Analytical Evaluation of the Energy Losses During the Duty Cycle of a Residential Heat Pump water Heater

YONGOUA Nana Joel

MASTERS OF PHYSICS (Research)

SUPERVISOR: MICHAEL Simon

CO-SPERVISOR: TANGWE Loh Stephen

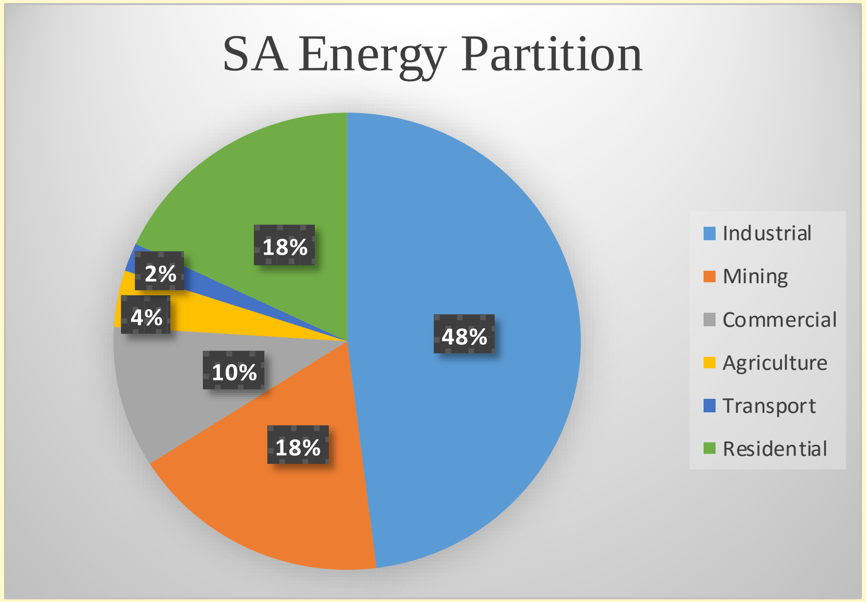
FORT HARE INSTITUTE OF TECHNOLOGY

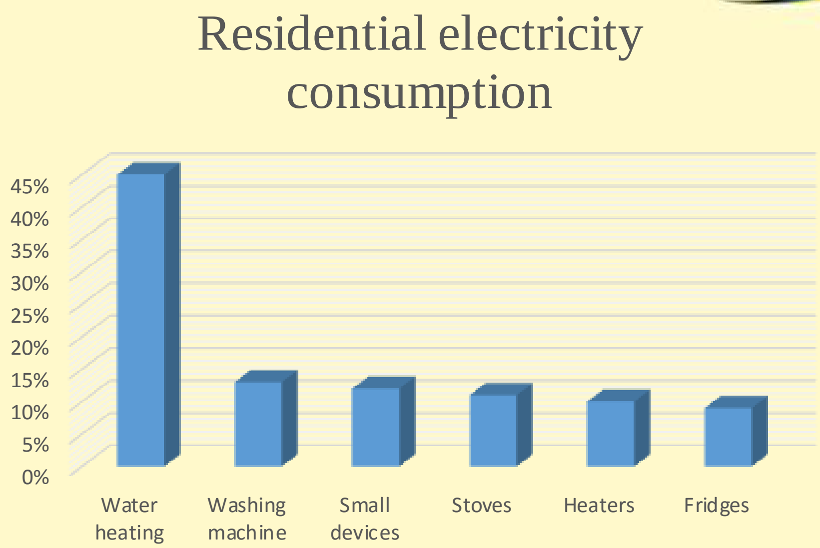
FHIT Renewable energy research

OUTLINE

- ❖ Background
- ❖ Problem statement
- ❖ Objectives
- ❖ Research methodology
- ❖ Results and discussion
- ❖ Conclusion

BACKGROUND





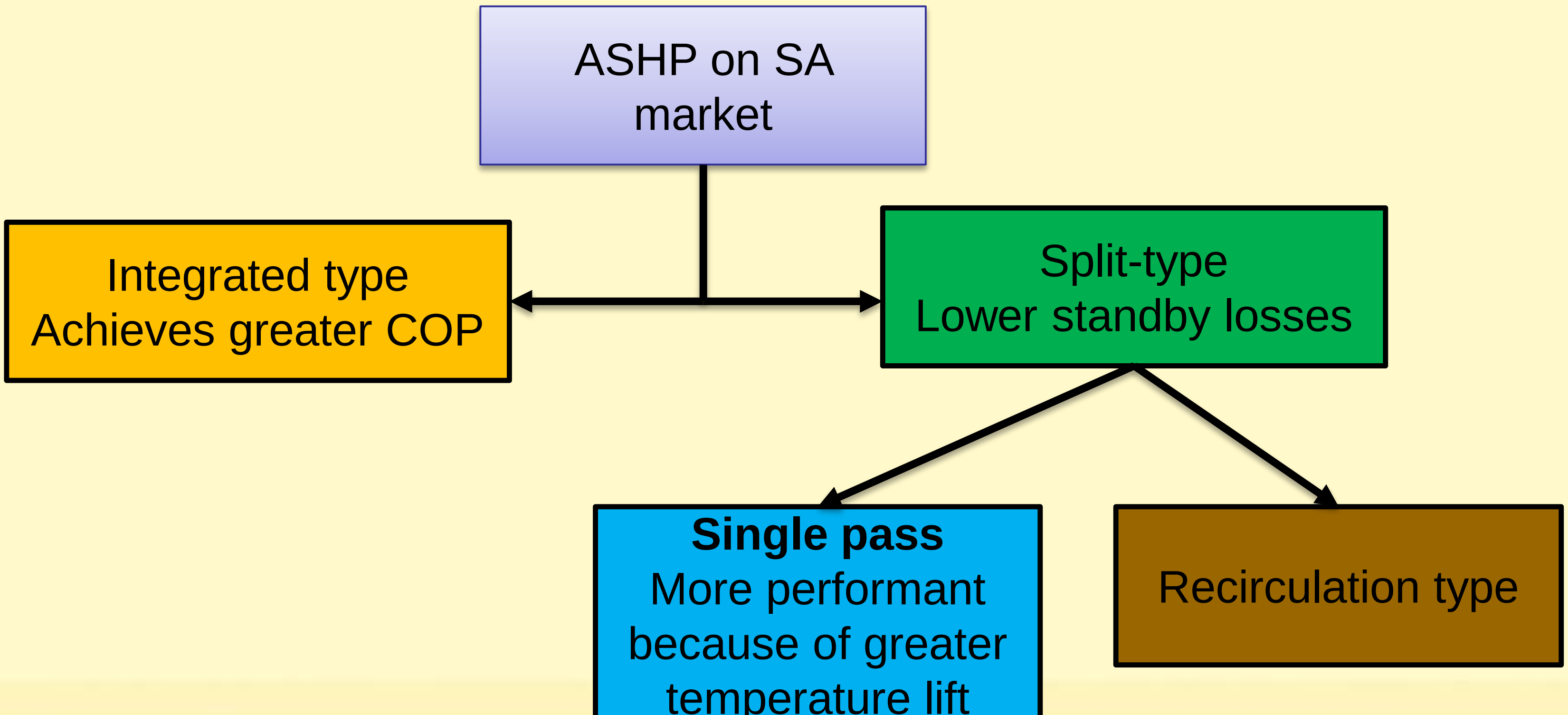
Source: Eskom Integrated Demand Management, 2013

- Heat Pump Rebate Program:
  - 10% electricity reduction in the residential sector
  - Mass roll out of 65,580 residential ASHP water heater units

BACKGROUND

ASHP water heater:

- ASHP water are electromechanical devices used to transfer heat from surrounding air to water (VCRC cycle).
- can save up to 67% of energy consumption compared to geysers for the same heating load



PROBLEM STATEMENT

- Performance of ASHP water depends on two major input variable:
  - Ambient temperature and relative humidity (Time of day/Time of Use)
  - Hot water usage pattern

OBJECTIVE

- Monitor the performance of a split-type residential ASHP water heater during summer and winter
  - Coefficient of Performance
  - Thermal performance of heat exchanger
- Establish the influence of ambient conditions
- Establish the influence of the hot water draw patterns

METHODOLOGY

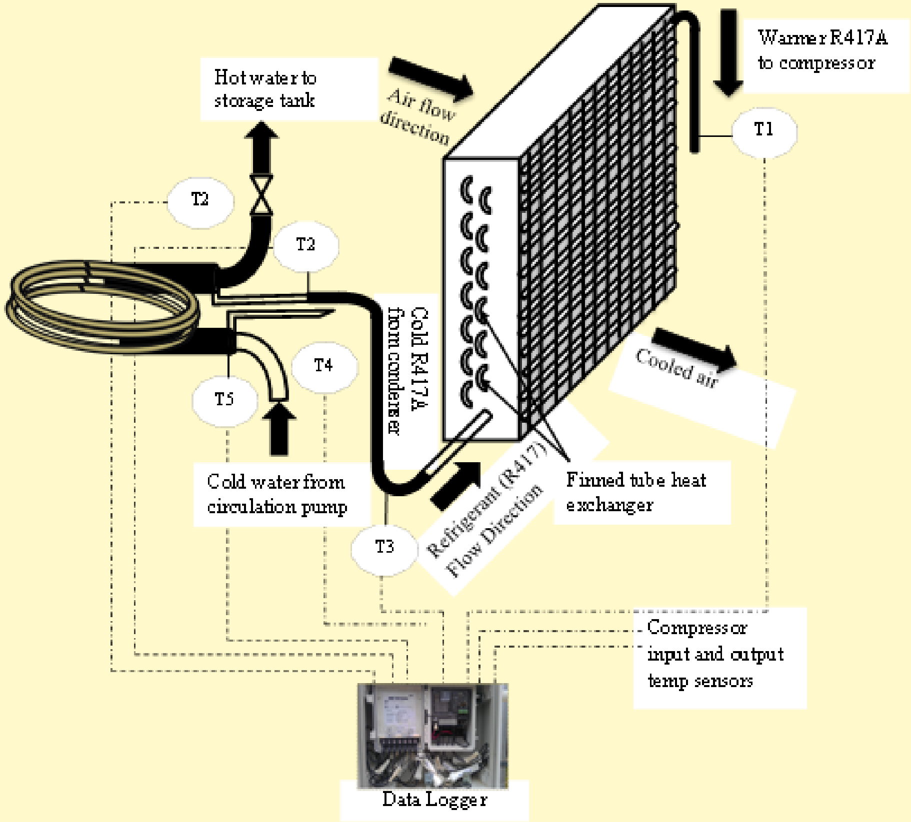


Figure 1: Installed Data Acquisition System on Heat Exchangers

- 1.3kW split type ASHP water heater retrofitting a 150l geyser with R417A as the primary fluid
- Equipment:
  - Power meter
  - 6 temperature sensors
  - Ambient temperature/Relative Humidity
  - Flow meter
  - U-30 NRC data logger
- Fluids all flow in one dimension. The tubes geometry was considered long, thin, uniform, horizontal and a uniform temperature distribution along their surfaces

METHODOLOGY

Table 1: Compressor Specifications

Designation	Specifications
Compressor Type	Rotary Compressor
Compressor Displacement	80.4 cc/rev
Refrigerant Type	417A
Electric Source	1ϕ 230V
Condenser Type	Shell-and-tube type

- Controlled water draws
  - Morning: 06:00-09:00am
  - Afternoon: 12:00-14:00pm
  - Evening: 17:00-20:00pm
- Repeated sequential draws
  - 150 liters
  - 100 liters
  - 50 liters
- Heat Exchanger parameters
  - Evaporator heat gain
  - Condenser rejected heat
  - Heat absorbed by water

RESULTS AND DISCUSSION

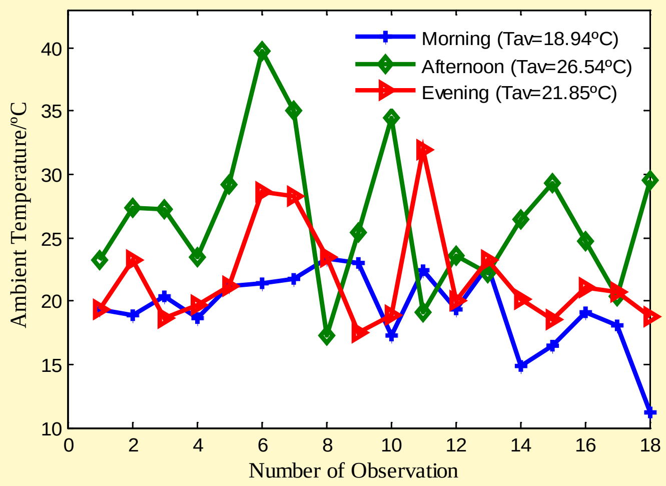


Figure 2: Summer Ambient Temperature Profiles

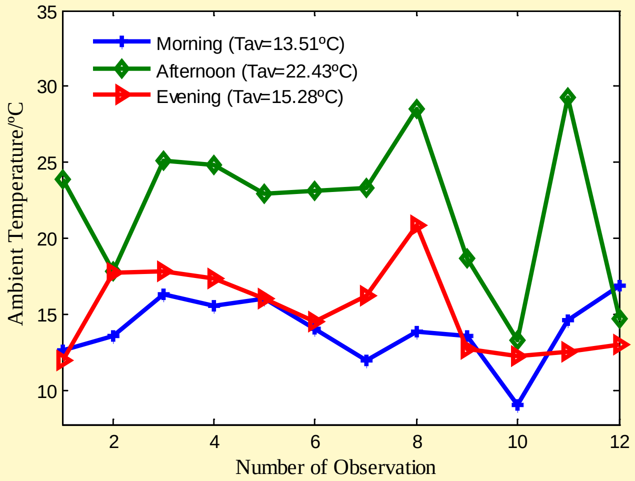


Figure 3: Winter Ambient Temperature Profiles

- Ambient temperature highest in the afternoon for both seasons
  - Summer: Maximum of 40ºC and minimum of 15ºC
  - Winter: Maximum of 30ºC and minimum of 3ºC

RESULTS AND DISCUSSION

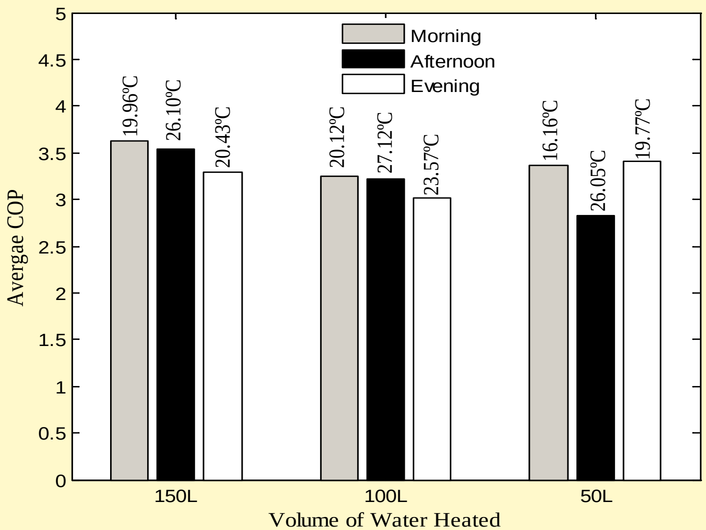


Figure 4: Summer average COP Profile against Volume of Water Heated up

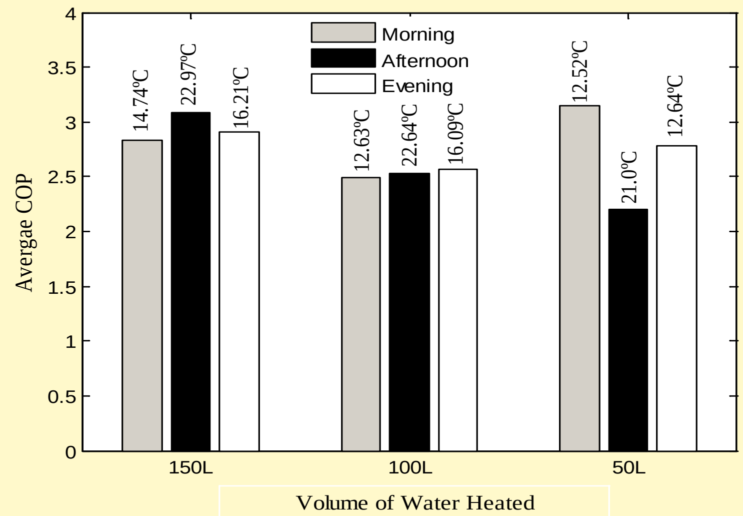


Figure 5: Winter average COP Profile against Volume of Water Heated up

Table 2: COP Variation with Volume of Hot Water and Time of Use

Volume of Water Heated/ Litres	COP					
	Summer			Winter		
	Morning	Afternoon	Evening	Morning	Afternoon	Evening
150	3.63251	3.54005	3.28997	2.82784	3.08308	2.90442
100	3.24688	3.22278	3.01557	2.49217	2.53084	2.57326
50	3.35890	2.82363	3.41383	3.14491	2.20786	2.78749

RESULTS AND DISCUSSION

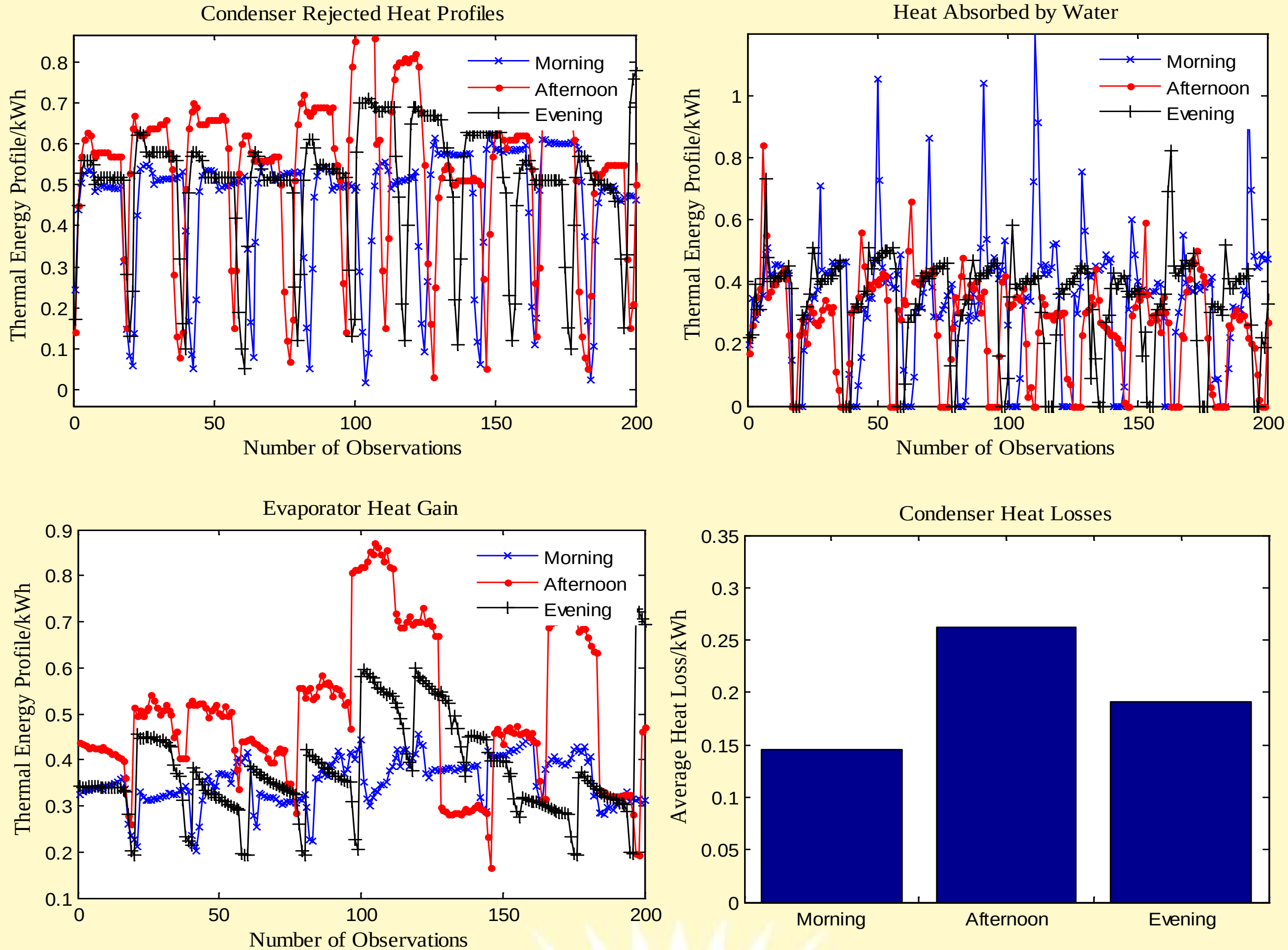


Figure 6: Summer Thermal Energy Profiles

RESULTS AND DISCUSSION

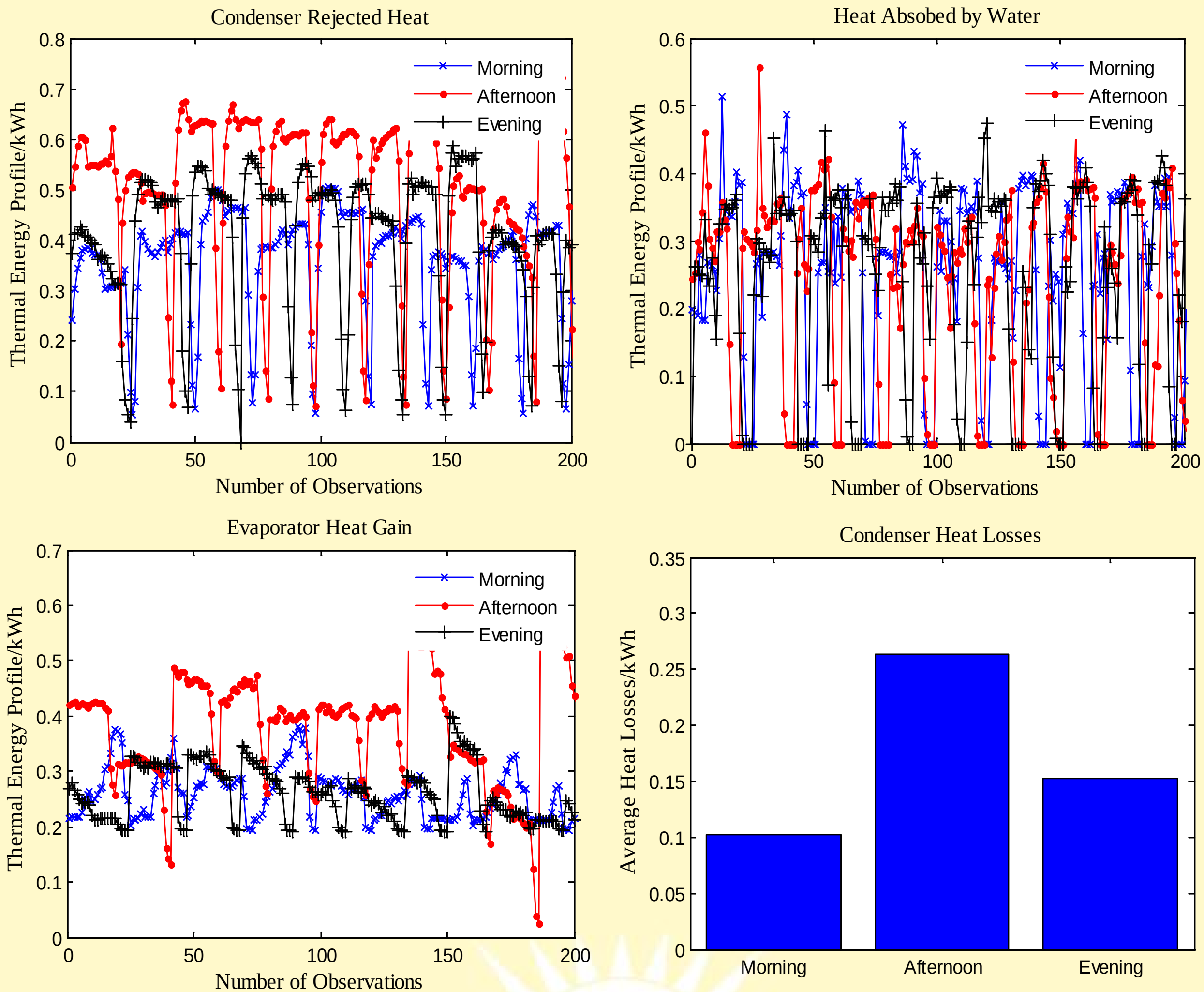


Figure 7: Winter Thermal Energy Profiles

RESULTS AND DISCUSSION

Table 3: Condenser Average Thermal Performance Parameters

Average Thermal Energies	Summer			Winter		
	Morning	Afternoon	Evening	Morning	Afternoon	Evening
Rejected Heat/kWh	0.43675	0.52936	0.48451	0.34360	0.50139	0.39883
Heat Absorbed by Water/kWh	0.30397	0.26899	0.29619	0.25389	0.23844	0.24721
Heat Loss/kWh	0.14614	0.26231	0.19137	0.10260	0.26324	0.15286

CONCLUSION

- Only about 75-79% of heat is effectively harnessed by water during heating up cycle

- Performance of heat exchanger is best in the morning and lowest in the afternoon

- High COP are be attained during huge hot water draws

- For a fixed pattern, higher COP are attained during the morning heating up cycle

REFERENCE

[1] T. Skinner (2012). Eskom: An overview of energy efficiency and demand side management in South Africa. Available: url

[2] University of Pretoria, "Measurement and verification guideline: Residential heat pump rebate program. Eskom, Pretoria. 2011

[3] E. Orhan, S. Savas and I. Yalcin, "Operation of compressor and electronic expansion valve via different controllers" P.E. Dadios (Ed): InTech, 2012, pp. 223-237

[4] K. Vinther, C. L. Hillerup, S. E. Baasch and H. Rasmussen "Evaporator superheat control with one temperature sensor using qualitative system knowledge". Amer contrl conf. 2012, pp 374-379.

[5] R. K. Green, N. Ahmadi, J. Claesson and D. R. Wilson "Microprocessor based control system for heat pumps" New ways to save energy (Ed). Netherlands. 1980, pp 154-163

ACKNOWLEDGEMENT

We are grateful to acknowledge the financial supports from Eskom and Fort Hare Institute of Technology, University of Fort Hare in this research in a bid to purchase our data acquisition system and the ASHP water heater system.

THANK YOU