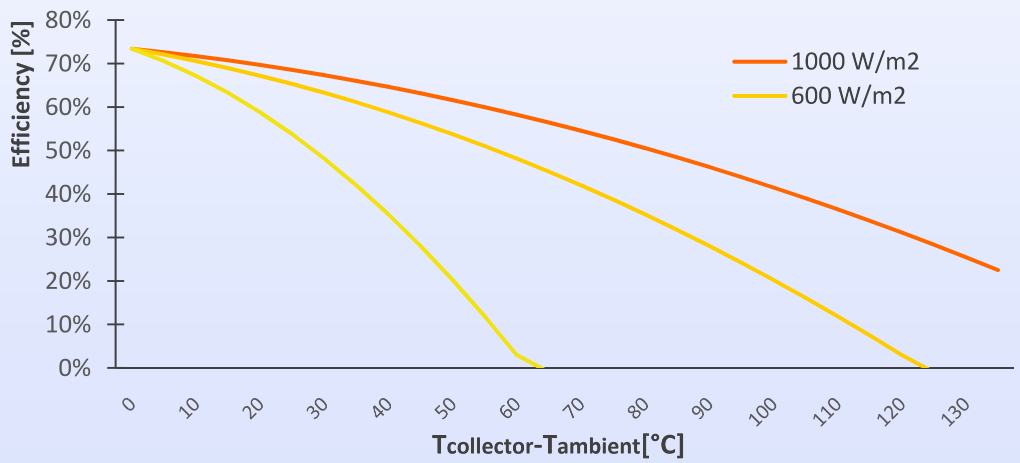
Table 2: Meteorological data

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Radiation [kWh/m^2]	5,6	5,1	4,3	2,8	1,7	2,1	1,9	2,9	4,3	4,5	4,9	5,4
Min T_{amb} [ºC]	13,4	13,4	12,1	10	8,61	6,96	6	6,2	7,23	8,59	9,99	12,2
Max T_{amb} [ºC]	24,7	24,3	21,8	18,5	14,9	12,1	11,4	12,5	15	17,8	20,3	22,6

- ✓ **Collector's performance**

  The energy production also depends on the collector's/system's performance. The performance of a solar collector depends on its technology, the radiation (the more radiation, the more efficient it is) and on the temperature the collector has work above the ambient temperature (the hotter the collector has to get, the more losses there are; therefore it gets less efficient). The exact performance of the collector is shown in the next chart for different radiations.

Chart 1: SP collector performance



This efficiency curve can be described mathematically by coefficients and so be used in the model. These coefficients are determined by an international testing standard, Solarkeymark, and are shown in the next table.

Table 3: Technical parameters of SP collector, Solarkeymark certified

Parameter	Value
η	73%
a1	1,53
a2	0,02
Aperture area	2,79 m^2

- ✓ **Energy storage**
  The solar heat is stored in an insulated water tank, which size is 10 liters per tube approx. This size allows storing the heat excess from a sunny day and using it next day if it was more clouded.

- ✓ **Energy consumption**
  It is assumed that all the energy the solar system produces will be used. This means in this report the *available* energy is shown. Hence if the energy demand drops below expectations, less energy/money might be saved. As well it is assumed that the energy demand has a relatively constant behavior day to day.

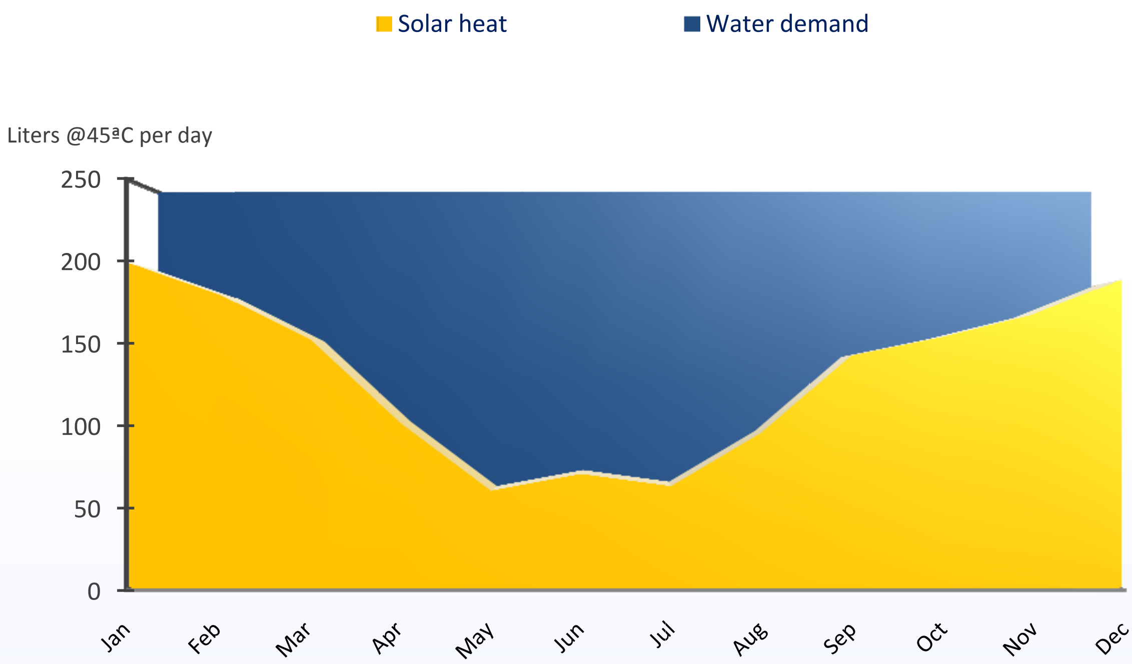
The before mentioned inputs and assumptions are only essentials from an energetic point of view. There are many other considerations which are of a technical or economic nature and thus are not shown here.

3 Savings

This part shows only the results of the energy calculations. For more details please see the energy calculation section at the end this report.

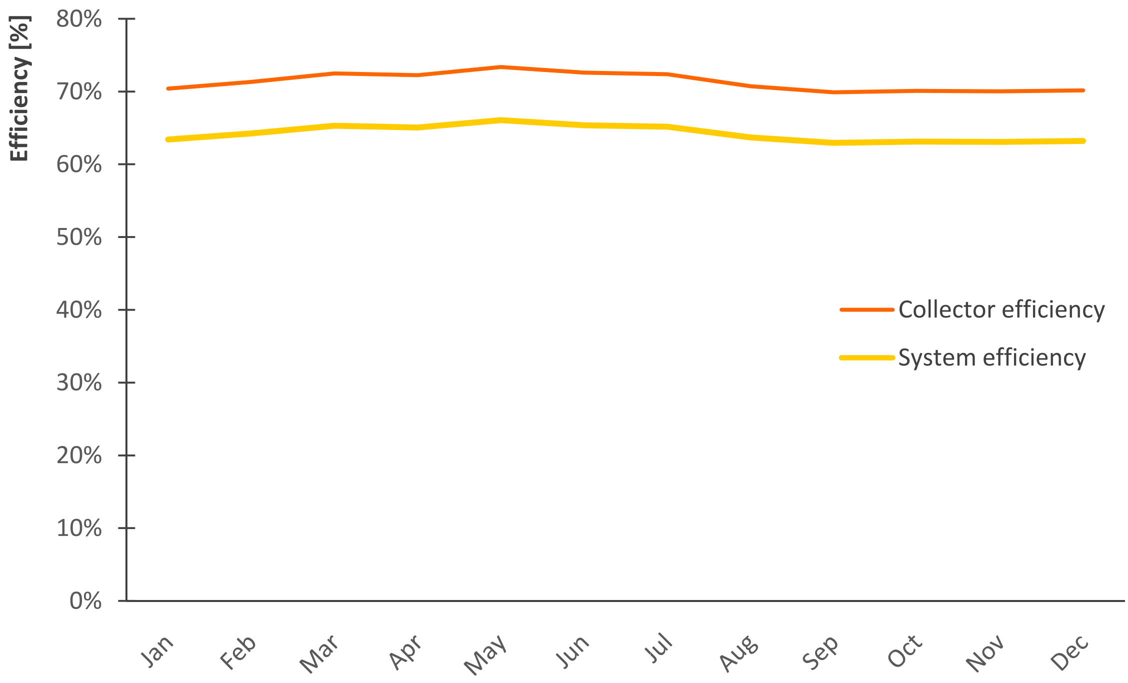
From the energy model we obtain the amount energy the solar system can produce every month. This is shown in the next chart as amount of liters the system can heat up from the cold inlet temperature until 45ºC (golden area). The total blue area (the part behind the golden and the visible area) is the total demand. Hence the visible blue area is the missing amount of energy the auxiliary system will need to provide once the solar system is installed.

Chart 2: Expected solar energy



The components of the solar system are chosen carefully and sized with precision in order to optimize the performance through the year. The efficiency is shown in the next chart. The orange line shows the efficiency of the collectors. It lies around 70%. This means 70% of the solar energy can be transformed into useful energy: hot water. The system's efficiency, golden line, lays a bit lower, since heat losses are considered.

Chart 3: Efficiency of solar collectors and solar system



This system will save 51% of the total energy demand for an average solar radiation in New Zealand per year. This is 2.500 kWh of heat the solar system will save yearly (check energy calculation section to see how we got to this number). To personalize location please use Table 4.

Chart 4: Yearly savings

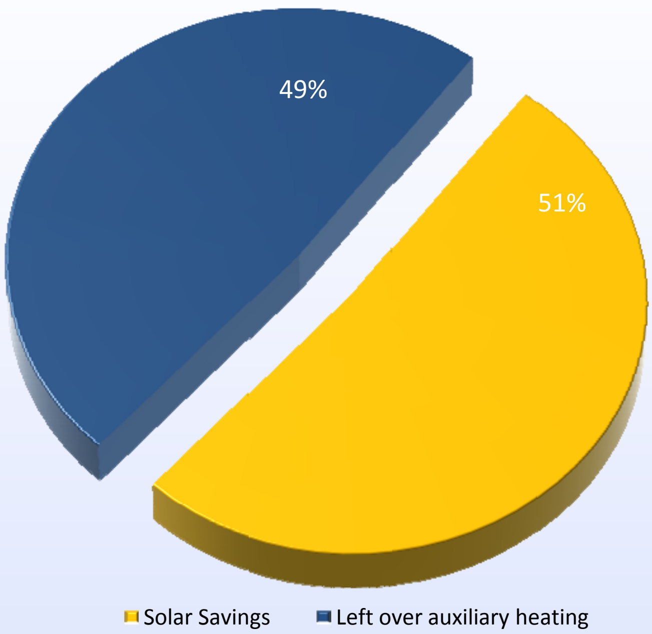


Table 4: Correction factor for New Zealand Cities

City	Correction factor*
Auckland	105%
Taupo	107%
Hastings	113%
Rotorua	107%
Palmerston	92%
Wellington	100%
Nelson	119%
Christchurch	107%
Dunedin	90%
Queenstown	105%

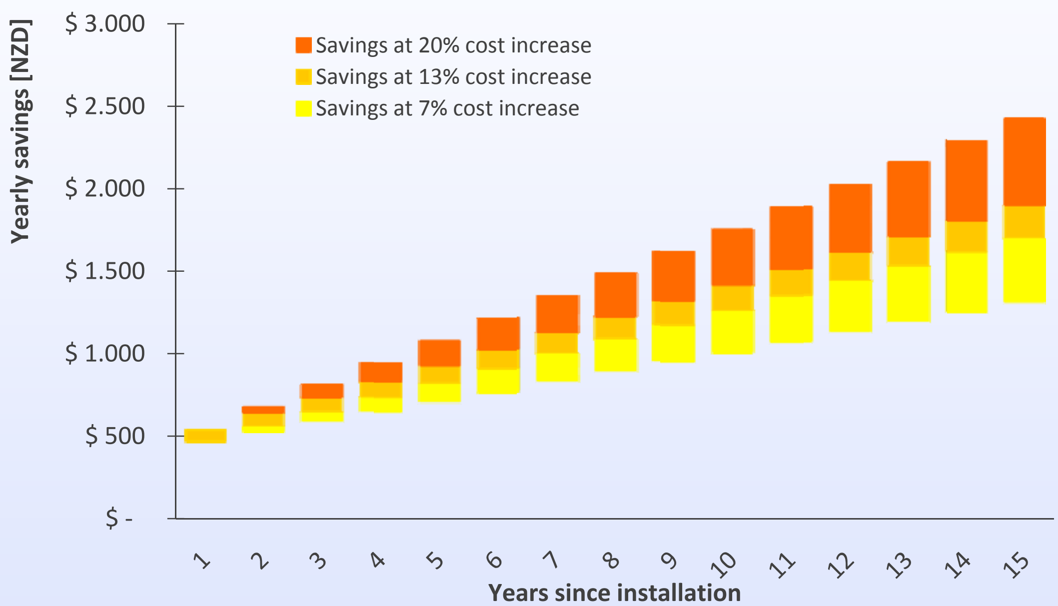
***C.F. was calculated using the optimum tilt and orientation for each city.**

We previously obtained a yearly solar saving of 51% (or equivalently 2.500 kWh) for an average radiation in New Zealand. Now, if we want to obtain the precise result for the city of this project, we just need to multiply the 53% (or 2.500) with the factor for the city we obtain from Table 4. For example, in Queenstown we would save: 51%·105%= 54% of the yearly energy demand (or 2.500 ·105% = 2.625 kWh/year).

To obtain the monetary savings we just need to multiply the yearly saved energy by the energy price. For a system with an energy cost of 0,2 NZD/kWh we will have a saving of 0,2· 2.500 ~ 500 NZD in the first year. Since energy prices rise continuously, the second year the system will save a bit more; even more the third year; and so on. This is shown in the next chart. There is no certainty of the amount energy prices will raise; therefore we created different scenarios for the cost analysis and let it up to the client which one to choose. These scenarios are:

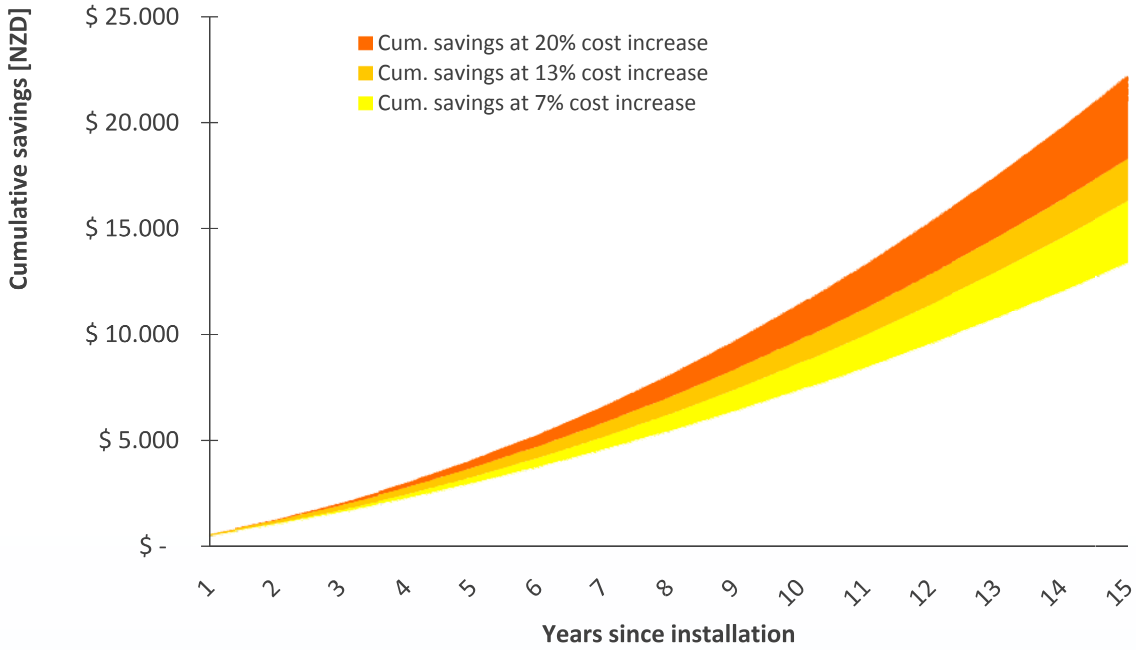
- Conservative scenario (yellow): energy prices increase by only 7% a year.
- Statistic scenario (gold): energy prices increase by 13% a year. This is approximately the average increase of the last 10 years.
- Accelerated –resource depletion- scenario (orange): energy prices increase 20% a year.

Chart 5: Yearly savings projections for next years at different scenarios



If we sum up the yearly savings we get the next chart. It shows how much we will have saved after a given number of years. For example 5 years after the installation, the system will have saved 4.000 NZD under the statistic scenario (orange). This is very helpful to determine the payback of the system and the total savings of the system.

Chart 6: Cumulative savings projections for next years at different scenarios



4 Energy calculation

This part shows the calculation steps to determine the energy and monetary savings.

The design parameters used for this system are shown in the next table.

Table 5: "Design parameters"

Parameter	Value	Unit
Num. Collectors	1,00	
Design flow rate	400	l/h/coll
Collectors in row	3	-

Therewith the total flow rate and the areas of the array are calculated:

Table 6: "Calculated parameters"

Parameter	Value	Unit
Flow rate	116,67	l/h
Array area (aperture)	2,8	m^2
Array area (gross)	5,00	m^2

The expected energy is calculated by using two different algorithms: the f-Chart algorithm and the hourly power production for 12 representative design days over the year. We will refer to the latter as "hourly method". The f-Chart algorithm is well documented in solar literature; hence we will only show the results of the f-Chart algorithm. The hourly method will be detailed in the next pages.

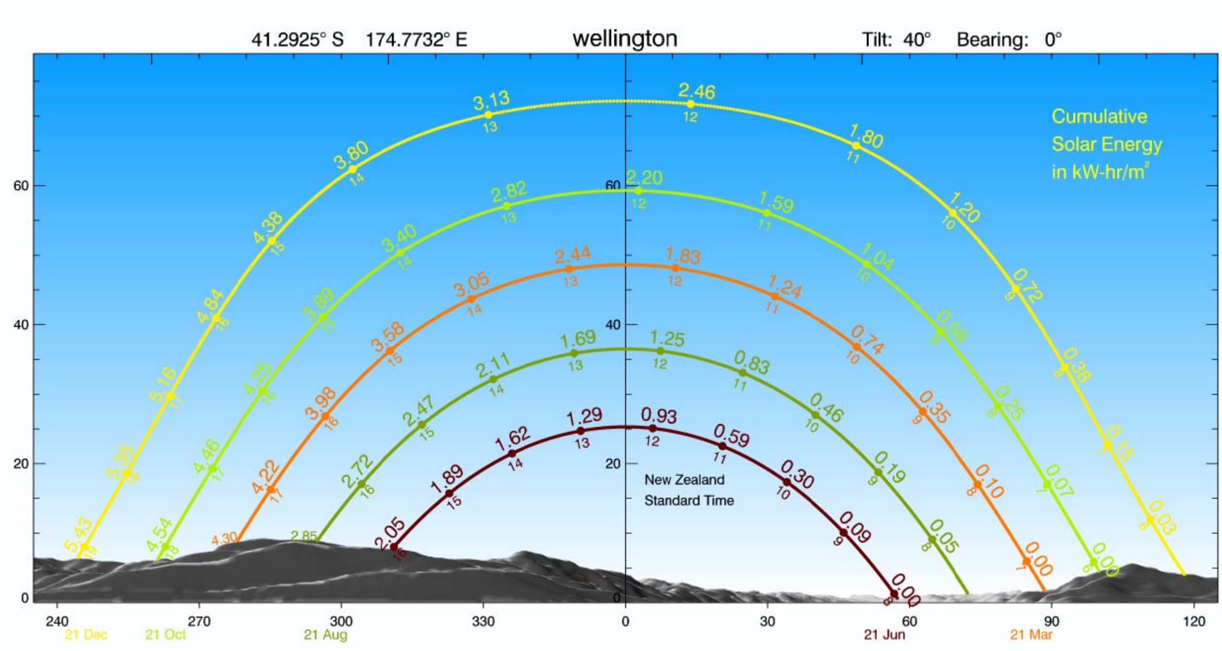
4.1 Hourly method

The first part is to determine the systems mean temperature, in order to later on determine the collector's efficiency. The mean temperature however, depends on the cold inlet (which is an input) and the hot outlet, which depends on the solar system's power (i.e. indirectly on the efficiency). This is a non linear equation which can be solved with the computer. The solution for each month is shown in the next table.

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Hot out [ºC]	42	38	33	24	16	17	15	21	30	33	36	40
Mean T. [ºC]	26,4	24,1	20,8	15,8	11,6	11,7	10,1	13,7	18,7	20,4	22,3	24,9

The solar energy data is downloaded from NIWA. Wellington is chosen as an average location for New Zealand. Please use the correction factor of Table 4 for other locations.

Figure 1: Cumulative Solar Energy (NIWA)



This data is digitalized in the next table.

Table 7: "Cumulative Solar Energy [kWh/m²]"

Time	Dec	Mar	Jun	Aug	Oct
6	0,03				
7	0,15	0			0,07
8	0,38	0,1	0	0,05	0,25
9	0,72	0,35	0,09	0,19	0,58
10	1,2	0,74	0,3	0,46	1,04
11	1,8	1,24	0,59	0,83	1,59
12	2,46	1,83	0,93	1,25	2,2
13	3,13	2,44	1,29	1,69	2,82
14	3,8	3,05	1,62	2,11	3,4
15	4,38	3,58	1,89	2,47	3,89
16	4,84	3,98	2,05	2,72	4,25
17	5,16	4,22		2,85	4,45
18	5,35	4,3			4,54
19	5,43				

The difference between the cumulative energy of each hour is the solar radiation (W/m^2). Months without information are statistically interpolated.

Table 8: "Solar radiation [W/m^2]"

Time	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
6 - 7	123	112	0	0	0	0	0	0	0	70	108	120
7 - 8	237	215	100	66	39	0	33	50	76	180	207	230
8 - 9	350	317	250	165	98	90	92	140	211	330	305	340
9 - 10	494	448	390	257	153	210	177	270	408	460	431	480
10 - 11	617	560	500	330	196	290	243	370	559	550	539	600
11 - 12	679	616	590	389	231	340	276	420	634	610	593	660
12 - 13	689	625	610	402	239	360	289	440	664	620	602	670
13 - 14	689	625	610	402	239	330	276	420	634	580	602	670
14 - 15	597	541	530	349	208	270	236	360	544	490	521	580
15 - 16	473	429	400	264	157	160	164	250	378	360	413	460
16 - 17	329	299	240	158	94	0	85	130	196	200	287	320
17 - 18	196	177	80	53	31	0	0	0	0	90	171	190
18 - 19	82	75	0	0	0	0	0	0	0	0	72	80
19 - 20	0	0	0	0	0	0	0	0	0	0	0	0

In Table 9 the hourly temperature is estimated by using a sinusoidal adjustment between the minimum and maximum temperature (see Table 2). At the end of the day, this adjustment loses accuracy, but fortunately these hours are less important due to lower radiation levels.

Table 9: "Estimated temperature distribution"

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
6 - 7	13,4	13,4	12,1	10,0	8,6	7,0	6,0	6,2	7,2	8,6	10,0	12,2
7 - 8	15,9	15,8	14,3	10,0	8,6	7,0	6,0	6,2	7,2	10,6	12,3	14,5
8 - 9	18,3	18,1	16,3	12,6	10,6	8,5	7,7	8,1	9,6	12,6	14,5	16,7
9 - 10	20,4	20,2	18,1	15,0	12,3	10,0	9,2	9,9	11,8	14,3	16,4	18,7
10 - 11	22,2	21,9	19,7	16,9	13,7	11,1	10,4	11,3	13,5	15,8	18,1	20,3
11 - 12	23,6	23,2	20,8	18,1	14,6	11,8	11,1	12,2	14,6	16,9	19,3	21,6
12 - 13	24,4	24,0	21,6	18,5	14,9	12,1	11,4	12,5	15,0	17,6	20,0	22,3
13 - 14	24,7	24,3	21,8	18,1	14,6	11,8	11,1	12,2	14,6	17,8	20,3	22,6
14 - 15	24,4	24,0	21,6	16,9	13,7	11,1	10,4	11,3	13,5	17,6	20,0	22,3
15 - 16	23,6	23,2	20,8	15,0	12,3	10,0	9,2	9,9	11,8	16,9	19,3	21,6
16 - 17	22,2	21,9	19,7	12,6	10,6	8,5	7,7	8,1	9,6	15,8	18,1	20,3
17 - 18	20,4	20,2	18,1	10,0	8,6	7,0	6,0	6,2	7,2	14,3	16,4	18,7
18 - 19	18,3	18,1	16,3	7,4	6,7	5,4	4,3	4,3	4,8	12,6	14,5	16,7

Now the efficiency can be calculated using following expression:

$$\eta(G, t_{col} - t_{amb}) = \eta_0 - \frac{a_1(t_{col} - t_{amb})}{G} - \frac{a_2(t_{col} - t_{amb})^2}{G},$$

where,

G is Solar irradiance (W/m^2).

η_0, a_1, a_2 are parameters of the collector (See Table 3)

t_{col}: average temperature (between cold inlet and hot outlet - expression (this is where we use the solution from the first step-) of the collector

t_{amb}: ambient temperature

Table 10: "Efficiency of solar system"

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
6 - 7	46%	51%	0%	0%	0%	0%	0%	0%	0%	32%	45%	47%
7 - 8	63%	65%	60%	56%	60%	0%	50%	41%	36%	61%	62%	63%
8 - 9	68%	70%	70%	70%	72%	67%	69%	66%	64%	68%	68%	68%
9 - 10	71%	72%	72%	73%	74%	72%	73%	71%	70%	71%	71%	71%
10 - 11	72%	73%	73%	74%	75%	73%	74%	72%	72%	72%	72%	72%
11 - 12	73%	73%	73%	74%	75%	73%	74%	73%	72%	72%	72%	73%
12 - 13	73%	73%	74%	74%	75%	74%	74%	73%	72%	73%	73%	73%
13 - 14	73%	73%	74%	74%	75%	73%	74%	73%	72%	73%	73%	73%
14 - 15	73%	73%	74%	74%	75%	73%	74%	72%	72%	72%	73%	73%
15 - 16	72%	73%	73%	73%	74%	72%	73%	71%	70%	72%	72%	72%
16 - 17	71%	72%	73%	70%	72%	0%	69%	65%	63%	69%	71%	71%
17 - 18	67%	69%	68%	51%	57%	0%	0%	0%	0%	60%	67%	67%
18 - 19	52%	57%	0%	0%	0%	0%	0%	0%	0%	0%	50%	51%

Assuming a heat loss of 5% and an average Incident Angle Modifier (IAM) of 95% the system losses can be calculated (see Table 11). Finally, the total heat conversion can be obtained as the sum of the product between the hourly available energy and the hourly system's efficiency:

$$Solar\ energy(monthly) = (1 - Heatlosses) \cdot IAM \cdot days_{month} \cdot Area_{collectors} \cdot \sum_{i=6}^{20} (\eta_i \cdot E_i)$$

The final (total) amount of energy considers and additional discount of 8% due to losses which have not been considered yet.

Table 11: "Final monthly solar energy"

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Daily Net [kWh]	3.915	3.596	3.119	2.048	1.237	1.489	1.354	2.017	3.010	3.184	3.398	3.792
IAM_avg (95%) [kWh]	196	180	156	102	62	74	68	101	150	159	170	190
Heat losses (5%) [kWh]	196	180	156	102	62	74	68	101	150	159	170	190
Daily Total [Wh/m2/day]	3.523	3.236	2.807	1.843	1.114	1.340	1.218	1.815	2.709	2.866	3.058	3.413
Total (-8%) [kWh]	280	233	223	142	89	103	97	144	209	228	236	272
Mean efficiency [-]	70%	71%	73%	72%	73%	73%	72%	71%	70%	70%	70%	70%

4.2 Energy balances

Until here we have shown the calculation steps of the hourly method. Now we will analyze the energy savings we can achieve, considering the results of the hourly method and the f-Chart algorithm.

The results of both procedures are shown in the next table. From this point on we will only use the 90% Average. This is the average of both methods, lowered by a 10% to avoid overestimations due to uncertainties of the input data.

Table 12: "Yearly expected energy, hourly method, f-chart method and average"

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Solar [kWh/m]	280	233	223	142	89	103	97	144	209	228	236	272
Solar f-Chart [kWh]	260	222	219	147	93	108	103	152	210	226	230	257
Average solar [kWh]	270	227	221	145	91	106	100	148	209	227	233	265
90%Average solar [kWh]	243	204	199	130	82	95	90	133	188	205	210	238

Hourly method= result of hourly method algorithm
Solar f-Chart = result of f-chart algorithm
Average solar = average of hourly method and f-Chart results
90% Average = 90% of the solar average

The current monthly raw energy demand is calculated as the energy necessary to heat up 250 liters per day, from the cold water temperature until 45ºC, multiplied by the amount of days of each month and divided by the current system's (such as an gas boiler for example) efficiency (assumed as 80%). The net energy (demand) considers solely the energy necessary to heat the water, without including the current boiler's efficiency. This is shown in the next table.

Once operative, the solar system will generate the amount of energy mentioned in Table 12 (90% Average). Only the difference between the solar energy and the net energy demand (divided by the boiler's efficiency) will then need to be generated by the current boiler. This results in the "future raw energy demand". The difference between the future raw energy demand and the current raw energy demand is the saving due to the solar system (this is not the same as the provided solar energy). This is also shown in the next table.

Table 13: Energy balances

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Raw Energy demand [kWh/m]	382	356	409	403	427	425	450	439	414	416	392	394
Net Energy demand [kWh/m]	306	284	327	322	342	340	360	351	331	333	314	315
90%Average solar [kWh]	243	204	199	130	82	95	90	133	188	205	210	238
Future net energy [kWh]	63	80	128	192	260	245	270	218	143	128	104	77
Raw left energy [kWh]	78	100	160	240	325	306	338	272	178	160	130	96

Raw energy demand= necessary energy to heat up water with a system of 80% efficiency
Net energy demand = necessary energy to heat up water with a system of 100% efficiency
90% Average= 90% of the solar average
Future net energy = current net energy – solar energy
Future raw energy = future net energy/system efficiency

Table 14: Solar savings

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Solar savings [kWh]	304	256	249	163	102	119	112	167	235	256	262	298
Solar hot water [l@45ªC	200	180	150	100	60	70	60	90	140	150	170	190
Solar savings [-]	80%	72%	61%	40%	24%	28%	25%	38%	57%	61%	67%	76%

Solar savings kWh = Current raw energy- future raw energy
Solar hot water [l@45ªC] = liters of hot water (45ºC) provided by solar system
Solar savings% = Solar savings/Current raw energy*100

All these results are shown in the body of the report as charts.

4.3 Monetary savings

To obtain the monetary savings we just need to multiply the yearly saved energy by the energy price. For a system with an energy cost of 0,2 NZD/kWh we will have a saving of 500 NZD in the first year approximately.

As explained on page 5, the saving projections have been calculated for 3 different scenarios. The previously shown charts (Chart 5 and Chart 6) are based on the following table.

Table 15: Monetary solar savings [NZD]

Year	7% Increase	13% Increase	20% Increase
1	465	500	535
2	498	565	642
3	530	630	749
4	563	695	856
5	595	760	963
6	628	825	1.070
7	660	890	1.177
8	693	955	1.284
9	725	1.020	1.391
10	758	1.085	1.498
11	791	1.150	1.605
12	823	1.215	1.712
13	856	1.280	1.819
14	888	1.345	1.926
15	921	1.410	2.033

Please note that scenario "7%"as conservative scenario, has an initial discount of 7% (year 1) and scenario "20%"has a 7% additional saving the first year. This is done to show that the savings are expected to be within a range and are not a precise number. This means that in the first year you will save between 465 NZD and 535 NZD (no matter the price increase rate). This range is due to climatic, operating, demand and input uncertainties. After the first year savings and prices increase according to each scenario.