
Presented by O.D. Dintchev

10th April 2013 Tshwane University of Technology
INTRODUCTION

The purpose of this presentation is to overview the common/accepted by M&V and Energy Audit Section- Assurance and Forensic Department of ESKOM methodologies and practices for quantifying and reporting of the energy savings resulting from domestic solar water heaters in the Eskom’s Solar Water Heating Programmes.
Presentation Outline

• Highlights from ESKOM IDM /EEDSM Programmes
• TUT Involvement in ESKOM’s EEDSM Initiatives
• Solar Water Heating Measurement and Verification (M&V) Guidelines for High Pressure SWHs
• M&V Standard Guideline for Low Pressure Solar Water Heating
• Future Research and Development
Energy Savings in South Africa

- South African Electricity supplier (ESKOM) is implementing a massive energy saving and energy management programme.
- For the year of 2013 the energy targets are 2010.18 GWh
- TUT M&V Team is involved in the programme and contributes towards the R&D process linked with scientific measurement and evaluation of the Energy savings from the initiatives.
TUT M&V Team

- TUT M&V team proudly was one of the first universities started the M&V activities in 2004. Since the beginning of M&V TUT is reporting on 200 Energy Management/ Saving Projects in Industrial, Mining, Commercial, Agricultural and Residential Sectors by Measuring and Verifying total savings of **700 MW**! This power is equivalent to **three turbine/generating units 200 MW each** (similar to the 10 units of Hendrina power station in Mpumalanga).

- TUT M&V Team facilitated the **VIRTUAL GENERATION** of **5 908,560 GWh** electricity per annum at 100% efficiency (Hendrina Power station works with only 33% efficiency). This PURE AND CLEAN ENERGY SAVED TO THE LOCAL AND GLOBAL ENVIRONMENTS the emissions of **5 million tons carbon dioxide p.a.**!
General

- Energy efficiency (EE) and demand-side management (DSM) projects are implemented to achieve energy consumption (kWh) and energy demand savings (kW) at specific time periods.
- The basis of a successful EEDSM project rests on the fact that impacts can be determined to a degree of accuracy, trust and cost that is acceptable to all stakeholders.
- This process is known as Measurement and Verification (M&V). The objectives of M&V are to provide an impartial, credible transparent and replicable process that can be used to quantify and assess the impacts and sustainability of EEDSM projects.
Why should we measure and verify?

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Solar Water Heating Programmes

On 23 June 2009, the Minister for Energy in her budget vote speech stated that: “The Department will ensure that one million solar water heaters (SWHs) are installed in households and commercial buildings over a period of five years.”
Solar Water Heating Programmes

• The government’s solar water heating (SWH) programme currently underway is managed by Eskom – the “SWH Rebate Programme”. Further a fiscus funded SWH programme through a Division of Revenue Act (DoRA) allocation is currently rolled out in various municipalities.
Solar Water Heating Programmes

- The mass rollout of SWHs has been gaining momentum of late compared to the commencement of the programme. From November 2008 to the end of August 2012 about 280 000 rebate funded and 30 000 SOP-funded SWH have been installed. These figures are spread across the country. Notwithstanding these lower than desired installation figures, the 2014 target is still in sight.
Solar Water Heating Programmes

Considering the large number of SWHs to be installed under the programme, there is a need to establish methodologies to evaluate their performance with respect to kWh savings and to lower electricity demand in particular during peak times.
M&V for Solar Water Heating Programmes

There are two fundamental SWH systems involved in ESKOM’s and DoE Programmes:

• High Pressure SWH systems
• Low Pressure SWH systems

The M&V methodology is developed to suit the above type of systems.
Solar Water Heating Guideline for High Pressure Systems

Developed by the North-West University
MEASUREMENT AND VERIFICATION OF A SOLAR WATER HEATING PROGRAM

The M&V solar water heating methodology is designed to provide an *impartial and credible* quantification and assessment of the program impacts that result from the DSM activities.

A number of standardised deliverables have been developed to achieve the objectives of this type of M&V program.
Solar Water Heating System Performance

The SWH system performance is a subject of the following:

- Geographic location of the installation site
- Seasonal ambient temperature changes (including of cold water input temperature)
- Amount of hot water usage in the household (HWP)
- Time of hot water usage in the household (HWP)
- Quality (make) and proper installation of the SWH system
- Generally: dependant of hot water usage pattern at the household in other words on the HUMAN BEHAVIOR.
Solar Water Heating Hot Water Usage Profile

• A Hot Water Usage Profile not only indicates the amount of hot water used but also when it is used.
• The hot water usage profile may vary according to the individual needs of persons living in a household.
• The hot water usage profile may also vary from household to household. Many reasons for the variation exist, but the main factors are:
  • Number of people living in a specific household
  • Occupancy during the day (Who is using the hot water and in what manner?)
Pre-determined Baseline Profiles

• Typical electrical hot water demand profiles (baseline profiles) for residential homes were acquired from other IDSM-supported research studies
  • Predetermined baseline profiles were acquired and categorised
  • The baseline profiles were categorised by their location and the amount of people living in the home.
  • The profiles are listed in the M&V Solar Water Heating Guideline
  • If no baseline profile is assigned to a category the average baseline profile for that location can be used
Typical weekday and weekend hot water demand profiles

![Graph showing typical hot water demand profiles with weekday and weekend demand curves.](image-url)
Example of some average weekday baseline profiles for different locations
In order to develop the baseline for a batch of solar water heating systems, the M&V Solar Water Heating Application requires *only the location of installation* and the *number of people living in the house* for each installation. The electrical hot water demand profile for each solar water heating system can then be selected in a drop-down menu in the application.
| Baseline (Hot Water Demand) Profile | 01:00 | 02:00 | 03:00 | 04:00 | 05:00 | 06:00 | 07:00 | 08:00 | 09:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | 00:00 |
|-----------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|                                  | 1.05  |       |       |       |       |       | 0.34  |       | 0.83  | 2.00  | 1.33  | 0.34  | 0.28  | 0.08  | 0.18  | 0.11  | 0.40  | 0.53  | 2.44  | 1.96  | 1.43  | 0.25  | 0.10  | 0.64  | 0.12  |
Simulating the Baseline

![Baseline Generator Interface]

<table>
<thead>
<tr>
<th>Project Name</th>
<th>SWH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Master Usage</td>
<td>Distributions</td>
</tr>
<tr>
<td>Master Average</td>
<td>Ave Used per event</td>
</tr>
<tr>
<td>Group</td>
<td>Group 1</td>
</tr>
<tr>
<td>Storage Capacity</td>
<td>134</td>
</tr>
<tr>
<td>Water Temperature</td>
<td>18</td>
</tr>
<tr>
<td>Set Point</td>
<td>60</td>
</tr>
</tbody>
</table>

![Graph of LOAD]

- Geyser Load Controlled
- Geyser Load without Control
- Notch Baseline
## Reporting of Performance Assessment

### Weekday (MW)

<table>
<thead>
<tr>
<th></th>
<th>Morning Off-peak</th>
<th>Morning Standard</th>
<th>Morning Peak</th>
<th>Midday Standard</th>
<th>Evening Peak</th>
<th>Evening Standard</th>
<th>Evening Off-peak</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline Demand</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Actual Demand</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Actual Impact</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intended Impact</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Over / Underperformance</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
</tbody>
</table>

### Saturday (MW) & Sunday (MW)

<table>
<thead>
<tr>
<th></th>
<th>Morning Off-peak</th>
<th>Morning Standard</th>
<th>Midday Off-peak</th>
<th>Evening Standard</th>
<th>Evening Off-peak</th>
<th>Sunday Off-peak</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline Demand</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Actual Demand</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Actual Impact</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intended Impact</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Over / Underperformance</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
</tbody>
</table>

### Baseline, Actual, Impact

<table>
<thead>
<tr>
<th></th>
<th>Weekday</th>
<th>Saturdays</th>
<th>Sundays</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Actual</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impact</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Simulation Model for Performance of Solar Water Heating Systems
Simulation Model Inputs

- Geographical Location (for weather condition purposes);
- Slope of the solar collector (°);
- Orientation of the solar collector (°);
- Alpha 1 Performance coefficient of the solar water heating system (m²);
- Alpha 2 Performance coefficient of the solar water heating system (MJ/K);
- Alpha 3 Performance coefficient of the solar water heating system (MJ);
- Heat loss coefficient of the solar water heating system (W/K);
- Average inlet water temperature (°C);
- Geyser set point (°C);
- Baseline (Hot water demand) profile (kW); and
- Electrical backup-installed or not.
In order to quantify the performance and energy saved (produced) by a SWH system the following measurements are needed:

- The volume of hot water used in the monitored household \([\text{L}]\) or \([\text{m}^3]\)
- The temperature of the cold water input to the SWH system \([\circ \text{C}]\)
- The temperature of the hot water output of the SWH system \([\circ \text{C}]\)
- The electrical energy consumed by the electric back-up element of the SWH system.
- The ambient temperature \([\circ \text{C}]\)
Examples of Recent SWH M&V Projects Executed by TUT M&V Team
## Project Audit Results

<table>
<thead>
<tr>
<th>Tank Capacity</th>
<th>SWH</th>
<th>150 l</th>
<th>200 l</th>
<th>265 l</th>
<th>300 l</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>1109</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Location</td>
<td>1109</td>
<td>959</td>
<td>150</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Location</td>
<td>350</td>
<td>210</td>
<td>140</td>
<td></td>
<td></td>
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<tr>
<td>Location</td>
<td>320</td>
<td>320</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Location</td>
<td>160</td>
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<tr>
<td>Location</td>
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<td>Location</td>
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<tr>
<td>Location</td>
<td>10</td>
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<td></td>
</tr>
<tr>
<td>Location</td>
<td>22</td>
<td>22</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>2075</td>
<td>594</td>
<td>300</td>
<td>959</td>
<td>150</td>
</tr>
</tbody>
</table>
Base Line and Post-Implementation Profiles

Weekdays

MW
# Project Reported Savings

<table>
<thead>
<tr>
<th>Savings</th>
<th>DSM Target</th>
<th>This Month March 2013</th>
<th>YTD</th>
<th>ITD</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>MW</td>
<td>n.a.</td>
<td>0.2405</td>
<td>0.022</td>
<td>0.2405</td>
<td>Evening peak 18-20 h , weekdays</td>
</tr>
<tr>
<td>MWh</td>
<td>n.a.</td>
<td>372</td>
<td>372</td>
<td>372</td>
<td></td>
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</tbody>
</table>
Measurement and Verification
Standard Guideline for Low Pressure Solar Water Heating Systems

Developed by TUT M&V Team
The purpose of the Guideline is to facilitate M&V teams involved in ESKOM’s EEDSM projects in quantifying and reporting of the energy savings resulting from ESKOM Low Pressure Solar Water Heating Programme.
The base line is determined on the basis of hot water usage heated by ELECTRICITY ONLY i.e. what the grid would "see"."
The main M&V question when dealing with LPSWH projects is to identify the electricity consumption and its time of use to heat water prior the retrofit. This may be achieved by the following ways:

*By interviews with the inhabitants*

*By dedicated SWH measurements after the retrofit*

*By measurements of the electricity prior and after retrofit.*
Interviews with the inhabitants
By dedicated SWH measurements after the retrofit
Measurements of the Electrical Energy prior and after Retrofit at the Household
Measurements of the Electrical Energy prior and after Retrofit at the Household
Measurements of the Electrical Energy prior and after Retrofit at the Household
Some Results from Energy Audits of 582 low-cost (RDP) houses

<table>
<thead>
<tr>
<th>Houses</th>
<th>Solar Water Heating Litres</th>
<th>Electric Water Heating up to the Boiling Point</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Litres</td>
<td>Litres</td>
</tr>
<tr>
<td>83</td>
<td>5 436.70</td>
<td>726.10</td>
</tr>
<tr>
<td>53</td>
<td>3 492.30</td>
<td>450.60</td>
</tr>
<tr>
<td>154</td>
<td>10 803.88</td>
<td>1 466.30</td>
</tr>
<tr>
<td>179</td>
<td>11 922.70</td>
<td>1 264.40</td>
</tr>
<tr>
<td>113</td>
<td>9 907.48</td>
<td>1 188.80</td>
</tr>
<tr>
<td>Totals</td>
<td>582.00</td>
<td>41 563.06</td>
</tr>
<tr>
<td>Total Litres Electrical Water Heating at Boiling Point</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average Consumption per House in Litres</td>
<td>71.41</td>
<td>17.49</td>
</tr>
</tbody>
</table>
Average Hot water Energy usage heated by electricity at an average low-costs household

<table>
<thead>
<tr>
<th>Hot Water Usage by Electricity Heating. Total Houses interviewed:</th>
<th>Litres heated at 96 °C</th>
<th>Energy Used</th>
<th>ΔT</th>
<th>C</th>
<th>T_{hot}</th>
<th>T_{cold}</th>
<th>Efficiency of heating</th>
</tr>
</thead>
<tbody>
<tr>
<td>582</td>
<td>17.49</td>
<td>1.81</td>
<td>80</td>
<td>0.001167</td>
<td>96</td>
<td>16</td>
<td>90</td>
</tr>
</tbody>
</table>
Mixing of hot water boiled by a kettle with cold water in ration 1:4 for further usage by the household.
Mixing of hot water boiled by all kettles with cold water in ration 1:4 for further usage by the household. The Base Line or entire hot water consumption by the household per day is determined as: **99 litres at 33.78 °C.**
Recommendations for Baseline Procedure

• Perform interviews and fill the information as required in Fieldworker Form
• Identify representative houses in terms of number and profile of occupants and install data loggers (if and where appropriate) to measure the electricity consumption prior the retrofit.
• Determine electrical energy and find out the time of its use for water heating, based on the information obtain above.
DETERMINATION OF THE SAVINGS

M&V RECOMMENDED OPTION

As per SANS 50010:2011: **4.2.2 Retrofit isolation (Option A)**
is recommended as a Standard Guideline for determination of the savings resulting from implementation Low Pressure Solar Water Heating Systems.
Retrofit Isolation: Key Parameter Measurement Savings are determined by field measurement of the key performance parameter(s) which is the current (power) and which define the energy use of the household under consideration. Parameters not selected for field measurement are estimated. These are the inputs to all the engineering calculations based on the interviews leading to determination the amount of electrically heated hot water used by the household.
Main M&V Question for Determination of the Savings Resulting from Low Pressure Solar Water Heating Systems

• The Baseline is determined as: energy kWh and power kW at its time of use, the amount of hot water in terms of volume (litres) and temperature (°C). It is more convenient to use as a volume the amount of water mixed (heated water by electricity with cold water). This allow to have a realistic figure for the amount of hot water usage.
THERMAL PERFORMANCE MODEL OF LOW PRESSURE SOLAR WATER HEATING SYSTEMS

Model Inputs

- Coefficient [W/K]
- Coefficient [MJ/K]
- Coefficient [MJ]
- Tank Heat capacity [MJ/K]
- Heat loss coefficient [W/K]
- Tank capacity (or portion of it used) [l]
- Volume of hot water usage [l]
- Installation Geographic location
- Incoming water (cold) temperature [°C]
- Angle of Deviation form the true North Direction [degrees]
- Month of the year under consideration

Model Outputs

- Energy of the Hot water produced [kWh]
- Temperature of the hot water [°C]
- Temperature of hot water in the morning [°C]
- Energy absorbed by the solar collector [kWh/m²]
SUMMARY

• The LPSWH system Project should be considered as Retrofit Projects not as Green Field Projects

• M&V Option: 4.2.2 Retrofit isolation (Option A) is suggested which recommends Retrofit Isolation: Key Parameter Measurement Savings are determined by field measurement of the key performance parameter(s) which is the current (power) and which define the energy use of the household(s) under consideration.

• Base Line determination: the energy used for electrical water heating of a household(s) is determined by: interviews, field measurements. Also the volume and the temperature of the hot water usage is identified.
SUMMARY

• Energy saving determination is based on modelling of LPSWH system(s). The model uses as inputs: the parameters determined by test report by SABS, the installation location, the hot water usage and the day/month under consideration. The model outputs are: hourly, daily, monthly thermal output in [kWh] of the LPSWH system and the temperature hot water produced.

• It is possible that in addition to the energy savings reported to be an excess of energy produced by the retrofit. This energy will be reported separately and will not be part of the savings that grid would “see”.
Example

Baseline Report
Characterization

- In the building the baseline, only the quantities heated by electricity was considered.

<table>
<thead>
<tr>
<th>Location</th>
<th>Audited</th>
<th>morning</th>
<th>day</th>
<th>evening</th>
<th>daily</th>
</tr>
</thead>
<tbody>
<tr>
<td>South Africa</td>
<td>houses</td>
<td>litres</td>
<td>litres</td>
<td>litres</td>
<td>litres</td>
</tr>
<tr>
<td></td>
<td>389</td>
<td>5691</td>
<td>429</td>
<td>2066</td>
<td>8187</td>
</tr>
<tr>
<td>%</td>
<td>69%</td>
<td>5.%</td>
<td>25%</td>
<td>100%</td>
<td></td>
</tr>
</tbody>
</table>
Characterization

- The major parameters used for the determination of the baseline are:
  - the pre-implementation hot-water consumption in the area
  - the distribution of the used hot water during the day
  - measured performance data for the used SWHs in the area, supplied by SABS tests on the particular systems
Characterization

• To determine these major parameters, additional data will be used – demographic composition of the area, audited data for 65.8% of the houses before the implementation, hot water heating techniques in the area, hot water consumption patterns and volumes.

• Most of this data as well as the operational hours will be determined from the data collected by the M&V team in door-to-door audits, carried out in representative number of houses for the Project.
Savings Calculation Methodology

- In most of the houses, after the installation of the SWHS, the consumption of hot water increased significantly and practically amounts to the whole volume of the hot water tank. The performance assessment though, will be done according to the adopted guidelines for low pressure SWH in the residential sector. According to it, the performance assessment will take into account only the replacement heating power of the solar water heaters for heating the same quantities of water before the implementation. It will be taken into account the necessary mixing of hot and cold water which was done prior to the installation of the solar water heaters.
Future Developments

• How the Rollout Programmes changed the energy usage patterns of the households and what is the impact of the SWH initiatives?
Future Developments

• IDM shared concerns that in some cases for SWH the reported savings are low.

A possible influencing factor is that the Income water temperature is very different during the year.
Example:

- Base Line Hot Water Usage 2.52 kWh/day for $t_{\text{cold}} = 16 \, ^\circ \text{C}$
- Base Line Hot Water Usage 2.62 kWh/day for $t_{\text{cold}} = 13 \, ^\circ \text{C}$

% change = 4 %

For 250 000 installed SWHs
Energy per year = 9 000 MWh
Future Developments

• How the installation / orientation angle affects the reporting of the savings of the Low – pressure SWH systems?
Future Developments

Study to Investigate and Identify Hot Water Usage Profile at the Low-income Housing in South Africa: 50 SWH systems supported by ESKOM

Long Term Performance Monitoring of a Randomly Selected Group of Residential SWH Systems under the One Million SWH Programme of the Republic of South Africa: supported by GIZ Pretoria
SWH Monitoring Sites in all nine Provinces in South Africa
Medium and High-cost Housing SWH Monitoring

1. Ambient Temperature Sensor
2. SWH Back up Element Electricity Consumption Sensor
3. Hot Water Outlet Temperature Sensor
4. Cold Water Inlet Temperature Sensor
5. Hot Water Flow Sensor
6. Pyranometer

Hot Water Outlet to SWH
Cold Water Inlet to LPSWH
PV panel and Battery Supply
Thank you for your Attention

Questions ?