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Diagnostic tools of energy performance for supermarkets using Artificial Neural Networks

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AIM & BACKGROUND

Supermarkets are one of the largest single end users of electricity in the UK, consuming approximately 120 TWh_{el} per annum, accounting for 3% of total UK electricity consumption and 1% of UK's GHG emissions [1]. Supermarket performance monitoring is of vital importance to ensure that no excess energy is used, minimise environmental impacts and reduce operating costs. It can also allow early detection of potential equipment faults that could disrupt the store's operation

The *objective* of this project is to develop a diagnostic tool using Artificial Neural Network Algorithms for a Sainsbury's supermarket. This tool will be used to evaluate the energy consumption of Sainsbury's Hythe store as a whole and of its refrigeration, HVAC, lighting and boiler systems separately as well as detect any fault in their operation.

BASELINE TOOL & ARTIFICIAL NEURAL NETWORKS

Feedforward Artificial Neural Networks (ANN) were developed for each system to provide the baseline for the diagnosis, which is modelled as a dependency between the energy consumption and suitable explanatory variables.

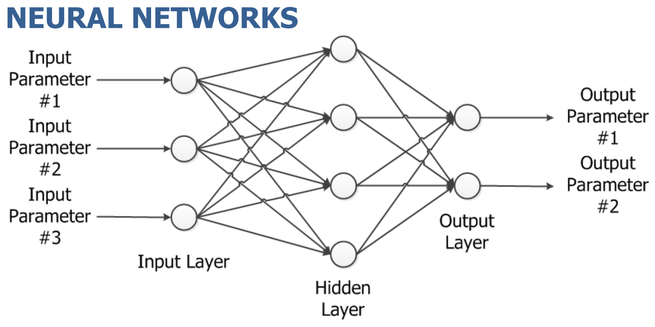

Figure 1. Feedforward Artificial Neural Networks

FAULT DIAGNOSIS & EVALUATION TOOL

The tool developed consists of three main stages:

1. The Data acquisition system, which provides the necessary data for the energy predictions as well as the actual energy consumption. This consists of supermarket remote monitoring and logging systems.
2. The prediction module, where the ANN models are placed
3. The diagnosis module, which assesses the performance of the system and detects any faults

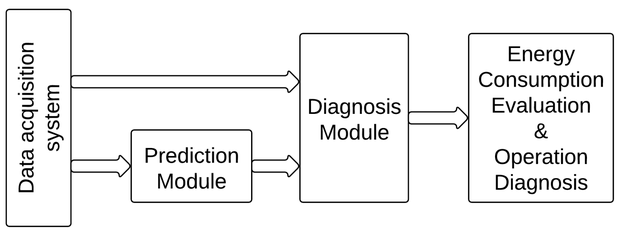

Figure 3. Diagnostic Tool

Prediction Module

Figure 4 shows the design concepts of the ANN models developed for the prediction module

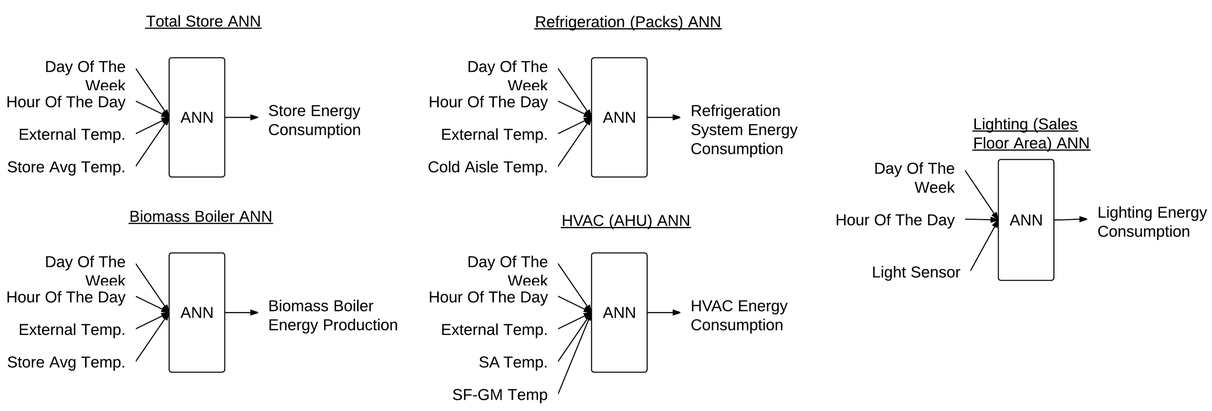

Figure 4. ANN Design Concepts

Diagnosis Module

The diagnosis module consists of two stages: The *first* stage performs the energy consumption evaluation marking the performance as *Good, Average* and *Bad.* The *second* stage detects if any fault has occurred in the equipment and its output signals include *Normal Operation, Low Probability of Failure, High Probability of Failure* and *Failure.* The two stages are shown below.

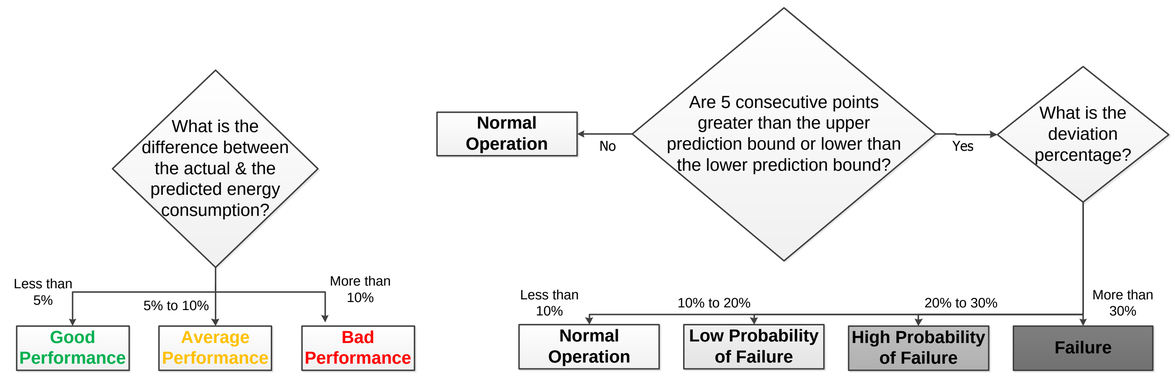

Figure 5. First and Second Level of the Diagnostic Tool

RESULTS

Figure 6 compares the actual energy consumption to the predicted values given by the ANN model for the Store's Energy Consumption. It is evident that the model has been effectively trained to predict the energy consumption.

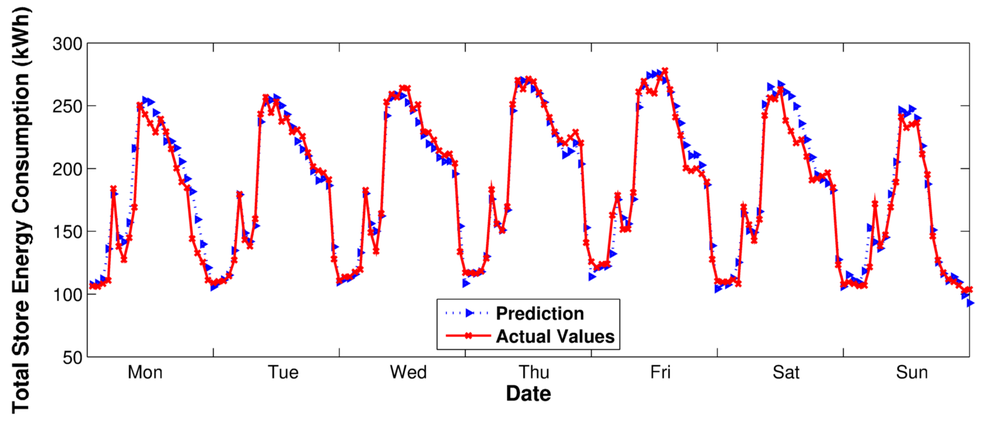

Figure 6. Comparison between predicted and actual data over a week's period using the ANN for the Total Store's Energy Consumption

The following table presents a summary of the results for the different ANN models developed. The R-value indicates the accuracy of the fit that has been achieved and the Mean Absolute Error represents the average prediction error for each model.

Table 1. ANN Models Accuracy Results

	Total Store	Refrigeration	Lighting	HVAC	Boiler
R-value	0.9808	0.9682	0.9777	0.8870	0.9708
Mean Absolute Error (kWh)	8.34	3.60	1.86	1.55	12.82

An example of the tool's output for the refrigeration system for a day when the performance is good and for a day with bad performance and High Probability of Failure is shown in Figures 7 and 8.

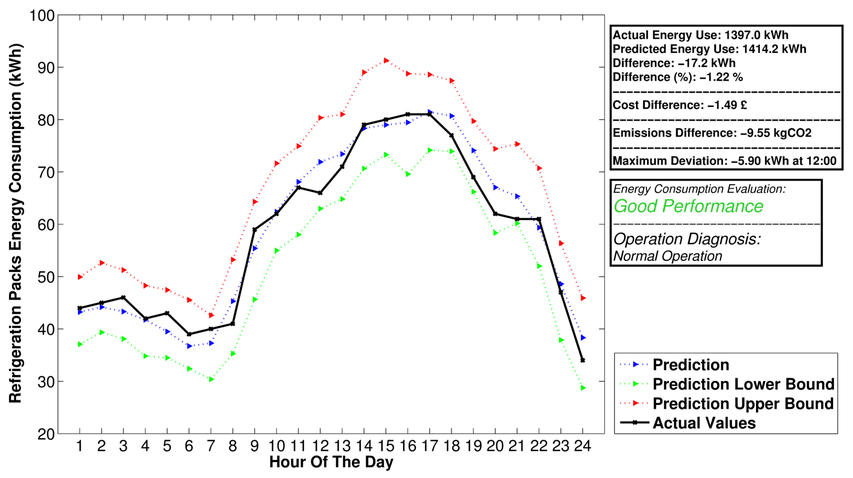

Figure 7. Diagnostic Tool's Output for Refrigeration System on a Good Performance Day

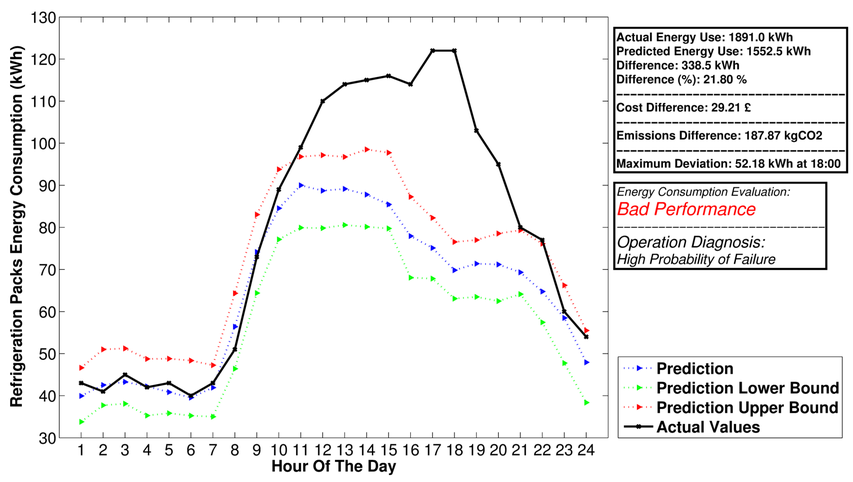

Figure 8. Diagnostic Tool's Output for Refrigeration System on a Bad Performance Day

CONCLUSIONS

- The results of the project showed that the ANN models achieved remarkable accuracy and thus are a viable tool for diagnosis purposes.
- The data used for the tool's development came from the advanced remote monitoring systems that were installed in the store, stressing the importance of accurate monitoring and logging.
- The generic nature of the development process allows the easy roll out to other stores, effectively offering a valuable analytical tool for better running of business.

REFERENCES

[1] Tassou, S. A., Ge, Yy., Hadawey, A. & Marriott, D. (2011) Energy consumption and conservation in food retailing. *Applied Thermal Engineering,* 31 (2-3), 147-156.

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