SOLAR ASSISTED HVAC
FOR TOYOTA TSUSHO AFRICA

Team Members

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ABSTRACT

Toyota Tsusho Africa (Pty) Ltd ("TTAF"), established in 1999, is a wholly owned subsidiary of Toyota Tsusho Corporation, Japan ("TTC"). Within the premises of TTAF there is an Administration and warehouse operation; Wheel and Tyre assembly line; including airbag, rubber linings and brakes assembly.

TTAF consumes an average of 154,186.73 kWh per month, a detailed energy audit TTFA found air-conditioning to be the highest potential for energy savings. Therefore, by upgrading the system and adding Solar Thermal assisted technology the HVAC load could be reduced resulting a net plant reduction of 17%.

Based on the financial feasibility study, TTAF have invested into KwaZulu Natal's (South Africa) first solar assisted cooling and heating ventilation and air-conditioning system (ACS). The Solar Thermal cooling and heating technology has patent and patent pending rights worldwide.

This paper focuses on the monitoring of the energy ACS as installed. Comparing to in-house developed base lines and determined the savings following a designed M&V process. The monitoring and evaluation established the savings, financial results and respective payback periods and other financial indicators.

BACKGROUND

Toyota Tsusho Africa has a committed energy and environmental strategy that aims to reduce greenhouse gas emissions and their net environmental impact. To achieve these goals a plant energy audit was undertaken. This energy audit recommended a proactive and structured approach to energy management that encompasses strategy, policy and operational improvements, coupled with investment in energy efficient equipment that offers the potential to reduce the annual energy consumption by around 29% and reduce energy costs by 539,448 kWh per annum.

Distributed sub-metering proved that the Administration facility accounted for half of the energy usage, and it was identified as having the highest potential for energy savings by up-grading the aged HVAC systems.

In addition, the old HVAC system which used R22 refrigerant and requires water for the cooling tower is viewed as an environmental risk with outdated refrigerant, high energy usage and potable water demand.

Further, the patented Solar Thermal Assisted HVAC systems had globally shown potential and preliminary system investigations and designs showed the same. A more detailed financial feasibility study supported the investment and after a risk assessment the project was supported by TTAF management and TTC head office in Japan.

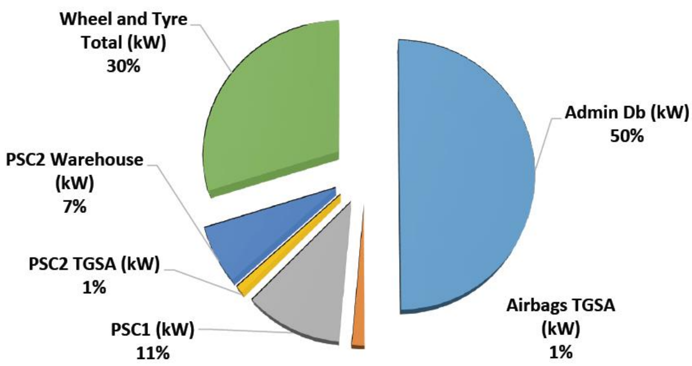

Figure 1: Load Distribution Toyota Tsusho

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COMMON OBSERVED CHALLENGES AFFECTING THE SUCCESS OF SOLAR ASSISTED HVAC

This is a new technology, we can not get away from that fact. As such many corporates view this as a high risk at first look.

This assumed risk was mitigated by careful technical evaluation and financial modelling. TTAF has taken this bold step and a detailed measurement and verification program is underway to validate the predicted savings of this extremely exciting new technology.

Solar Assisted HVAC Team; Toyota Tsusho, Real Time Energy & Durban University

FEASABILITY STUDY – ENERGY AUDIT

During the energy audit phase, the load profile energy usage and individual plants of the HVAC systems were assessed to prepare the financial feasibility study needed for TTAF to invest. The entire load to the Administration facility was measured and the weekday and weekend load profile is shown below.

Area	Power (kw)	Approx area	Type of units
Upstairs Chiller	82.9	1100m2	SCREW TYPE
Downstairs Chiller	67	893m2	SCREW TYPE
Server Room 1	17	Server load	DUCTED
Server Room 2	12.5	170m2	CASSETTES
Boardroom	2.2	50m2	CASSETTE
UPS Room	12	150m2	CASSETTES
Main Canteen	14.4	390m2	CASSETTES
Total	208		

Table 1: Old HVAC Systems

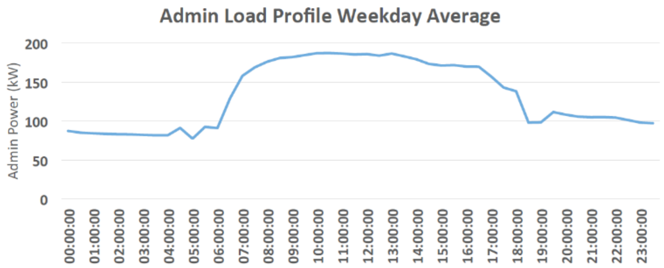

Figure 2: Weekday Load Profile

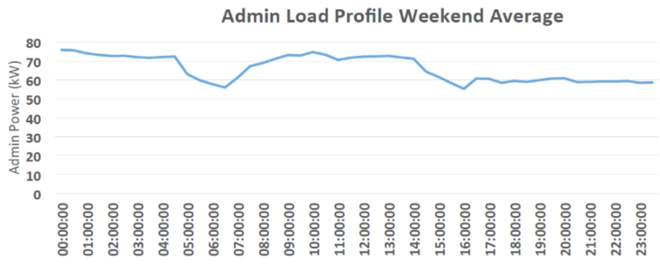

Figure 3: Weekend Load Profile

Based on the installed capacity and load profiles a net energy savings of 314,332 kWh per annum was predicted on the HVAC technology upgrade and Solar Assisted add-on. This would result in a pay-back of the full capital expenditure of the whole system in less than 10 years. Given the HVAC system was a required capital expenditure for TTAF, the additional expenditure vs. efficiency gains of solar thermal boasted an ROI well below 3-years.

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MEASURMENT AND VERIFICATION

The M&V plan, was developed in accordance with the M&V Guideline for Performance Contracting, the IPMVP framework document (2&3) as well as SANS 50010 (1) (i.e.: South Africa Bureau of Standards for Measurement and Verification of energy savings). The resulting baseline needs to be agreed upon by all stakeholders.

The M&V methodology used was Retrofit Isolation and is based on a continuous measurement of the air conditioning system and dedicated data loggers were installed.

Six months of continuous measurement and logging were used to create a credible baseline and a post-implementation verification for this project.

The parameters used for the determination of the baseline were:

- The actual air conditioning load, subject to replacement in kW before the implementation.
- The ambient air temperature.
- The set temperature inside.

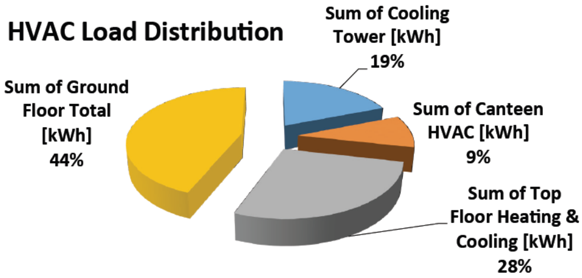

Figure 4: Pie chart of HVAC Energy

REGRESSION ANALYSIS

All data was integrated into daily values and a regression analysis was performed relative to the Cooling and Heating degree days. It's relevant to note that TTAF is located in Durban, South Africa which has a humid sub-tropical climate (Koppen climate classification cFa), with hot and humid summers and pleasantly warm and dry winters, which are snow and frost-free. Factors influencing the regression conformance are, physical factors such as false air ingress (air leaks), human factors such as operator controlled set points, open and closed interior and exterior doors and exterior humidity that will influence both fresh air pre-treatment and false air.

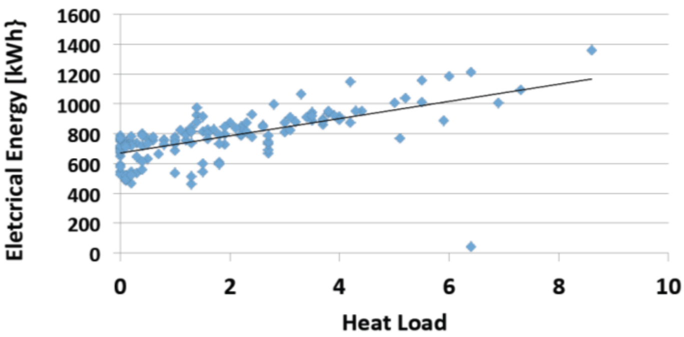

Figure 5: Regression Analysis

SAVINGS DETERMINATION

Saving is calculated based on the measured values compared to the adjusted baseline using the following formula (4):

Savings kWh=old energy use kWh – new energy use kWh (1)

WEEKDAY SAVINGS
= Baseline (kWh) – Measured (kWh)
= (57.769 x (Heat Load) + 669.864) – Measured (kWh)

SATURDAY SAVINGS
= (11.463 x (Heat Load) + 312.572) – Measured (kWh)

SUNDAY SAVINGS
= (45.531 x (Heat Load) + 225.406) – Measured (kWh)

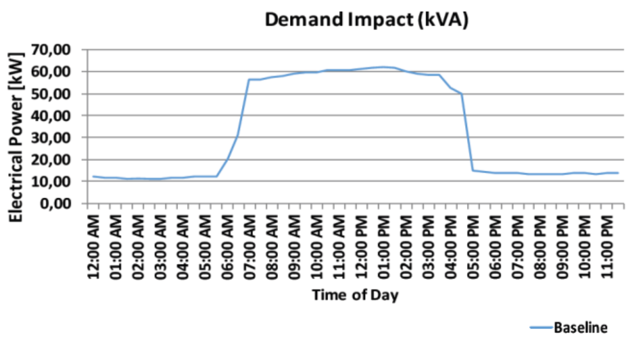

Figure 6: Baseline Demand Profile

SAVINGS RESULTS

The project certificate of completion was issued in February 2017 and final setup adjustments were made in March 2017. Therefore, savings were calculated from April 2017 onwards. The results of these energy savings are shown below:

MONTH	Energy Savings	% Savings (kWh)
April 2017	14492.4	77.7%
May 2017	16886.3	86.6%
June 2017	15880.2	90.3%

It is important to note that these savings represent a composite of the technology upgrade and the addition of the solar assisted thermal panels. This measurement and verification study reports on these savings collectively.

As the cooling tower provided a high baseload, winter months (May to August in South Africa), has lower energy savings but higher percentage reduction. In summer the energy (kWh) savings will increase but the percentage of savings will decrease.

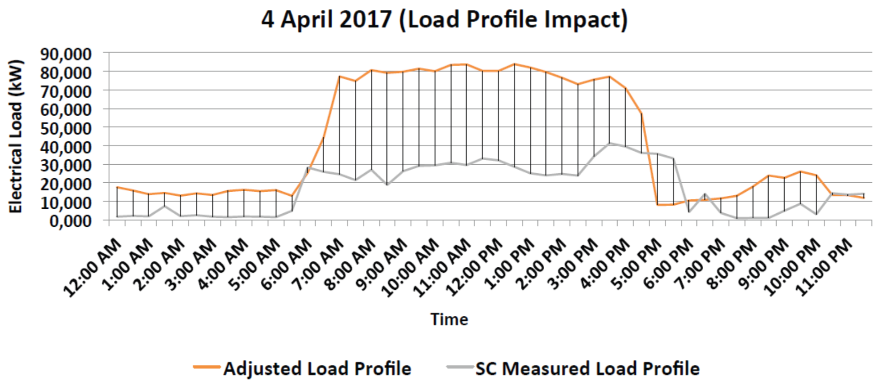

Figure 7: Demand Savings

TTAF, is billed by the Ethekweni municipality for electrical energy. The tariff has a high season (winter) and a low season (summer) rate. In addition, they are billed for both Demand and energy charges. The impact on the HVAC electrical demand is show in Figure 7, since the implementation of this energy efficiency renewable energy intervention the dominant process variable, ambient temperature no longer defines HVAC energy demand but rather occupancy, internal heat sources and false air.

WHAT IS SOLAR ASSISTED AIR CONDITIONING?

In short terms – a Solar Thermal assisted air conditioning is a patented renewable energy technology, which involves the installation of a thermal solar panel in the refrigerant line, adding an element of the heat which would under normal circumstances be generated by the compressor, allowing the modulating compressor or compressors to unload. This process accelerates the heat transfer at condensation point, thus improving the quantity of liquid flow through the expansion valve, thus reducing or eradicating flash gas. As a result, the cooling capacity in the evaporator is enhanced, thus achieving the observed energy reductions. The technology works on all modulating system sizes.

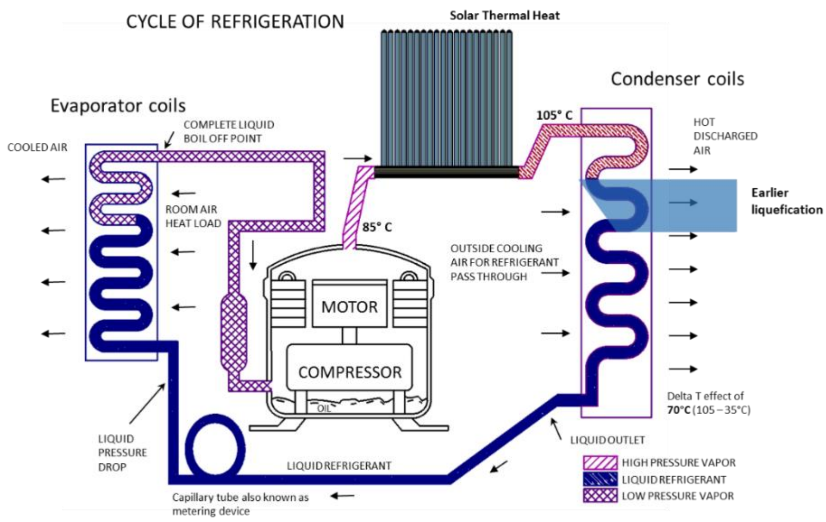

Figure 8: Refrigeration System

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SUMMARY

Solar Assisted Air Conditioning and refrigeration is an exciting new renewable energy technology that maximizes the benefits of HVAC systems that have variable speed drives or modulating multi-staged compressors. The more modern the HVAC infrastructure, the higher the return on investment.

Unlike technology such as solar PV, solar assisted HVAC requires significant pre-engineering assessment and design. Clients and system integrators who can afford compliant measurement and verification will benefit from the peace of mind that their investment is working for them.

Whilst this study does not include the full life-cycle costing, it's relevant to note that the working load on the HVAC components is significantly less and as a result will increase its life expectancy.

In areas where power quality is an issue it is worth measuring and reporting power quality issues as this can affect compressor and VSD life and premature failures can incorrectly be attributed to Solar Assisted HVAC interventions. This is especially relevant on retrofit systems.

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