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CENTURION BUILDING SEA POINT

CENTRAL HOT WATER SUPPLY AND ENERGY SAVINGS

BACKGROUND

In August 2017, Solarex approached the Centurion Building body corporate with a proposal to replace the existing electric boilers with a hybrid solar thermal and heat pump hot water system. The intention was to use free solar energy backed up by efficient heat pumps to save up to 70% of the electricity being used by the boilers.

The building had energy monitoring data for the boilers going back several years, and using the latest data, a baseline for monthly energy use was developed.

After negotiation, the share or energy savings was agreed, with a formal agreement being signed in November 2017.

Solarex designed the plant and Freepower installed the capital equipment, with the plant being commissioned in February 2018.

SYSTEM DESIGN

Design of the hot water system was based on SANS 10252-1 for apartment buildings.

The SANS specification requires 115-140 litres per capita per day (average 127lpd)

Assuming 80 apartments with average 1,5 occupants, with a 70% occupancy rate, total hot water demand is 10,700 litres per day.

Energy

Originally, we specified 3 X Enerflow ERHP-SU26-MS 9,7kW heat pumps giving a rated output of 209 lph. The 3 heat pumps can generate 12,000 litres per day at 50°C.

In addition to the heat pumps, we filled most of the available roof area with solar collectors (68m^2) with a maximum rated output of 47kW and producing up to 8,000 lpd (depending on weather). We have since squeezed in a further 12m^2 of panels.

Final solar output is 55kW and the solar fraction about 39%.

We have chosen to use multiple smaller heat pumps rather than 2 larger industrial units. Specifications of the larger heat pumps are very similar for both applications and industrial machines are more robust. In this application, we prefer to use multiple smaller units that can be staged to make maximum savings.

You can see this from the metering data below, where heat pumps are all running early, but are dropped out in series as the water temperature reaches the set point. As hot water is used in the evenings, the heat pumps kick in in series to maintain the required temperature.

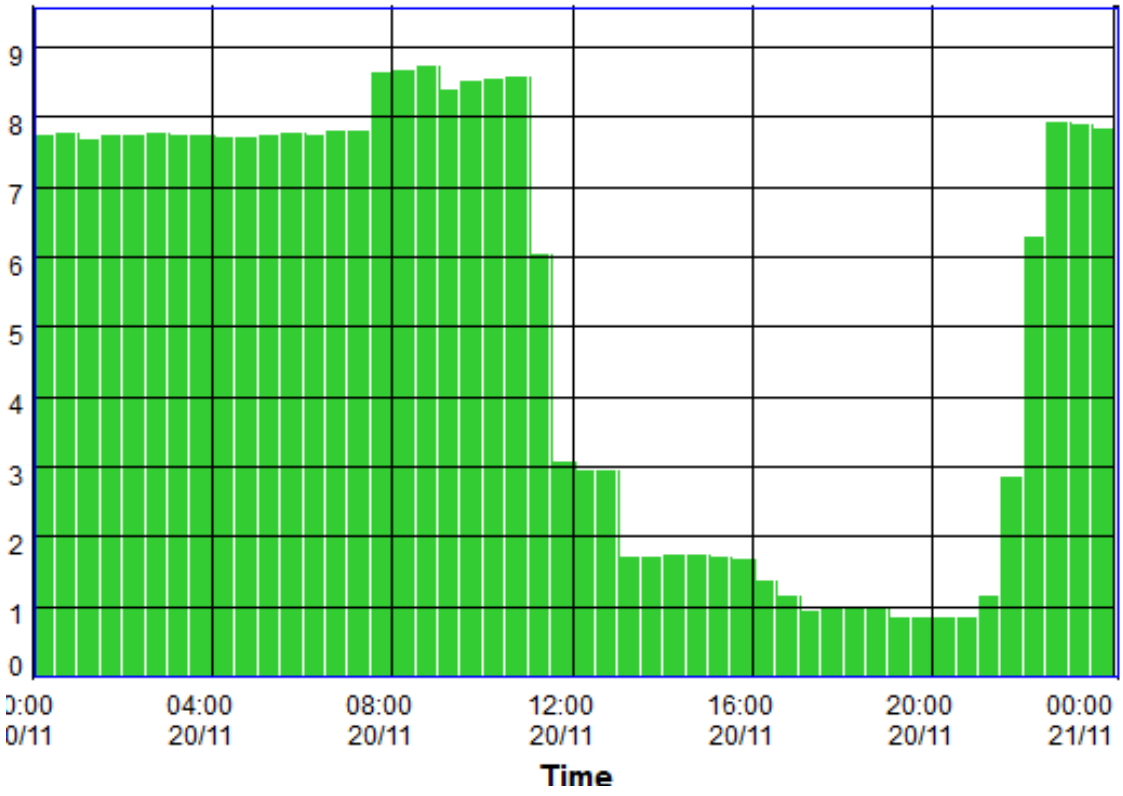

Figure 1: Typical summer daily energy use

On this day, only 3 heat pumps were needed to keep the water at the set point of 55°C, with solar supplying most of the heat which was stored in the (large) tank over the course of the day.

The difference in summer and winter are shown in the graphs below.

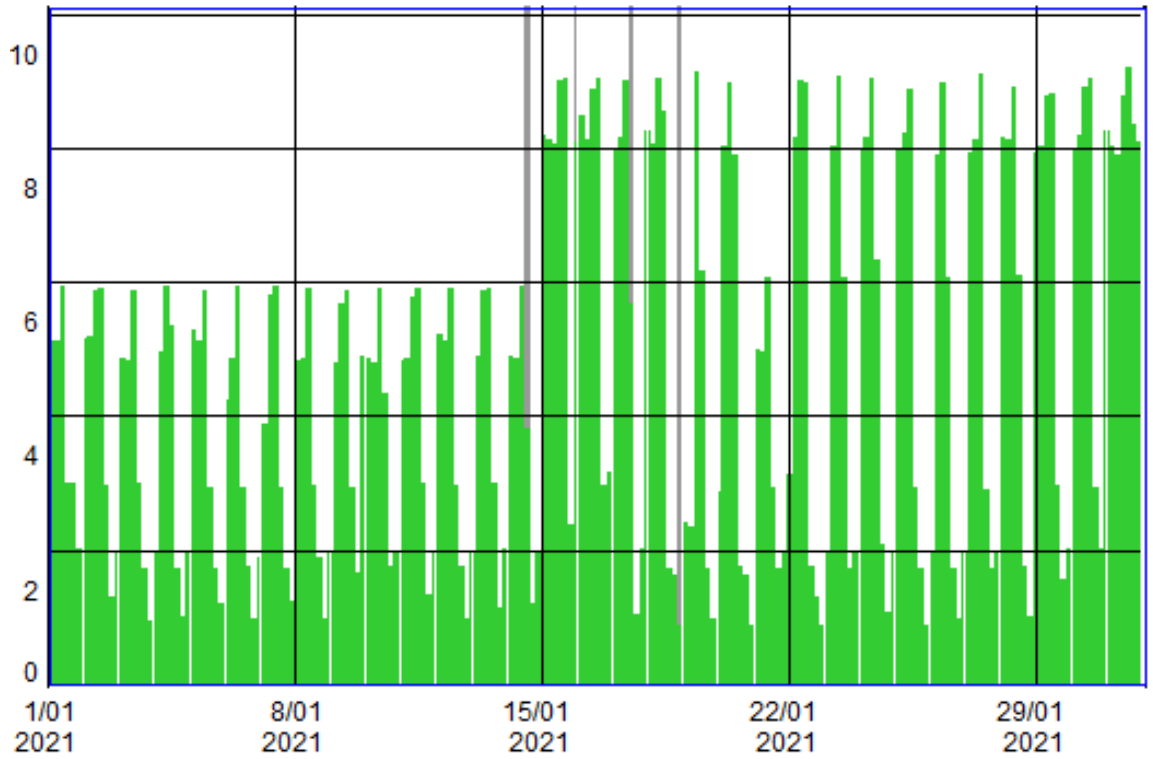

Figure 2: Typical summer month energy use

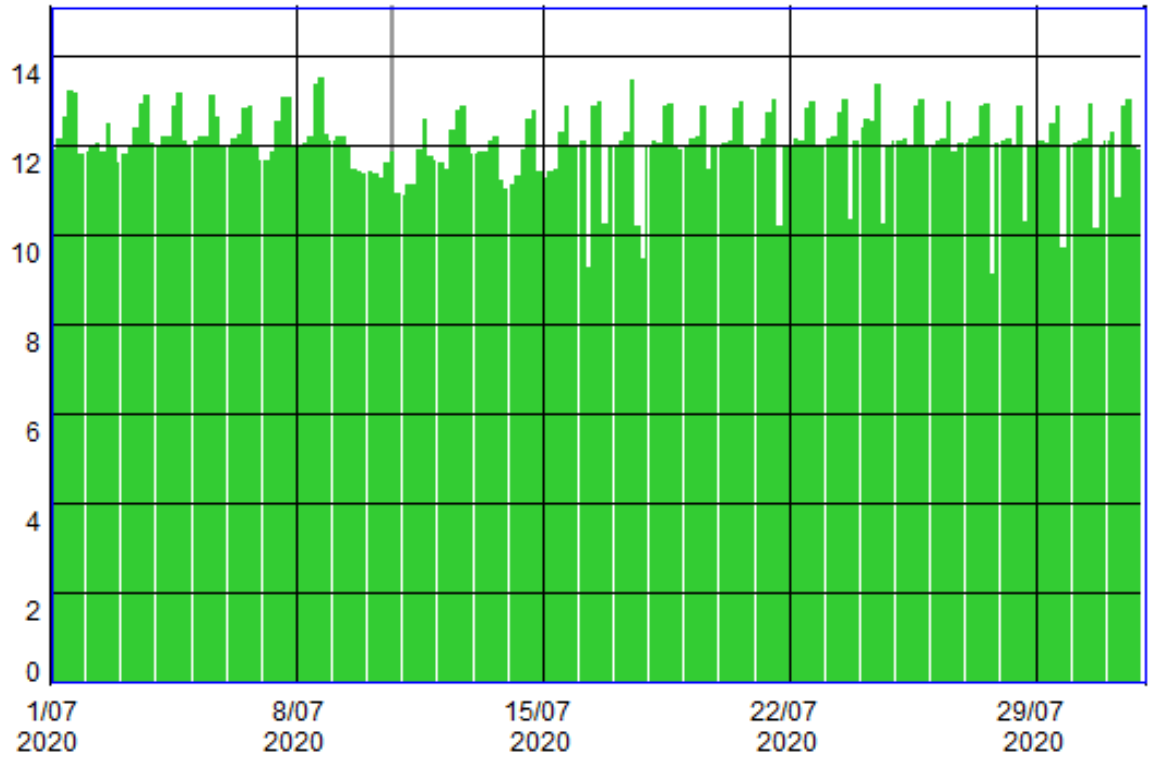

Figure 3: Typical winter month energy use

Hot water storage

The usable water tank volume is about 14 000 litres - tank water level inside 0.8m x 17.2m^2 area. SANS suggests a total of 25-35 litres per capita, i.e., 5,180 litres.

However, when using solar collectors, this volume is doubled to store the excess heat collected during the day. So, we need about 10,000 litres. This is confirmed by the RETScreen energy model and is best practice for industrial solar thermal design.

The existing water storage tank is somewhat oversized for the amount of water required. However, the cold-water feed at the end of the tank feeding the solar collectors and the hot water outlet at the other end at the top forms a thermocline, with the hot water on top.

There is very little mixing of the fresh feed and hot water in the tank, so the hot section stays hot.

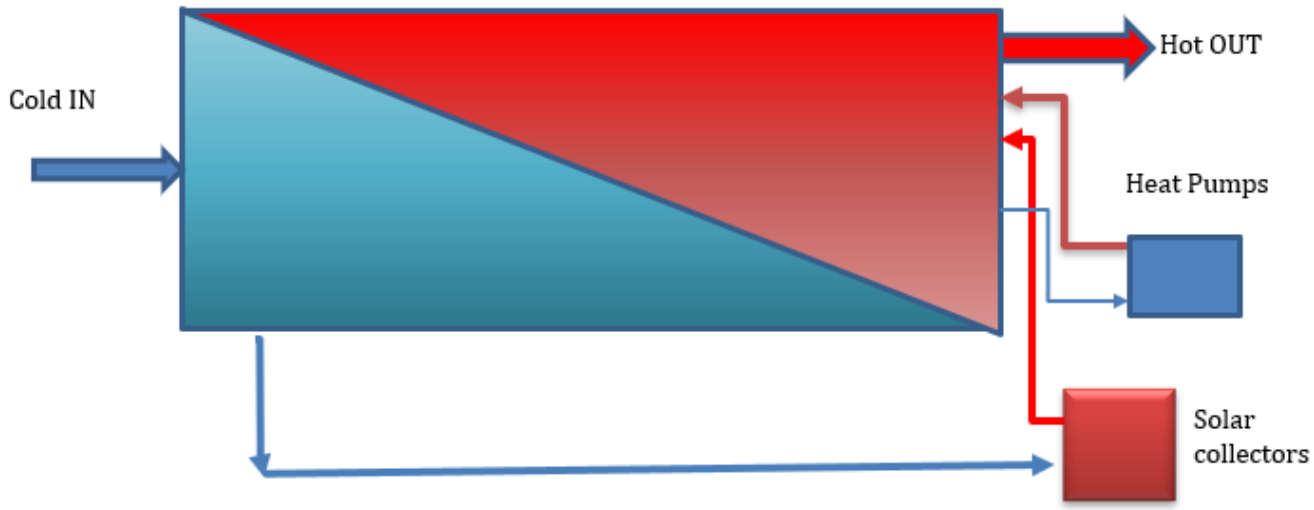

Figure 4: Hot water storage layout

PROBLEMS EXPERIENCED & SOLUTIONS IMPLEMENTED

1. During the first winter the heat pumps froze up in cold weather. This was caused by little/no solar contribution, heat pumps running continuously (no defrost cycle possible) and hot water demand being high. Clearly, the heat pumps could not produce the required water demand under these conditions (during extreme cold weather the heat pumps underperform and deliver water at lower temperature).

   Centurion was advised to start the boilers to take over for a week (the result can be seen in the energy savings graph overleaf.

   We installed a 4th heat pump, which solved the problem until recently. In 2019 we had an exceptionally wet and cold winter, and the same freezing occurred.

2. We have recently installed a 5th heat pump to add extra capacity. This unit can produce water at 60°C so will add capacity in cold weather.

   - Total heating capacity of the heat pumps is now 22,000 litres per day at 55°C, vs demand of say 10,000 lpd. Even in winter, with heat pumps operating at about 60% capacity, this should be sufficient to supply peak demand. Any contribution by the solar collectors simply reduces electricity use.

   - Note that we believe energy losses in the old ring main are very high.

3. We also experienced problems during load-shedding, when the ring main circulation pump sometimes did not automatically re-start. The variable-speed drive was replaced by a standard gearbox – this reduced the efficiency but is more robust.

4. There were some vibration issues with the pump being transmitted through the building structure. We inserted a flexible coupling and thicker mounting pads. This has stopped the vibration issue.

5. There were complaints that the system was making a noise. When we checked the rooftop system was silent, but there was noise emanating from within the plumbing. On investigation it was found that a faulty mixer was causing water hammer in the apartment. Centurion plumbers addressed the problem.

   - We have a suspicion that there may be more leaking mixers. This will lead to either cold water entering the hot water ring main, or loss of hot into the cold-water supply. Every apartment with mixers should be checked.

ENERGY AND COST SAVING TO DATE

The table and charts below give the total energy consumption and saving since the start of the system.

Table 1: Energy saving to date

CENTURION ENERGY SAVINGS

	MONTHLY				CUMULATIVE	
MONTH	Benchmark kWh	Solar & heat pumps kWh	Saving vs Benchmark kWh	Savings %	Savings kWh	Total Savings %
Mar 18	16 595	3 895	12 700	77%	12 700	77%
Apr 18	16 760	3 585	13 175	79%	25 875	78%
May 18	18 551	5 460	13 091	71%	38 966	75%
Jun 18	21 915	5 701	16 214	74%	55 180	75%
Jul 18	24 067	5 834	18 233	76%	73 413	75%
Aug 18	22 885	9 672	13 213	58%	86 626	72%
Sep 18	22 045	15 576	6 469	29%	93 095	65%
Oct 18	22 383	5 608	16 775	75%	109 870	67%
Nov 18	19 742	5 311	14 431	73%	124 301	67%
Dec 18	17 191	4 921	12 270	71%	136 571	68%
Jan 19	16 210	4 523	11 687	72%	148 258	68%
Feb 19	14 406	3 788	10 618	74%	158 876	68%
Mar 19	16 595	5 399	11 196	67%	170 072	68%
Apr 19	16 760	6 483	10 277	61%	180 349	68%
May 19	18 551	7 462	11 089	60%	191 438	67%
Jun 19	21 915	8 408	13 507	62%	204 945	67%
Jul 19	24 067	8 458	15 609	65%	220 554	67%
Aug 19	22 885	9 436	13 449	59%	234 003	66%
Sep 19	22 045	7 613	14 432	65%	248 435	66%
Oct 19	22 383	5 582	16 801	75%	265 236	67%
Nov 19	19 742	5 311	14 431	73%	279 667	67%
Dec 19	17 191	4 291	12 900	75%	292 567	67%
Jan 20	16 210	3 950	12 260	76%	304 827	68%
Feb 20	14 406	3 740	10 666	74%	315 493	68%
Mar 20	16 595	4 909	11 686	70%	327 179	68%
Apr 20	16 760	5 447	11 313	68%	338 492	68%
May 20	18 551	6 171	12 380	67%	350 872	68%
Jun 20	21 915	7 844	14 071	64%	364 943	68%
Jul 20	24 067	8 440	15 627	65%	380 570	68%
Aug 20	22 885	6 800	16 085	70%	396 655	68%
Sep 20	22 045	6 902	15 143	69%	411 798	68%
Oct 20	22 383	5 609	16 774	75%	428 572	68%
Nov 20	19 742	4 923	14 819	75%	443 391	68%
Dec 20	17 191	3 381	13 810	80%	457 201	68%
Jan 21	16 210	2 788	13 422	83%	470 623	69%
TOTAL	683 844	213 221	470 623		Savings	69%

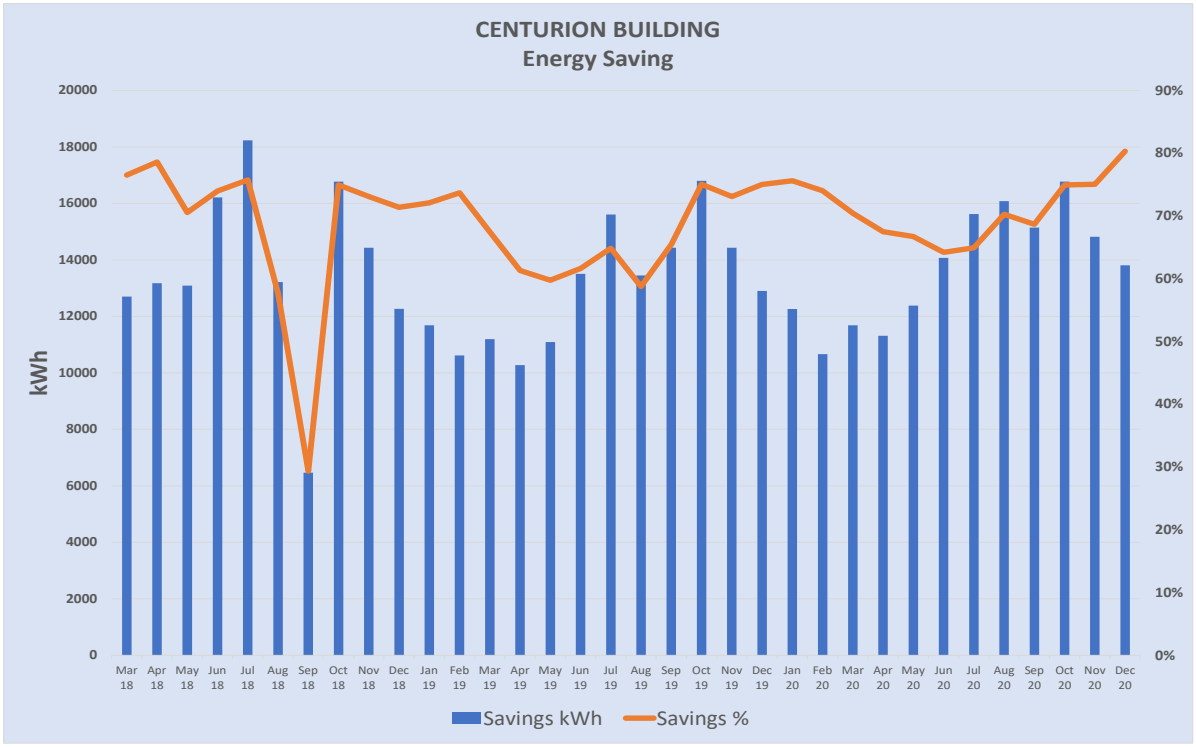

Figure 5: Monthly energy saving vs benchmark

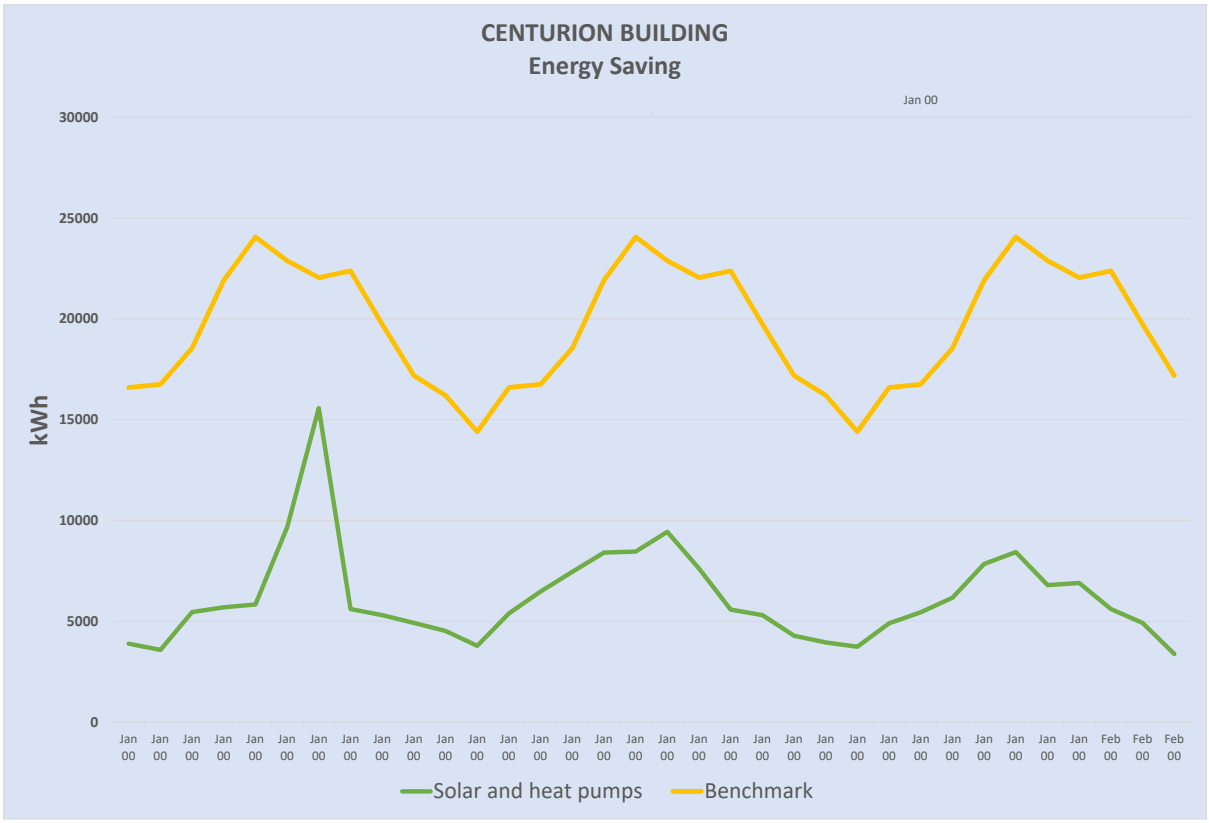

Figure 6: Solar/heat pumps vs Benchmark

- Since commissioning the system has saved 470MWh of electricity, equal to 69%.

- Equipment efficiency has not changed significantly, as shown by the cumulative savings trend.

- The energy use for December 2020 was 5331 kWh or 2.4kWh per apartment per day. Heating the same volume of water, including geyser losses would have consumed almost 8 kWh had each flat had its own geyser.

  Using the boiler would have used 22,000kWh (9,2kWh per day) at a monthly cost of R35,000.

- The actual saving made by Centurion is R220,000 since the start of operations, with zero input costs.

WATER CONSUMPTION

We do not know the details of the occupancy of the building. However, we take readings of the water feed to the hot water system which shows the average consumption of hot water.

Table 2: Building's hot water consumption

CENTURION HOT WATER						
DATE	**DAYS**	**READING**	**USE**	**AVG l/day**	**l/apt**	**Energy used kWh**
22 06 2018		717 681				
25 06 2018	3	744 681	27 000	9 000	113	
26 06 2018	1	753 394	8 713	8 713	109	
27 06 2018	1	762 180	8 786	8 786	110	5 701
06 08 2018	40	1 134 473	372 293	9 307	116	5 834
31 08 2018	25	1 345 301	210 828	8 433	105	9 672
24 01 2019	146	2 584 862	1 239 561	8 490	106	15 576
30 01 2019	6	2 635 387	50 525	8 421	105	5 608
06 02 2019	7	2 701 475	66 088	9 441	118	5 311
28 02 2019	22	2 878 949	177 474	8 067	101	4 921
15 03 2019	15	3 012 966	134 017	8 934	112	4 523
22 03 2019	7	3 074 115	61 149	8 736	109	3 788
15 07 2020	481	7 482 015	4 407 900	9 164	115	96 991
16 07 2020	1	7 492 973	10 958	10 958	137	269
01 09 2020	47	7 993 818	511 425	10 881	136	12 287
04 09 2020	3	8 026 467	32 649	10 883	136	748
01 10 2020	27	8 298 132	271 665	10 062	126	7 610
20 10 2020	19	8 452 854	154 722	8 143	102	3 381
25 11 2020	36	8 765 161	312 307	8 675	108	6 246
05 02 2021	72	9 294 007	528 846	7 345	92	7 584
AVG	**959**		**7 591 031**	**7 916**	**99**	**204**
Apartments	**80**					

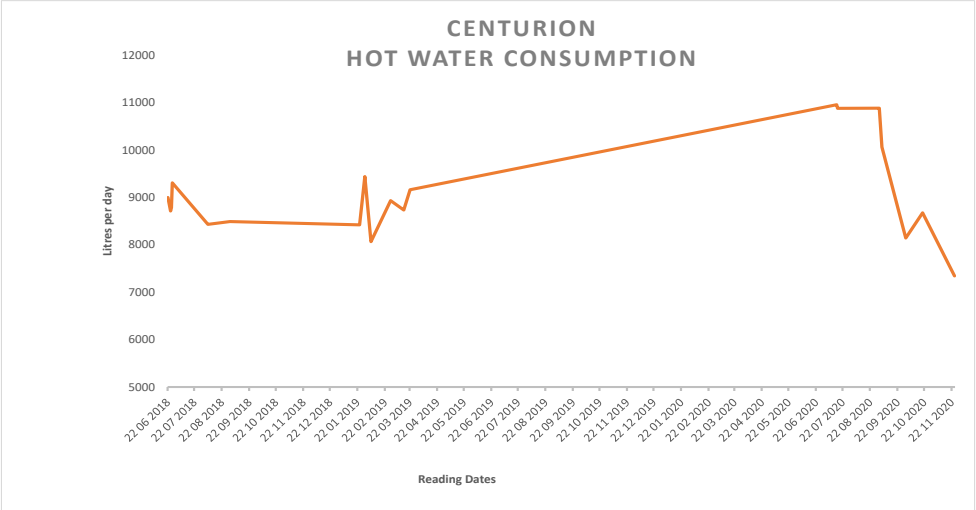

Figure 7: Make-up water feed to hot system

The average water use per apartment over the past 3 years has been 128l per apartment per day or 9400l per day. This is in line with SANS recommendations if the building was 100% occupied, however the reported occupancy has been around 70%, so flats are using about 180lpd on average. In winter consumption is a lot higher – around 225lpd per apartment.

We also measured the water temperature over a short period in September (but before installation of the new heat pump). Note that the temperature sensor is attached to the hot water outlet pipe, so under-reads by 5°C.

Temperatures were generally within specification.

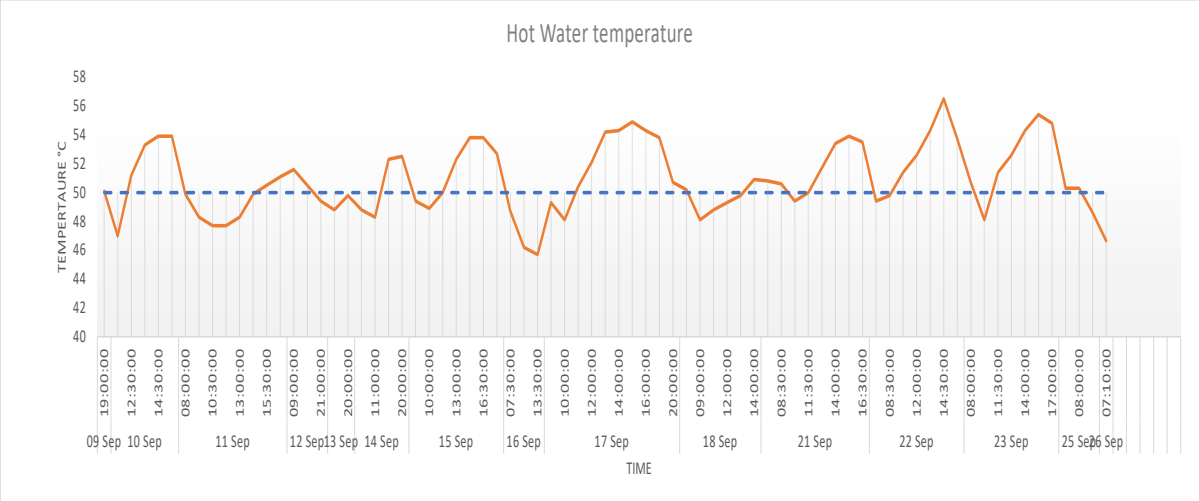

Figure 8: Hot water temperature

BUSINESS MODEL AND FUNDING

1. For this project, Centurion and Solarex entered into a 10-year partnership agreement. This means that Solarex has invested time and money in installing capital equipment and doing the required operations and maintenance over nearly the last 3 years. Centurion is not required to make any investment but remains responsible for paying the City of Cape Town bill.

   Solarex also does monitoring and reporting to ensure that the plant saves as much electricity as possible on a monthly basis. Both parties then share the saving on the agreed basis.

2. The plant was built with the assistance of AEE Intec, who had technical input into the design and quality control of the installation.

3. Grant funding of ZAR256,000 was received as part of the Soltrain programme, with approximately 35% of the capital cost being covered by the grant.

   This funding allowed the project to increase the calculated ROI from 43% to 66%, thus allowing for a higher proportion of the savings to be shared with the client.

   Solarex payback was calculated at 24 months.

OTHER ISSUES

1. Prevention of Legionnaire's Disease (*Legionella pneumophila*).

   Legionnaires is usually found in air-conditioning systems but could occur in hot water systems if not controlled. Usually, it is necessary to increase the hot water temperature to 60°C for an hour to kill any microbes. In hospitals this operation is scheduled once per month.

   In the Centurion case, all fresh water passes through the solar collectors. Collectors have a measured outlet temperature of over 80°C for a few hours per day, even in winter. There is no chance of bacteria surviving in this system.