Managing peak demand and energy costs through PV and intelligent scheduling of water heaters at two schools in South Africa

Stellenbosch University

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Introduction

Motivation:

• Global emissions are increasing
• South Africa is coal heavy
• Many schools are underfunded and can benefit from solar intervention

South Africa’s CO₂ emissions from solid fuel consumption (millions of tons); Site: Worldbank.org
Introduction

Overview:

- Two primary schools evaluated
- Both employ a demand-based tariff structure
- Primary objectives:
  - Reduce emissions
  - Reduce utility bill
Simulation Setup

Approach:

4 Configurations:

- Baseline
- Smart Scheduling EWH
- Solar intervention
- Solar and Smart Scheduling EWH intervention

• Simulate configurations using:
  - Verified Solar and EWH models
  - Using data obtained by sensors

Average daily measured energy usage for both Schools (plotted for each week)
Simulation Setup

System Simulation Diagram:
System Modelling

Solar PV simulation:

**Inputs**
- Measured school energy usage:
  - Basic energy
  - Peak demand
- Weather data
- Solar system simulation parameters

**Calculations**
- System Advisor Model libraries:
  - Single diode solar model
  - Empirically derived inverter model

**Results**
- Basic energy savings
- Demand savings
- Lost energy
System Modelling

EWH simulation:

Inputs

• Measured school EWH usage:
  – Electricity usage
  – Hot water usage
• EWH simulation parameters

Calculations

• Verified two-node EWH model
• Simulation method:
  – Thermostat control
  – Smart schedule control

Results

• Basic energy savings
• Demand savings
• User comfort
System Modelling

EWH Smart-Scheduling algorithm:

Begin

Calculate heating priority for each EWH

Is excess PV available?

True

Heat EWH with solar

False

Looped through entire priority list?

True

Heat EWH with grid

False

Looped through entire priority list?
Results

Energy and peak demand savings:

Average kWh used per day

Maximum kVA per month

Stellenbosch Primary: Base - - Solar intervention - - Solar & Smart Scheduling intervention
Results

Seasonality:

Max kVA for a winter’s day

Max kVA for a summer’s day

- Stellenbosch Primary: Base
- Solar intervention
- Solar & Smart Scheduling intervention
Results

Simulation results for Stellenbosch Primary:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>School Baseline</th>
<th>With smart-scheduling intervention</th>
<th>With solar intervention</th>
<th>With solar and smart-scheduling intervention</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Energy Usage</td>
<td>157.3</td>
<td>155.6 (1.08%)</td>
<td>109.2 (30.7%)</td>
<td>105.4 (32.7%)</td>
<td>MWh</td>
</tr>
<tr>
<td>Mean Daily Energy Usage</td>
<td>430</td>
<td>426</td>
<td>299</td>
<td>289</td>
<td>kWh</td>
</tr>
<tr>
<td>Daily peak demand [min,median,max]</td>
<td>[8,37,72]</td>
<td>[8,36,71] (2.70%)</td>
<td>[0,30,55] (19.1%)</td>
<td>[0,29,54] (21.2%)</td>
<td>kVA</td>
</tr>
<tr>
<td>Yearly CO₂ Emissions</td>
<td>117 065</td>
<td>115 808</td>
<td>81 274</td>
<td>78 445</td>
<td>kg</td>
</tr>
<tr>
<td>Percentage utility bill reduction</td>
<td>0</td>
<td>1.4</td>
<td>23.6</td>
<td>25.8</td>
<td>%</td>
</tr>
</tbody>
</table>
## Results

Simulation results for Eikestad Primary:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>School Baseline</th>
<th>With solar intervention</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Energy Usage</td>
<td>114.8 MWh</td>
<td>71.8 (37.4%) MWh</td>
<td>MWh</td>
</tr>
<tr>
<td>Mean Daily Energy Usage</td>
<td>315 kWh</td>
<td>197 kWh</td>
<td>kWh</td>
</tr>
<tr>
<td>Daily peak demand [min,median,max]</td>
<td>[6,31,62] kVA</td>
<td>[0,25,55] (19.3%) kVA</td>
<td>kVA</td>
</tr>
<tr>
<td>Yearly CO₂ Emissions</td>
<td>85 436 kg</td>
<td>50 458 kg</td>
<td>kg</td>
</tr>
<tr>
<td>Percentage utility bill reduction</td>
<td>0 %</td>
<td>30.13 %</td>
<td>%</td>
</tr>
</tbody>
</table>
Conclusion

- Interventions resulted in reductions in utility bill and emissions.
- The estimated payback period was favorable, making it viable for the schools investigated.
- Optimal battery storage can possibly lead to improved results.
Thank you