A Brief Summary of the Article:

Diagnostic Tools of energy performance for supermarkets using

Artificial Neural Network algorithms

* ANN have been characterised as a “black box” model and unlike models that are based on physical principles, a detailed description of the modelled system configuration is not required. An ANN model can identify the relationship between input and output parameters by utilizing previously recorded data. Their main areas of application are classification, forecasting, control systems, and optimisation and decision making problems. The main advantage of ANN is that they can implicitly detect complex non-linear relationships between dependent and independent variables.
* *"Feedforward"s are used in the usage of ANN. Which means t*he connection weights that used to “store knowledge”. The number of neurons in the input and output layer are equal to the number of independent and dependent variables of the problem respectively.
* Training refers to the process finding the network parameters that lead to the best performance by minimisation of an error function. In neural network literature the term *learning rule* refers to the procedure of modifying the weights of a network.
* In this study, the artificial neural networks method was used in order to predict the energy consumption of an existing supermarket in Scotland using a half-hourly step, for diagnosis purposes.
* Limitations of the ANN method include overfitting and limited extrapolation ability. The Early Stopping technique can be utilised to prevent overfitting by introducing a validation set
* Fault Detection:
* The first approach is called *energy benchmarking* and it includes the comparison of the system with the current or previous performance of a similar system
* The second method is called *energy baselining*, in which the reference behaviour is defined as the previous (historically best) or ideal (theoretical) performance of the system. In this case, a model for the energy consumption of the store or the examined system must be created. Hence, the second approach has been chosen for this work
* Therefore, *Day Of The Week* and *Hour Of The Day* are the two first input variables. Other important factors are weather data such as temperature, humidity, daylight illuminance and wind speed. Finally, other external factors such as occupancy level of the store could influence the energy consumption of its systems.
* The majority of supermarkets in the UK solely log temperature values for the internal and external environment. In order to avoid overparameterisation and enhance the replicability of the model, the only weather related variables that are used are indoor and outdoor temperature as well as light sensor readings for the case of the lighting system.
* For this study the multi-layer feedforward architecture has been used to build the prediction component of the diagnostic tool.

Preprocessing

* Before the data is fed to the network, it has to be normalised to eliminate any bias for one input variable over the others, by using the same range for all the variables.
* The normalisation range lies between 0 to 1 when a logistic sigmoid transfer function is used and -1 to +1 when a linear or tangent hyperbolic transfer function is used.
* Multi-layer feedforward networks with one hidden layer have been characterised as *universal approximators.*
* The performance of the ANN models is optimised, using the number of neurons in the hidden layer

Two-Level Diagnostic Tool

* At this stage, as was previously mentioned, there are two levels of diagnosis. In the first level, the actual total daily energy consumption of the store or the system is compared to the predicted consumption. If the actual value exceeds the predicted by 10% or more, then the performance is labelled as *Bad*. If the performance exceeds the predicted value by 5% to 10%, then the performance is characterised as *Average*. In every other case the performance can be classified as *Good*.
* The second diagnostic level is applied only in the case of the different subsystems to identify if the operation is normal or some fault has occurred.
* Even if the energy consumption of each subsystem is not equal to the predicted value, if it lies inside the confidence bounds, the operation of the system can be classified as normal

Energy Comsumption

* In terms of electrical energy, the *refrigeration system* is the major consumer with almost 40% of the total energy. The *lighting* system at the store consumes approximately 30% of the energy with the HVAC system consuming about 8.9% of the electrical energy. Considerable amounts of energy are consumed in the *Hot Food and Bakery ovens*, corresponding to 8.9% and 7.4% of the total respectively
* *Boiler* consumes about 34.2% of the total energy of the store; providing both hot water and space heating services. Together with the HVAC system they constitute 40% of the total energy use.
* One can firstly notice that the store consumes more energy during trading hours (when the store is open). From the power profile, it becomes evident that from 11pm to 4 am, when the store is closed, it operates at base load. Then at around 4.30am there is a peak in power demand due to the Bakery ovens turning on but then it decreases once they have reached their operating temperature. The next peak is observed at 8am, when the store opens, due to the turning on of Air-Handling Units, Hot Food Ovens and Lighting..
* The reason that the performance has been labelled as Bad is that the total daily energy consumption is higher than the expected by almost 18%, hence above the 10% threshold for the Bad Performance label.
* From the information panel on the right, it can be seen that the actual energy consumption is by 46% smaller than the predicted value. However, in this case, this does not indicate good energy performance, since this has occurred due to component failure.