CE51 TOGETHER

D.T1.3.2 Master train the trainers - analytic
DSM material

Version 1
03 2017

Krakow, Poland, Master Train-the-Trainer workshop

Development of the Together Training material – Analytical DSM

City of Zagreb, City Office for Energy, Environment and Sustainable development

Demand Side Management

Analytical DSM

Module 1: Collection, analysis, verification and presentation of the consumption data

Module 2: Development of energy-related data bases

Module 3: Standard energy monitoring/management systems

Module 4: Smart energy monitoring/ management systems

Module 5: Advanced energy management systems (e.g. BEMS)

Module 6: Using ICT to analyse and reduce energy consumption in buildings

Module 7: Practical use of monitoring data - development of energy optimisation and adaptation scenarios

Module 8: Practical use of monitoring data: educating and involving building users

ANALYTICAL DSM

- focuses on the actions people take to alter energy use as a result of data analysis and equipment monitoring.

- Aim – monitoring the change brought about by implementing measures of behavior change and analyzing that impact

- Methods – focused on equipment monitoring and data analysis

CONTENT OF MODULES

- Word references
- Ppt presentation
- Exercise
- Case study
- Further suggestions

Collection, analysis, verification and presentation of the consumption data

- Gathering data on the object (complex – several buildings, one building, part of a building)
  - Starting information on the physics of the building from the existing documentation, caretaker…
  - Detailed information on the physics of the building from energy audits and certificates as well as project documentation (if any)
  - Data on energy and water consumption through monthly bills

Collection, analysis, verification and presentation of the consumption data

- Data analysis
  - Calculation of total consumption kWh,m3
  - Calculation of specific consumption kWh/m2, m3/user
  - Price calculation EUR/kWh
  - Calculation of possible savings

- Verification and presentation of consumption data
  - Control and „locking” data
  - Production of charts and reports on the state and planning on the object on monthly, annual level

Development of energy-related data bases

- A need to develop an information system – relay database
- Multiple objects (complex– multiple buildings, buildings, parts of buildings) need to be relayed to the subjects (object users) and in turn both have to be in connection with the metering points (energy and water meters) and all in a time domain

Development of energy-related data bases

- Reason – the building consumes energy which is measured at meters and charged to the subject who uses the building in a specific timeframe
- There exist energy efficiency measures for each building. These measures need to be in connection with the consumption and the building.
- A lot of unsorted data = chaos
- Structured data in a time domain = data system

Standard energy monitoring/management systems

- Monthly data gathering through manual entry
- Manual entry of energy savings and savings measures
- Data control and management based on a simple analysis of acquired data
- Production of standard and simple reports

Smart energy monitoring/management systems

- Automatic gathering of data on consumption from two sources:
  - distributer/supplier
  - directly from the meter
- Control of consumption and payment of the consumed energy
- Analysis of the impact of planned and implemented measures
- Setting the alarm on specific parts of the system, if they differ from the expected values
- Smart system management
- Detailed reports on hourly consumption level

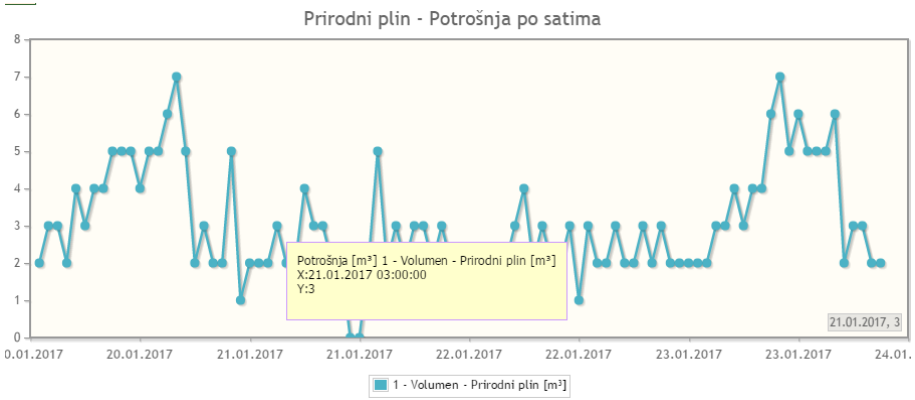
Advanced energy management systems (e.g. BEMS)

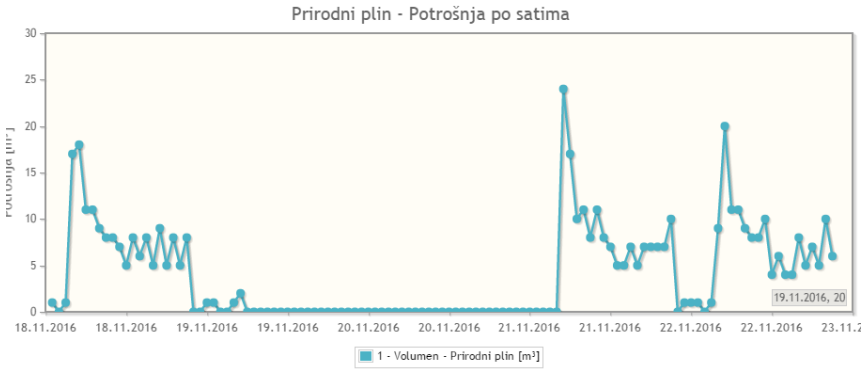
- two-way system management
- Control of meters and setting parameters (SCADA systems)
- Advanced analysis of expected outcomes and managing the system and parts of the system for the purpose of reaching optimal efficiency
- Control of ambient parameters that impact the decisions within the system (energy demand, price, temperature, humidity,…)
- Real-time display of all details
- Production of detailed reports

Using ICT to analyses and reduce energy consumption in buildings

- Comparation and analysis of all entered data
- Planned energy efficiency measures in the building with a prediction/ planned price for movements of energy and calculation of the movement of environmental temperature along with an analysis of the current state of energy consumption.
  Using a regression model allows for obtaining more accurate data on how a specific measure will impact a reduction of consumption and predict the impact.
- The more accurate data is obtained in a previous period and the longer the said period is, the more exact the analysis and predictions will be in the future

Practical use of monitoring data - development of energy optimisation and adaptation scenarios



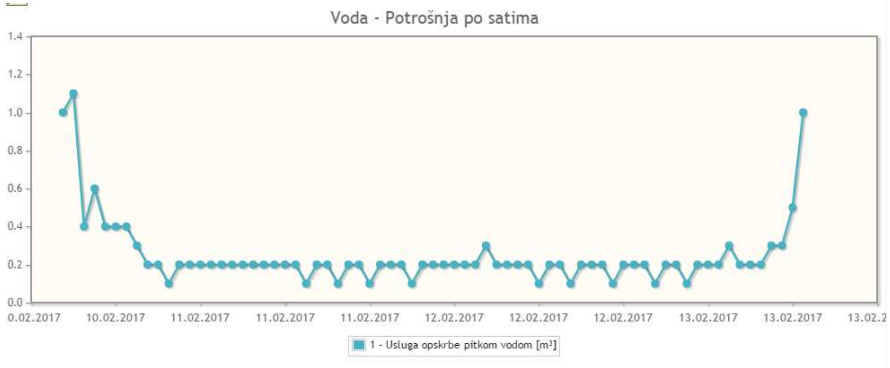


Consumption before energy refurbishment: unbalanced heating system

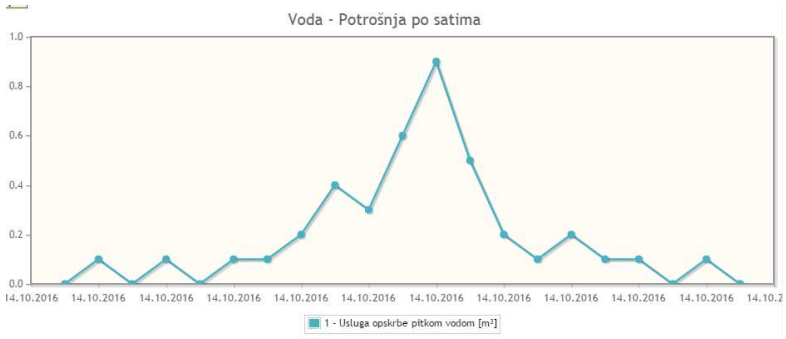
Consumption after energy refurbishment: balanced heating system

Practical use of monitoring data: educating and involving building users

An example of water consumption analysis



Consumption during the weekend



Consumption during the work day

Analyzing these charts with the users themselves and through education of users, we can achieve less consumption.

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Data Analytics and DSM

Generating Knowledge to foster Energy Efficiency

Crakow, February 23rd 2017

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ENERGY CONSUMPTION TRENDS & THE IMPORTANCE OF DATA ANALYTICS FOR ENERGY EFFICIENY

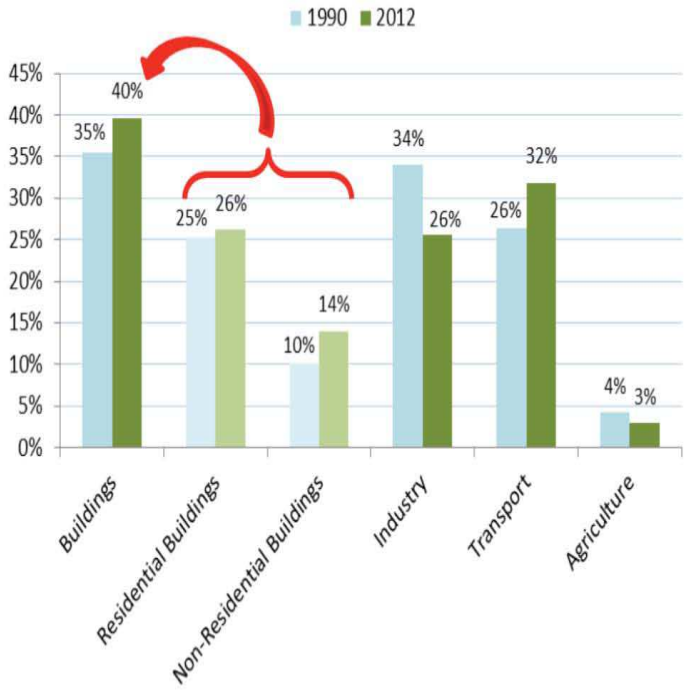
ENERGY CONSUMPTION IN THE BUILDING SECTOR

Buildings account for around 40 % of the final energy consumption and 55% of the electricity consumption in EU-28 in 2012 and. The building sector is the world's largest energy consumer sector, overpassing the transportation sector in terms of **final energy consumption** [1, 2].

Energy consumption in the tertiary sector increased rather rapidly until 2008, and has been decreasing since the economic downturn, by 1.5%/year.

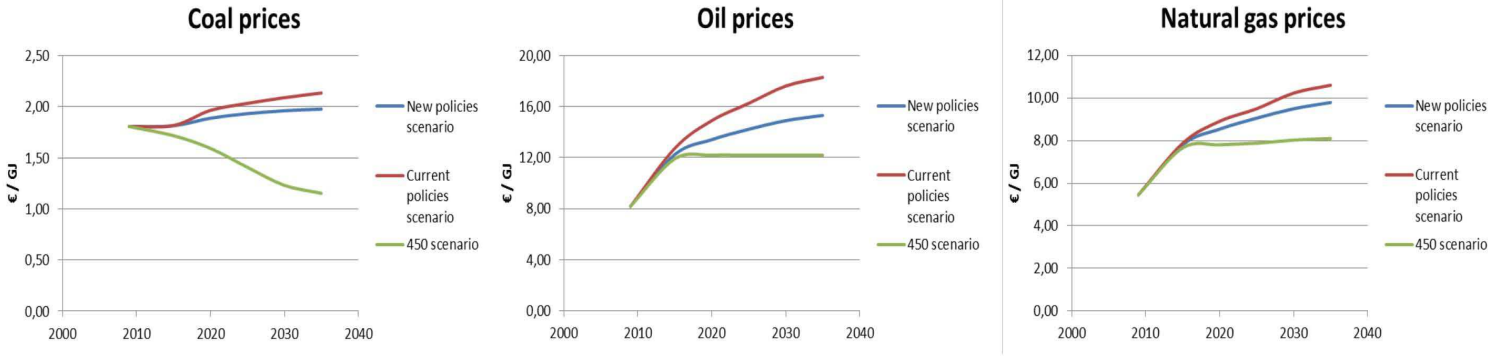
Electricity consumption in the tertiary sector has continued growing since 2008 but at a lower pace (1.1%/year, against +3%/year before).

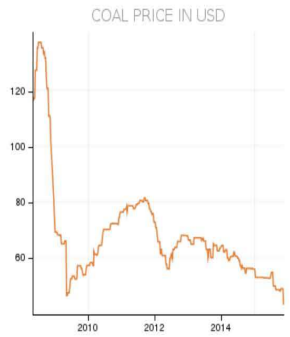
Energy efficiency investment is the most cost effective manner to reduce the EU's reliance, and expenditure, on energy imports costing over €400 billion a year.[3]

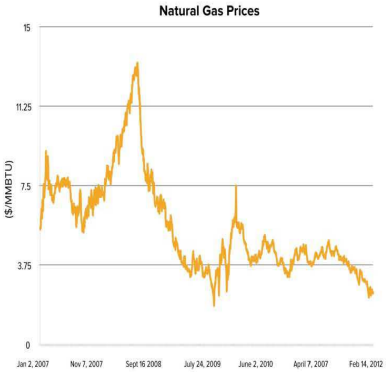


1 – Energy Efficiency Trends in Buildings in the EU, Enerdata, 2012
2 - Share of buildings in final energy consumption in EU-28 , Eurostat
3 - "Energy Efficiency – the first fuel for the EU Economy, How to drive new finance for energy efficiency investments", Energy Efficiency Financial Institutions Group, 2015

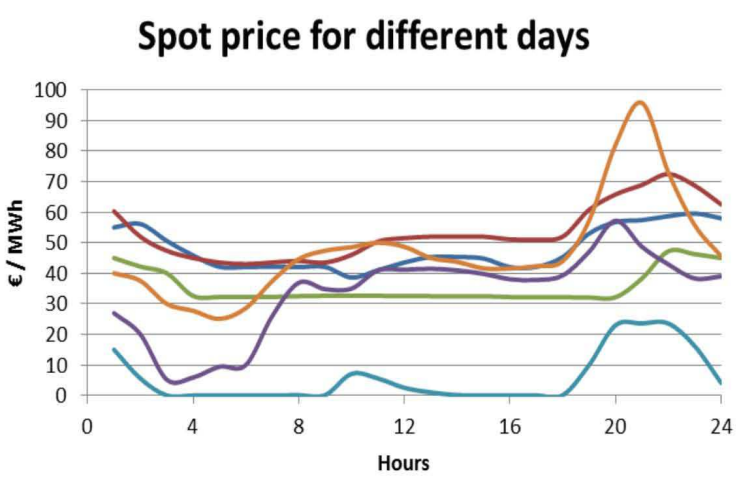
ENERGY TRENDS - HIGH UNCERTAINTY IN COMODITY DUTURE PRICES

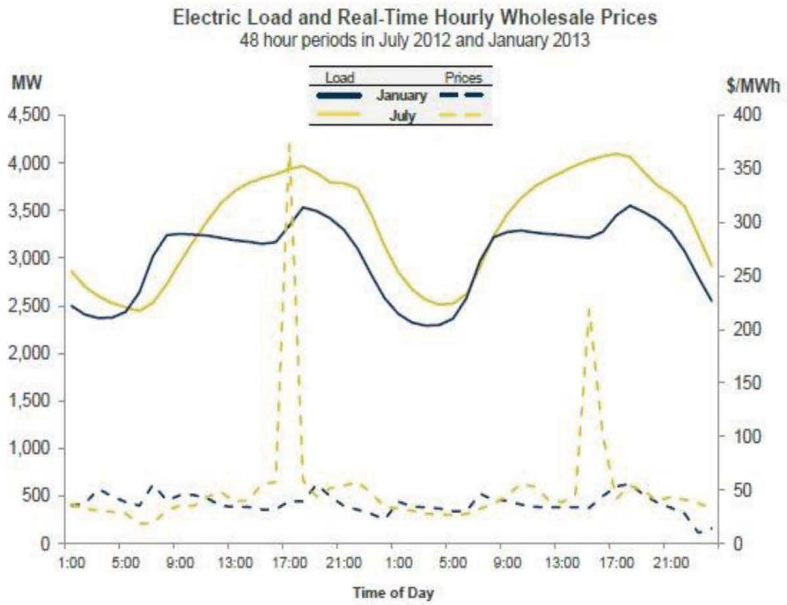






ENERGY TRENDS - HIGH VARIABILTY IN ENERGY PRICES

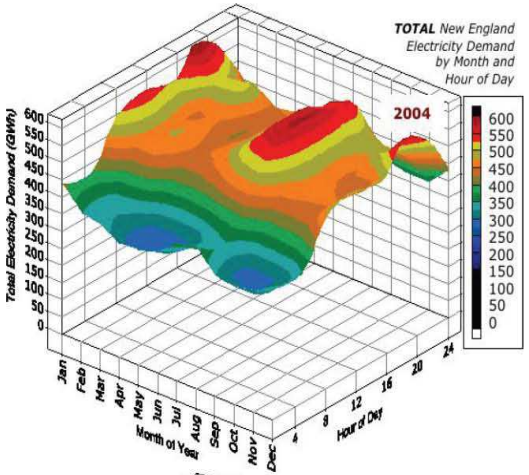




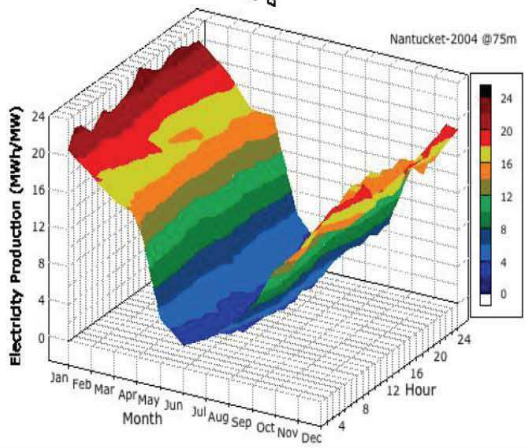
ENERGY TRENDS – UNPREDICTABLITY OF RENEWABLE RESOURCES

Proliferation of decentralized energy production (small-scale Solar PV and Wind) along with their production variation and uncertainty causes additional stress to the grid.

Total New England Electricity demand by month and hour of day



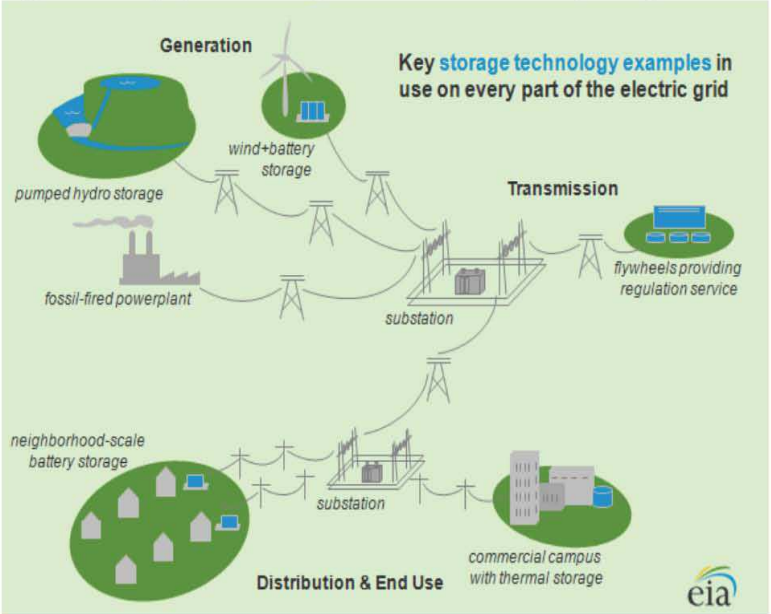
Generation from wind by month and hour of day



ENERGY TRENDS – DISTRIBUTED ENERGY STORAGE

The advance of distributed energy storage solutions, (including EV's and small scale storage come to create another layer of complexity in grid management and optimization but also present new possibilities.

Hypothetical deployment of storage assets across an electric power system



THE EPBD AND ENERGY MANAGEMENT SYSTEMS

The Energy Performance of Buildings Directive (EPBD) **requires all new buildings as from 1.1.2021 (public buildings as from 2019 on) to be built as nearly zero energy buildings** (nZEB's) that **combine a nearly zero or at least very low energy use with a significant share of renewable energy**.

Central control systems with concerted control of all energy related components
Sophisticated central systems that guarantee producer-independent compatibility

Monitoring and providing feedback
a) to the realized energy consumption to ensure that the calculated (low) energy demand is met.
b) to the users to encourage them to save energy

Capable of "forecasting"
a) supply & demand
b) Weather

Load shifting (renewables & storage management)
a) to increase the coverage rates of the energy demand by PV
b) Energy related, to increase free cooling potentials
c) Grid price related

Ensuring the thermal comfort
By timely controlling heating or cooling related solutions by incorporating weather forecasts

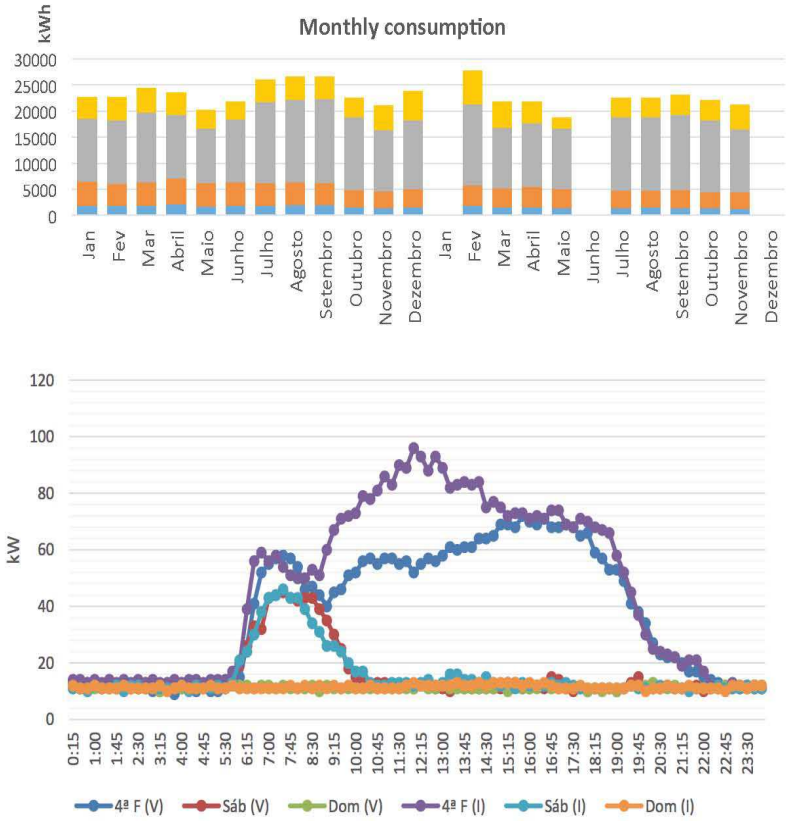
Source: Role of Building Automation related to Renewable Energy in nZEB's, ECOFYS

DATA ANALYTICS / 1ST STEP – ACQUIRING CONSUMPTION DATA

Before applying Data Analytics concepts we need 1st to have a robust data acquisition process to gather energy consumption data:

i) Historical data (monthly consumption data)
ii) Data from Energy audit (building envelope, existing equipment and time of usage, etc.)
iii) Higher resolution data (real-time or near real-time)

Higher resolution data allows for the identification of consumption dynamics that would not otherwise be observed if only historical data was available and are key for performing automated controls schemes where an action is required in real-time.



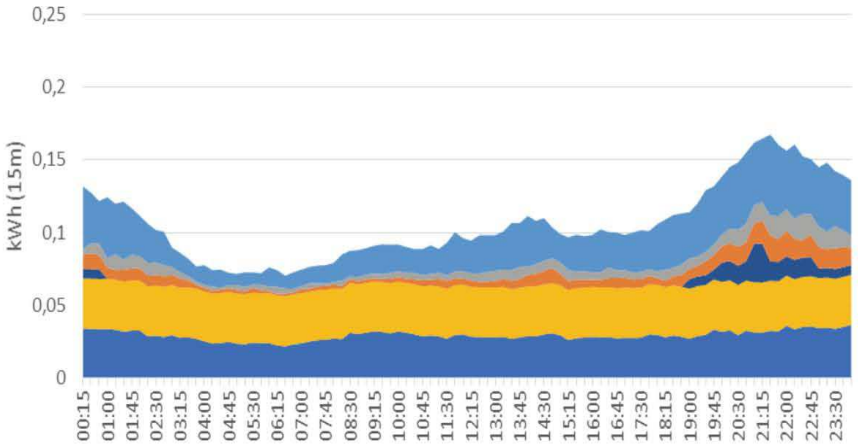
SMART METERS & POST METERS

SMART METERS

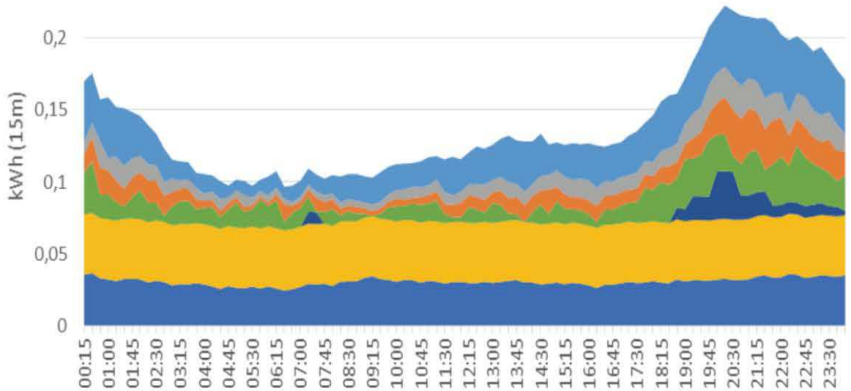
	Electricity	Gas
Traditional Meters		
Smart Meters		

POST METERS

ENERGY CONSUMPTION PROFILES IN THE RESIDENTIAL SECTOR



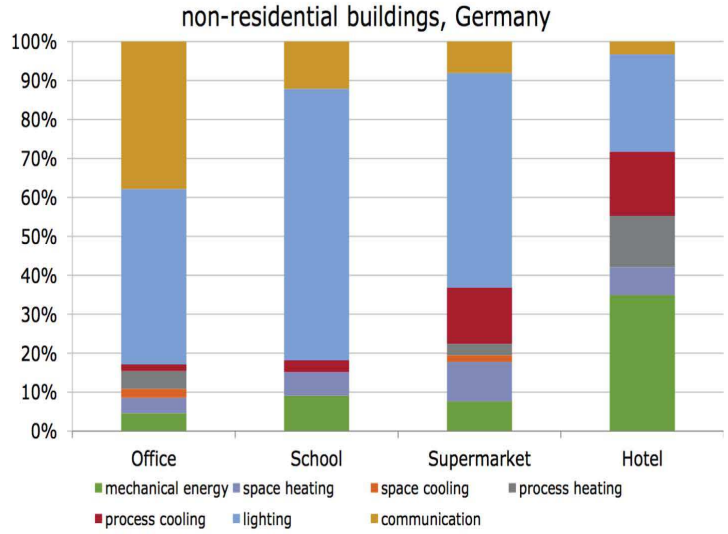
Load disaggregation for the average electricity consumption profile for an apartment in the **summer** (Portugal)



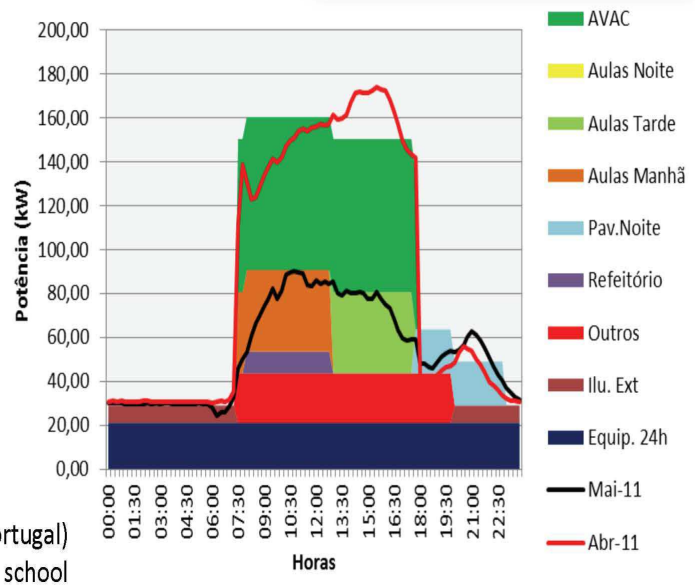
- Fridge/freezer
- Stand-by
- Lighting
- Heating
- Washers
- Dish-washers
- Others

Load disaggregation for the average electricity consumption profile for an apartment in the **winter** (Portugal)

ENERGY CONSUMPTION PROFILES IN SERVICES BUILDINGS'



Electricity consumption (Germany) for four non-residential building types.
Source: Schlomann, Kleeberger et al, 2011.

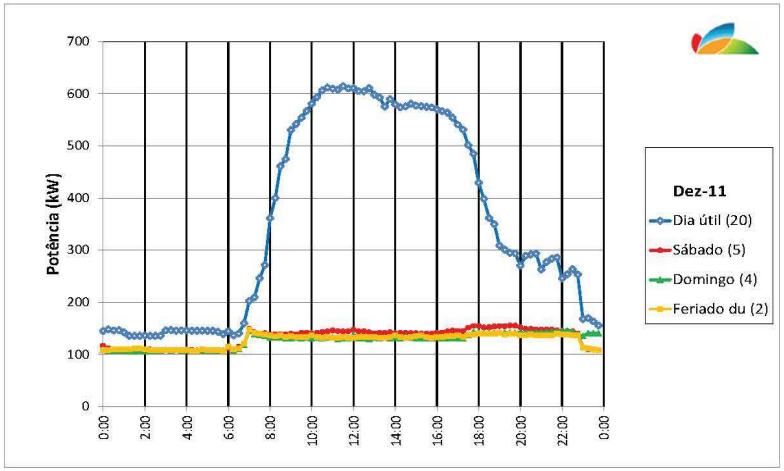


Daily electricity consumption (Portugal) for the Passos Manuel school

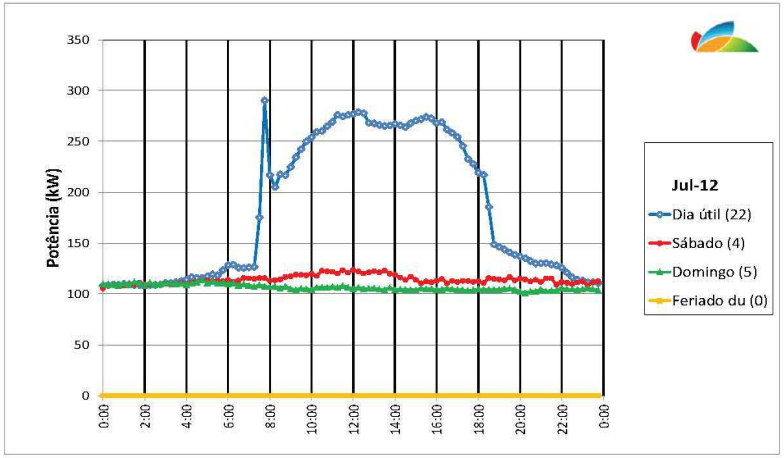
ENERGY CONSUMPTION PROFILES IN SERVICES BUILDINGS'

Large office building (with lab and Data centers) **with** energy management

- December 2011



- July 2012



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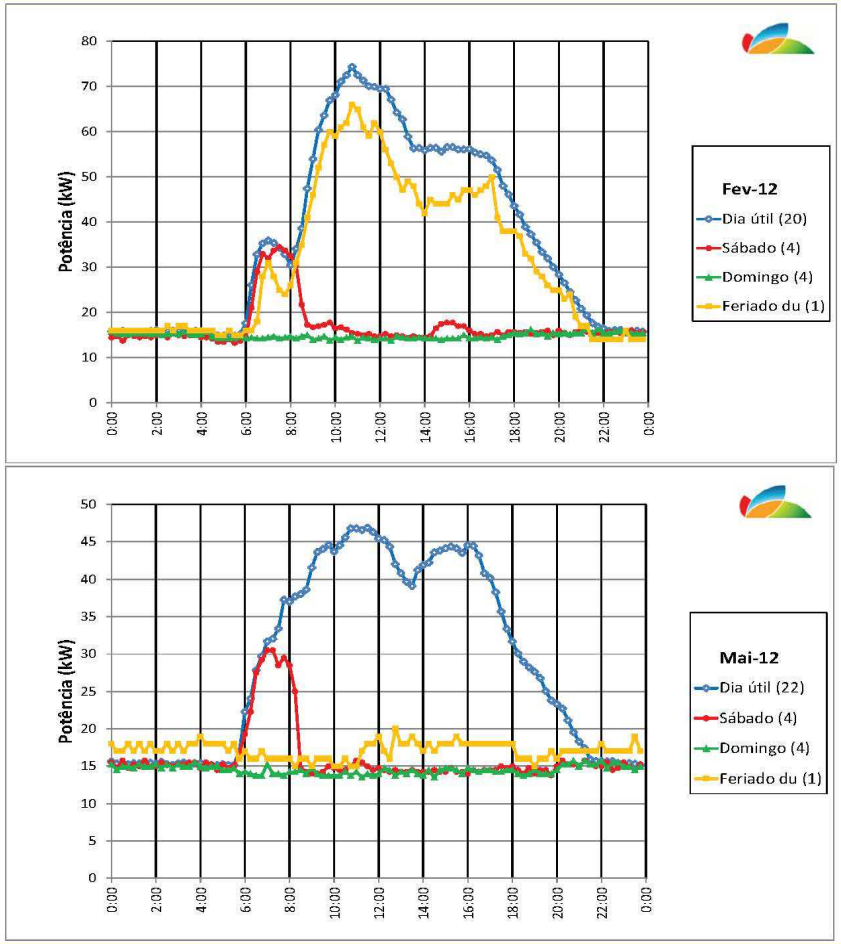
ENERGY CONSUMPTION PROFILES IN SERVICES BUILDINGS'

Small office building (with lab and Data centers) **without** energy management

- February 2012

- May 2012



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watt-is intelligent Solutions

BUILDING ENERGY MANAGEMENT SYSTEMS & DSM

Miguel Carvalho
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Cracow, February 23rd 2017

BUILDING ENERGY MANAGEMENT SYSTEMS

An optimized BEMS is estimated to be able to provide savings between 10% and 30%; saving can be higher in older or poorly buildings.

BEMS can be particularly valuable when no other intervention in terms of the building envelope can be made (for instance in historical buildings).

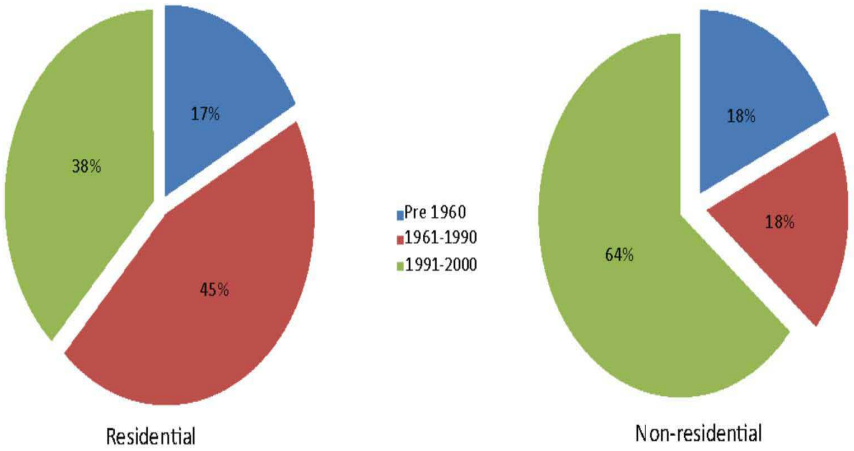


Figure 2 – European Building Stock Age.

Source: APPLICATION NOTE BUILDING AUTOMATION AND ENERGY EFFICIENCY: ECI Publication No Cu0163 Available from www.leonardo-energy.org/node/156301

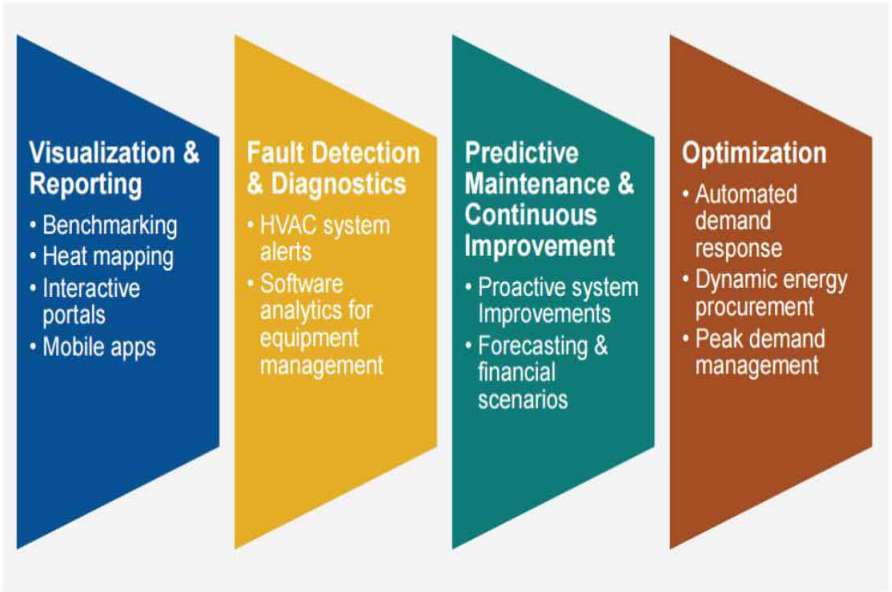
BEMS OFFERINGS

Existing BEMS have different offering categories that go from the simpler (energy moniotirzation) to the most complex (building automation)

Typically these systems are focused on the needs of large buidlings and therefore are CAPEX & OPEX intensive and require a strong HR skillset for its implementation and maintenance.

Typical BEMS incumbent players:
Honeywell
Johnson Controls, Inc.
Pacific Controls
Schneider Electric
Siemens

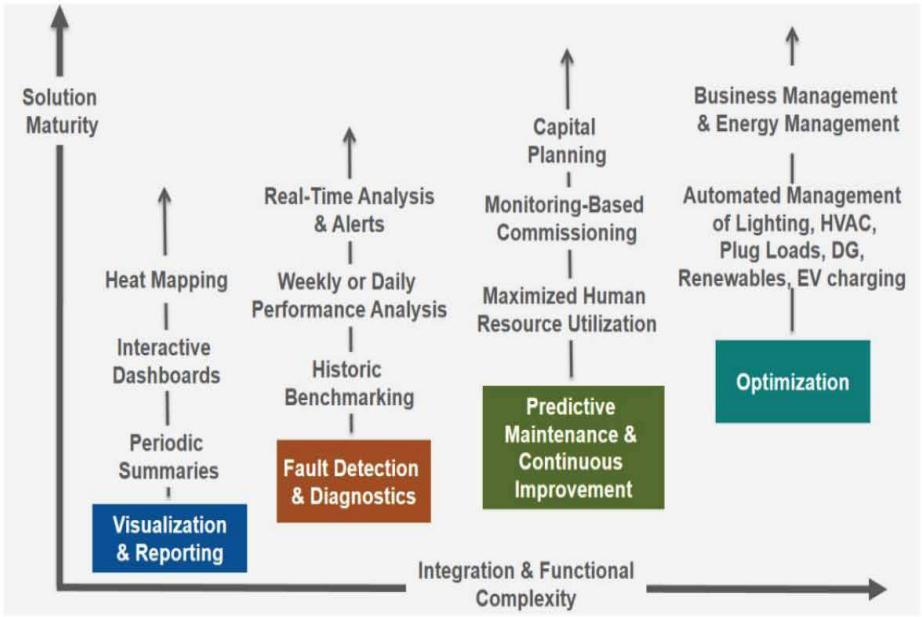
Figure 1.1 BEMS Offering Classes



(Source: Navigant Research)

BEMS COMPLEXITY LEVEL

Figure 1.1 BEMS Offerings Roadmap



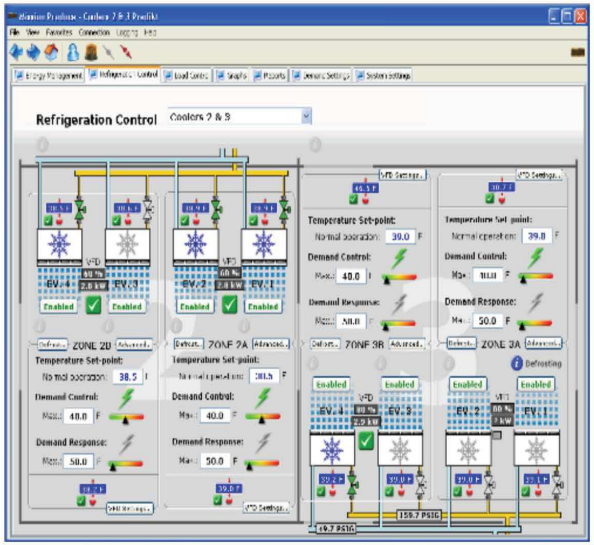
(Source: Navigant Research)

BEMS CURERNT LIMITATIONS

Existing BEMS they tipically address the needs of building managers but do not address well the objectives of user behavior change.

They are more monitoring tools rather than data analytics engines with self-learning capabilities, not being capable to automate more complex optimization or reinforcement learning algorithms.

Even though some of them are built on top of “open-source” standards the specificities for implementation will heavily depend on each specific vendor thus creating a difficulty on connecting solutions from different vendors into one seamless solution. It creates a vendor lock-in effect that restrains scalability in the future for the deployment of specific needs not considered from the start.



CHARACTERISTICS OF A BEMS FOR

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Real-time energy monitoring for multiple facilities **(multi-site)** and metering points (**sub-metering**)

Intelligent alarm features fueled by data analytics to timely inform of abnormal occurrences

Data Analytics capabilities to provide self-learning algorithms aimed at DSM

Automation capability to connect or disconnect specific energy loads

Benchmarking with other facilities from the same economic sector

Automated reporting capabilities

Hardware agnostic to be able to integrate different devices (meters, sensors, actuators) from different vendors, guaranteeing future scalability and the integration of contextual information

Multi-platform environment allowing the involvement with users

BUILDING ENERGY MANAGEMENT SYSTEMS WITH DATA ANALYTICS CAPABILITIES

A PROPOSED SYSTEMS ARCHITECTURE

DATA ACCESS & VISUALIZATION LAYER

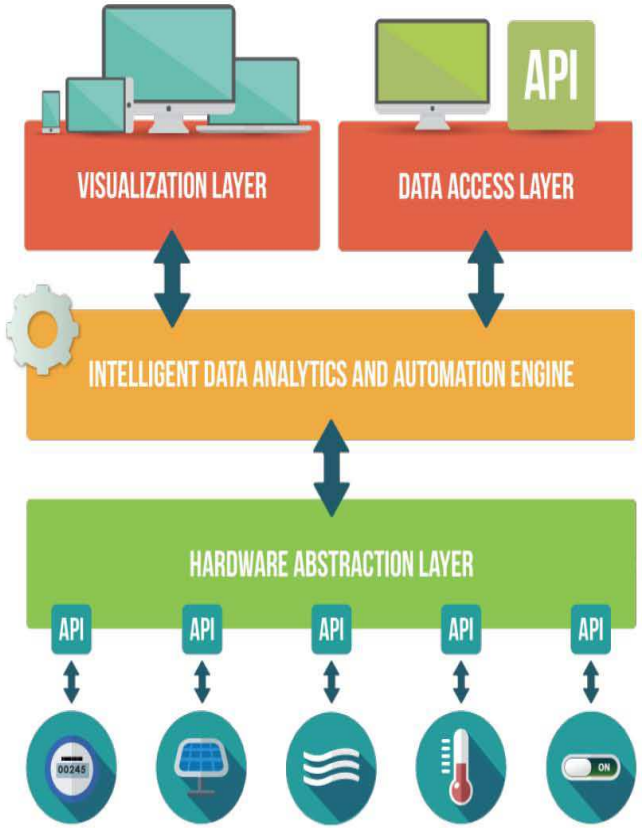
This layer interacts with the end user, be it a building manager (through visualization application) or another energy management application (through specific API's).

INTELLIGENT DATA ANALYTICS & AUTOMATION LAYER

By applying self-learning data analytics techniques it is responsible for processing & analyzing the data gathered. **It should provide support Data Analytics of historical data but also for real-time (or near real-time) data** to provide **historical analytics features** (energy tariff optimization, benchmarking, energy efficiency optimization) and **real-time features** (like anomalous consumption alarms, DSM, etc.)

HARDWARE ABSTRACTION LAYER

Providing seamless capability to interact with multiple equipment's (meters, sensors and actuators) by developing specific API's to connect with them. It **avoids vendor lock-in** by making possible to integrate several kind of equipment's from different vendors.



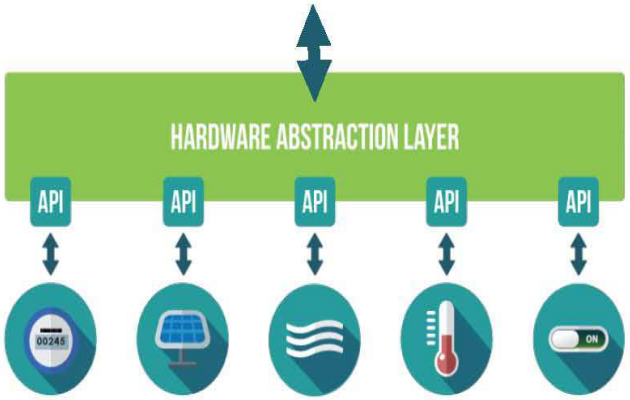
BEMS – HARDWARE ABSTRACTION LAYER

HARDWARE ABSTRACTION LAYER

Provides seamless capability for the top layers to interact with multiple devices (meters, sensors and actuators) from different vendors (**avoiding vendor lock-in and guaranteeing scalability)**, by developing specific API's to connect with each one of them.

Depending on the devices they may possess different communication protocols (Mbus, Modbus, internet API) and in some cases with different data structures (JSON, XML, different implementations of Mbus or Modbus depending on the vendor).

It enables not only the collection of data from the different devices but also sending **automation commands to specific devices with automation capabilities (active DSM).**



INTELLIGENT DATA ANALYTICS & AUTOMATION LAYER

A common problem that needs to be addressed is the **multiplicity of data resolutions/units (1 min, 15 min, 1 hr, variable resoluion / W, kW, Wh, kWh) being collected by different devices**. To overcome this it is usually useful to either:
i) Transform it into a **unique internal resolution and unit** (main issue relates with transforming lower resolution into higher resolution data)
ii) Guarantee that every module that works with the data has the capability to convert it and interpret.

This layer is responsible for processing the data and extracting meaningful information and actions (within a DSM approach) from historical (Relational DB) and near real-time data (Time-series DB).

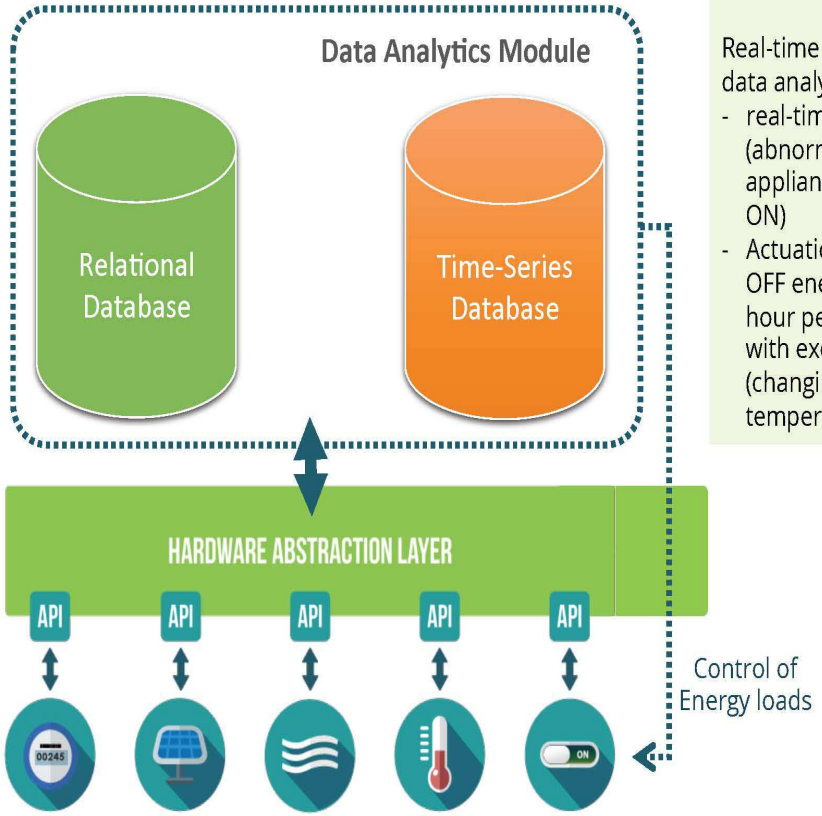
Several implementation options exist in what regards the data analytics modules, in which some of them are highlighted**: i) R, ii) MATLAB, iii) Python, iv) Rlang**. To select between one it should be weighted the **licensing costs, the existence of a community of developers, the easiness to recruit skilled resources and the overall architecture being deployed**.

BEMS – INTELLIGENT DATA ANALYTICS & AUTOMATION LAYER

Relational Database

Ensures persistence of energy data over time in a usual relational model and provides data analytics features that do not require real-time (or near-real time) capabilities, such as:

- Benchmarking
- Energy Tariff Optimization
- Energy Efficiency Measures
- Baseline modeling



Time-Series Database

Real-time (or near real-time) data analytics that enable:

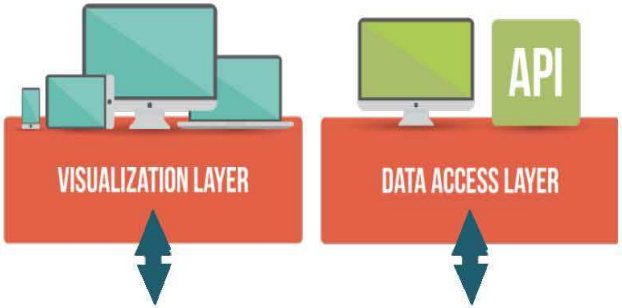
- real-time notifications (abnormal consumptions, appliances or equipment's left ON)
- Actuation by switching ON & OFF energy loads either by hour periods or by co-relating with exogenous variables (changing HVAC ventilation by temperature forecast)

DATA ACCESS & VISUALIZATION LAYER

This layer interacts with the end user, be it a building manager (through a visualization application) or another energy management application (making available the data or specific data analytics results through specific API's).

It should not only provide monitorization capabilities, but also to make available additional added-value features that support on the decision making process of energy managers, such as:

i) Submetering capabilities being possible to measure different devices or sensors
ii) Automated tariff optimization modules
iii) Abnormal consumptions identification and report (email, sms)
iv) Benchmarking
v) Report generation



Exercise – bottom-up to a classroom amphitheater

1) Analyze the room schedule and the equipment existing in the room.

	# luminaires	# bulbs/ luminaire	power/bulb [kW]	Total power
Compact fluorescent non integrated	22	2	0.026	1.144
Emergency	4	1	0.008	0.032
LCD projector	1		0.35	0.35
Laptop	1		0.065	0.065

2) Calculate the average load, in kW, for a typical week.

3) Cross it with real average load and discuss differences.

4) Is there room for efficiency?

	Mon	Tues	Wed	Thur	Fri
07:00-07:30	0.7	0.7	0.7	0.7	0.7
07:30-08:00					
08:00-08:30			1		
08:30-09:00			1		
09:00-09:30			1		
09:30-10:00	1	1	1	1	1
10:00-10:30	1	1	1	1	1
10:30-11:00	1	1	1	1	1
11:00-11:30		1	1		1
11:30-12:00		1	1	1	1
12:00-12:30		1	1	1	1
12:30-13:00				1	
13:00-13:30				1	
13:30-14:00	1		1	1	1
14:00-14:30	1		1	1	1
14:30-15:00	1	1	1	1	
15:00-15:30	1	1	1	1	
15:30-16:00	1	1	1	1	
16:00-16:30	1	1	1		
16:30-17:00		1	1		
17:00-17:30		1	1		
17:30-18:00			1		

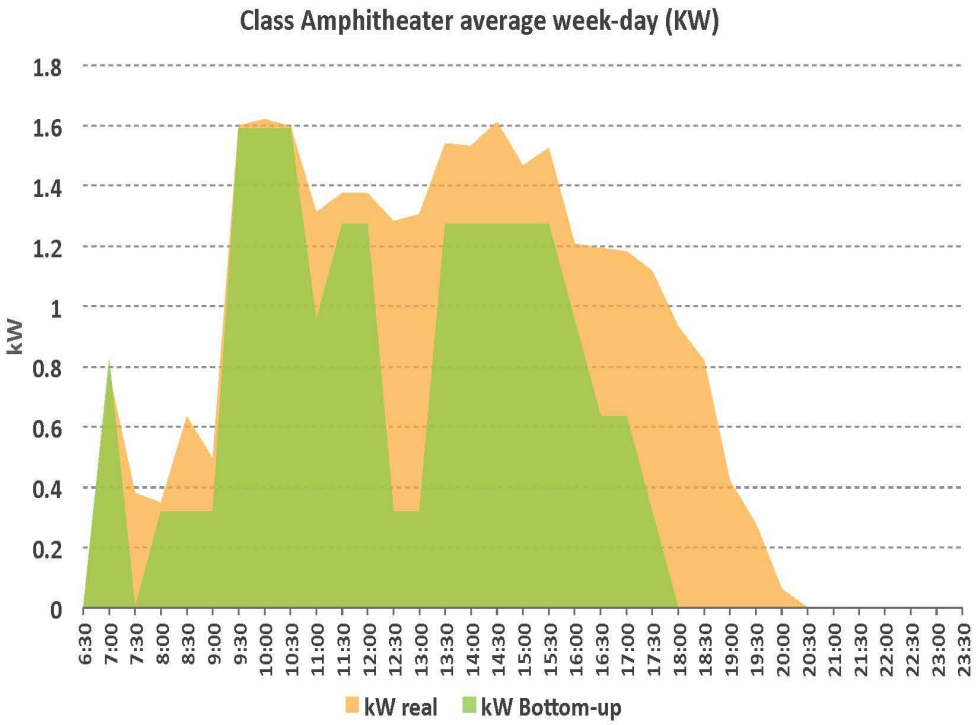
Case Study I / Class Amphitheatre – Real vs Bottom-up (KW)

The cleaning process starts at 06:30 (and finishes before 07:30) but lights are left on, even though there are typically not classes before 09:00.

During lunch time it can also be seen that lights and other equipment's are left ON while no classes are being taught.

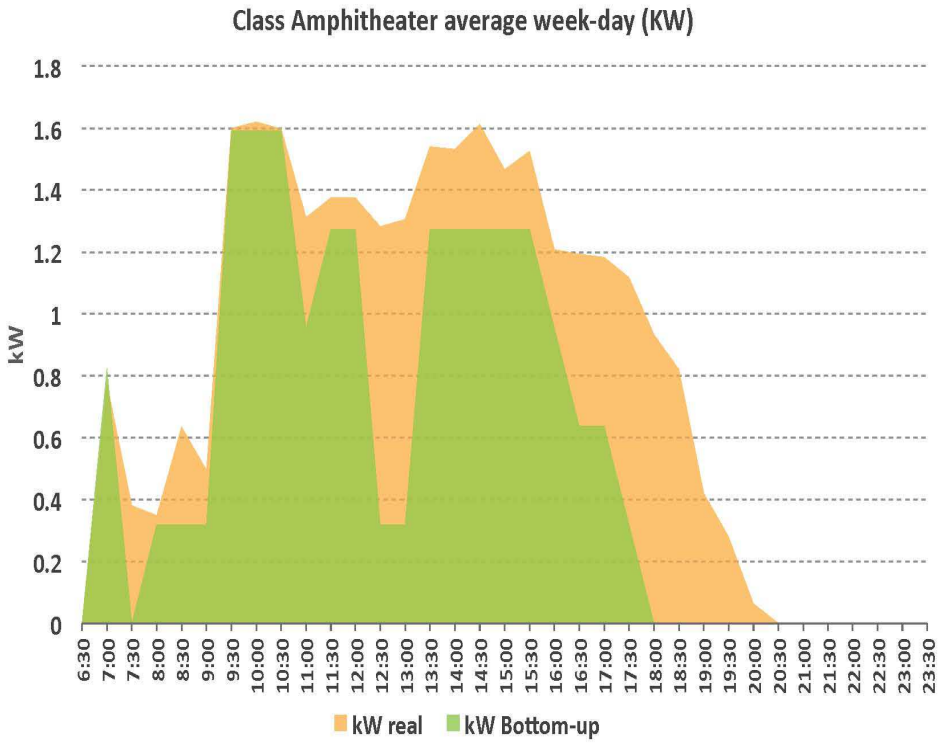
In most of the days all the days classes end before 17:30, nonetheless only after between 18:30 - 19:00 does consumption decreases significantly.

What could be the proposed EE Measures?



Case Study I / Class Amphitheatre – Take Aways

Only by acquiring knowledge about: i) the **effective energy consumption** at a relevant resolution and ii) the **expected consumptions** (through the bottom-up approach in this case) are we able to analyze energy consumption deviations and derive corrective plans.



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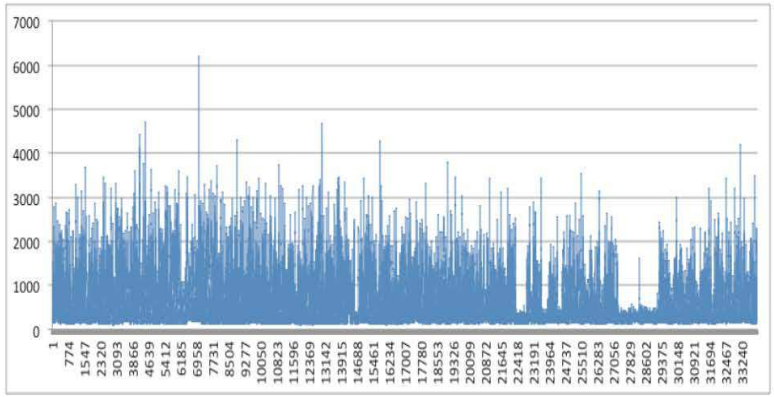
HOW DO WE ENABLE BEMS WITH DATA ANALYTICS & SELF-LEARNING CAPABILITIES ?

Miguel Carvalho
mcarvalho@watt-is.com
Cracow, February 23rd 2017



Energy consumption over 1 year with 15 min resolution (residential sector)

'To develop a model, 80% of the time is just for data treatment'

Data Gaps

- Very common when dealing with real data.
- What to do? Highly depends... Interpolation, rejection of the data set, ...

Data Normalization

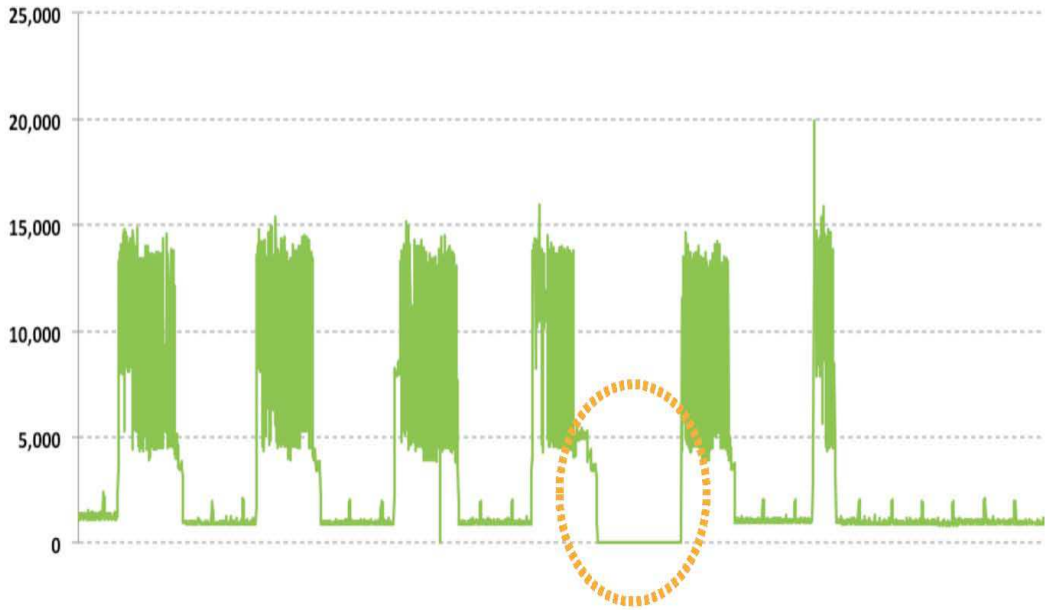
- Important to better perceive impact of each variable (e.g. in a linear regression)
- Different types: z-norm; standard deviation; data box (very common): [0, 1], ...

Data Outliers

- Unexpected values: easy to detect if looking at the plot with raw data
- Be careful, sometimes outliers may be meaningful values (e.g. steep variations in the stock market)
- What to do? Eliminate them and then check the quality of data (*Data gaps*)

What to do when we have DATA GAPS?

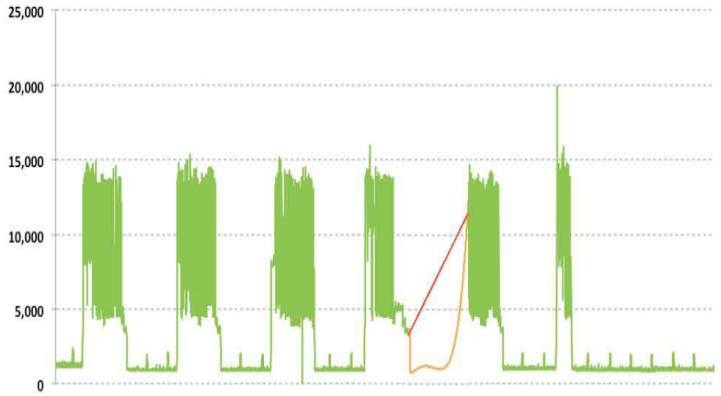
Week – 02/01/2017



Substitute directly by the consumption registered in other similar consumption periods

Week – 02/01/2017 vs 09/01/2017

Substitute by a linear interpolation or if possible by a regression that typically follows the known consumption on similar consumption periods

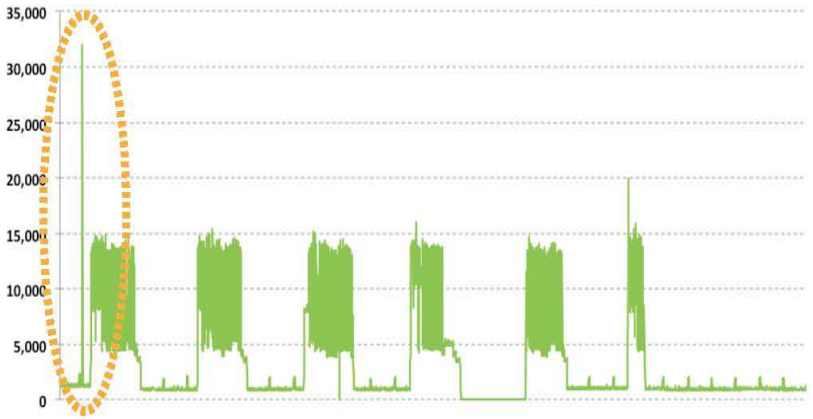


Data Outliers

- Unexpected values: easy to detect if looking at the plot with raw data
- Be careful, sometimes outliers may be meaningful values (e.g. steep variations in the stock market)

What to do?

If they are indeed an error in measurement eliminate them and then check the quality of data (*Data gaps*)



SO... AFTER TREATING THE DATA WHAT CAN DATA ANALYTICS MODELS BE USEFUL FOR?

1. Consumption baseline modeling

2. Identification of past consumption profiles (operational & non-operational periods)

3. Calculation of most suitable energy efficiency tariffs

4. Intelligent alarms
- Abnormal consumptions
- Preventive maintenance

5. Demand Side Management
- Balancing of demand, supply & storage (between distributed renewable sources & the grid), controlling shiftable loads
- Guarantee that not useful consumptions are turned OFF during non-operational hours
- Optimization of HVAC use having in consideration thermal loads, Time of Use tariffs (ToU) and weather forecasts
- Day-light harvesting

6. Foster user engagement to trigger behavior change
- Share of energy information like benchmarking (identifying EE achievers or non achievers) with users of the same activity sector to create competition or co-opetition (corrected of specific operational factors)

7. Load disaggregation models

8. Identification of specific Energy Efficiency measures
- Appliance substitution programs
- Solar PV's

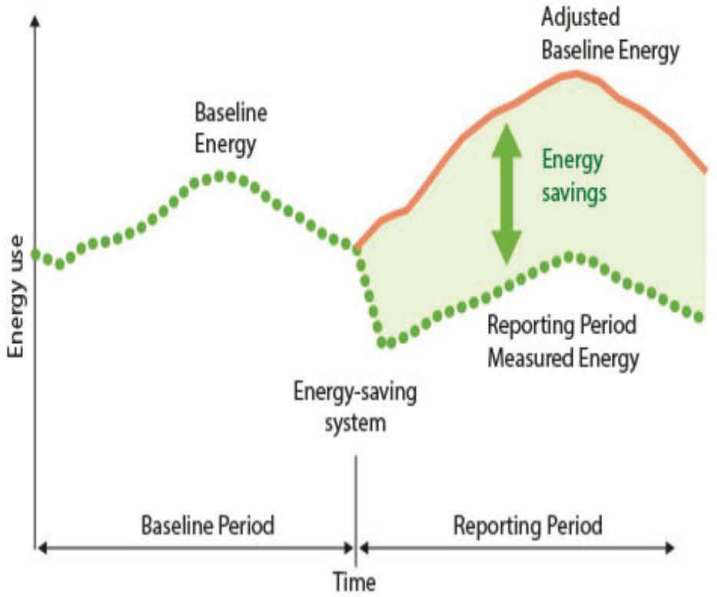
DATA ANALYTICS – So... why to develop a baseline model?

'We can only correct what we can measure'

Allows to identify abnormal consumption patterns and estimate achieved energy savings

Several norms (e.g. International Performance and Verification Protocol – IPMVP) determine quantification of saving measures by comparing consumption evolution with:

i. Control groups (not always available; require more monitoring equipment)
ii. Baseline consumption



DATA ANALYTICS – DEVELOPING A BASELINE MODEL

Select relevant input variables

- Occupancy, weather, lighting hours, etc.

Assess **inter-relations between variables** and combinations of variables for better perception

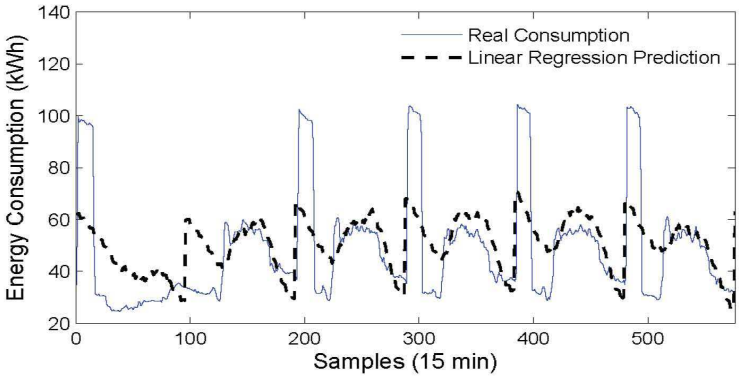
Do we have a **representative data set**? (No rule for that, depends on user sensitivity)

Check for **outliers, data gaps**, … And treat them accordingly

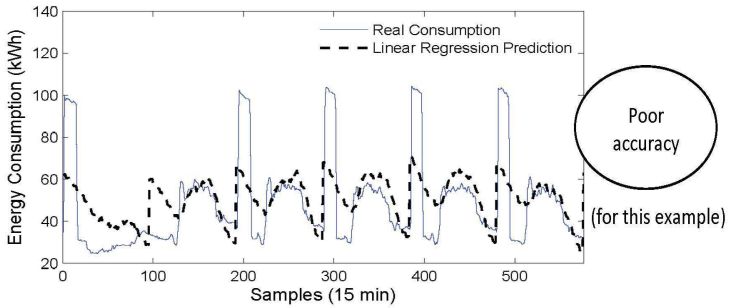
Split **training set (60% of data)** and testing set **(40% of data)** ← Important to better evaluate performance

Develop models with preferred parametrization (e.g. confidence interval, …)

Fine-tune the model by rearranging combinations of variables and parameterization (check for contextualization of variables, etc.)

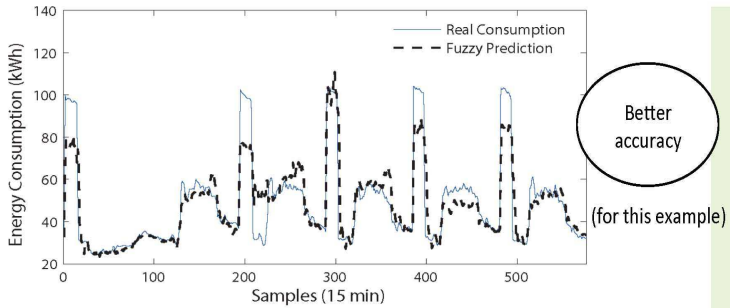


DATA ANALYTICS – MODELLING BASELINE CONSUMPTION



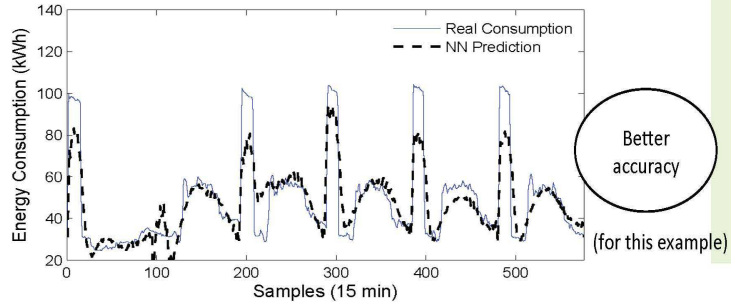
Poor accuracy

(for this example)



Better accuracy

(for this example)



Better accuracy

(for this example)

Several modelling techniques:

- Linear regressions;
- Fuzzy set theory;
- Neural networks;

More complex, describe non-linear dependencies

Input variables (non exhaustive list):

- Occupancy-related **(LR, FZ, NN)**
- Time of day **(LR, FZ, NN)**
- Type of day (working day, holiday, …) **(LR, NN)**
- Schedules of activities (e.g. classes, exams)
- Indoor temperature
- Outdoor temperature **(LR)**
- Other weather variables
- Etc….

OPTIMIZATION MODELS

Step-by-step definition of:

The problem: *What to optimize (minimize),*

The objective functions,

The constraints: *Limits to temperature, consumption, air quality (ppm CO_2), …*

The state functions: *The system's dynamics; how are affected by actions.*

Example:

A multiobjective optimization that includes:

- PV production with batteries,
- Electricity from the grid,
- Time-sensitive tariff, and
- Thermal comfort of users.

Objective function:

$$min_F \left\{ \sum_{i=0}^{24} \left[\lambda_i^{dscmf} u_i^{dscmf}(s_i, d_i) + \lambda_i^{cost} u_i^{cost}(s_i, d_i) \right] \right\}$$

Importance given to discomfort and economic cost

Cost functions describing discomfort and economic cost

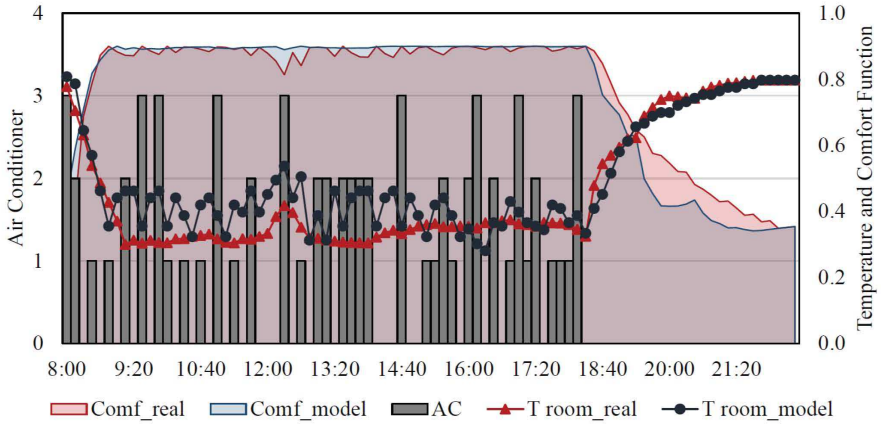
Constrained to:

$$\lambda_i^{dscmf} + \lambda_i^{cost} = 1$$

DATA ANALYTICS – Boosting the potential benefits of BEMS

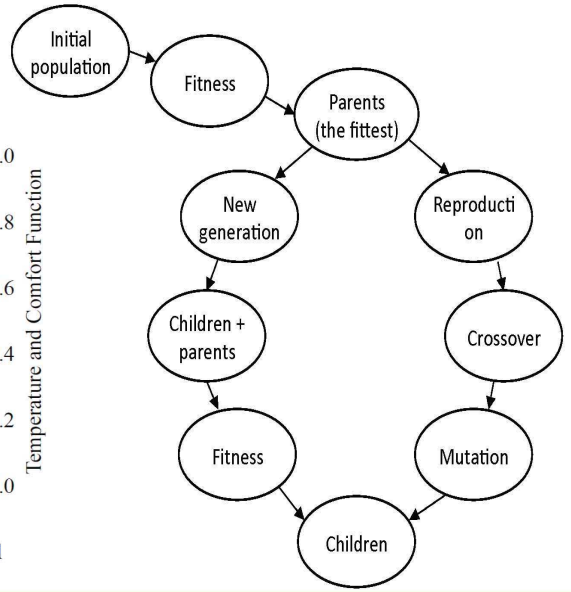
Self-learning multiobjective optimization
- Time-sensitive tariff
- Users' thermal comfort

USING GENETIC ALGORITHMS



- Runs recursively from the last instance to the first one,
- Follows the same decisions functions, state functions, transition rules and objective function.

Finds the optimal solution through:
- Inspired by evolution of biological systems,
- Survival of the 'fittest' individuals with competition,
- Generation of solutions through 'mutations', 'genes crossover', ...
- **Requires rules for selecting the best solutions → Objective function**

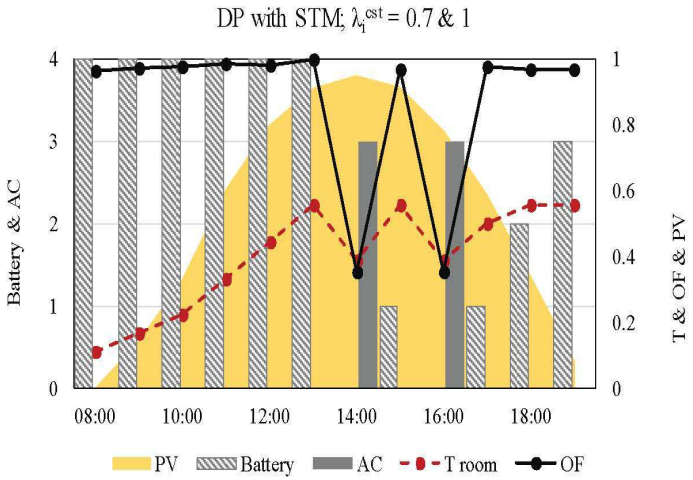


DATA ANALYTICS – Boosting the potential benefits of BEMS

Self-learning multiobjective optimization

- PV with batteries
- Time-sensitive tariff
- Users' thermal comfort (T room)

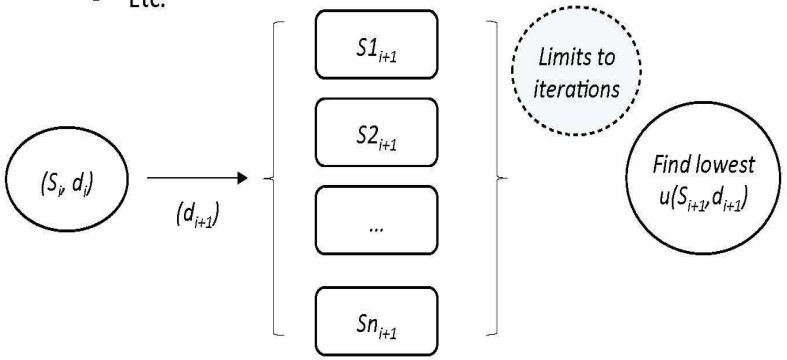
USING DYNAMIC PROGRAMING



- Runs recursively from the last instance to the first one,
- Follows the same decisions functions, state functions, transition rules and objective function.

Finds the optimal solution through:

- Analyzing each possible solution as a consequence of the decision for that moment in time.
- Choose the one with the lowest objective function value.
- To prevent analyzing an infinite number of stages, strategies exist:
  - Discretize the system dynamics,
  - Limit the number of iterations,
  - Etc.



DATA ANALYTICS & DSM – OPTIMIZING HVAC OPERATION

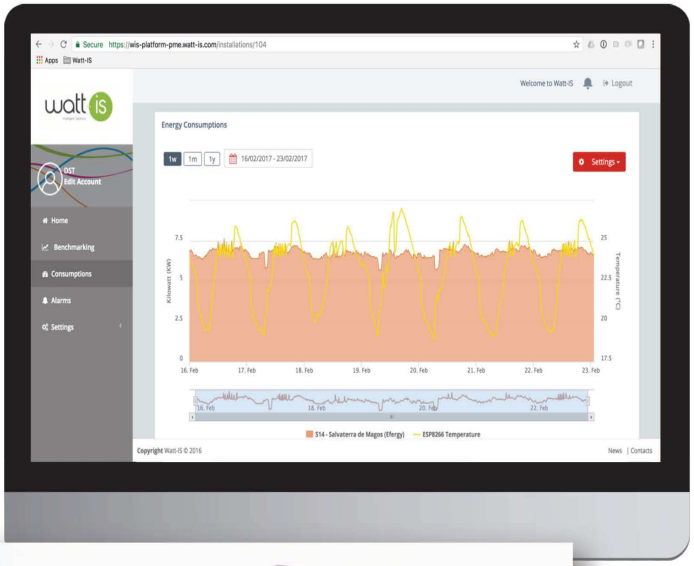
Through selected optimization models (e.g. genetic algorithms, dynamic programing, fuzzy controller, ...), develop a multiobjective optimization control of HVAC for sea container Data Centres.

Input variables:
Indoor temperature
Time-sensitive tariff
Weather forecasts

Output variables:
Cost as a function of kWh
Indoor temperature

Objective function: $$min_F \left\{ \sum_{i=0}^{24} [\lambda_i^{cost} u_i^{cost}(s_i, d_i)] \right\}$$

Constrained to a maximum temperature that the servers can handle (22ºC).



CASE STUDY – SMART CAMPUS / IST- TAGUSPARK

Smart CAMPUS

SMART-CAMPUS

Amphitheatre (A4)

Library

13 Offices 2N14-10

Energy lab (1.58)

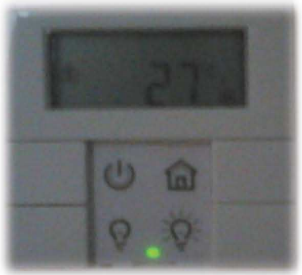
DATA ANALYTICS & DSM – REINFORCEMENT LEARNING EXAMPLES

Unsupervised reinforcement learning characterization of thermal comfort in a office room

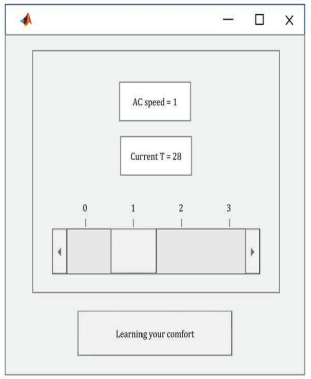
- A system that sets HVAC velocity
- User interaction (he can reject the system's decisions) – positive or negative rewards to the system

User Interaction mechanisms

1. Wall switch



2. PC controllable App



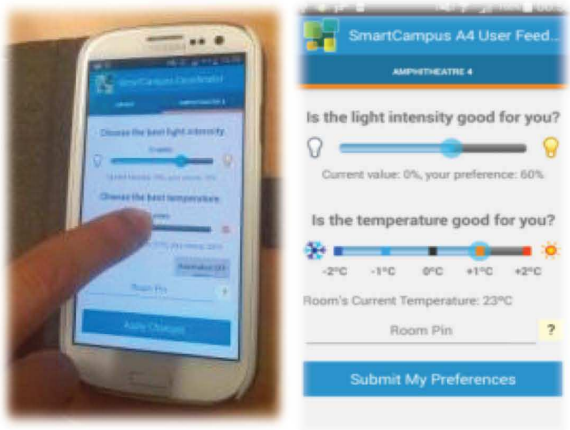
DATA ANALYTICS & DSM – REINFORCEMENT LEARNING EXAMPLES

Characterizing comfort through users interaction in a university amphitheatre

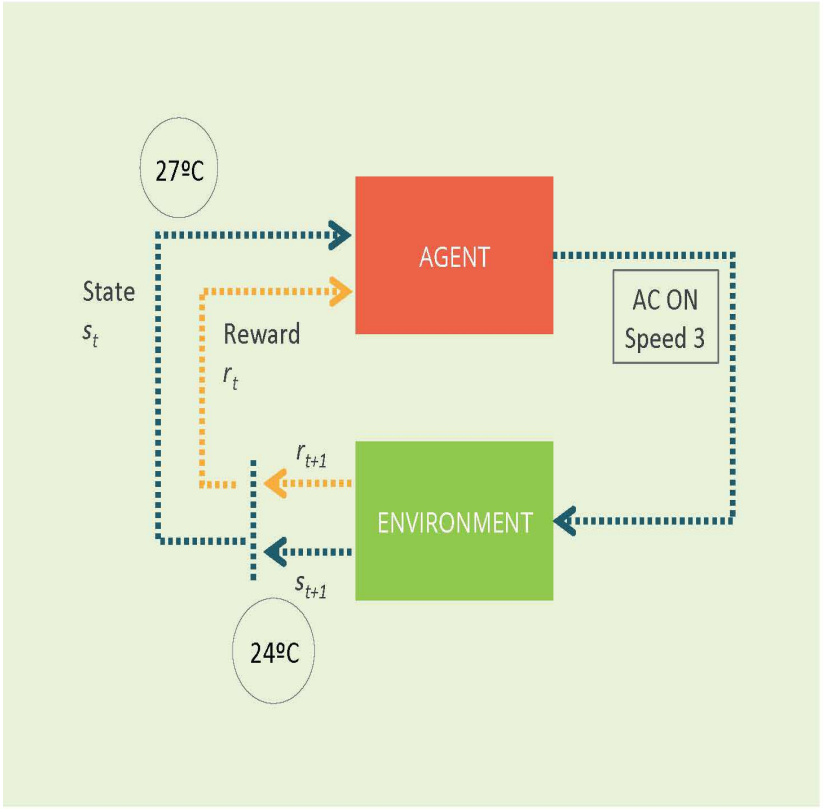
- Mobile App
- Control of HVAC and lighting
- Cooperative multi-user comfort optimization

User Interaction mechanism

1. Mobile phone app



DATA ANALYTICS & DSM – SELF-LEARNING COMFORT TEMPERATURE THROUGH REINFORCEMENT

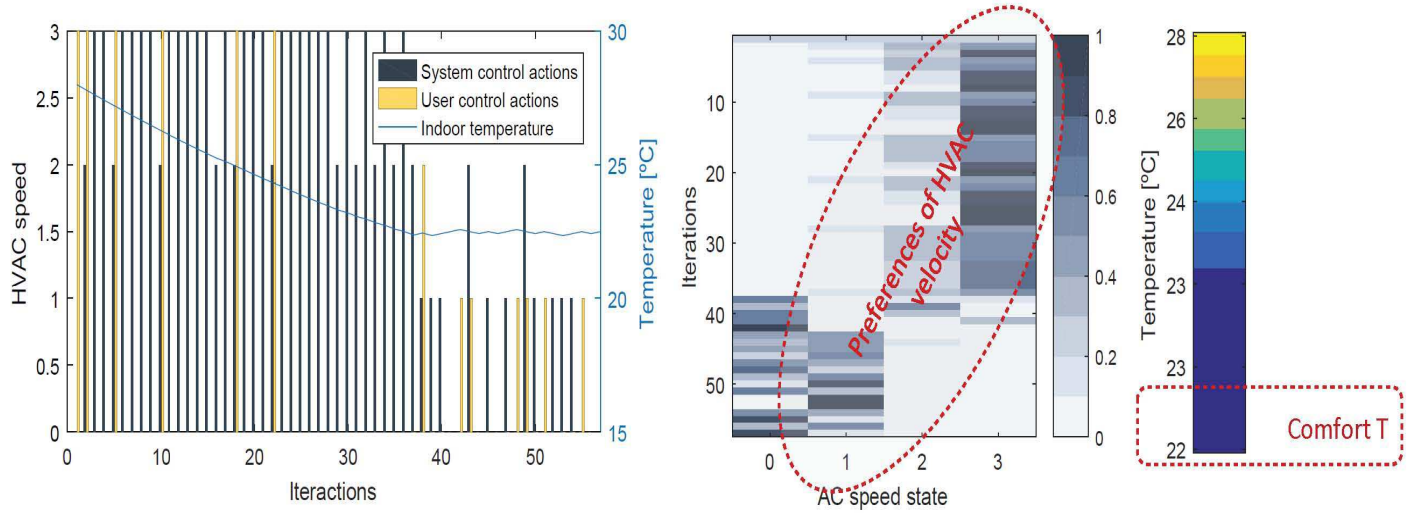


State (t) - T = 27ºC			
AC = 0	AC = 1	AC = 2	**AC = 3**
0.25	0.25	0.25	**0.25**

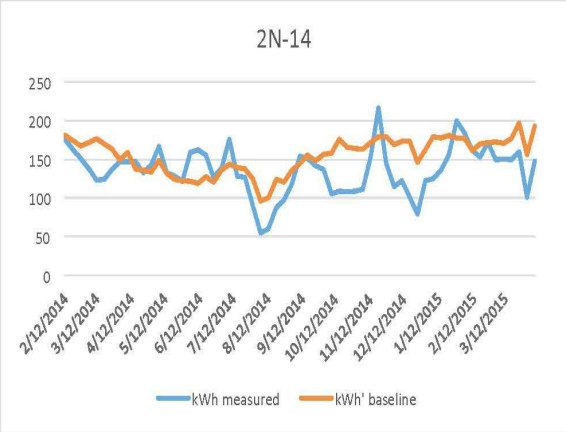
State (t+1) - T = 27ºC			
AC = 0	AC = 1	AC = 2	**AC = 3**
0.216	0.216	0.216	**0.35**

Unsupervised reinforcement learning characterization of thermal comfort

- A system that sets HVAC velocity
- User interaction (he can reject the system's decisions) – positive or negative rewards to the system



CASE STUDY – SMART CAMPUS / IST- TAGUSPARK - Offices



Real and baseline energy consumption for 2N-14

Summary:

- Energy savings increased along time whit the improvement of algorithm control for HVAC system
- **Global savings are around 12%** due to lighting energy savings in the corridor and less time using HVAC

CASE STUDY – SMART CAMPUS / IST- TAGUSPARK - Offices

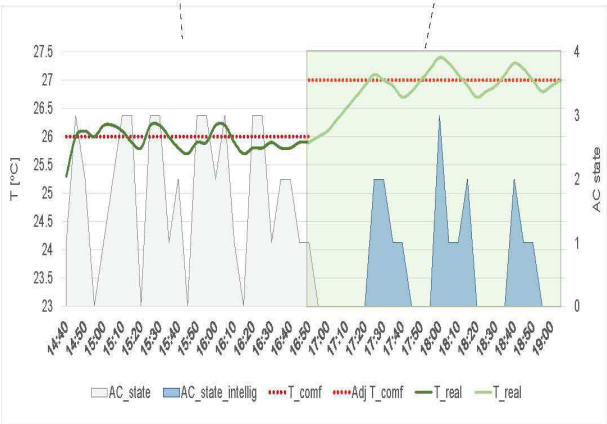
Intelligent detection of comfort temperature

Intelligent control: Adjust temperature set point in 1ºC

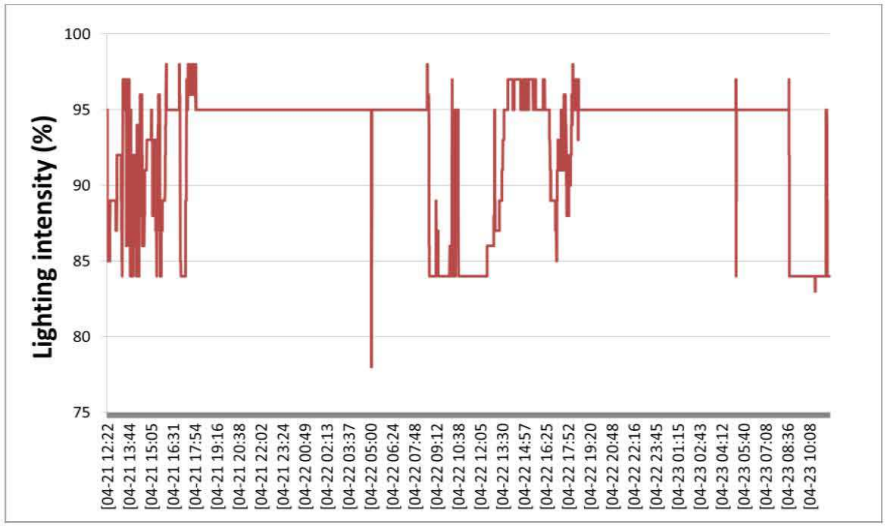
Typical day in the Summer
- Exterior office: 25ºC → 26ºC
- Interior office: 26ºC → 27ºC

Typical day in the Winter
- Exterior office: 20ºC → 19ºC
- Interior office: 19ºC → 18ºC

Estimated savings (EnergyPlus): 16% (for cooling periods)

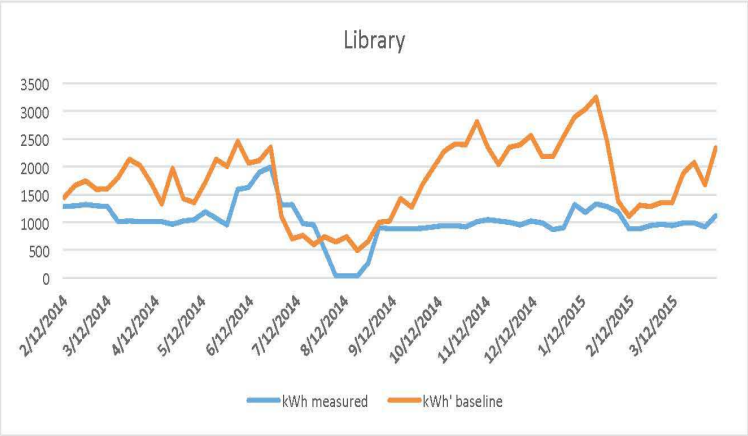


Intelligent control of the HVAC system example



Lighting intensity profile – Daylight Harvesting in two consecutive days

- During daytime lighting intensity fluctuates according to the illumination levels in the library (light sensors were placed in two facades to ensure minimum lighting level).
- **Daylight harvesting allows savings of approximately 10%.**



Real and baseline energy consumption for the Library

Summary:

- Immediate energy savings due to ballasts improvement and dimming options.
- **Global savings are around 42%** but expected to increase with daylight harvesting in the spring and summer.

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Your partner in energy data analytics

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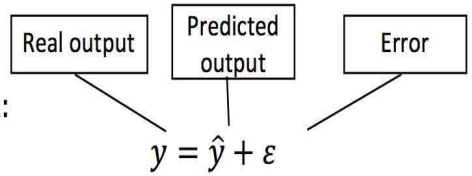
Miguel Carvalho
mcarvalho@watt-is.com

Variation for each observation:



Goal: Minimize total deviation between y_i (real outputs) and $\hat{y}_i$ (outputs from the regression):

$$\sum_{i=1}^{n}(y_i - \hat{y}_i)^2 = \sum_{i=1}^{n}(\hat{y}_i - \bar{y}_i)^2 + \sum_{i=1}^{n}(y_i - \hat{y}_i)^2$$

$$SST = SSR + SSE$$

Total sum of squares (SST)

Explained variation (regression sum of squares, SSR)

Unexplained variation (total sum of squares, SSE)

Where $\bar{y}_i$ is the population mean.

The coefficient of determination, R^2, evaluates the equation performance:

$$R^2 = \frac{SSR}{SST}$$

DATA ANALYTICS – Linear regressions

A statistically meaningful regression:
R^2 must be high (>90 – 95%)
Define interval of confidence (typically *95%* → α = *5%*)
P-Value and *Signficiance (F)* < 0.05

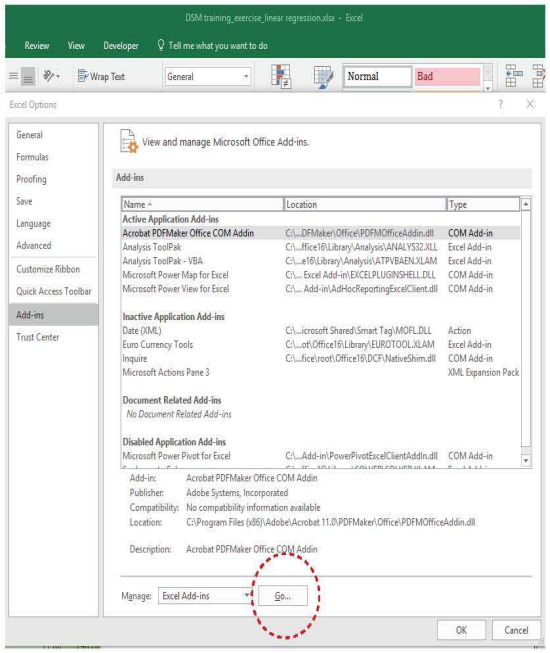
Regression equation looks like:

$$y = inters. + \alpha_1 * var_1 + \alpha_2 * var_2 + \cdots + \alpha_n * var_n$$

Compute a linear regresison in Microsoft Excel

1st enable 'Data analytics' toolbox: File → Options → Add-ins → 'Manage Excel Addins (Go...)'

2nd Enable 'Analysis toolpak'

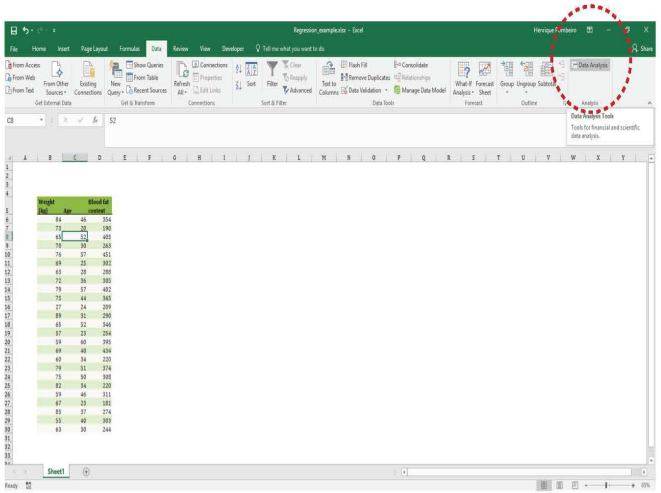


Compute a linear regresison in Microsoft Excel

Example: *Age and weight are to be related to blood fat content.* http://people.sc.fsu.edu/~jburkardt/datasets/regression/x09.txt

Weight (kg)	Age	Blood fat content
84	46	354
73	20	190
65	52	405
70	30	263
76	57	451
69	25	302
63	28	288
72	36	385
79	57	402
75	44	365
27	24	209
89	31	290
65	52	346
57	23	254
59	60	395
69	48	434
60	34	220
79	51	374
75	50	308
82	34	220
59	46	311
67	23	181
85	37	274
55	40	303
63	30	244

1) 'Data' → 'Data analysis'



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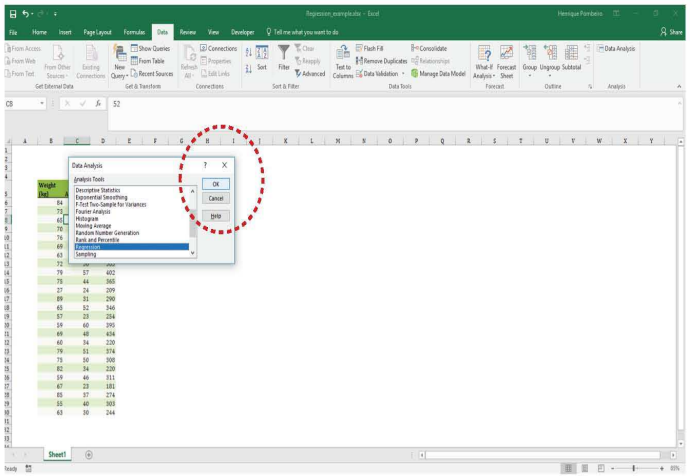
1) 'Data' → 'Data analysis'
2) 'Regression'



Compute a linear regresison in Microsoft Excel

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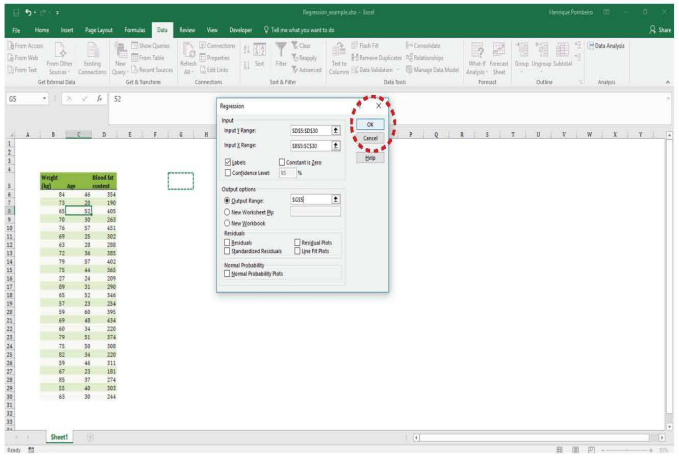
67	23	181
85	37	274
55	40	303
63	30	244

1) 'Data' → 'Data analysis'
2) 'Regression'
3.1) Select 'Input Y Range' (outputs y)
3.2) Select 'Input X Range' (input variables)
3.3) Select 'labels' (in our case, we are including the columns title)
3.4) Confidence level: 95%
3.5) Output options: select 'Output range' (to see reults in this sheet) or 'New worksheet ply'

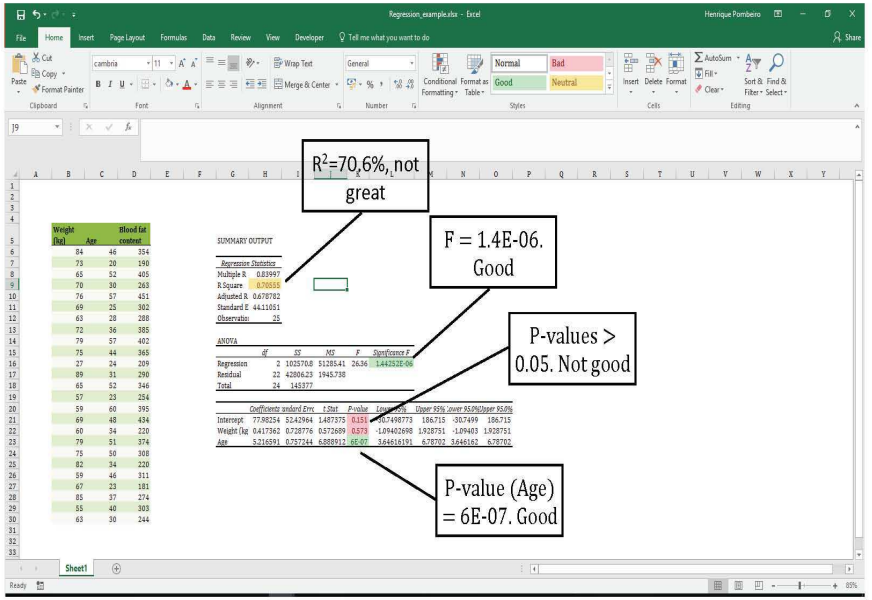


Compute a linear regresison in Microsoft Excel

Example: *Age and weight are to be related to blood fat content.* http://people.sc.fsu.edu/~jburkardt/datasets/regression/x09.txt

Weight (kg)	Age	Blood fat content
84	46	354
73	20	190
65	52	405
70	30	263
76	57	451
69	25	302
63	28	288
72	36	385
79	57	402
75	44	365
27	24	209
89	31	290
65	52	346
57	23	254
59	60	395
69	48	434
60	34	220
79	51	374
75	50	308
82	34	220
59	46	311
67	23	181
85	37	274
55	40	303
63	30	244

4) Check results… R^2 = 70.6%, F = 1.4E-06, P-value (intersec) = 0.151, P-value (Weight) = 0.573, P-value (Age) = 6E-07



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89	31	290
65	52	346
57	23	254
59	60	395
69	48	434
60	34	220
79	51	374
75	50	308
82	34	220
59	46	311
67	23	181
85	37	274
55	40	303
63	30	244

What does it mean, that P-value for intersection and weight are > 0.05?
Means that, under a statistical confidence of 95%, we cannot reject the 'null hypothesis'.

'Null hypothesis'

Is the hypothesis that there is no statistical relation between the input variables and the output.
If we cannot reject this hypothesis, then we cannot affirm that there is a statistical relation between the inputs and the output.

In our case, we cannot reject the hypotesis that there is no statistical relation between weight and blood fat content.

50000&1 SEAPs

ENERGY MANAGEMENT FOR SUSTAINABLE ACTION PLANS

Co-funded by the Intelligent Energy Europe Programme of the European Union

Standard energy management systems - ISO 50001, EEA (experience of the 50000&1 SEAPs project)

TOGETHER, MASTER TRAIN-THE-TRAINER WORKSHOP, Kraków 23 Feb 2017

Polska Sieć Energie Cités

Marcin Łojek, project manager

Association of Municipalities Polish Network „Energie Cités”

CONTENT

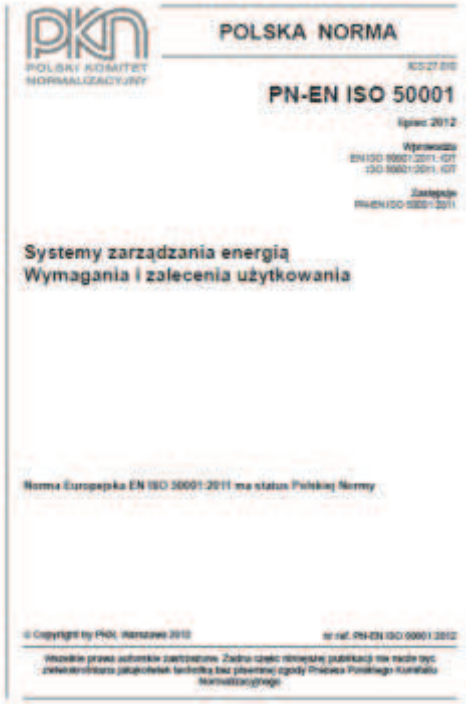
ENERGY MANAGEMENT SYSTEM - ISO 50001

EMS & SEAP INTEGRATION (50000&1 SEAPS)

EUROPEAN ENERGY AWARD

ENERGY MANAGEMENT SYSTEMS ISO 50001 INTRODUCTION

- European Standard on Energy Management System EN ISO 50001:2011 was established in October 2011. As a Polish Standard it was introduced as a PN EN ISO 50001:2011, and it has worked as PN EN ISO 50001:2012 since July 2012.
- It enables a systematic approach, in order to achieve continual improvement of energy performance, energy efficiency and energy conservation → **energy savings** (and costs related to energy).


POLSKA NORMA

PN-EN ISO 50001

Systemy zarządzania energią
Wymagania i zalecenia użytkowania

EMS GENERAL AIMS

- Knowledge of energy use: energy review and baseline;
- Improvement of energy performance;
- Determination of energy performance indicators;
- Monitoring and continuous improvements.

ISO 50001 - MAIN STEPS

1. Identification of top management responsibilities
2. Energy policy preparation
3. Energy planning
4. EMS implementation.
5. Check
6. Management review

EMS STEP BY STEP

1. Identification of top management responsibilities

- Superiors engagement (Top management shall demonstrate its commitment and support to the EMS and to continually improve its effectiveness)
- Designation of top management representative (actually it is a person who will be responsible for the EMS establishment, implementation, maintaining and improvement), who identifies „energy team".
- Providing the resources necessary for the EMS;
- Identifying the scope and boundaries of the EMS;

2. Energy policy preparation

ENERGY POLICY ≠ ACTION PLAN

(Action plan is a tool for energy policy implementation)

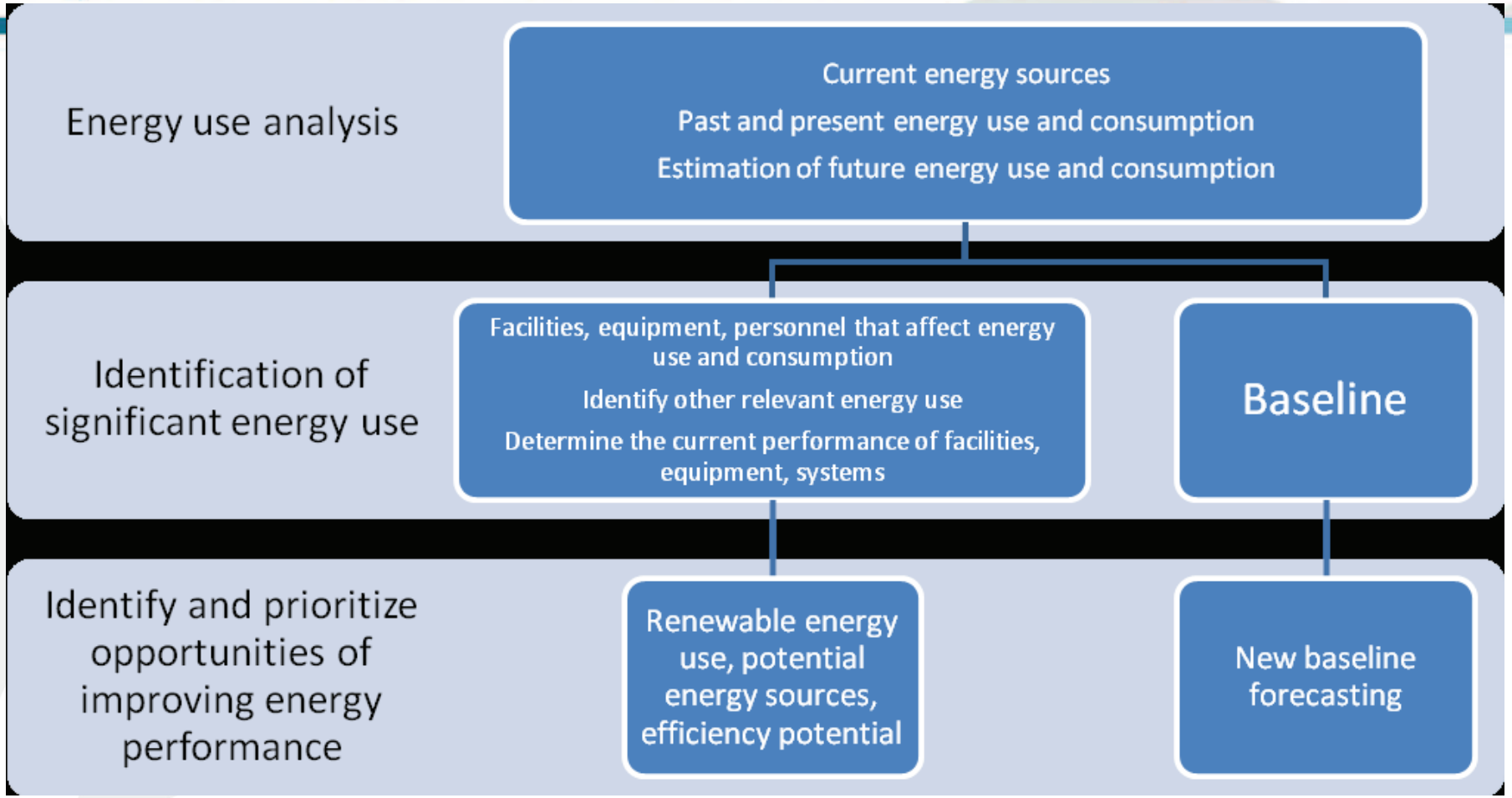
Energy policy is a commitment to:

- continuous improvement of the energy performance;
- accessibility to resources and information;
- ensure that EMS is compatible with existing legal and other requirements;

3. Energy planning

Review of actions which can influence the energy performance. Leads to identification of improvement possibilities.

- Legal and other requirements;
- Energy review: 1. energy use analysis (current energy sources, past and present energy use, estimation of future energy use); 2. identification of significant energy use; 3. identification and prioritization of energy performance improvements;
- Energy baseline: energy used in determined time; EB shall be maintained and recorded; any changes of energy performance shall be compare to the EB;
- Identification of energy performance indicators: proper to energy performance measure and monitoring, methodology of EPI determination shall be described and recorded, regular reviews (compared to the EB).
- Objectives, targets and action plan (with timeframes, resources and verification methods)



Source: How to develop a Sustainable Energy Action Plan integrated with an Energy Management System based on ISO 50001:2011. Guidebook. Sogesca, Energy for Mayors project

Energy reviev and baseline example

	Energy use					CO2 emission per year
Year	Electricity	gas	district heating	other	total	
	[MWh]	[m³]	[GJ]	[kWh]	[MWh]	[t]
2006	1229,231	339 705	10 416		7 472	3607,9
2007	1256,042	305 946	8 999		6 773	3372,9
2008	1312,653	295 588	9 967		6 996	3556,1
2009	3284,97	410 475	12 698		10 860	6518,5
2010	1414,743	357 850	14 194		8 886	4397,1
2011	1390,423	305 260	10 751		7 387	3778,1
2012	1397,724	339 037	11 060		7 813	3897,5
2013						0
2014						0
2015						0
2016						0
2017						0
2018						0
2019						0
2020						0
CO2 emission factors [t/MWh]	1,191	0,202	0,507			

Bilans energii | oświetlenie ulic | Żłobek Miejski | PP 1 | PP 2 | PP 7 | SP 3 | SP 5 | Sp 6 | SP 9 | SP 9 Schronisko | GM 1 | GM 3 | Ratusz

School nr 2			address		Energy use					Consumption per unit		Changes compared to the EB	CO2 emission per year
Number of users				Year	Electricity	gas	district heating	other	Total	[kWh/(m² *year)]	[kWh/m³ *year)]		
Building data					[kWh]	[m³]	[GJ]	[kWh]	[MWh]			[%]	[t]
Heating area		[m²]	4829	2006	64 792	1 480	1 764		569,4	117,9	22,9	13,1	328,6
Heating volume		m³	24 912	2007	64 545	1 641	1 521		503,2	104,2	20,2	0,0	294,3
Contractual power	electricity	[kW]		2008	56 032	1 704	1 738		555,6	115,1	22,3	10,4	314,9
	gas	[m³/h]		2009	61 126	0	1 935		598,6	124,0	24,0	18,9	345,3
	district heating	[kW]		2010	61 979	0	1 834		571,4	118,3	22,9	13,5	332,1
	other	[kW]		2011	64 682	0	1 122		376,5	78,0	15,1	-25,2	235,1
	total	[MW]		2012	56 535	0	1 051		348,5	72,2	14,0	-30,8	215,3
Energy baseline		[kWh/(m² * year)]	104,2	2013					0	0,00	0,00	-1,00	0
				2014					0	0,00	0,00	-1,00	0
				2015					0	0,00	0,00	-1,00	0
Building renovation in 2011				2016					0	0,00	0,00	-1,00	0
				2017					0	0,00	0,00	-1,00	0
				2018					0	0,00	0,00	-1,00	0
				2019					0	0,00	0,00	-1,00	0
				2020					0	0,00	0,00	-1,00	0
		CO2 emission factors [t/MWh]			1,191	0,202	0,507						

School nr 2			address	Energy use					Consumption per unit		Changes compared to the EB	CO2 emission per year
Number of users				Year	Electricity [kWh]	gas [m³]	district heating [GJ]	other [kWh]	Total [MWh]	[kWh/(m² *year)]	[kWh/m³ *year)]	[%]	[t]
Building data													
Heating area		[m²]	4829	2006	64 792	1 480	1 764		569,4	117,9	22,9	13,1	328,6
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Energy baseline		[kWh/(m²* year)]	104,2	2013					0	0,00	0,00	-1,00	0
				2014					0	0,00	0,00	-1,00	0
				2015					0	0,00	0,00	-1,00	0
Building renovation in 2011				2016					0	0,00	0,00	-1,00	0
				2017					0	0,00	0,00	-1,00	0
				2018					0	0,00	0,00	-1,00	0
				2019					0	0,00	0,00	-1,00	0
				2020					0	0,00	0,00	-1,00	0
		CO2 emission factors [t/MWh]			1,191	0,202	0,507						

Action plan example:

Area: Municipal buildings

Main objective: 25 % energy consumtion of municipal buildings decrase (from 2006 baseline)

Specific objectve: Increasing energy awarness of users.

Targets	Responsible	Costs	Financing sources	Completion date	Energy reduction MWh/year	Emission reduction Mg CO_2/year
Implementation of Green public procurement procedures	PP Department	No costs	Municipal budget	IX 2016	10	6
School no1 - building renovation with new heating system	Investments Department	400 000	Municipal budget + external founds (ROP)	X 2016	220	211
Training for buildings users	Prom. Office	2000	Project ABC	III 2016	3	3

4. **EMS implementation (1)**:

- **Outputs from the energy planning phase (include action plan) are put into practice.**
- **Ensure competences** of employees/EMS users (verification of competences, trainings if needed) and **ensure awareness** of the energy policy, EMS procedures, roles and results
- **Communication** - interior (eg. every employee can comment/suggest improvements) and exterior (facultative - if yes, describe information flow).
- **EMS documentation** - descriptions of procedures, objectives, targets, action plan, and all required regulations; supervision procedure for documentation acceptation, changes review, updates).

4. **EMS implementation (2)**:

- **Operational control** - identify operations / activities linked with significant energy consumptions , especially in terms of effective functioning and setting criteria for carrying out operations and maintenance; e.g.: scheduling boiler maintenance; setting up proper pressure and temperature for heating systems.
- It should be considered the possibility of energy performance improvement while new buildings are **design** or at **modification and renovation** of existing buildings, equipment or systems.
- Taking energy efficiency into account when **buying** energy consuming equipments, goods, etc. and when buying energy related services, such as heating or public lighting tenders.

5. Check (periodically!):

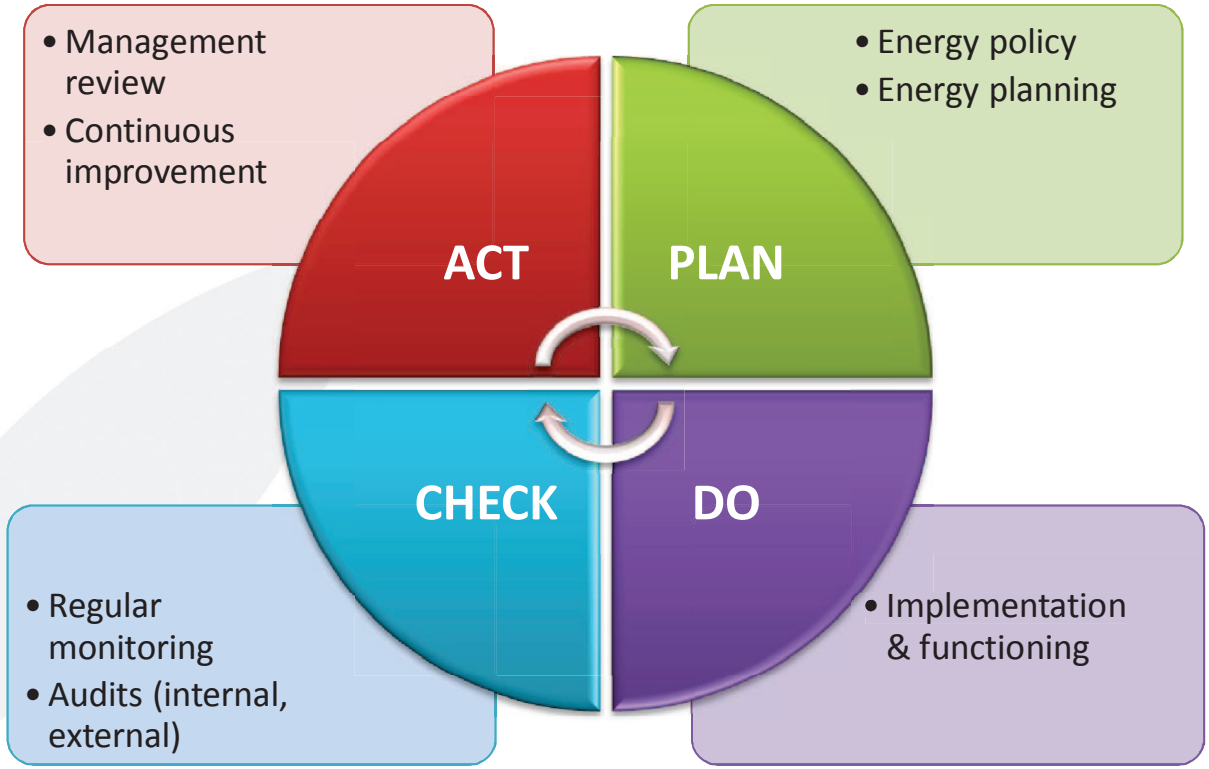
All crucial issues related to the energy performance (eg. energy consumption, outputs from energy review, indicators, effectiveness of action plan) shall be **measured, monitored and analyzed** in defined periods.

- **Compliance** with legal obligations and other requirements shall be ensured.
- **Internal audits** - systematic review of the EMS to assess whether EMS operates (in accordance with the organization's own requirements together with those of the ISO Standard) and if the EMS improves the energy performance.
- Conducting **inspections of non-compliance** or potential non-compliance, determination of corrective and preventive actions;
- **Controlling records:** ensure that the necessary documentation is provided to demonstrate the achievement of targets, action plans and other requirements of the EMS.

6. Management review

- Ensure suitability, adequacy and effectiveness of the EMS.
- The management review shall be planned at predefined intervals (eg. once or twice per year).
- Discuss all EMS crucial issues (eg. energy review, performance, legal compliance etc.) - reviews inputs and outputs shall be defined.
- It shall provide confirmation of the energy performance improvements for the latest period.

DEMING'S CYCLE (PDCA)



DOCUMENTS

- energy policy;
- procedure of legal requirements;
- registers of: legal requirements, inconsistencies, preventive and corrective actions, suggestion of improvements;
- energy action plan with energy performance indicators;
- instruction for energy use and savings in municipal buildings;
- energy review and energy baseline;
- audits and training schedules;
- management review protocols.

The certificate is valid for three years, but an inspection audit is conducted every year. The results of the audit shall confirm the validity of the certificate and check the use of adopted standards.

If significant deviations (non-compliance with the standard) will be discover, the certificate may be revoked.

ESTIMATED CERTIFICATION COSTS IN POLAND

Objects	Scope	Certification audit cost	Next 2 years	Full 3 years fee
city hall public lightning schools	46 pers 812 lamps 130 pers	3 375 €	2x 1 500 €	6 375 €
city hall	57 pers	2 500 €	2x 1 125 €	4 750 €
city hall schools	80 pers 280 pers	4 000 €	2x 2 250 €	8 500 €

10 SEAP'S RULES (FIT WITH EMS)

- Commitment for a reduction of CO2 emissions by at least 20 % by 2020
- CO2 baseline emission inventory (BEI)
- Comprehensive measures that cover the key sectors of activity
- Strategies and actions until 2020
- Adaptation of city structures
- Mobilisation of the civil society
- Financing
- SEAP approval by the municipal council
- Monitoring and reporting
- SEAP submission and filling the template

An idea: SEAPs implementation and monitoring may be problematic in d2d management of municipality

SEAP and EMS integration helps to solve this problem through:

- very systematic approach to implementation and monitoring of implementation;
- direct appoitment of responsible persons, resources and indicators for tasks realization;
- help with common difficulties encountered in this process, eg. rotation of involved people .

PROJECT 50000&1 SEAPs

Title: Supporting Local Authorities in the development and integration of SEAPs with Energy Management Systems according to ISO 50001

Coordinator: SOGESCA (IT)

Supported by: Intelligent Energy Europe (IEE)

Budget: 1,62 mln €

Project duration: 36 months (March 2014 – February 2017)

Consortium: 13 partners from 9 EU countries

CONSORTIUM

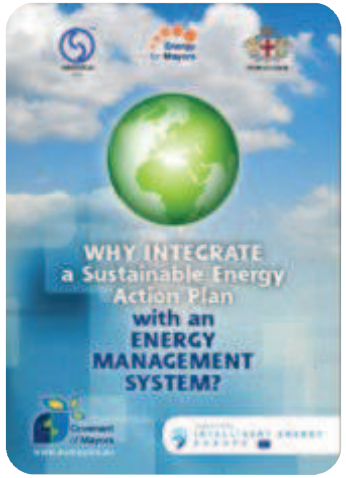
SOGESCA (Coordinator) - www.sogesca.it
CRES - www.cres.gr
PNEC - www.pnec.org.pl
EKODOMA - www.ekodoma.lv
ARM - www.arm-bg.net
ECQ - www.ecq-bg.com
AMET - www.amet.ro
DENKSTATT - www.denkstatt.ro
DEPUTACION OURENSE - www.depourense.es
ALBEA - www.albea-transenergy.com
AMORCE - www.amorce.asso.fr
MT PARTENAIRES INGÉNIERIE - www.mt-partenaires.com
ICLEI Europe - www.iclei-europe.org

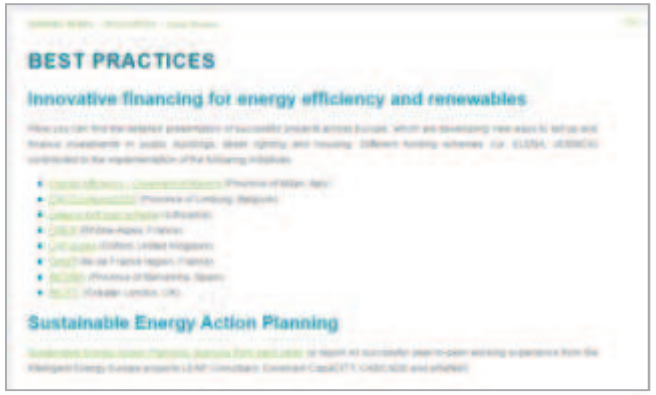
PROJECT AIMS

- **To create a coherent approach** – the 50000&1 SEAPs methodology - for the integration of EnMS and SEAPs that can be replicated across Europe
- **To develop, implement and monitor SEAPs** and established energy management standards according to ISO50001 **in 40 selected municipalities** in eight countries..
- To **institutionalise** sustainable energy policies and ensure the effective implementation of SEAPs during and after the project's lifetime.
- To make the **results widely available** and enlarge the number of trained Covenant of Mayors Supporters, Coordinators and municipalities implementing the 50001SEAPs approach.

PART 1. METHODOLOGY

- **Preparation of educational materials** (guidebook, brochure)
- **Trainings**
- Collecting and dissemination of **existing tools**.




BEST PRACTICES

Innovative financing for energy efficiency and renewables

Sustainable Energy Action Planning

PART 2. INTEGRATION

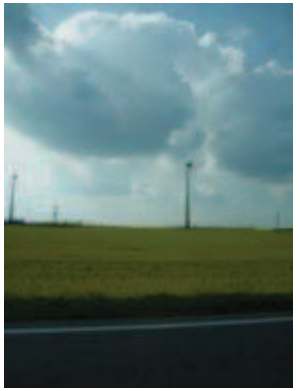
- **Selection** of municipalities **and support** in joining the Covenant of Mayors
- **Preparation of SEAPs integrated with EMS**
- **Engagement of local stakeholders and citizens** (energy forums)
- **Formal approval** of SEAPs and EMS certification

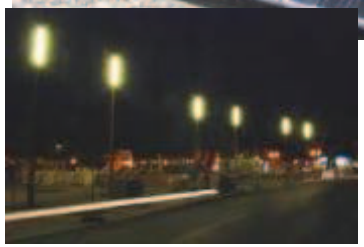
Porozumienie Burmistrzów
w sprawie Klimatu i Energii

ISO 50001
ENERGY MANAGEMENT

PART 3. IMPLEMENTATION

- Selection of **3 actions** and sources of financing
- Implementation of actions
- Implementation of EMS.





PART 4. MONITORING

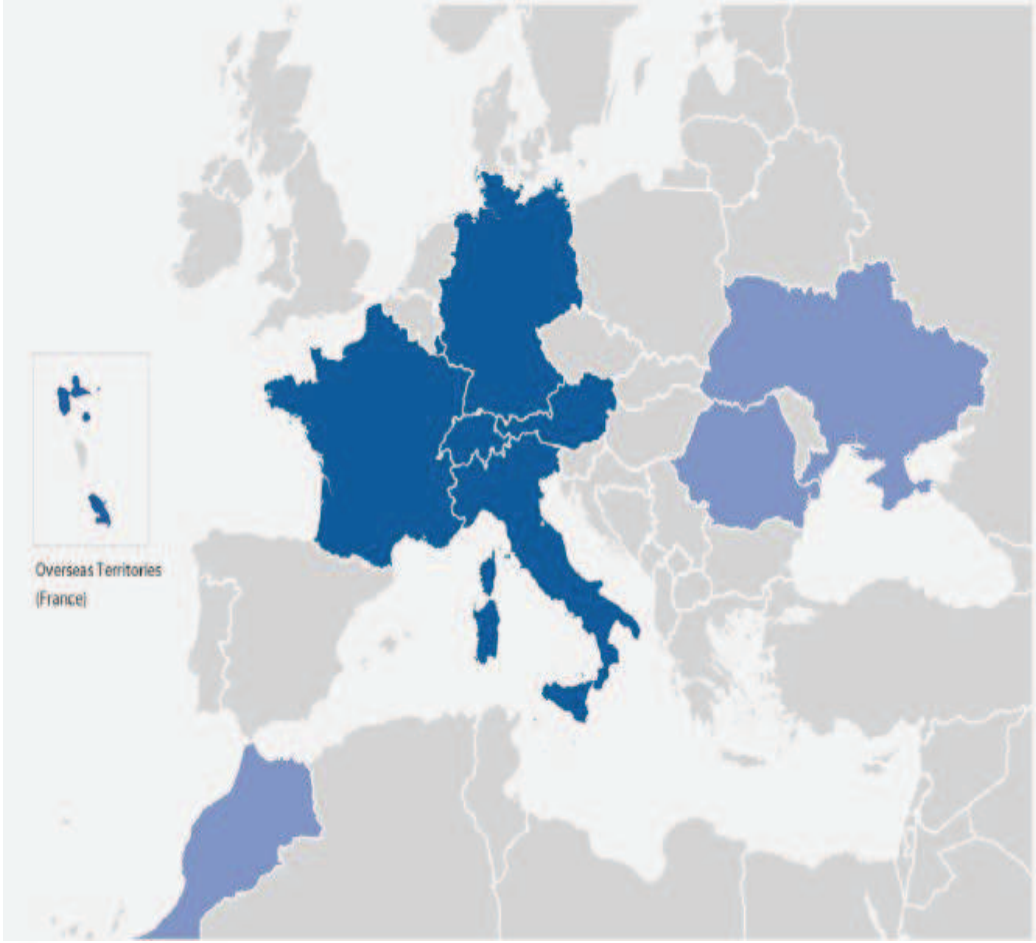
- **Monitoring** of SEAPs and EMS implementation
- **Analysis** of advantages from integration
- **Recommendations**

EUROPEAN ENERGY AWARD

- Quality management and certification system for municipalities and regions.
- Supports local authorities in planning and implementing of effective energy and climate policy measures

european energy award

www.european-energy-award.org



Ordinary member countries with national programmes

Austria

Liechtenstein

France

Luxembourg

Germany

Monaco

Italy

Switzerland

Pilot countries

Morocco, Romania, Ukraine

www.european-energy-award.org

EUROPEAN ENERGY AWARD

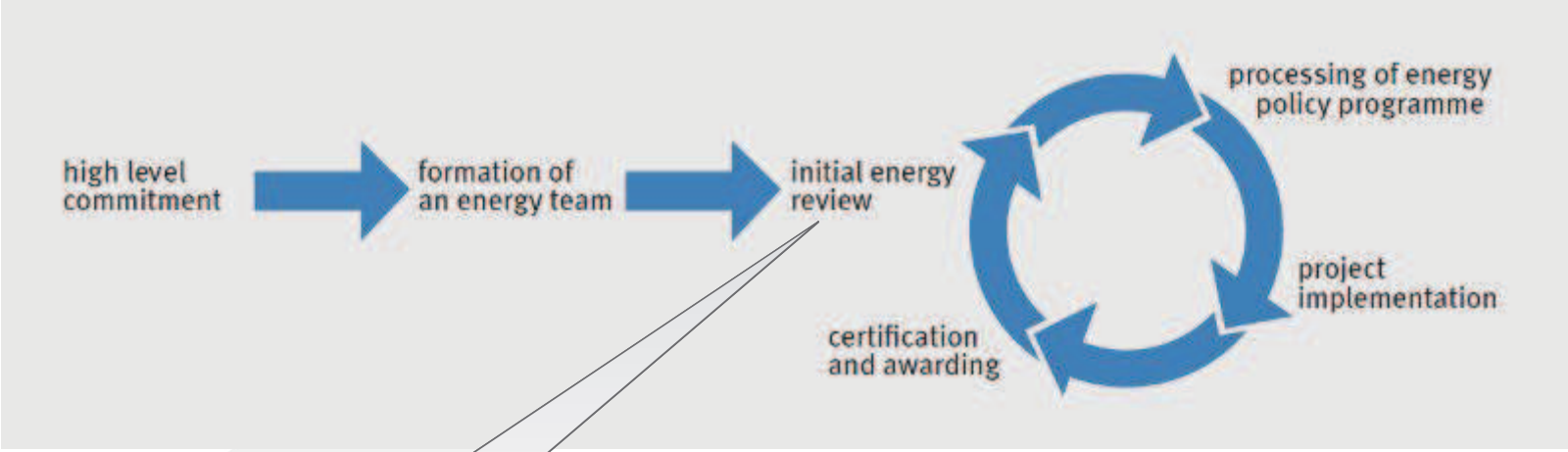
EEA is based on a **process of continuous improvement**, which ensures that eea municipalities continually increase their energy efficiency, the use of renewable energies and the sustainability of approaches to mobility.

Additional key factors for success:

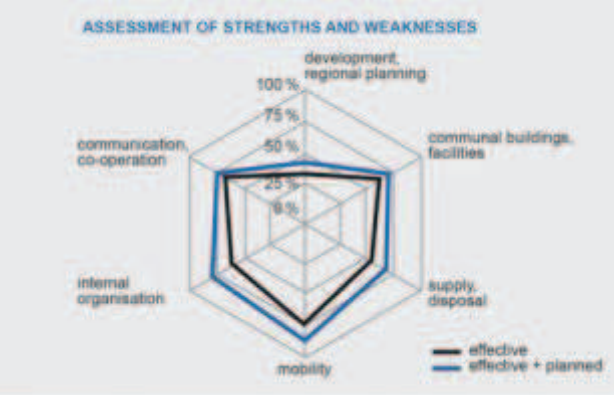
1. Each municipality is assisted by an external **eea advisor**, who provides technical and organisational support throughout the entire eea process.
2. Certification under the EEA provides an incentive for other municipalities (that are not yet certified), and ability to use the award for location marketing purposes.

www.european-energy-award.org

EEA - STEPS



= SWOT analysis in 6 Areas of activity



www.european-energy-award.org

EEA - CERTIFICATION

- Confirmation of quality of energy and climate protection policy implementation by eea auditor and national eea committee.
- External audit.
- Certification under:
  - the European Energy Award (implementation of 50% of the scope of action) or
  - the European Energy Award Gold (implementation of 75% of the scope of action).

www.european-energy-award.org

EEA - TOOLS

- **Catalogue of Measures:** 79 Climate and energy measures, 6 Areas of Activity (Development & Spatial Planning, Municipal buildings & facilities, Supply & disposal, Mobility, Internal Organisation, Communication & Cooperation).
- **Competitive online processing tool:** eea-Management-Tool (EMT) is the online processing instrument of the catalogue of measures for all participating municipalities.
- **Indicators** (qualitative & quantitative).
- **National tools.**

www.european-energy-award.org

SUMMARY: TIPS & ADVANTAGES

- define EMS boundaries correctly, targets need to be in line and integrated with other plans (eg. SEAP);
- strong commitment of top level politicians and of top managers; multi-departmental and cross-sector involvement
- continuously aware of legal requirements (eg. new efficiency standards);
- analyse direct energy consumption data;
- energy review updated at defined intervals, well defined indicators and monitoring of EMS implementation allows to answer if long-time targets are achieved;
- communication strategy and campaign;
- strict rules for documentation.

Thank you for your attention!

Marcin Łojek, project manager
Association of Municipalities Polish Network „Energie Cités”
marcin.lojek@pnec.org.pl
www.pnec.org.pl

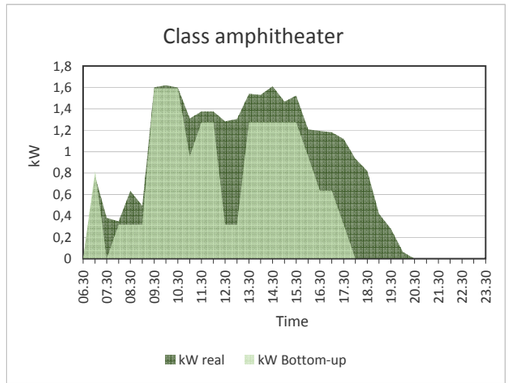
	Mon	Tues	Wed	Thur	Fri
07:00-07:30	0,7	0,7	0,7	0,7	0,7
07:30-08:00					
08:00-08:30			1		
08:30-09:00			1		
09:00-09:30			1		
09:30-10:00	1	1	1	1	1
10:00-10:30	1	1	1	1	1
10:30-11:00	1	1	1	1	1
11:00-11:30		1	1		1
11:30-12:00		1	1	1	1
12:00-12:30		1	1	1	1
12:30-13:00				1	
13:00-13:30				1	
13:30-14:00	1		1	1	1
14:00-14:30	1		1	1	1
14:30-15:00	1	1	1	1	
15:00-15:30	1	1	1	1	
15:30-16:00	1	1	1	1	
16:00-16:30	1	1	1		
16:30-17:00		1	1		
17:00-17:30		1	1		
17:30-18:00			1		

	# luminaires	# bulbs / luminaire	power / bulb [kW]	Total kW
Compact fluorescent non integrated	22	2	0,026	1,144
Emergency	4	1	0,008	0,032
LCD projector	1		0,35	0,35
Laptop	1		0,065	0,065

Notes of schedule:
Cleaning - 07:00
Classes - remaining identified periods

Exercise:
This is a classroom apmhitheater with a pre-defined schedule of classes. We want to perform a bottom-up approach to characterize the baseline consumption.
1) Analyze the room schedule and the equipment existing in the room.
2) Calculate the average load, in kW, for a typical week. Use Excel template.
3) Cross it with real average load and discuss differences.
4) Is there room for efficiency?

	Mon	Tues	Wed	Thur	Fri	kW Bottom-up	kW real
06.30	0	0	0	0	0	0	0
07.00	0,8232	0,8232	0,8232	0,8232	0,8232	0,8232	0,773333
07.30	0	0	0	0	0	0	0,38
08.00	0	0	1,591	0	0	0,3182	0,348889
08.30	0	0	1,591	0	0	0,3182	0,633333
09.00	0	0	1,591	0	0	0,3182	0,495185
09.30	1,591	1,591	1,591	1,591	1,591	1,591	1,6
10.00	1,591	1,591	1,591	1,591	1,591	1,591	1,62
10.30	1,591	1,591	1,591	1,591	1,591	1,591	1,597778
11.00	0	1,591	1,591	0	1,591	0,9546	1,311111
11.30	0	1,591	1,591	1,591	1,591	1,2728	1,375556
12.00	0	1,591	1,591	1,591	1,591	1,2728	1,375556
12.30	0	0	0	1,591	0	0,3182	1,282222
13.00	0	0	0	1,591	0	0,3182	1,304444
13.30	1,591	0	1,591	1,591	1,591	1,2728	1,54
14.00	1,591	0	1,591	1,591	1,591	1,2728	1,531111
14.30	1,591	1,591	1,591	1,591	0	1,2728	1,611111
15.00	1,591	1,591	1,591	1,591	0	1,2728	1,466667
15.30	1,591	1,591	1,591	1,591	0	1,2728	1,524444
16.00	1,591	1,591	1,591	0	0	0,9546	1,208889
16.30	0	1,591	1,591	0	0	0,6364	1,193333
17.00	0	1,591	1,591	0	0	0,6364	1,182222
17.30	0	0	1,591	0	0	0,3182	1,117778
18.00	0	0	0	0	0	0	0,933333
18.30	0	0	0	0	0	0	0,82
19.00	0	0	0	0	0	0	0,42
19.30	0	0	0	0	0	0	0,277778
20.00	0	0	0	0	0	0	0,062222
20.30	0	0	0	0	0	0	0
21.00	0	0	0	0	0	0	0
21.30	0	0	0	0	0	0	0
22.00	0	0	0	0	0	0	0
22.30	0	0	0	0	0	0	0
23.00	0	0	0	0	0	0	0
23.30	0	0	0	0	0	0	0



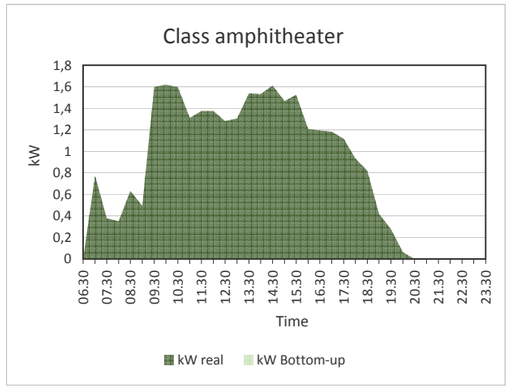
	Mon	Tues	Wed	Thur	Fri
07:00-07:30	0,7	0,7	0,7	0,7	0,7
07:30-08:00					
08:00-08:30			1		
08:30-09:00			1		
09:00-09:30			1		
09:30-10:00	1	1	1	1	1
10:00-10:30	1	1	1	1	1
10:30-11:00	1	1	1	1	1
11:00-11:30		1	1		1
11:30-12:00		1	1	1	1
12:00-12:30		1	1	1	1
12:30-13:00				1	
13:00-13:30				1	
13:30-14:00	1		1	1	1
14:00-14:30	1		1	1	1
14:30-15:00	1	1	1	1	
15:00-15:30	1	1	1	1	
15:30-16:00	1	1	1	1	
16:00-16:30	1	1	1		
16:30-17:00		1	1		
17:00-17:30		1	1		
17:30-18:00			1		

	# luminaires	# bulbs / luminaire	power / bulb [kW]	Total kW
Compact fluorescent non integrated	22	2	0,026	1,144
Emergency	4	1	0,008	0,032
LCD projector	1		0,35	0,35
Laptop	1		0,065	0,065

Notes of schedule:
Cleaning - 07:00
Classes - remaining identified periods

Exercise:
This is a classroom apmhitheater with a pre-defined schedule of classes. We want to perform a bottom-up approach to characterize the baseline consumption.
1) Analyze the room schedule and the equipment existing in the room.
2) Calculate the average load, in kW, for a typical week. Use Excel template.
3) Cross it with real average load and discuss differences.
4) Is there room for efficiency?

	Mon	Tues	Wed	Thur	Fri	kW Bottom-up	kW real
06.30						#DIV/0!	0
07.00						#DIV/0!	0,773333
07.30						#DIV/0!	0,38
08.00						#DIV/0!	0,348889
08.30						#DIV/0!	0,633333
09.00						#DIV/0!	0,495185
09.30						#DIV/0!	1,6
10.00						#DIV/0!	1,62
10.30						#DIV/0!	1,597778
11.00						#DIV/0!	1,311111
11.30						#DIV/0!	1,375556
12.00						#DIV/0!	1,375556
12.30						#DIV/0!	1,282222
13.00						#DIV/0!	1,304444
13.30						#DIV/0!	1,54
14.00						#DIV/0!	1,531111
14.30						#DIV/0!	1,611111
15.00						#DIV/0!	1,466667
15.30						#DIV/0!	1,524444
16.00						#DIV/0!	1,208889
16.30						#DIV/0!	1,193333
17.00						#DIV/0!	1,182222
17.30						#DIV/0!	1,117778
18.00						#DIV/0!	0,933333
18.30						#DIV/0!	0,82
19.00						#DIV/0!	0,42
19.30						#DIV/0!	0,277778
20.00						#DIV/0!	0,062222
20.30						#DIV/0!	0
21.00						#DIV/0!	0
21.30						#DIV/0!	0
22.00						#DIV/0!	0
22.30						#DIV/0!	0
23.00						#DIV/0!	0
23.30						#DIV/0!	0



SUMMARY OUTPUT - simulation with all variables with a 95% confidence interval.

Regression Statistics	
Multiple R	94,6%
R Square	89,5%
Adjusted R	89,0%
Standard E	9,1%
Observatio	172

The R2 is 89.5%, which is not bad.

ANOVA

	df	*SS*	*MS*	*F*	*ignificance F*
Regression	7	11,44717	1,635311	199,1639	9,77E-77
Residual	164	1,346584	0,008211		
Total	171	12,79376			

	Coefficients	*andard Erro*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*.ower 95.0%*	*Jpper 95.0%*
Intercept	0,172021	0,028035	6,135982	6,13E-09	0,116665	0,227376	0,116665	0,227376
Day_type	0,635129	0,023804	26,68214	1,49E-61	0,588128	0,68213	0,588128	0,68213
Occup [occ	0,15672	0,035363	4,431708	1,7E-05	0,086894	0,226546	0,086894	0,226546
DayLength	-0,03	0,038659	-0,77609	0,438812	-0,10634	0,046331	-0,10634	0,046331
T High [ºC]	-0,3689	0,184531	-1,99912	0,047247	-0,73326	-0,00454	-0,73326	-0,00454
T Avg [ºC]	0,602863	0,320047	1,883672	0,061379	-0,02908	1,234807	-0,02908	1,234807
T Low [ºC]	-0,24081	0,16997	-1,41678	0,158444	-0,57642	0,094802	-0,57642	0,094802
solar radiat	-0,02498	0,039304	-0,63569	0,525867	-0,10259	0,052622	-0,10259	0,052622

Day length, average T, low T and solar radiation provide a P-value higher than 5%, therefore we cannot reject the null hypothesis
Therefore, let's try to perform a linear regression without these variables.

SUMMARY OUTPUT

Regression Statistics	
Multiple R	94,4%
R Square	89,1%
Adjusted R	88,9%
Standard E	9,1%
Observatio	172

ANOVA

	df	*SS*	*MS*	*F*	*ignificance F*
Regression	3	11,39576	3,798585	456,4811	1,68E-80
Residual	168	1,398004	0,008321		
Total	171	12,79376			

	Coefficients	*andard Erro*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*Jpper 95.0%*
Intercept	0,150162	0,024717	6,075217	8,03E-09	0,101366	0,198958	0,101366	0,198958
Day_type	0,643201	0,023451	27,42696	6,17E-64	0,596903	0,689498	0,596903	0,689498
Occup [occ	0,13604	0,030021	4,531531	1,11E-05	0,076773	0,195307	0,076773	0,195307
T High [ºC]	-0,05099	0,032005	-1,59332	0,112967	-0,11418	0,012189	-0,11418	0,012189

Now we see that maximum T does not provide statistical confidence in the model.

SUMMARY OUTPUT

Regression Statistics	
Multiple R	94,3%
R Square	88,9%
Adjusted R	88,8%
Standard E	9,2%
Observatio	172

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	11,37463	5,687315	677,2858095	2,01611E-81
Residual	169	1,419129	0,008397		
Total	171	12,79376			

	Coefficients	*andard Erro*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*.ower 95.0%*	*Upper 95.0%*
Intercept	0,120077	0,016023	7,49405	3,56727E-12	0,088446327	0,151708	0,088446	0,151708
Day_type	0,650583	0,023094	28,17157	9,60626E-66	0,604993753	0,696172	0,604994	0,696172
Occup [occ	0,14599	0,029498	4,949215	1,79056E-06	0,087758481	0,204221	0,087758	0,204221

Now we have a model with statistical significance of 95%, where we can reject the null hypothesis, which means that we can reject, with a confidence of 95%, that day type and occupancy cannot describe electricity consumption of this library.

The regression equation is:
kWh' = 0.120 + 0.651 * day_type + 0.146 * occupancy

Time resolution: 1 day

Day_type	Occup [occp/h]	DayLength [h/day]	T High [ºC]	T Avg [ºC]	T Low [ºC]	solar radiation [W/m2]	kWh
1	0,40	12,07	15,5	11,5	8,0	234,97	207,41
1	1,32	12,10	12,0	10,0	8,0	28,73	225,25
1	0,32	12,15	15,0	12,5	9,0	116,85	213,02
1	5,52	12,20	15,5	13,5	12,0	175,97	204,68
1	11,66	12,22	15,5	13,5	11,5	45,35	203,30
0,5	9,42	12,27	13,5	11,5	8,5	134,89	140,65
0,5	6,69	12,30	15,0	13,0	11,0	61,12	141,35
1	8,05	12,35	15,0	14,0	13,0	31,13	192,98
1	9,71	12,38	15,0	14,0	14,0	29,21	189,36
1	12,37	12,43	15,5	14,0	12,5	55,24	182,73
1	7,66	12,48	15,5	14,0	12,5	165,31	181,85
1	4,82	12,52	16,0	15,0	14,0	34,20	122,45
0,5	3,93	12,57	17,0	15,0	13,5	171,05	127,30
0,5	4,67	12,60	15,0	15,0	13,5	31,71	137,74
1	4,33	12,65	16,0	13,5	11,0	62,39	201,48
1	12,75	12,68	16,5	14,0	11,5	214,50	203,82
1	10,88	12,73	15,5	13,0	10,0	110,26	200,43
1	11,16	12,77	16,5	14,0	11,5	30,78	197,98
1	11,44	12,82	13,0	11,0	9,0	251,11	200,93
0,5	13,05	12,85	14,5	11,0	8,5	181,79	128,01
0,5	10,57	12,90	15,5	12,5	9,0	232,57	129,92
1	13,82	12,93	16,0	13,0	11,0	225,18	184,73
1	14,66	12,98	15,5	14,0	13,0	32,27	206,13
1	16,80	13,02	15,0	14,0	14,0	17,80	198,28
1	13,90	13,07	16,5	14,0	12,0	115,10	193,10
1	18,13	13,10	16,5	14,5	11,5	165,75	196,83
0,5	11,84	13,15	21,0	15,5	11,0	258,65	135,15
0,5	7,86	13,17	19,5	16,5	13,0	285,50	131,52
1	12,91	13,22	19,0	16,0	12,5	231,19	205,01
1	17,95	13,25	21,0	16,0	12,0	305,30	213,63
1	14,58	13,30	20,0	15,5	12,0	307,48	193,69
1	15,68	13,33	18,0	15,0	12,0	282,42	197,18
1	14,76	13,37	22,0	16,0	11,5	284,80	199,49
0,5	12,36	13,42	25,0	19,0	14,5	299,97	128,24
0,5	4,87	13,45	19,5	16,0	13,0	299,46	125,53
1	4,62	13,48	21,0	16,5	12,5	293,14	194,83
1	11,32	13,53	22,0	18,0	15,5	312,89	199,13
1	16,27	13,57	24,5	19,5	14,5	317,03	189,73

1st - Normalize data. We can range for [0; 1]
Variable_normalized = [Variable(i) - min(variables)] / [max(variables) - min(variables)]

How to perform a linear regression in Excel:
File' - 'Options' - 'Add-ins' - 'Add-ins Go' - Select 'Analysis Toolpack'
Data' - 'Data analysis' - 'Regression'
Select X (kWh); select Y range (input variables); select confidence interval of 95%

Day_type	Occup [occp/h]	T High [ºC]	DayLength [h/day]	T Avg [ºC]	T Low [ºC]	solar radiation [W/m2]	kWh
1	0,016471	0,134615	0	0,068182	0	0,617909659	0,917266
1	0,0541	0	0,011834	0	0	0,031097027	1
1	0,012937	0,115385	0,029586	0,113636	0,052632	0,28180569	0,943272
1	0,225742	0,134615	0,047337	0,159091	0,210526	0,450035507	0,904629
1	0,476667	0,134615	0,053254	0,159091	0,184211	0,078364982	0,898215
0,5	0,385399	0,057692	0,071006	0,068182	0,026316	0,333151944	0,607698
0,5	0,273561	0,115385	0,08284	0,136364	0,157895	0,123249977	0,610944
1	0,329134	0,115385	0,100592	0,181818	0,263158	0,037902095	0,850336
1	0,39701	0,115385	0,112426	0,181818	0,315789	0,032460411	0,833565
1	0,50595	0,134615	0,130178	0,181818	0,236842	0,10652184	0,802805
1	0,313081	0,134615	0,147929	0,181818	0,236842	0,419709089	0,798748
1	0,197286	0,153846	0,159763	0,227273	0,315789	0,046651468	0,523302
0,5	0,16068	0,192308	0,177515	0,227273	0,289474	0,436022284	0,545792
0,5	0,190963	0,115385	0,189349	0,227273	0,289474	0,039562898	0,5942
1	0,176945	0,153846	0,207101	0,159091	0,157895	0,126865911	0,889752
1	0,521573	0,173077	0,218935	0,181818	0,184211	0,559675348	0,900611
1	0,444836	0,134615	0,236686	0,136364	0,105263	0,26307397	0,884922
1	0,456317	0,173077	0,248521	0,181818	0,184211	0,036929942	0,873561
1	0,467798	0,038462	0,266272	0,045455	0,052632	0,66383794	0,88724
0,5	0,533491	0,096154	0,278107	0,045455	0,026316	0,466597668	0,549076
0,5	0,432197	0,134615	0,295858	0,113636	0,052632	0,611069024	0,557926
1	0,56503	0,153846	0,307692	0,136364	0,157895	0,590061044	0,81208
1	0,599663	0,134615	0,325444	0,181818	0,263158	0,041150507	0,911315
1	0,686963	0,115385	0,337278	0,181818	0,315789	0	0,874913
1	0,56827	0,173077	0,35503	0,181818	0,210526	0,276826372	0,850916
1	0,741263	0,173077	0,366864	0,204545	0,184211	0,420965774	0,868189
0,5	0,484279	0,346154	0,384615	0,25	0,157895	0,685272718	0,582193
0,5	0,321574	0,288462	0,390533	0,295455	0,263158	0,761669684	0,565345
1	0,527909	0,269231	0,408284	0,272727	0,236842	0,607144847	0,906136
1	0,734245	0,346154	0,420118	0,272727	0,210526	0,818018966	0,946093
1	0,596273	0,307692	0,43787	0,25	0,210526	0,824219403	0,853659
1	0,641178	0,230769	0,449704	0,227273	0,210526	0,752920311	0,869812
1	0,603643	0,384615	0,461538	0,272727	0,184211	0,759701668	0,880555
0,5	0,5056	0,5	0,47929	0,409091	0,342105	0,802855757	0,550158
0,5	0,199247	0,288462	0,491124	0,272727	0,263158	0,801409384	0,537561
1	0,189056	0,346154	0,502959	0,295455	0,236842	0,783412706	0,858954
1	0,46305	0,384615	0,52071	0,363636	0,394737	0,839619722	0,878855
1	0,66553	0,480769	0,532544	0,431818	0,342105	0,851380397	0,835304

1	10,97	13,60	25,5	20,0	13,0	316,26	137,74
1	6,59	13,65	16,5	14,5	13,0	299,48	180,79
0,5	8,68	13,68	15,0	12,0	10,0	327,28	124,66
0,5	6,41	13,72	13,5	12,0	9,0	268,68	124,30
1	7,07	13,77	14,5	12,0	9,5	269,80	193,31
1	13,08	13,80	15,5	12,5	10,0	143,10	199,71
1	17,91	13,83	17,0	14,5	11,0	290,01	144,32
1	7,85	13,87	19,0	15,0	11,0	337,24	190,77
1	11,31	13,90	23,5	18,0	13,5	335,45	189,09
0,5	16,20	13,93	24,5	19,0	14,0	334,62	124,41
0,5	5,47	13,98	24,5	19,5	14,5	332,64	122,56
1	5,47	14,02	19,0	17,0	14,5	288,01	186,28
1	12,41	14,03	22,0	20,0	17,0	288,19	192,16
1	16,43	14,07	23,0	19,5	16,5	329,99	199,46
1	16,18	14,10	21,0	18,0	13,5	326,21	192,75
1	12,23	14,13	20,0	15,5	12,0	317,01	181,60
0,5	13,92	14,17	18,5	14,5	12,0	351,67	122,53
0,5	6,65	14,20	21,5	18,0	13,0	349,85	125,89
1	7,99	14,23	27,0	18,5	14,0	318,24	188,92
1	14,53	14,27	16,5	14,0	13,0	345,43	201,62
1	17,78	14,30	15,5	13,0	11,5	234,01	199,13
1	14,75	14,32	15,5	13,0	11,5	143,64	195,11
1	12,06	14,35	15,0	12,5	10,5	112,37	195,13
0,5	12,41	14,37	15,5	12,5	10,5	112,66	125,62
0,5	8,69	14,40	15,5	12,5	10,0	163,86	126,18
1	8,20	14,43	16,5	13,5	10,5	137,10	190,61
1	18,77	14,45	18,0	14,5	12,0	99,66	194,33
1	16,09	14,48	20,0	15,5	12,5	351,87	202,88
1	13,60	14,52	17,0	15,0	13,0	353,24	194,89
1	14,76	14,53	20,0	16,0	13,0	356,70	198,28
0,5	12,33	14,55	17,0	15,0	13,0	362,16	124,38
0,5	9,32	14,58	17,5	14,5	12,5	360,83	126,38
1	11,45	14,60	17,5	14,5	12,5	349,05	193,79
1	17,59	14,63	16,5	14,0	11,5	313,52	197,81
1	19,85	14,63	17,0	15,0	13,0	154,96	193,08
1	17,32	14,67	17,0	14,5	12,0	360,19	208,38
1	24,45	14,68	21,0	16,5	13,0	362,95	218,28
0,5	21,44	14,68	24,0	19,5	14,0	361,19	128,47
0,5	15,56	14,72	30,0	23,0	16,5	362,03	129,13
1	18,22	14,73	28,5	23,0	20,0	364,42	197,11
1	23,68	14,73	28,0	22,5	17,0	350,57	194,87
1	23,60	14,77	21,0	17,0	14,0	363,02	208,94
1	21,69	14,78	18,0	16,0	14,0	303,73	195,48
1	24,07	14,78	17,0	15,0	13,0	243,90	145,56
0,5	16,28	14,80	16,0	15,0	14,0	128,21	143,01
0,5	14,11	14,80	16,5	15,0	14,0	238,02	143,76
1	17,24	14,83	18,5	16,0	14,5	286,32	147,85
1	18,91	14,83	20,5	17,5	14,5	355,24	207,20
1	20,07	14,85	23,0	18,5	15,5	353,80	193,61
1	21,40	14,85	22,5	18,0	14,0	358,62	195,70
1	19,40	14,87	22,5	17,5	13,5	364,94	189,77
0,5	18,41	14,87	21,5	18,0	14,0	366,59	126,33
0,5	11,51	14,87	21,0	17,5	14,5	358,45	124,06

1	0,448771	0,519231	0,544379	0,454545	0,263158	0,849210837	0,594211
1	0,269426	0,173077	0,56213	0,204545	0,263158	0,801456806	0,79384
0,5	0,355007	0,115385	0,573964	0,090909	0,105263	0,880568686	0,533542
0,5	0,262094	0,057692	0,585799	0,090909	0,052632	0,713830886	0,53188
1	0,289282	0,096154	0,60355	0,090909	0,078947	0,717016582	0,851882
1	0,534789	0,134615	0,615385	0,113636	0,105263	0,356500915	0,88156
1	0,732639	0,192308	0,627219	0,204545	0,157895	0,774519051	0,624701
1	0,320912	0,269231	0,639053	0,227273	0,157895	0,908885	0,840115
1	0,462721	0,442308	0,650888	0,363636	0,289474	0,903802065	0,832329
0,5	0,662597	0,480769	0,662722	0,409091	0,315789	0,901439379	0,532383
0,5	0,223548	0,480769	0,680473	0,431818	0,342105	0,895809785	0,523804
1	0,223681	0,269231	0,692308	0,318182	0,342105	0,76882532	0,819267
1	0,507525	0,384615	0,698225	0,454545	0,473684	0,769341272	0,846549
1	0,672049	0,423077	0,710059	0,431818	0,447368	0,888278922	0,8804
1	0,661698	0,346154	0,721893	0,363636	0,289474	0,877520869	0,849293
1	0,500149	0,307692	0,733728	0,25	0,210526	0,851328115	0,797589
0,5	0,569139	0,25	0,745562	0,204545	0,210526	0,94995406	0,523688
0,5	0,272119	0,365385	0,757396	0,363636	0,263158	0,944784224	0,539261
1	0,326576	0,576923	0,769231	0,386364	0,315789	0,854840312	0,831517
1	0,594324	0,173077	0,781065	0,181818	0,263158	0,932194492	0,890409
1	0,727317	0,134615	0,792899	0,136364	0,184211	0,615164632	0,878893
1	0,603022	0,134615	0,798817	0,136364	0,184211	0,358057307	0,860229
1	0,493069	0,115385	0,810651	0,113636	0,131579	0,269068239	0,860345
0,5	0,507512	0,134615	0,816568	0,113636	0,131579	0,269883188	0,537986
0,5	0,355417	0,134615	0,828402	0,113636	0,105263	0,415585503	0,540614
1	0,335541	0,173077	0,840237	0,159091	0,131579	0,339426596	0,839362
1	0,767689	0,230769	0,846154	0,204545	0,210526	0,232918983	0,856596
1	0,657828	0,307692	0,857988	0,25	0,236842	0,950520635	0,896244
1	0,55601	0,192308	0,869822	0,227273	0,263158	0,954425606	0,859224
1	0,60349	0,307692	0,87574	0,272727	0,263158	0,964256558	0,874952
0,5	0,504135	0,192308	0,881657	0,227273	0,263158	0,979802463	0,532228
0,5	0,380948	0,211538	0,893491	0,204545	0,236842	0,976019012	0,541541
1	0,468455	0,211538	0,899408	0,204545	0,236842	0,942490773	0,854123
1	0,71923	0,173077	0,911243	0,181818	0,184211	0,841419864	0,872768
1	0,811884	0,192308	0,911243	0,227273	0,263158	0,390247413	0,850839
1	0,708412	0,192308	0,923077	0,204545	0,210526	0,974185318	0,921787
1	1	0,346154	0,928994	0,295455	0,263158	0,98204043	0,967695
0,5	0,876759	0,461538	0,928994	0,431818	0,315789	0,977045462	0,551202
0,5	0,636193	0,692308	0,940828	0,590909	0,447368	0,979444782	0,554255
1	0,744927	0,634615	0,946746	0,590909	0,631579	0,986240366	0,869503
1	0,968323	0,615385	0,946746	0,568182	0,473684	0,946829301	0,859108
1	0,965166	0,346154	0,95858	0,318182	0,315789	0,982239365	0,924376
1	0,886973	0,230769	0,964497	0,272727	0,315789	0,813550858	0,861929
1	0,98449	0,192308	0,964497	0,227273	0,263158	0,643322082	0,630458
0,5	0,665885	0,153846	0,970414	0,227273	0,315789	0,314141145	0,618634
0,5	0,576946	0,173077	0,970414	0,227273	0,315789	0,626580311	0,622111
1	0,705147	0,25	0,982249	0,272727	0,342105	0,764009015	0,641085
1	0,773451	0,326923	0,982249	0,340909	0,342105	0,960117085	0,9163
1	0,82062	0,423077	0,988166	0,386364	0,394737	0,956017209	0,853273
1	0,875187	0,403846	0,988166	0,363636	0,315789	0,96972871	0,862972
1	0,793363	0,403846	0,994083	0,340909	0,289474	0,987709858	0,835459
0,5	0,752706	0,365385	0,994083	0,363636	0,315789	0,99240903	0,541271
0,5	0,470752	0,346154	0,994083	0,340909	0,342105	0,96924133	0,53076

1	9,61	14,88	18,0	16,0	14,0	301,67	188,56
1	18,90	14,88	18,5	16,0	14,0	290,13	189,23
1	17,41	14,87	19,0	16,0	14,5	72,74	200,88
1	20,28	14,87	20,0	16,5	14,0	141,97	197,17
1	20,91	14,88	19,5	17,0	14,5	256,33	197,23
0,5	20,63	14,88	26,0	19,5	15,0	361,81	128,43
0,5	15,64	14,87	24,0	19,0	15,5	365,06	127,83
1	18,46	14,87	32,5	25,0	19,5	368,53	198,83
1	19,53	14,87	33,0	29,0	26,0	369,26	204,78
1	20,33	14,87	29,0	26,0	22,0	366,57	219,61
1	15,98	14,85	28,0	25,0	22,0	359,45	214,68
1	18,40	14,85	29,0	26,0	21,0	361,83	208,36
0,5	9,75	14,83	32,0	29,0	26,0	364,15	143,87
0,5	4,29	14,83	33,0	29,0	24,0	360,38	149,54
1	4,24	14,82	24,0	19,0	15,0	358,43	190,45
1	5,85	14,82	19,0	17,0	15,0	358,28	179,91
1	9,52	14,82	28,0	24,0	19,0	356,14	179,63
1	7,65	14,80	36,0	31,0	26,0	355,39	178,22
1	9,89	14,77	36,0	30,0	27,0	354,05	193,50
0,5	6,45	14,77	38,0	32,0	27,0	346,47	131,08
0,5	4,02	14,75	37,0	31,0	26,0	355,62	146,59
1	5,41	14,75	32,0	27,0	24,0	361,15	197,62
1	7,30	14,72	36,0	29,0	23,0	355,17	194,04
1	7,55	14,70	33,0	25,0	17,0	359,80	203,11
1	7,43	14,70	23,0	20,0	18,0	355,89	193,97
1	6,44	14,67	19,0	18,0	17,0	345,74	177,85
0,5	5,79	14,65	21,0	19,0	18,0	360,92	117,73
0,5	6,70	14,63	20,0	19,0	17,0	358,11	120,63
1	6,32	14,62	23,0	20,0	17,0	318,90	176,43
1	5,91	14,58	28,0	21,0	17,0	354,65	174,81
1	6,19	14,55	27,0	21,0	17,0	355,52	186,59
1	8,35	14,55	24,0	20,0	17,0	355,23	181,83
1	5,19	14,52	24,0	20,0	17,0	353,52	171,71
0,5	4,29	14,48	23,0	20,0	18,0	346,53	118,33
0,5	4,44	14,47	23,0	20,0	17,0	345,65	120,96
1	4,78	14,43	26,0	21,0	18,0	345,73	155,28
1	3,85	14,42	25,0	22,0	19,0	340,61	170,80
1	3,59	14,38	26,0	23,0	20,0	342,26	153,05
1	3,31	14,37	24,0	21,0	18,0	334,52	172,55
1	2,85	14,33	21,5	19,5	18,0	186,71	171,98
0,5	1,89	14,30	21,5	19,5	18,0	249,20	112,86
0,5	0,89	14,27	22,5	20,0	18,0	110,76	115,42
1	2,02	14,25	24,5	21,5	18,0	325,42	175,67
1	1,10	14,22	32,5	25,0	18,5	342,22	162,20
1	2,60	14,18	30,0	24,0	19,0	343,09	165,10
1	1,91	14,15	28,0	21,0	17,0	330,58	159,96
1	1,50	14,12	24,0	21,0	18,0	332,39	176,65
0	0,77	14,08	25,0	21,0	17,0	334,90	53,82
0	0,20	14,05	26,0	20,0	17,0	335,71	9,60
0	0,00	14,02	25,0	20,0	17,0	321,85	35,56
0	0,00	14,00	25,0	21,0	18,0	313,77	9,79
0	0,00	13,97	24,0	20,0	17,0	321,66	24,79
0	0,13	13,93	28,0	21,0	17,0	332,40	9,79

1	0,393203	0,230769	1	0,272727	0,315789	0,807680717	0,829855
1	0,772753	0,25	1	0,272727	0,315789	0,774864758	0,832986
1	0,712099	0,269231	0,994083	0,272727	0,342105	0,156305536	0,887008
1	0,829242	0,307692	0,994083	0,295455	0,315789	0,353295301	0,869774
1	0,855201	0,288462	1	0,318182	0,342105	0,678692075	0,870044
0,5	0,843617	0,538462	1	0,431818	0,368421	0,978796878	0,551009
0,5	0,639541	0,461538	0,994083	0,409091	0,394737	0,988062322	0,548226
1	0,754774	0,788462	0,994083	0,681818	0,605263	0,997923743	0,877463
1	0,798577	0,807692	0,994083	0,863636	0,947368	1	0,905054
1	0,831257	0,653846	0,994083	0,727273	0,736842	0,992359948	0,973839
1	0,653316	0,615385	0,988166	0,681818	0,736842	0,972098866	0,950962
1	0,752374	0,653846	0,988166	0,727273	0,684211	0,978872991	0,921671
0,5	0,398873	0,769231	0,982249	0,863636	0,947368	0,985478886	0,622614
0,5	0,175246	0,807692	0,982249	0,863636	0,842105	0,974751538	0,64893
1	0,173361	0,461538	0,976331	0,409091	0,368421	0,969189165	0,838627
1	0,239246	0,269231	0,976331	0,318182	0,368421	0,968769954	0,789744
1	0,389487	0,615385	0,976331	0,636364	0,578947	0,962673846	0,788469
1	0,312841	0,923077	0,970414	0,954545	0,947368	0,960544714	0,7819
1	0,404652	0,923077	0,95858	0,909091	1	0,956739803	0,852771
0,5	0,263869	1	0,95858	1	1	0,935146991	0,563297
0,5	0,164289	0,961538	0,952663	0,954545	0,947368	0,961188231	0,63525
1	0,221085	0,769231	0,952663	0,772727	0,842105	0,976918964	0,87186
1	0,298464	0,923077	0,940828	0,863636	0,789474	0,959901433	0,855282
1	0,308693	0,807692	0,934911	0,681818	0,473684	0,973082044	0,897326
1	0,303867	0,423077	0,934911	0,454545	0,526316	0,961959196	0,854935
1	0,263283	0,269231	0,923077	0,363636	0,473684	0,933090414	0,780199
0,5	0,236837	0,346154	0,91716	0,409091	0,526316	0,976275446	0,50143
0,5	0,274018	0,307692	0,911243	0,409091	0,473684	0,968290517	0,514878
1	0,25832	0,423077	0,905325	0,454545	0,473684	0,856709335	0,773591
1	0,241802	0,615385	0,893491	0,5	0,473684	0,958428266	0,766095
1	0,253233	0,576923	0,881657	0,5	0,473684	0,960917925	0,820736
1	0,341366	0,461538	0,881657	0,454545	0,473684	0,960085905	0,798632
1	0,212268	0,461538	0,869822	0,454545	0,473684	0,955214354	0,75172
0,5	0,175238	0,423077	0,857988	0,454545	0,526316	0,935318421	0,504212
0,5	0,18161	0,423077	0,852071	0,454545	0,473684	0,932830659	0,516385
1	0,195396	0,538462	0,840237	0,5	0,526316	0,933056507	0,675555
1	0,15749	0,5	0,83432	0,545455	0,578947	0,91848228	0,747508
1	0,146812	0,538462	0,822485	0,590909	0,631579	0,923172442	0,665198
1	0,135177	0,461538	0,816568	0,5	0,526316	0,90115449	0,755623
1	0,116718	0,365385	0,804734	0,431818	0,526316	0,480603778	0,752956
0,5	0,077259	0,365385	0,792899	0,431818	0,526316	0,658388313	0,478824
0,5	0,036349	0,403846	0,781065	0,454545	0,526316	0,264480035	0,490687
1	0,082796	0,480769	0,775148	0,522727	0,526316	0,875262866	0,770075
1	0,044972	0,788462	0,763314	0,681818	0,552632	0,923076887	0,707628
1	0,106367	0,692308	0,751479	0,636364	0,578947	0,925539041	0,721076
1	0,078249	0,615385	0,739645	0,5	0,473684	0,889955886	0,697233
1	0,061212	0,461538	0,727811	0,5	0,526316	0,895093119	0,774635
0	0,03161	0,5	0,715976	0,5	0,473684	0,902242234	0,205039
0	0,008277	0,538462	0,704142	0,454545	0,473684	0,904546829	0
0	0	0,5	0,692308	0,454545	0,473684	0,865107666	0,120373
0	0,000142	0,5	0,686391	0,5	0,526316	0,84211602	0,000889
0	0,000142	0,461538	0,674556	0,454545	0,473684	0,864580332	0,070446
0	0,005252	0,615385	0,662722	0,5	0,473684	0,895135088	0,000889

0	0,03	13,88	36,5	28,5	21,5	330,16	9,80
0	0,02	13,85	36,5	29,0	22,5	324,31	9,60
0	0,00	13,82	34,5	25,0	18,0	321,93	9,60
0	0,00	13,78	26,5	21,0	17,5	326,23	9,78
0	0,03	13,73	27,5	22,5	18,5	324,27	9,86
0	0,14	13,70	30,0	23,5	18,5	316,66	9,79
0	0,01	13,68	30,0	23,0	18,0	315,85	9,80
0	0,00	13,65	24,5	20,0	17,0	317,94	9,79
0	0,03	13,60	25,0	21,0	19,0	308,50	9,60
0	0,00	13,57	27,0	21,5	18,0	306,44	9,60
0,2	0,00	13,52	29,5	24,0	19,0	306,62	60,61
0,2	0,75	13,48	35,0	27,5	20,0	307,03	75,06
0,2	0,75	13,45	31,0	23,0	17,0	308,09	52,25
0,2	0,82	13,40	28,5	21,5	18,5	298,75	51,62
0,2	1,18	13,37	24,5	20,5	18,0	296,76	52,03
0,2	2,10	13,32	23,5	20,0	17,0	293,07	50,14
0,2	0,65	13,30	29,5	22,0	16,5	299,31	50,52
0,2	1,84	13,27	25,5	20,0	16,0	298,19	52,10
0,2	1,40	13,22	27,0	21,0	16,5	295,56	58,73
0,2	1,10	13,18	27,5	21,0	16,0	290,09	68,74
0,2	1,65	13,13	30,0	23,0	17,0	286,07	120,79
0,2	1,18	13,10	29,5	24,0	19,0	263,56	134,37
0,2	1,12	13,05	32,0	26,0	22,0	284,15	131,89
0,2	2,48	13,02	30,0	24,0	19,0	284,75	106,21
1	1,08	12,97	30,5	26,0	21,5	280,72	139,45
1	2,62	12,95	31,5	26,0	21,5	276,57	158,79
1	4,01	12,90	28,5	24,0	19,0	274,74	132,51
1	3,26	12,85	27,0	21,0	18,0	275,79	154,39

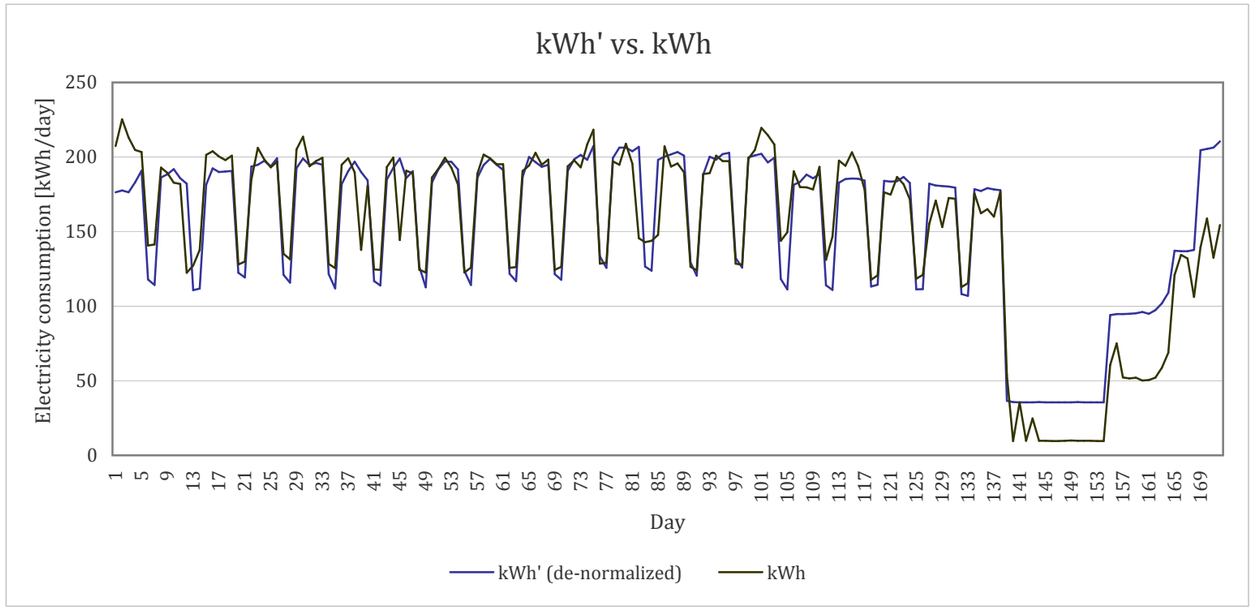
0	0,001133	0,942308	0,64497	0,840909	0,710526	0,888746148	0,000927
0	0,000706	0,942308	0,633136	0,863636	0,763158	0,872094716	0
0	0	0,865385	0,621302	0,681818	0,526316	0,865346673	0
0	0	0,557692	0,609467	0,5	0,5	0,877583584	0,000812
0	0,001033	0,596154	0,591716	0,568182	0,552632	0,872002362	0,001198
0	0,005824	0,692308	0,579882	0,613636	0,552632	0,850350153	0,000889
0	0,000568	0,692308	0,573964	0,590909	0,526316	0,848038919	0,000927
0	0	0,480769	0,56213	0,454545	0,473684	0,853972962	0,000889
0	0,001133	0,5	0,544379	0,5	0,578947	0,827131	0
0	0	0,576923	0,532544	0,522727	0,526316	0,821268801	0
0,2	0	0,673077	0,514793	0,636364	0,578947	0,821784991	0,236533
0,2	0,030523	0,884615	0,502959	0,795455	0,631579	0,822940311	0,30354
0,2	0,030527	0,730769	0,491124	0,590909	0,473684	0,825963113	0,197774
0,2	0,033505	0,634615	0,473373	0,522727	0,552632	0,799386951	0,194837
0,2	0,048157	0,480769	0,461538	0,477273	0,526316	0,793708157	0,196769
0,2	0,085773	0,442308	0,443787	0,454545	0,473684	0,783229183	0,187998
0,2	0,026688	0,673077	0,43787	0,545455	0,447368	0,80097156	0,189736
0,2	0,075419	0,519231	0,426036	0,454545	0,421053	0,797783374	0,197079
0,2	0,057224	0,576923	0,408284	0,5	0,447368	0,790303489	0,227838
0,2	0,045155	0,596154	0,39645	0,5	0,421053	0,774728183	0,274248
0,2	0,067581	0,692308	0,378698	0,590909	0,473684	0,763297565	0,515612
0,2	0,04829	0,673077	0,366864	0,636364	0,578947	0,699251205	0,578561
0,2	0,045717	0,769231	0,349112	0,727273	0,736842	0,757848176	0,567084
0,2	0,101553	0,692308	0,337278	0,636364	0,578947	0,75954885	0,447987
1	0,04416	0,711538	0,319527	0,727273	0,710526	0,74806844	0,602133
1	0,107322	0,75	0,313609	0,727273	0,710526	0,736284765	0,691823
1	0,163825	0,634615	0,295858	0,636364	0,578947	0,731054465	0,569944
1	0,133367	0,576923	0,278107	0,5	0,526316	0,734064345	0,67142

1) Let's try to perform a linear regression with all variables with a confidence level of 95%
2) After analyzing the results, let's try another regression with day type, occupancy and maximum T
3) The second simulation does provide a statistical significant model, with the following regression equation:
kWh' = 0.120 + 0.651 * day_type + 0.146 * occupancy

kWh' =	intercep	Var1	var2	var3
kWh' =	0,12	0,651	0,146	

Therefore, now we apply this equation to check the outputs, de-normalizing as well.

kWh'	kWh' (de-normalized)	kWh
0,773405	176,38	207,41
0,778899	177,57	225,25
0,772889	176,27	213,02
0,803958	182,97	204,68
0,840593	190,87	203,30
0,501768	117,81	140,65
0,48544	114,29	141,35
0,819053	186,23	192,98
0,828964	188,37	189,36
0,844869	191,80	182,73
0,81671	185,72	181,85
0,799804	182,08	122,45
0,468959	110,73	127,30
0,473381	111,68	137,74
0,796834	181,44	201,48
0,84715	192,29	203,82
0,835946	189,87	200,43
0,837622	190,23	197,98
0,839299	190,59	200,93
0,52339	122,47	128,01
0,508601	119,28	129,92
0,853494	193,66	184,73
0,858551	194,75	206,13
0,871297	197,50	198,28
0,853967	193,76	193,10
0,879224	199,20	196,83
0,516205	120,92	135,15
0,49245	115,80	131,52
0,848075	192,49	205,01
0,8782	198,98	213,63
0,858056	194,64	193,69
0,864612	196,05	197,18
0,859132	194,87	199,49
0,519318	121,59	128,24
0,47459	111,95	125,53
0,798602	181,82	194,83
0,838605	190,45	199,13
0,868167	196,82	189,73



0,836521	190,00	137,74
0,810336	184,35	180,79
0,497331	116,85	124,66
0,483766	113,92	124,30
0,813235	184,97	193,31
0,849079	192,70	199,71
0,877965	198,93	144,32
0,817853	185,97	190,77
0,838557	190,43	189,09
0,542239	126,53	124,41
0,478138	112,71	122,56
0,803657	182,91	186,28
0,845099	191,85	192,16
0,869119	197,03	199,46
0,867608	196,70	192,75
0,844022	191,61	181,60
0,528594	123,59	122,53
0,485229	114,24	125,89
0,81868	186,15	188,92
0,857771	194,58	201,62
0,877188	198,77	199,13
0,859041	194,85	195,11
0,842988	191,39	195,13
0,519597	121,65	125,62
0,497391	116,86	126,18
0,819989	186,43	190,61
0,883083	200,04	194,33
0,867043	196,58	202,88
0,852177	193,37	194,89
0,85911	194,87	198,28
0,519104	121,54	124,38
0,501118	117,67	126,38
0,839394	190,62	193,79
0,876008	198,51	197,81
0,889535	201,43	193,08
0,874428	198,17	208,38
0,917	207,35	218,28
0,573507	133,28	128,47
0,538384	125,70	129,13
0,879759	199,32	197,11
0,912375	206,35	194,87
0,911914	206,25	208,94
0,900498	203,79	195,48
0,914735	206,86	145,56
0,542719	126,64	143,01
0,529734	123,84	143,76
0,873951	198,07	147,85
0,883924	200,22	207,20
0,890811	201,70	193,61
0,898777	203,42	195,70
0,886831	200,85	189,77
0,555395	129,37	126,33
0,51423	120,49	124,06

0,828408	188,25	188,56
0,883822	200,20	189,23
0,874966	198,29	200,88
0,892069	201,97	197,17
0,895859	202,79	197,23
0,568668	132,23	128,43
0,538873	125,81	127,83
0,881197	199,63	198,83
0,887592	201,01	204,78
0,892363	202,04	219,61
0,866384	196,44	214,68
0,880847	199,55	208,36
0,503736	118,23	143,87
0,471086	111,19	149,54
0,796311	181,32	190,45
0,80593	183,40	179,91
0,827865	188,13	179,63
0,816675	185,72	178,22
0,830079	188,61	193,50
0,484025	113,98	131,08
0,469486	110,84	146,59
0,803278	182,83	197,62
0,814576	185,26	194,04
0,816069	185,59	203,11
0,815365	185,43	193,97
0,809439	184,16	177,85
0,480078	113,13	117,73
0,485507	114,30	120,63
0,808715	184,00	176,43
0,806303	183,48	174,81
0,807972	183,84	186,59
0,820839	186,61	181,83
0,801991	182,55	171,71
0,471085	111,19	118,33
0,472015	111,39	120,96
0,799528	182,02	155,28
0,793993	180,82	170,80
0,792435	180,49	153,05
0,790736	180,12	172,55
0,788041	179,54	171,98
0,45678	108,10	112,86
0,450807	106,82	115,42
0,783088	178,47	175,67
0,777566	177,28	162,20
0,78653	179,22	165,10
0,782424	178,33	159,96
0,779937	177,79	176,65
0,124615	36,47	53,82
0,121208	35,74	9,60
0,12	35,48	35,56
0,120021	35,48	9,79
0,120021	35,48	24,79
0,120767	35,64	9,79

0,120165	35,51	9,80
0,120103	35,50	9,60
0,12	35,48	9,60
0,12	35,48	9,78
0,120151	35,51	9,86
0,12085	35,66	9,79
0,120083	35,50	9,80
0,12	35,48	9,79
0,120165	35,51	9,60
0,12	35,48	9,60
0,2502	93,95	60,61
0,254656	94,73	75,06
0,254657	94,73	52,25
0,255092	94,81	51,62
0,257231	95,18	52,03
0,262723	96,15	50,14
0,254096	94,92	50,52
0,261211	97,33	52,10
0,258555	101,79	58,73
0,256793	108,93	68,74
0,260067	137,17	120,79
0,25725	136,83	134,37
0,256875	136,79	131,89
0,265027	137,76	106,21
0,777447	204,61	139,45
0,786669	205,47	158,79
0,794918	206,23	132,51
0,790472	210,40	154,39

Time resolution: 1 day

Day_type	Occup [occp/h]	DayLength [h/day]	T High [ºC]	T Avg [ºC]	T Low [ºC]	solar radiation [W/m2]	kWh
1	0,40	12,07	15,5	11,5	8,0	234,97	207,41
1	1,32	12,10	12,0	10,0	8,0	28,73	225,25
1	0,32	12,15	15,0	12,5	9,0	116,85	213,02
1	5,52	12,20	15,5	13,5	12,0	175,97	204,68
1	11,66	12,22	15,5	13,5	11,5	45,35	203,30
0,5	9,42	12,27	13,5	11,5	8,5	134,89	140,65
0,5	6,69	12,30	15,0	13,0	11,0	61,12	141,35
1	8,05	12,35	15,0	14,0	13,0	31,13	192,98
1	9,71	12,38	15,0	14,0	14,0	29,21	189,36
1	12,37	12,43	15,5	14,0	12,5	55,24	182,73
1	7,66	12,48	15,5	14,0	12,5	165,31	181,85
1	4,82	12,52	16,0	15,0	14,0	34,20	122,45
0,5	3,93	12,57	17,0	15,0	13,5	171,05	127,30
0,5	4,67	12,60	15,0	15,0	13,5	31,71	137,74
1	4,33	12,65	16,0	13,5	11,0	62,39	201,48
1	12,75	12,68	16,5	14,0	11,5	214,50	203,82
1	10,88	12,73	15,5	13,0	10,0	110,26	200,43
1	11,16	12,77	16,5	14,0	11,5	30,78	197,98
1	11,44	12,82	13,0	11,0	9,0	251,11	200,93
0,5	13,05	12,85	14,5	11,0	8,5	181,79	128,01
0,5	10,57	12,90	15,5	12,5	9,0	232,57	129,92
1	13,82	12,93	16,0	13,0	11,0	225,18	184,73
1	14,66	12,98	15,5	14,0	13,0	32,27	206,13
1	16,80	13,02	15,0	14,0	14,0	17,80	198,28
1	13,90	13,07	16,5	14,0	12,0	115,10	193,10
1	18,13	13,10	16,5	14,5	11,5	165,75	196,83
0,5	11,84	13,15	21,0	15,5	11,0	258,65	135,15
0,5	7,86	13,17	19,5	16,5	13,0	285,50	131,52
1	12,91	13,22	19,0	16,0	12,5	231,19	205,01
1	17,95	13,25	21,0	16,0	12,0	305,30	213,63
1	14,58	13,30	20,0	15,5	12,0	307,48	193,69
1	15,68	13,33	18,0	15,0	12,0	282,42	197,18
1	14,76	13,37	22,0	16,0	11,5	284,80	199,49
0,5	12,36	13,42	25,0	19,0	14,5	299,97	128,24
0,5	4,87	13,45	19,5	16,0	13,0	299,46	125,53
1	4,62	13,48	21,0	16,5	12,5	293,14	194,83
1	11,32	13,53	22,0	18,0	15,5	312,89	199,13
1	16,27	13,57	24,5	19,5	14,5	317,03	189,73

1st - Normalize data. We can range for [0; 1]
Variable_normalized = [Variable(i) - min(variables)] / [max(variables) - min(variables)]

How to perform a linear regression in Excel:
File' - 'Options' - 'Add-ins' - 'Add-ins Go' - Select 'Analysis Toolpack'
Data' - 'Data analysis' - 'Regression'
Select X (kWh); select Y range (input variables); select confidence interval of 95%

Day_type	Occup [occp/h]	T High [ºC]	DayLength [h/day]	T Avg [ºC]	T Low [ºC]	solar radiation [W/m2]	kWh

1	10,97	13,60	25,5	20,0	13,0	316,26	137,74
1	6,59	13,65	16,5	14,5	13,0	299,48	180,79
0,5	8,68	13,68	15,0	12,0	10,0	327,28	124,66
0,5	6,41	13,72	13,5	12,0	9,0	268,68	124,30
1	7,07	13,77	14,5	12,0	9,5	269,80	193,31
1	13,08	13,80	15,5	12,5	10,0	143,10	199,71
1	17,91	13,83	17,0	14,5	11,0	290,01	144,32
1	7,85	13,87	19,0	15,0	11,0	337,24	190,77
1	11,31	13,90	23,5	18,0	13,5	335,45	189,09
0,5	16,20	13,93	24,5	19,0	14,0	334,62	124,41
0,5	5,47	13,98	24,5	19,5	14,5	332,64	122,56
1	5,47	14,02	19,0	17,0	14,5	288,01	186,28
1	12,41	14,03	22,0	20,0	17,0	288,19	192,16
1	16,43	14,07	23,0	19,5	16,5	329,99	199,46
1	16,18	14,10	21,0	18,0	13,5	326,21	192,75
1	12,23	14,13	20,0	15,5	12,0	317,01	181,60
0,5	13,92	14,17	18,5	14,5	12,0	351,67	122,53
0,5	6,65	14,20	21,5	18,0	13,0	349,85	125,89
1	7,99	14,23	27,0	18,5	14,0	318,24	188,92
1	14,53	14,27	16,5	14,0	13,0	345,43	201,62
1	17,78	14,30	15,5	13,0	11,5	234,01	199,13
1	14,75	14,32	15,5	13,0	11,5	143,64	195,11
1	12,06	14,35	15,0	12,5	10,5	112,37	195,13
0,5	12,41	14,37	15,5	12,5	10,5	112,66	125,62
0,5	8,69	14,40	15,5	12,5	10,0	163,86	126,18
1	8,20	14,43	16,5	13,5	10,5	137,10	190,61
1	18,77	14,45	18,0	14,5	12,0	99,66	194,33
1	16,09	14,48	20,0	15,5	12,5	351,87	202,88
1	13,60	14,52	17,0	15,0	13,0	353,24	194,89
1	14,76	14,53	20,0	16,0	13,0	356,70	198,28
0,5	12,33	14,55	17,0	15,0	13,0	362,16	124,38
0,5	9,32	14,58	17,5	14,5	12,5	360,83	126,38
1	11,45	14,60	17,5	14,5	12,5	349,05	193,79
1	17,59	14,63	16,5	14,0	11,5	313,52	197,81
1	19,85	14,63	17,0	15,0	13,0	154,96	193,08
1	17,32	14,67	17,0	14,5	12,0	360,19	208,38
1	24,45	14,68	21,0	16,5	13,0	362,95	218,28
0,5	21,44	14,68	24,0	19,5	14,0	361,19	128,47
0,5	15,56	14,72	30,0	23,0	16,5	362,03	129,13
1	18,22	14,73	28,5	23,0	20,0	364,42	197,11
1	23,68	14,73	28,0	22,5	17,0	350,57	194,87
1	23,60	14,77	21,0	17,0	14,0	363,02	208,94
1	21,69	14,78	18,0	16,0	14,0	303,73	195,48
1	24,07	14,78	17,0	15,0	13,0	243,90	145,56
0,5	16,28	14,80	16,0	15,0	14,0	128,21	143,01
0,5	14,11	14,80	16,5	15,0	14,0	238,02	143,76
1	17,24	14,83	18,5	16,0	14,5	286,32	147,85
1	18,91	14,83	20,5	17,5	14,5	355,24	207,20
1	20,07	14,85	23,0	18,5	15,5	353,80	193,61
1	21,40	14,85	22,5	18,0	14,0	358,62	195,70
1	19,40	14,87	22,5	17,5	13,5	364,94	189,77
0,5	18,41	14,87	21,5	18,0	14,0	366,59	126,33
0,5	11,51	14,87	21,0	17,5	14,5	358,45	124,06

1	9,61	14,88	18,0	16,0	14,0	301,67	188,56
1	18,90	14,88	18,5	16,0	14,0	290,13	189,23
1	17,41	14,87	19,0	16,0	14,5	72,74	200,88
1	20,28	14,87	20,0	16,5	14,0	141,97	197,17
1	20,91	14,88	19,5	17,0	14,5	256,33	197,23
0,5	20,63	14,88	26,0	19,5	15,0	361,81	128,43
0,5	15,64	14,87	24,0	19,0	15,5	365,06	127,83
1	18,46	14,87	32,5	25,0	19,5	368,53	198,83
1	19,53	14,87	33,0	29,0	26,0	369,26	204,78
1	20,33	14,87	29,0	26,0	22,0	366,57	219,61
1	15,98	14,85	28,0	25,0	22,0	359,45	214,68
1	18,40	14,85	29,0	26,0	21,0	361,83	208,36
0,5	9,75	14,83	32,0	29,0	26,0	364,15	143,87
0,5	4,29	14,83	33,0	29,0	24,0	360,38	149,54
1	4,24	14,82	24,0	19,0	15,0	358,43	190,45
1	5,85	14,82	19,0	17,0	15,0	358,28	179,91
1	9,52	14,82	28,0	24,0	19,0	356,14	179,63
1	7,65	14,80	36,0	31,0	26,0	355,39	178,22
1	9,89	14,77	36,0	30,0	27,0	354,05	193,50
0,5	6,45	14,77	38,0	32,0	27,0	346,47	131,08
0,5	4,02	14,75	37,0	31,0	26,0	355,62	146,59
1	5,41	14,75	32,0	27,0	24,0	361,15	197,62
1	7,30	14,72	36,0	29,0	23,0	355,17	194,04
1	7,55	14,70	33,0	25,0	17,0	359,80	203,11
1	7,43	14,70	23,0	20,0	18,0	355,89	193,97
1	6,44	14,67	19,0	18,0	17,0	345,74	177,85
0,5	5,79	14,65	21,0	19,0	18,0	360,92	117,73
0,5	6,70	14,63	20,0	19,0	17,0	358,11	120,63
1	6,32	14,62	23,0	20,0	17,0	318,90	176,43
1	5,91	14,58	28,0	21,0	17,0	354,65	174,81
1	6,19	14,55	27,0	21,0	17,0	355,52	186,59
1	8,35	14,55	24,0	20,0	17,0	355,23	181,83
1	5,19	14,52	24,0	20,0	17,0	353,52	171,71
0,5	4,29	14,48	23,0	20,0	18,0	346,53	118,33
0,5	4,44	14,47	23,0	20,0	17,0	345,65	120,96
1	4,78	14,43	26,0	21,0	18,0	345,73	155,28
1	3,85	14,42	25,0	22,0	19,0	340,61	170,80
1	3,59	14,38	26,0	23,0	20,0	342,26	153,05
1	3,31	14,37	24,0	21,0	18,0	334,52	172,55
1	2,85	14,33	21,5	19,5	18,0	186,71	171,98
0,5	1,89	14,30	21,5	19,5	18,0	249,20	112,86
0,5	0,89	14,27	22,5	20,0	18,0	110,76	115,42
1	2,02	14,25	24,5	21,5	18,0	325,42	175,67
1	1,10	14,22	32,5	25,0	18,5	342,22	162,20
1	2,60	14,18	30,0	24,0	19,0	343,09	165,10
1	1,91	14,15	28,0	21,0	17,0	330,58	159,96
1	1,50	14,12	24,0	21,0	18,0	332,39	176,65
0	0,77	14,08	25,0	21,0	17,0	334,90	53,82
0	0,20	14,05	26,0	20,0	17,0	335,71	9,60
0	0,00	14,02	25,0	20,0	17,0	321,85	35,56
0	0,00	14,00	25,0	21,0	18,0	313,77	9,79
0	0,00	13,97	24,0	20,0	17,0	321,66	24,79
0	0,13	13,93	28,0	21,0	17,0	332,40	9,79

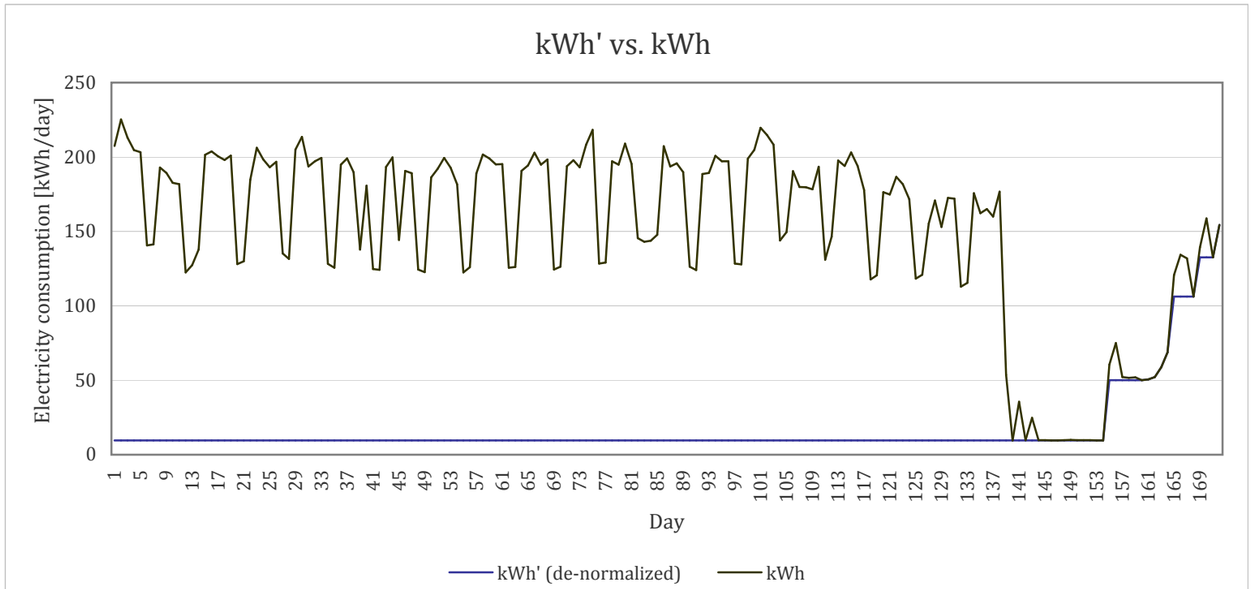
0	0,03	13,88	36,5	28,5	21,5	330,16	9,80
0	0,02	13,85	36,5	29,0	22,5	324,31	9,60
0	0,00	13,82	34,5	25,0	18,0	321,93	9,60
0	0,00	13,78	26,5	21,0	17,5	326,23	9,78
0	0,03	13,73	27,5	22,5	18,5	324,27	9,86
0	0,14	13,70	30,0	23,5	18,5	316,66	9,79
0	0,01	13,68	30,0	23,0	18,0	315,85	9,80
0	0,00	13,65	24,5	20,0	17,0	317,94	9,79
0	0,03	13,60	25,0	21,0	19,0	308,50	9,60
0	0,00	13,57	27,0	21,5	18,0	306,44	9,60
0,2	0,00	13,52	29,5	24,0	19,0	306,62	60,61
0,2	0,75	13,48	35,0	27,5	20,0	307,03	75,06
0,2	0,75	13,45	31,0	23,0	17,0	308,09	52,25
0,2	0,82	13,40	28,5	21,5	18,5	298,75	51,62
0,2	1,18	13,37	24,5	20,5	18,0	296,76	52,03
0,2	2,10	13,32	23,5	20,0	17,0	293,07	50,14
0,2	0,65	13,30	29,5	22,0	16,5	299,31	50,52
0,2	1,84	13,27	25,5	20,0	16,0	298,19	52,10
0,2	1,40	13,22	27,0	21,0	16,5	295,56	58,73
0,2	1,10	13,18	27,5	21,0	16,0	290,09	68,74
0,2	1,65	13,13	30,0	23,0	17,0	286,07	120,79
0,2	1,18	13,10	29,5	24,0	19,0	263,56	134,37
0,2	1,12	13,05	32,0	26,0	22,0	284,15	131,89
0,2	2,48	13,02	30,0	24,0	19,0	284,75	106,21
1	1,08	12,97	30,5	26,0	21,5	280,72	139,45
1	2,62	12,95	31,5	26,0	21,5	276,57	158,79
1	4,01	12,90	28,5	24,0	19,0	274,74	132,51
1	3,26	12,85	27,0	21,0	18,0	275,79	154,39

1) Let's try to perform a linear regression with all variables with a confidence level of 95%
2) After analyzing the results, let's try another regression with day type, occupancy and maximum T
3) The second simulation does provide a statistical significant model, with the following regression equation:
kWh' = 0.120 + 0.651 * day_type + 0.146 * occupancy

kWh' =	intercep	Var1	var2	var3
kWh' =				

Therefore, now we apply this equation to check the outputs, de-normalizing as well.

kWh'	kWh' (de-normalized)	kWh
0	9,60	207,41
0	9,60	225,25
0	9,60	213,02
0	9,60	204,68
0	9,60	203,30
0	9,60	140,65
0	9,60	141,35
0	9,60	192,98
0	9,60	189,36
0	9,60	182,73
0	9,60	181,85
0	9,60	122,45
0	9,60	127,30
0	9,60	137,74
0	9,60	201,48
0	9,60	203,82
0	9,60	200,43
0	9,60	197,98
0	9,60	200,93
0	9,60	128,01
0	9,60	129,92
0	9,60	184,73
0	9,60	206,13
0	9,60	198,28
0	9,60	193,10
0	9,60	196,83
0	9,60	135,15
0	9,60	131,52
0	9,60	205,01
0	9,60	213,63
0	9,60	193,69
0	9,60	197,18
0	9,60	199,49
0	9,60	128,24
0	9,60	125,53
0	9,60	194,83
0	9,60	199,13
0	9,60	189,73



0	9,60	137,74
0	9,60	180,79
0	9,60	124,66
0	9,60	124,30
0	9,60	193,31
0	9,60	199,71
0	9,60	144,32
0	9,60	190,77
0	9,60	189,09
0	9,60	124,41
0	9,60	122,56
0	9,60	186,28
0	9,60	192,16
0	9,60	199,46
0	9,60	192,75
0	9,60	181,60
0	9,60	122,53
0	9,60	125,89
0	9,60	188,92
0	9,60	201,62
0	9,60	199,13
0	9,60	195,11
0	9,60	195,13
0	9,60	125,62
0	9,60	126,18
0	9,60	190,61
0	9,60	194,33
0	9,60	202,88
0	9,60	194,89
0	9,60	198,28
0	9,60	124,38
0	9,60	126,38
0	9,60	193,79
0	9,60	197,81
0	9,60	193,08
0	9,60	208,38
0	9,60	218,28
0	9,60	128,47
0	9,60	129,13
0	9,60	197,11
0	9,60	194,87
0	9,60	208,94
0	9,60	195,48
0	9,60	145,56
0	9,60	143,01
0	9,60	143,76
0	9,60	147,85
0	9,60	207,20
0	9,60	193,61
0	9,60	195,70
0	9,60	189,77
0	9,60	126,33
0	9,60	124,06

0	9,60	188,56
0	9,60	189,23
0	9,60	200,88
0	9,60	197,17
0	9,60	197,23
0	9,60	128,43
0	9,60	127,83
0	9,60	198,83
0	9,60	204,78
0	9,60	219,61
0	9,60	214,68
0	9,60	208,36
0	9,60	143,87
0	9,60	149,54
0	9,60	190,45
0	9,60	179,91
0	9,60	179,63
0	9,60	178,22
0	9,60	193,50
0	9,60	131,08
0	9,60	146,59
0	9,60	197,62
0	9,60	194,04
0	9,60	203,11
0	9,60	193,97
0	9,60	177,85
0	9,60	117,73
0	9,60	120,63
0	9,60	176,43
0	9,60	174,81
0	9,60	186,59
0	9,60	181,83
0	9,60	171,71
0	9,60	118,33
0	9,60	120,96
0	9,60	155,28
0	9,60	170,80
0	9,60	153,05
0	9,60	172,55
0	9,60	171,98
0	9,60	112,86
0	9,60	115,42
0	9,60	175,67
0	9,60	162,20
0	9,60	165,10
0	9,60	159,96
0	9,60	176,65
0	9,60	53,82
0	9,60	9,60
0	9,60	35,56
0	9,60	9,79
0	9,60	24,79
0	9,60	9,79

0	9,60	9,80
0	9,60	9,60
0	9,60	9,60
0	9,60	9,78
0	9,60	9,86
0	9,60	9,79
0	9,60	9,80
0	9,60	9,79
0	9,60	9,60
0	9,60	9,60
0	50,14	60,61
0	50,14	75,06
0	50,14	52,25
0	50,14	51,62
0	50,14	52,03
0	50,14	50,14
0	50,52	50,52
0	52,10	52,10
0	58,73	58,73
0	68,74	68,74
0	106,21	120,79
0	106,21	134,37
0	106,21	131,89
0	106,21	106,21
0	132,51	139,45
0	132,51	158,79
0	132,51	132,51
0	154,39	154,39