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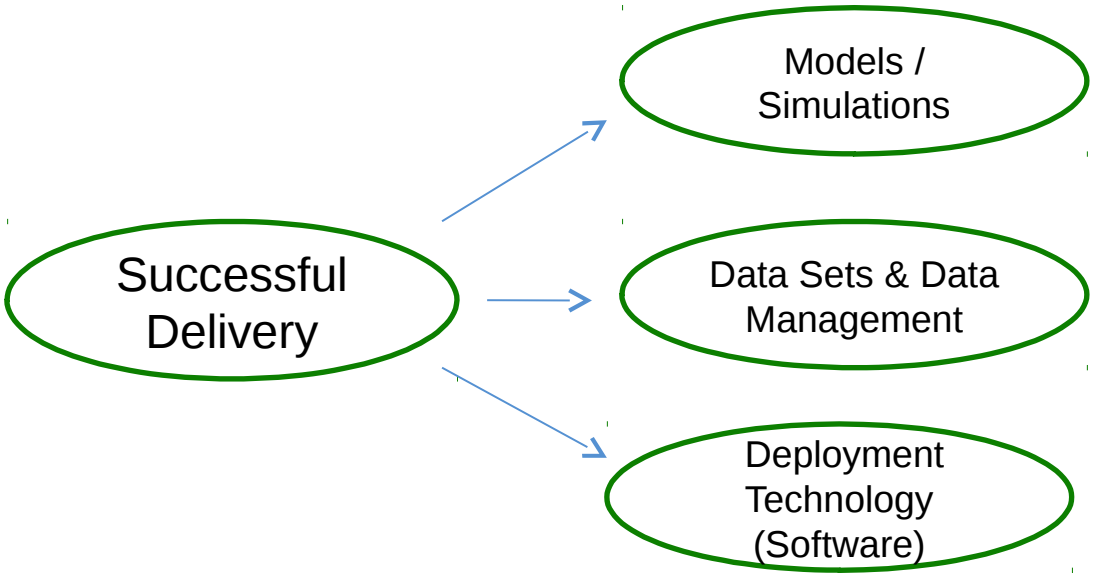
Hot Water Modelling using DLR inputs

November 2014

enerweb
an EOH company

Background



NRS034 DTPET + IEEE published Geyser Model (GVH)

10 years worth of NRS034 (DLR) Data Sets

R Shiny = Open Source Components

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Successful Delivery

Objective

Combine the outputs of NRS-034 (DTPET), with a hot water simulation program, to be able to determine the effects of TOU switched Smart-Meters, given a specific population type

Business Application

Ability to perform simulations for scenarios for which there is no data – link together previously established models from different sources (e.g. IEEE, NRS034) models

Milestones

1. Implement NRS034 DTPET
2. Implement Geyser Penetration
3. Implement Geyser Simulator

Data Sources

NRS034 Data collected over past 10 years

Hot water consumption patterns obtained from Instant Water Heater pilot study Table-View

Methodology

Use NRS-034 DtPet Model to obtain consumption, for the year of interest

Use Penetration model to determine the ratio of single/double geyser installations

Use histograms from measurements, as source to generate hot water consumption events, for single, double and family dwellings

Use environmental factors, including tariff based switching, via a physical based model for a geyser (simple lumped parameter model, single order D.E)

Derive element switching patterns

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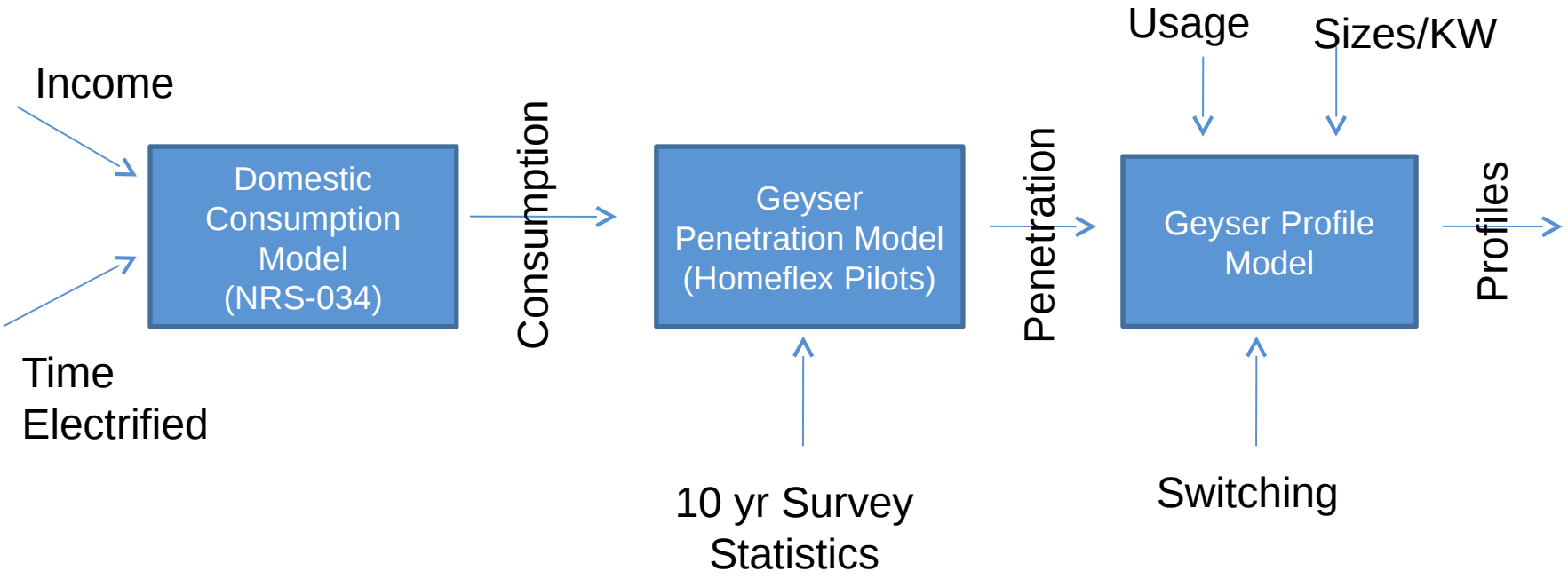
Models / Simulations



Final model is a combination of 3 previously developed/published models, 2 from the NRS-034 industry collaboration, and 1 from a IEEE published PhD paper.

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Data Sets & Data Management

NRS-034 is an industry collaboration, with participants from all electrical industry sectors, and is a guideline for electrical network decision

This collaboration has been collecting domestic load research data (metering and survey statistics), for the past 10 years, and publishes its finding from time to time, being available to all industry

NRS034 data sets were used ostensibly to derive the DTPET model (see previous) presentations, as well as the geyser penetration model

The hot-water consumption statistics were obtained from an instant water heater pilot study conducted in Table View

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Technology Delivery Platform R-Shiny

R is data analysis software used by data scientists, statisticians, analysts, and quants

R is used by those who need to make sense of data using analysis, data visualization, and predictive modelling.

R is a programming language, a complete, interactive, object-oriented language: designed by statisticians, for statisticians.

R is an environment for statistical analysis, data-management, simulation and interactive visualisation

Shiny is a rapid, web application delivery framework, delivered as a R package

Shiny natively utilises CSS and JS, and thus instantly deploys Highcharts, D3 which are current some of the most popular and powerful interactive visualisation libraries

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MODELS USED

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Model 1 : DTPET

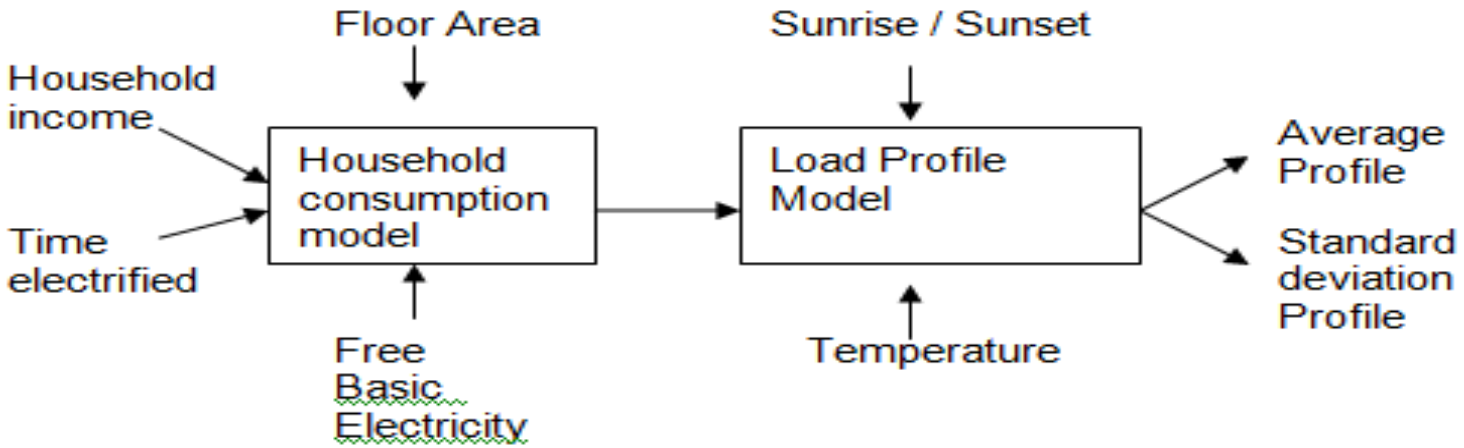

Figure 1: Structure of the load profile model

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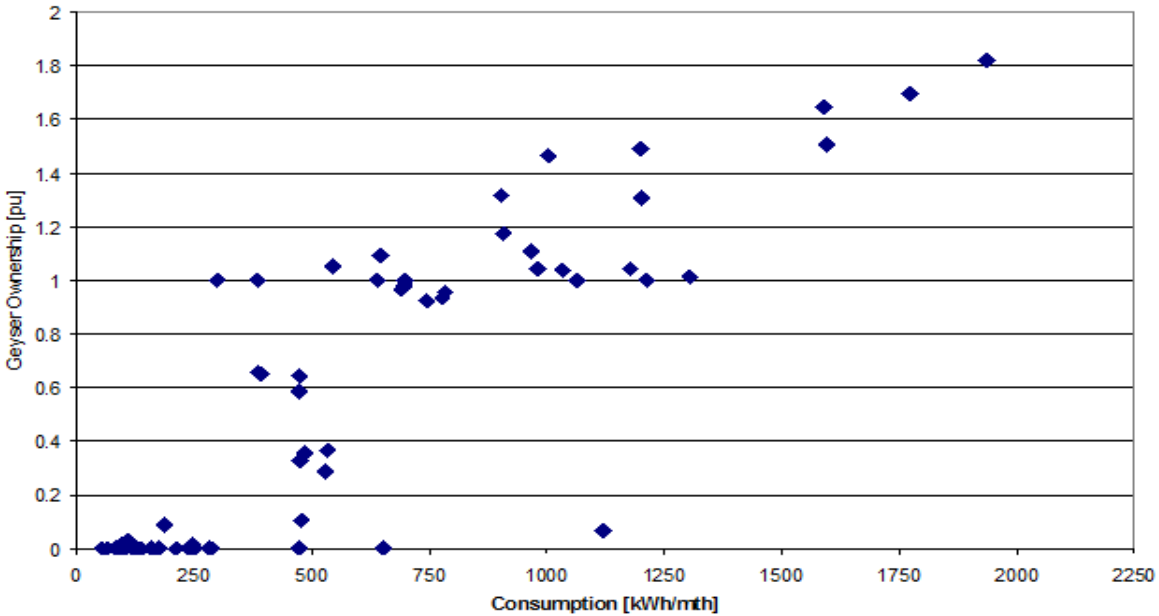
Model 2: Geyser Penetration

Data collected by the NRS LR project was queried to estimate the penetration of hot water geysers in communities with different levels of consumption.

The figure below illustrates findings from data collected over period of 10 years. Each point represents aggregate measures from groups of 60 or more households.



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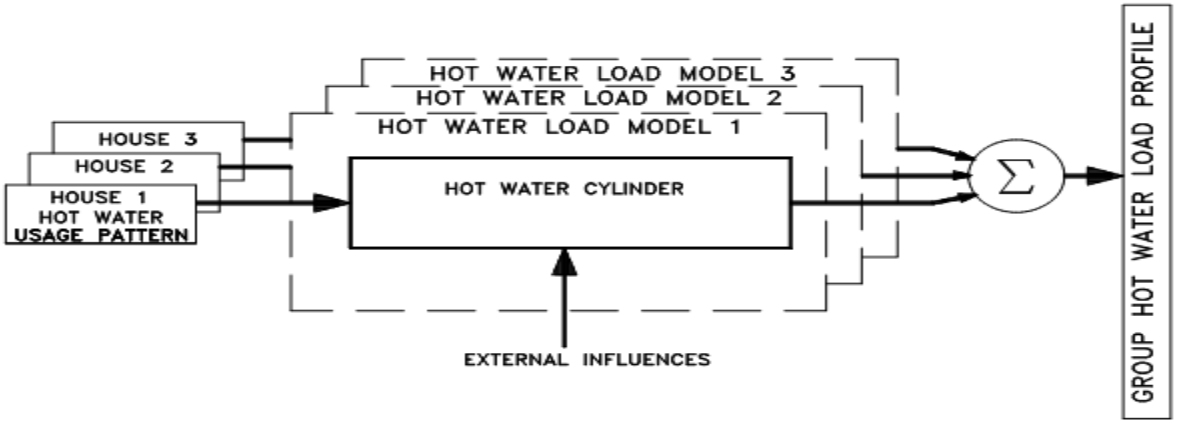
Model 3 : Geyser Simulations



$$MC\frac{dT}{dt} = g(t)Q_e - HA[T - Ta(t)] - \dot{m}(t)C[T - Ti(t)]$$

Lumped parameter differential equation

$$T_{K+1} = \frac{\Delta t}{MC}\left\{g_K Q_e - HA[T_K - Ta_K] - \dot{m}_K C[T_K - Ti_K]\right\} + T_K$$

Numerical difference equation that can be solved by stepping through time

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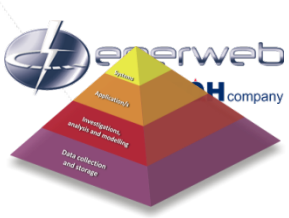

DATA MANAGEMENT

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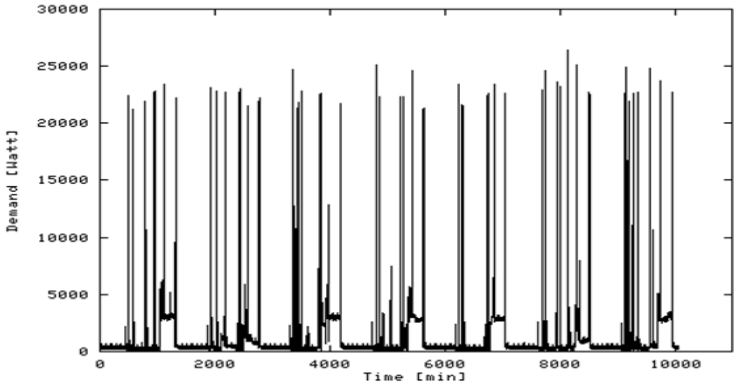
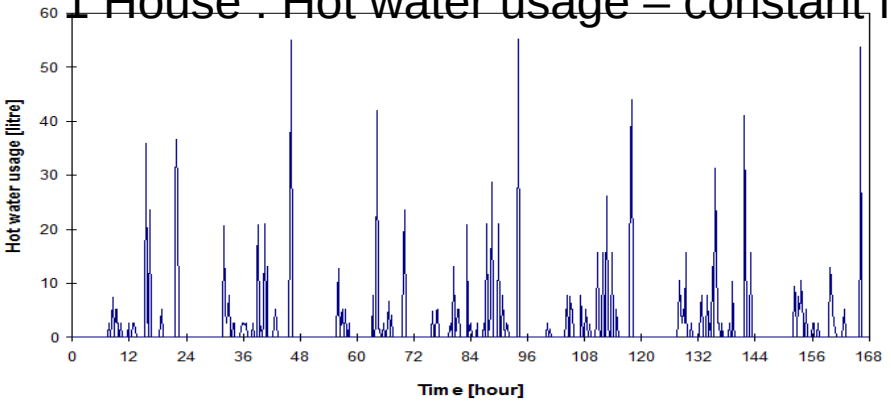
Data Sets

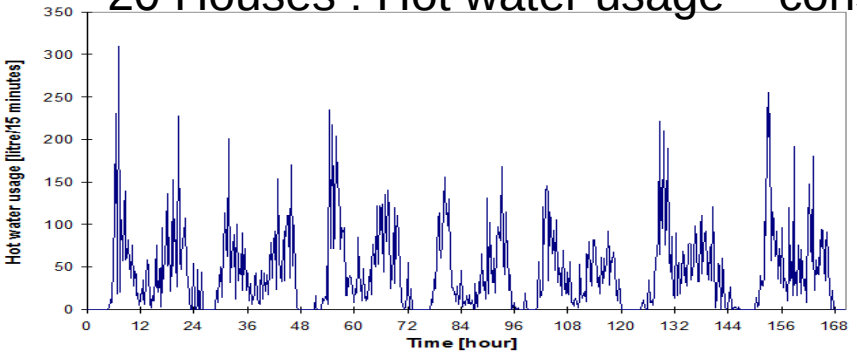
1 house -1 min consumption pattern



1 House : Hot water usage – constant flow



20 Houses : Hot water usage – constant flow



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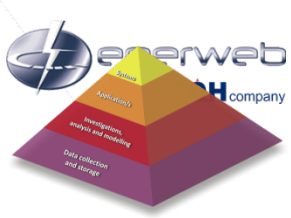

MODEL DELIVERY

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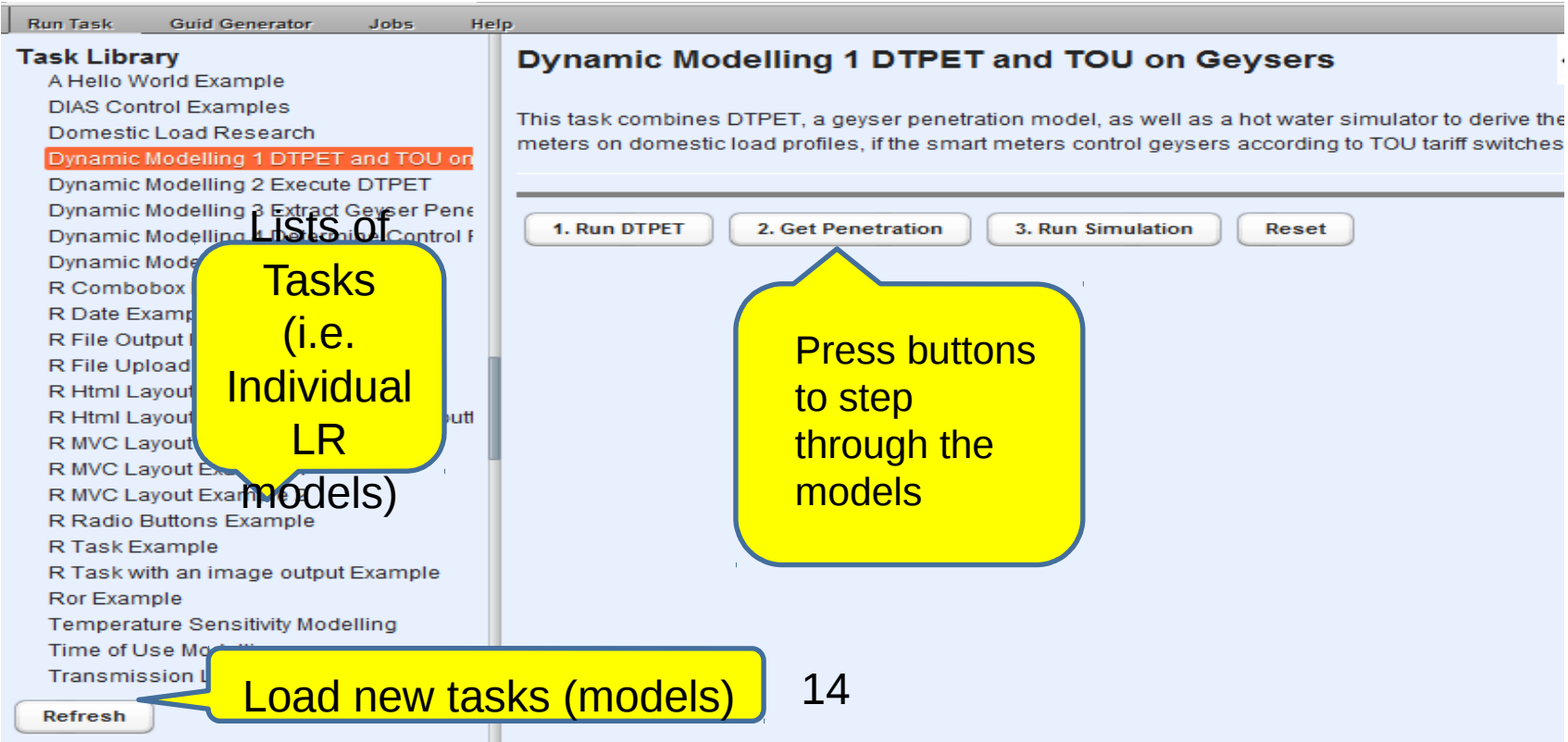
Technology Delivery Platform

Web Browser window



Lists of Tasks (i.e. Individual LR models)

Press buttons to step through the models

Load new tasks (models)

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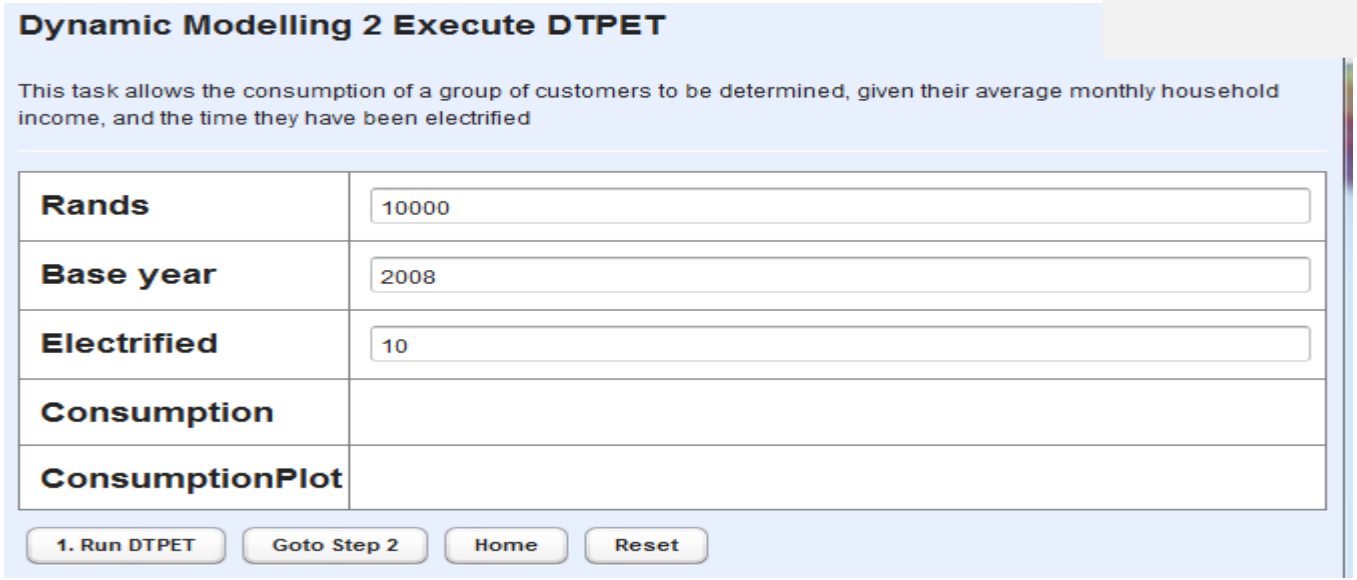
Input Parameters to DTPET



Fill in parameters in order to derive aggregate monthly consumption, per house
Press “1. Run DTPET” button, to execute model

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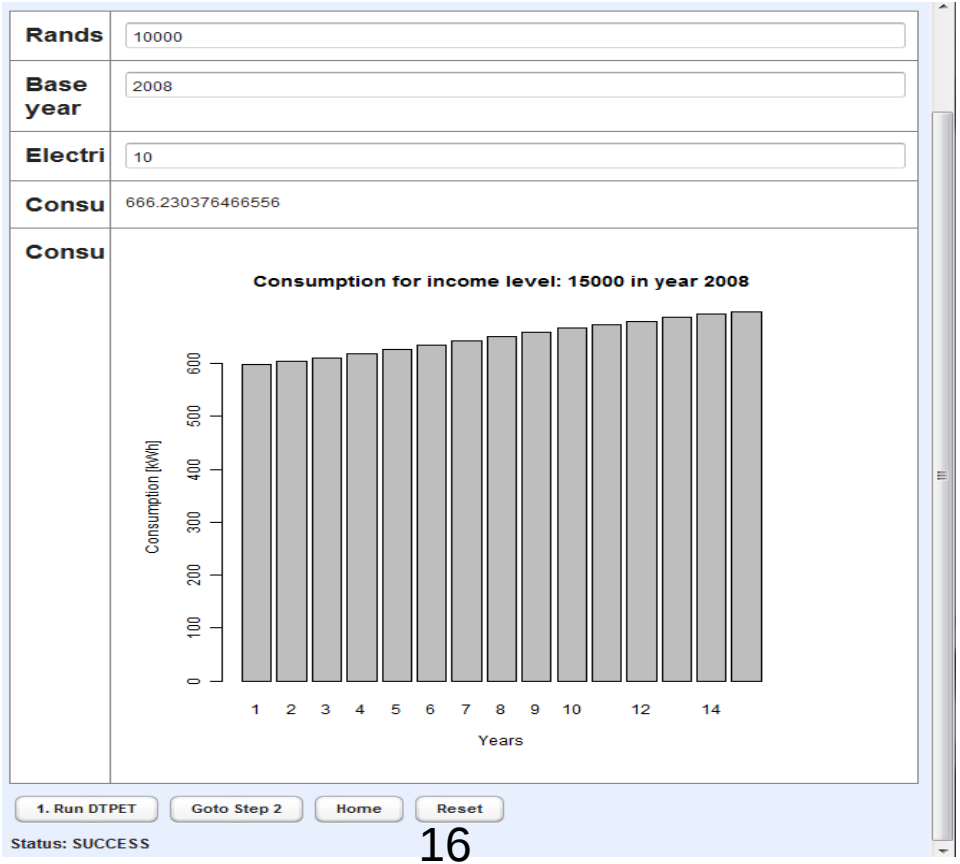
Running DTPET



Note that Consumption calculated, now press “Goto Step 2” to proceed to next part of the model

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Ready to Run the Geyser Penetration Model

Having obtained the Consumption, now press “2. Run Penetration”, to execute the 2nd part of the model

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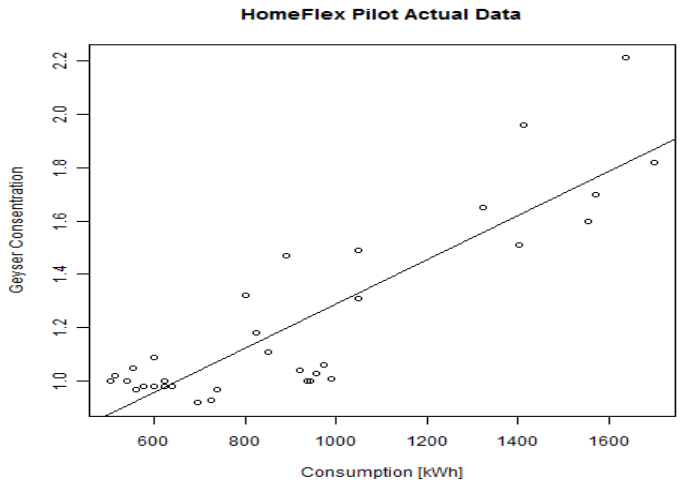
Obtain Geyser Penetration

Dynamic Modelling 3 Extract Geyser Penetration

This task allows uses practical measurements and survey questionnaires, from the Eskom Homeflex pilots, to obtain a relationship between monthly consumptions, and number of geysers installed in a particular home. This model froms the bridge between the DTPET model, and the Geyser Profile Simulator

Co	666.230376466556
Pe	1.01499356321028

Pe



2. Run Penetration | Goto Step 3 | Home | Reset

Status: SUCCESS

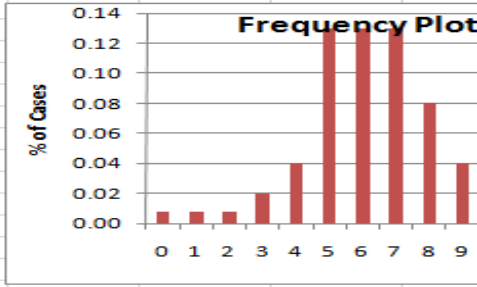
A linear model is fitted to the data, and the Penetration factor is obtained for the specified Consumption

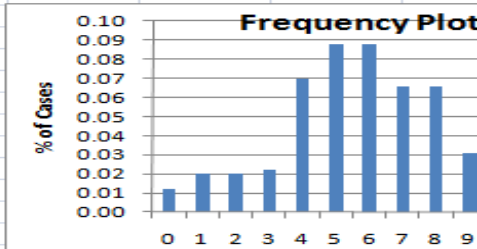
Setup Simulations Constants in Excel

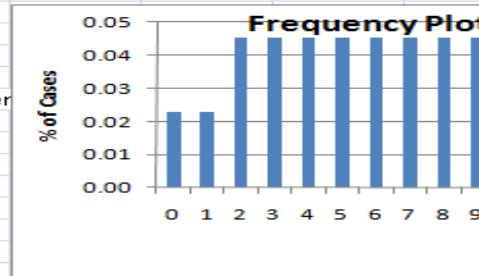
HR	TOU Control	Bigs	Mediums	Smalls	Bigs	Mediums	Smalls	Bigs	Mediums	Smalls
0	1	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02
1	1	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
2	1	0.01	0.02	0.02	0.02	0.02	0.05	0.02	0.02	0.05
3	1	0.02	0.02	0.04	0.04	0.02	0.05	0.04	0.02	0.05
4	1	0.04	0.07	0.04	0.09	0.08	0.05	0.09	0.05	0.05
5	1	0.13	0.09	0.05	0.15	0.08	0.05	0.15	0.06	0.05
6	1	0.13	0.09	0.05	0.11	0.08	0.05	0.11	0.06	0.05
7	0	0.13	0.07	0.05	0.08	0.03	0.05	0.08	0.03	0.05
8	0	0.08	0.07	0.05	0.05	0.03	0.05	0.05	0.03	0.05
9	0	0.04	0.03	0.04	0.01	0.05	0.05	0.01	0.05	0.05
10	1	0.01	0.02	0.04	0.01	0.05	0.05	0.01	0.05	0.05
11	1	0.								
12	1	0.								
13	1	0.								
14	1	0.								
15	1	0.								
16	1	0.								
17	1	0.								
18	0	0.								
19	0	0.								
20	1	0.								
21	1	0.								
22	1	0.02	0.03	0.03	0.02	0.03	0.02	0.02	0.03	0.02
23	1	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.03	0.02
Totals		1.01	1.00	1.00	1.00	1.02	1.00	1.00	1.00	1.00

M	150	200	250	Size of Tank
Element	2500	2500	2500	Save size of the heater elements, for these households
Tambient	15	15	15	Ambient (air) temperature, during the simulation
Tinput	5	5	5	Water inlet temperature
Hlosses	1	1.25	1.5	Losses coefficient, obtained from manufacturer, for cylinder
SwitchHi	65	62	60	High temperature, switch off point, of the thermostat
SwitchLo	55	52	50	Low Temperature, switch on point, of the thermostat
No of 2's	0	0	0	Calculated total, do not edit
Houses	100	200	100	Total number of houses to simulate in each group
dT	300	300	300	Time increment of simulation in seconds

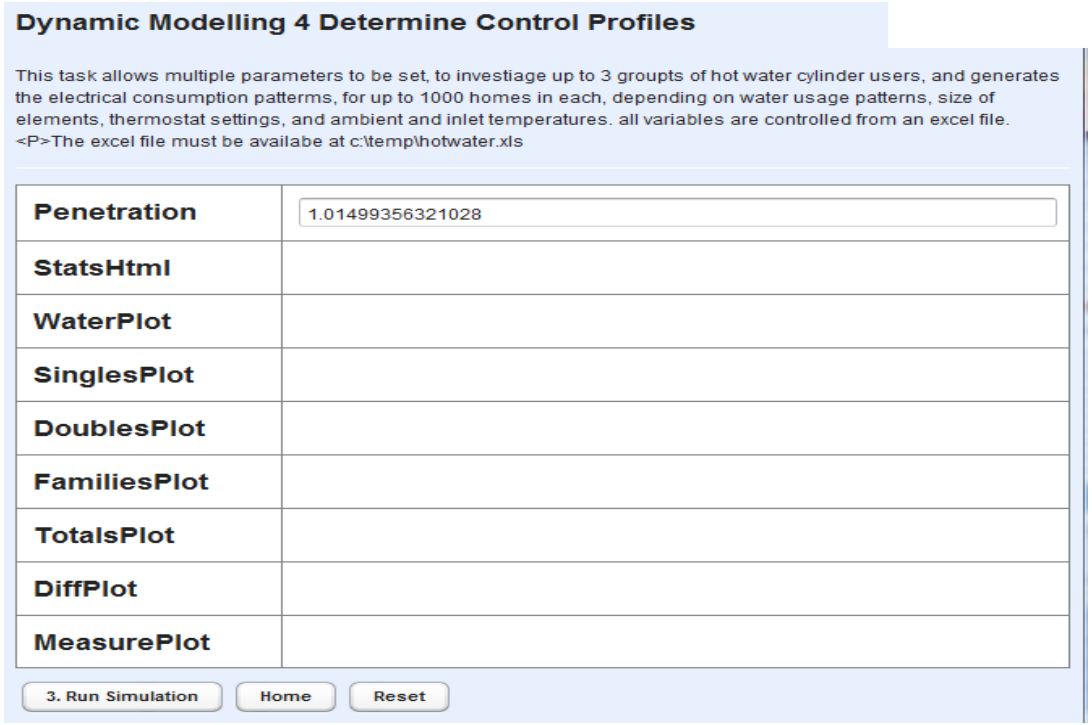
Multiple physical constants are easily configured from within Excel







Ready to Run Profile Simulator



After having obtained the Penetration, and all the physical constants from Excel, the simulation is ready to run.

Start the simulation by pressing “3. Run Simulation”

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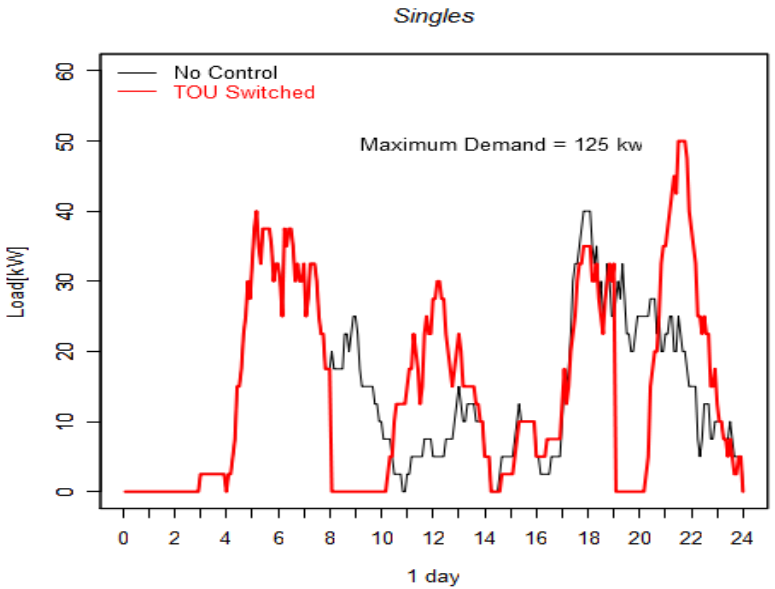
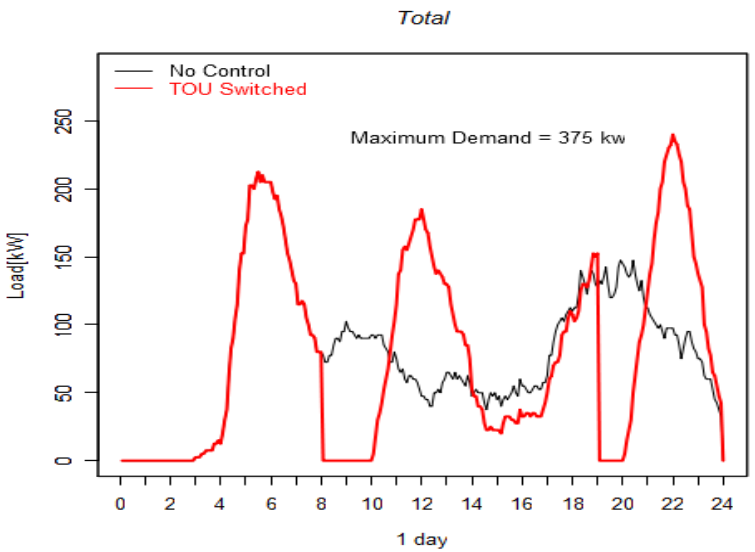
Geyser Load Profiles





Hot water cylinder ADMD, of +/- 30-40% of installed capacity, as shown by simulations, confirmed by various practical measurements (e.g. Various Notch tests, TOU studies)

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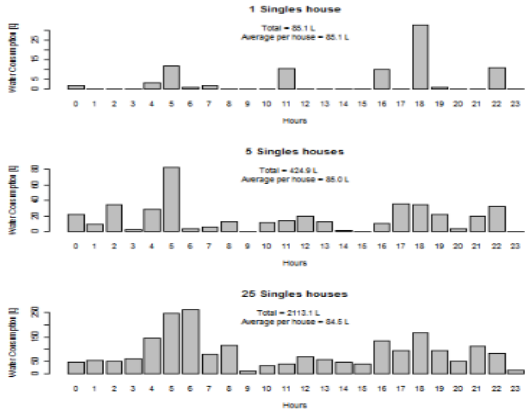
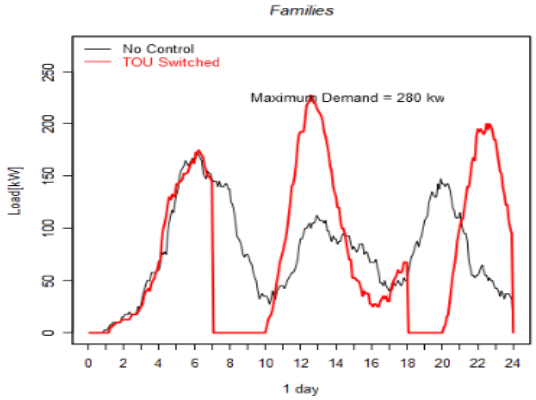
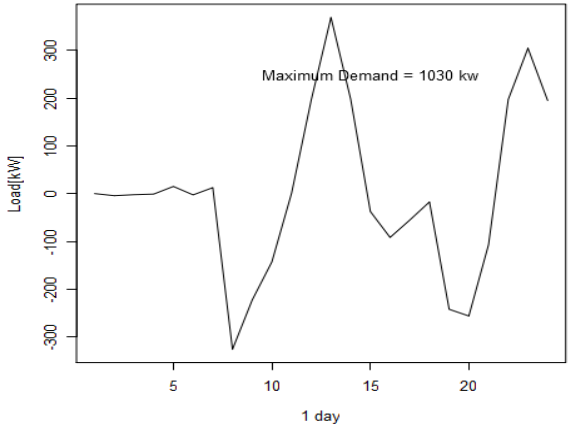
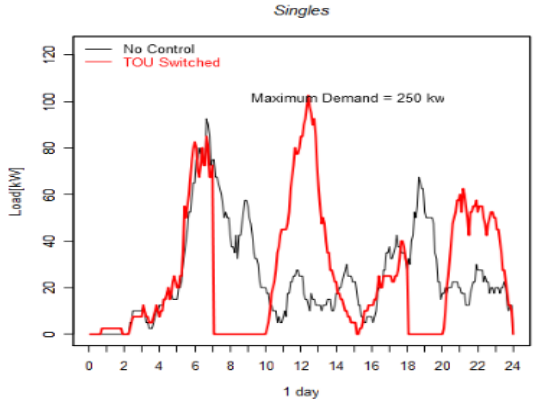
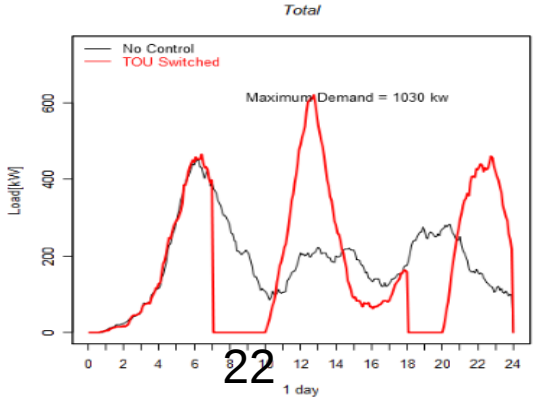
Results from Profile Simulator

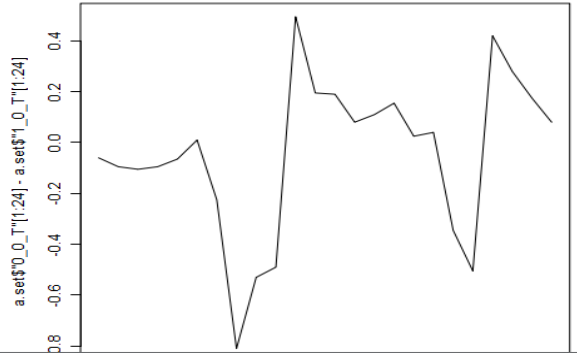




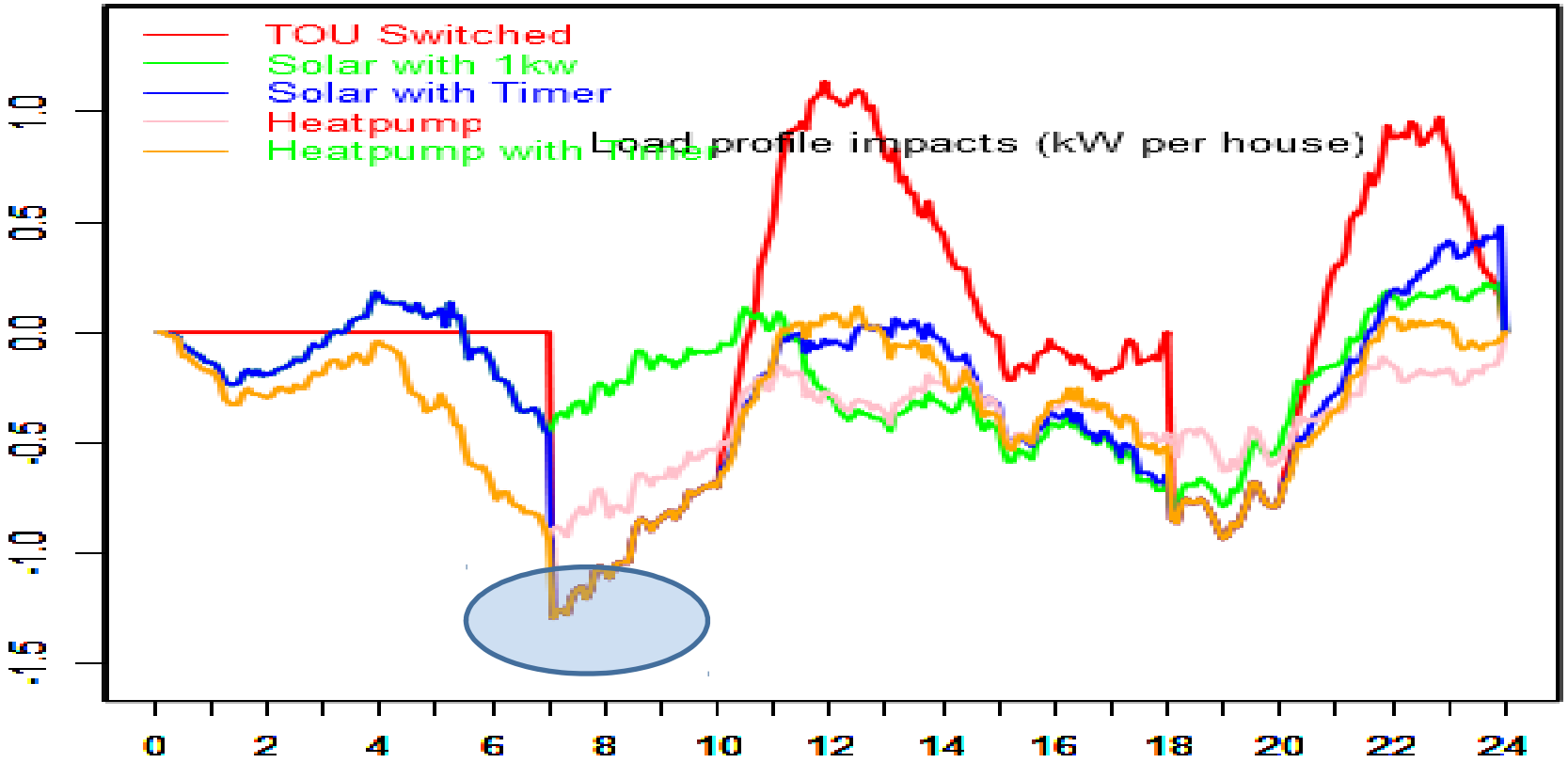




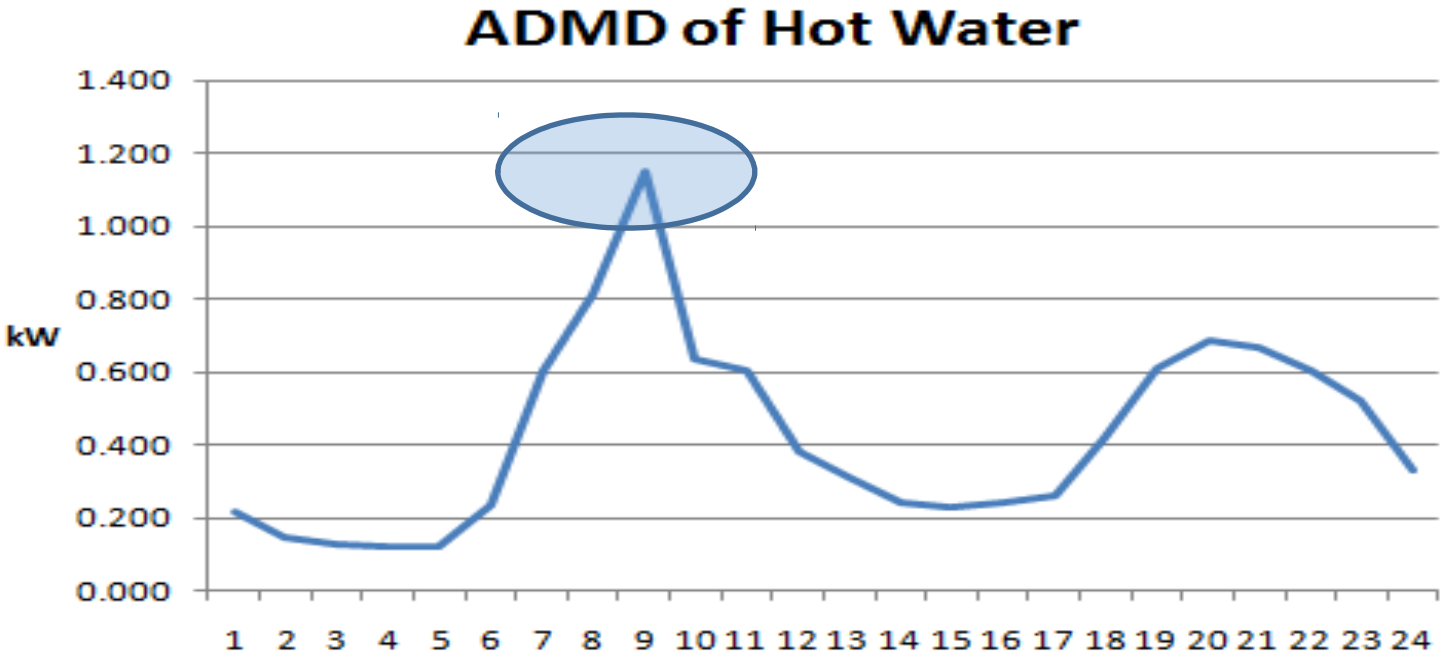




B. ADMD Nett Profile Impacts – Geyser as Base Case



C. Calibrate with Practical Results



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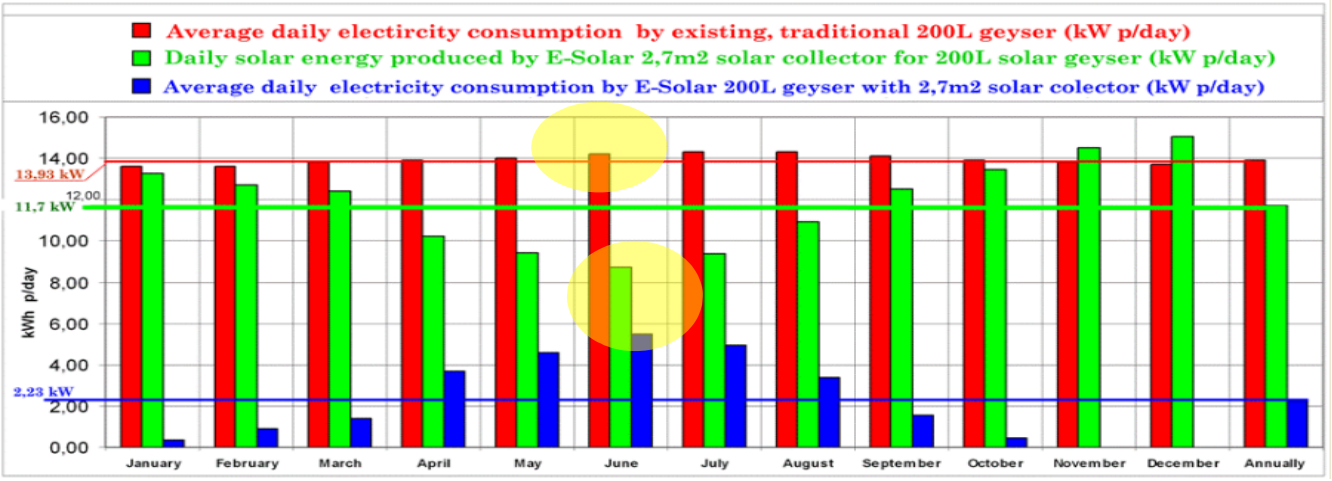
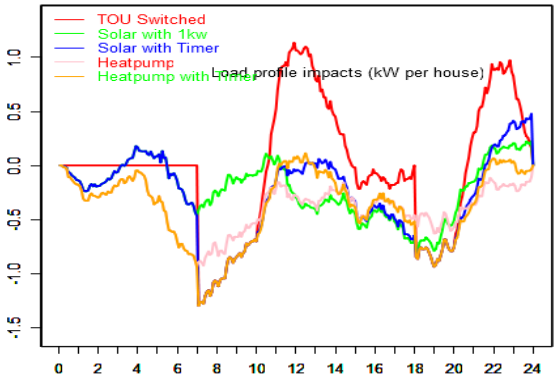
C. Good correlation with practical measurements



http://www.easysolar.co.za



	scenario	energy_kwh
1	geyser.noc	13.3
2	geyser.timer	12.9
3	solar.noc	8.2
4	solar.timer	6.3
5	heatpump.noc	4.3
6	heatpump.timer	4.0

Determine Cold Event Days

- Simulation : actual measured hot water usage patterns, 35 houses, 15 minute intervals
- 3 weather periods were used, summer, winter and in-between (in terms of ambient temperatures and inlet water temperatures)
- Houses with an average daily usage of greater than 200L ,were assumed to have 200L geysers, the rest had 150L geysers
- A evening peak TOU control function was used to override element power, thus not allowing any heating between 18h00 and 20h00
- Results showing average tank temperatures, flows, element switches and the control function
- A cold water event was triggered when the average tank temperature fell below 30 degC, at ANY time during a daily 24 hour period
- When one or more cold events on a day is detected, that day is flagged as a cold event day for that particular house

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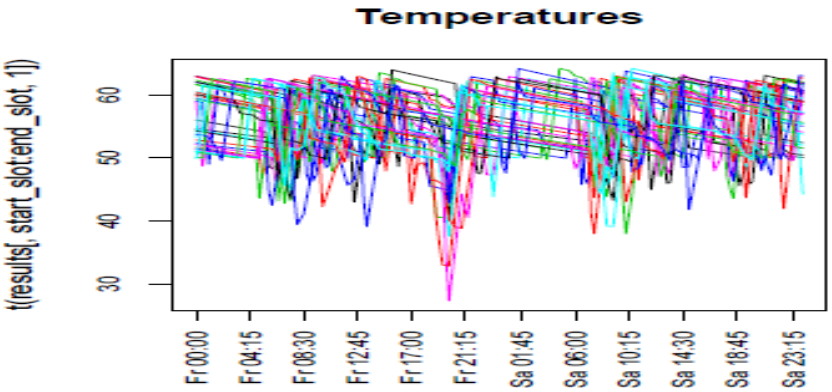
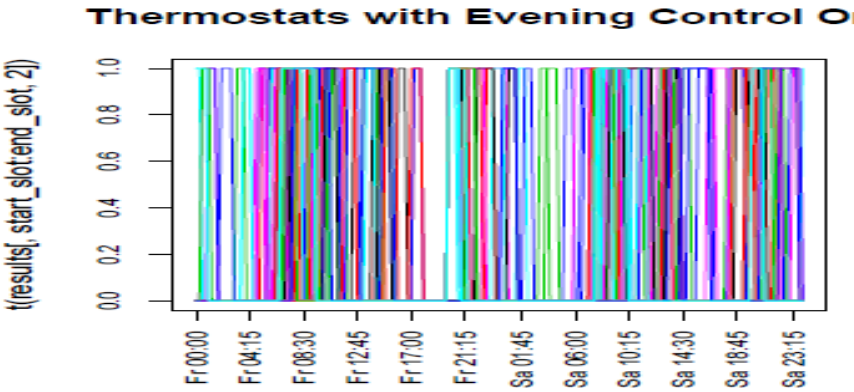
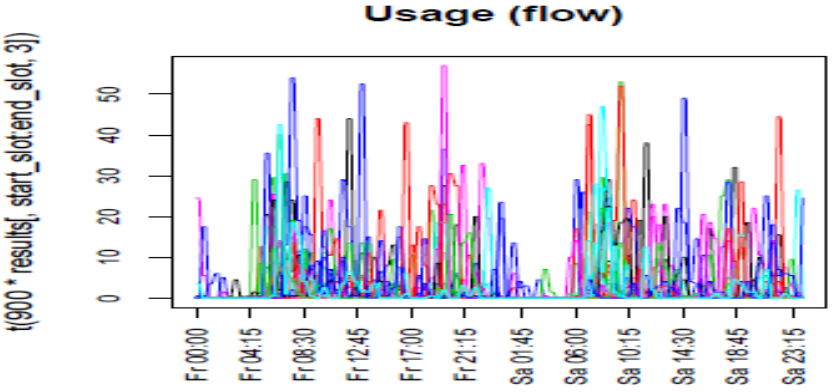
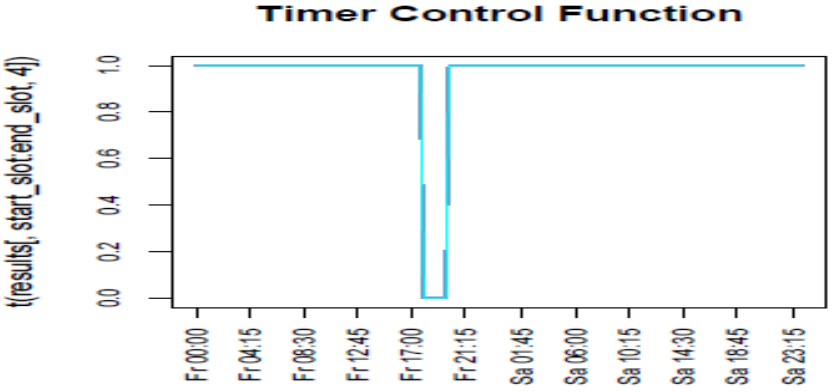
Application 1 – Determine Cold Event Days

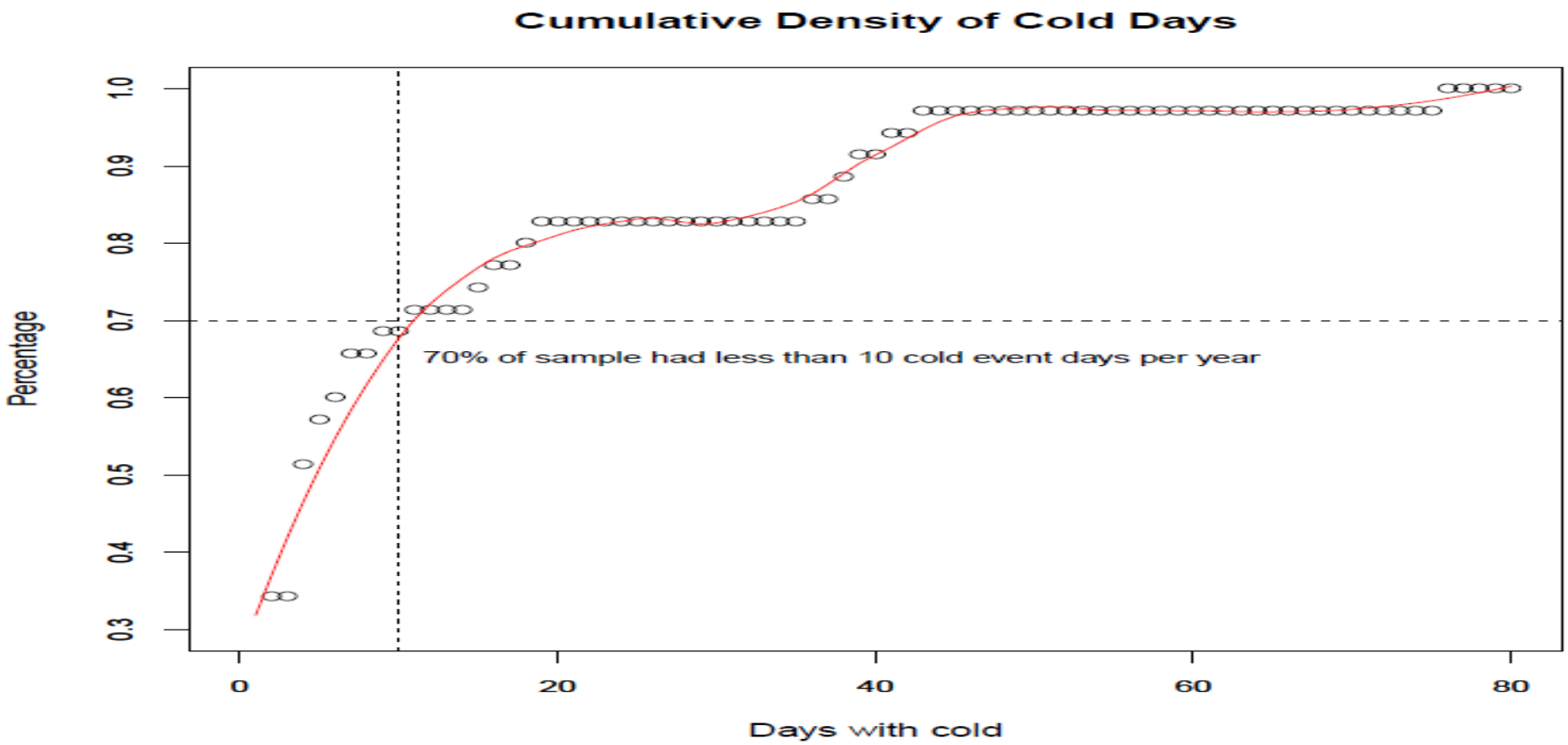








Application 1 – Determine Cold Event Days



Road Ahead - Potential Usages

- Provide Data Inputs for Potential Applications
  - Cost/Tariff impact modeling
  - Local/Global Network impact modeling
  - Spatial Impact Modeling (different areas / weathers effects)
  - Technology interaction modeling (e.g. timer & solar)
  - Hot water control algorithm design (different goals)
  - Comfort Impact Modeling

- Basic simulator can in future be extended to deliver business applications – as above

- Basic simulator toolbox can also be extended into additional models (pumps, lighting, cooling etc)

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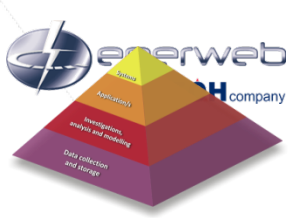
Conclusion



NRS034 and IEEE Models, together with NRS034 Data was combined for this paper, to deliver a simulator which can estimate Geyser control profiles, via bottom-up simulation

It is proposed that NRS034 also consider utilising this same, open-source (free) platform (R Shiny) for deployment of its data-sets and models

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