Table 4. Connection weight approach analyzing the level of importance of the input factors

	Hidden 1	**Hidden 2**	**Hidden 3**	**Hidden 4**	**Hidden 5**
DTT	-0.3235	0.3417	0.4898	1.2086	0.1751
FTT	-0.0845	-1.6253	1.146	0.0239	1.3108
R&D	0.6381	-0.1962	0.0953	-0.1177	-0.1491
			x		
	-0.4642	1.0023	-0.4697	0.5243	-0.5615
			=		
DTT	0.1504922	0.3424	-0.23	0.6336	-0.0983
FTT	0.0393	-1.629	-0.5382	0.0125	-0.736
R&D	-0.2968	-0.1966	-0.0447	-0.0617	0.0837
			=		

	Level of Importance	**Percentage**
DTT	0.7981	-32%
FTT	-2.7389	111%
R&D	-0.5161	21%

5. Conclusion

This paper introduces technology transfers and R&D activities as factors which are critical in deciding the optimal use of energy. These activities are quantified to show their level of importance on energy consumption reduction so that their significance can be taken seriously among the energy community. In order to have a clearer picture how these activities contribute to energy reduction, a designed model, integrating both artificial neural network and data envelopment analysis was established. In this regard, the artificial neural network was used to investigate and establish the baseline of the energy consumption based on the impacts of the various activities. Data envelopment analysis conducted a sensitivity analysis on the various inputs omitted one after the other. The result of the data envelopment analysis was validated with the connection weight approach of the artificial neural network. The South African case study gives a wider margin of how these activities contribute to energy reduction. It is very important that the country starts to concentrate on indigenous technologies and R&D activities so as to reduce the margin between them and the concentration on foreign technology transfer.

References

Amina, M., Kodogiannis, V. S., Petrounias, I. P., Lygouras, J. N. & Nychas, G.-J. E. 2012. Identification of the Listeria monocytogenes survival in UHT whole milk utilising local linear wavelet neural networks. . *Expert system with Applications,* 39**,** 1435-1450.

Audretsch, D. & Feldman, M. 1996. R&D spillovers and the geography of innovation and production. *American Economic Reviews,* 86**,** 253-73.

Azadeh, A., Arab, R. & Behfard, S. 2010. An adaptive intelligent algorithm for forecasting long term gasoline demand estimation: The case of USA, Canada, Japan, Kuwait and Iran. *Expert Systems with Applications,* 37**,** 7427 - 7437.

DOE 1995. Energy R&D: Shaping our nations future in a competitive world. Task force on strategic Energy Research and Development. *In:* ENERGY, D. O. (ed.). Washington DC, USA.

El-Mashaleh, M., Rababeh, S. M. & Hydri, K. H. 2010. Utilizing data envelopment analysis to benchmark safety performance of construction contractors. . *International Journal of Project Management,* 28**,** 61-67.

Fu, X., Pietrobelli, C. & Soete, L. 2011. The role of foreign technology and indigenous innovation in the emerging economies: technological change and catching-up. *World Development,* 39**,** 1204-1212.

Garrone, P. & Grilli, L. 2010. Is there a relationship between public expenditures in energy R&D and carbon emissions per GDP? An empirical investigation. *Energy Policy,* 38**,** 5600-5613.

Hagedoorn, J. 1993. Understanding the rationale productivity differences among countries. *American Economic Reviews,* 60**,** 895-911.

Hayati, M. & Shirvany, Y. 2007. Artificial Neural Network Approach for Short Term Load Forecasting for Illam Region. *World Academy of Science, Engineering and Technology.*

Henriksson, E., Soderholm, P. & Warell, L. 2012. Industrial electricity demand and energy efficiency policy: The role of price changes and private R&D in the Swedish pulp and paper industry. *Energy Policy,* 47**,** 437-446.

Herrerias, M. J., Cuadros, A. & Luo, D. 2015. Foreign versus indigenous innovation and energy intensity: Further research across Chinese regions. *Applied Energy,* In Press.

Hsu, C.-C. & Chen, C.-Y. 2003. Regional load forecasting in Taiwan-applications of artificial neural networks. . *Energy conversion and Management,* 44**,** 1941-1949.

Kabnurkar, A. 2001. Mathematical Modeling for Data Envelopment Analysis with Fuzzy Restrictions on weights in Industrial and Systems Engineering. . Virginia: Virginia Polytechnic Institute and State University.

Kemp, S. J., Zaradic, P. & Hansen, F. 2007. An approach for determining relative input parameter importance and significance in artificial neural networks. *Ecological Modelling,* 204**,** 326-334.

Kljajic, M., Gvozdenac, D. & Vukmirovic, S. 2012. Use of Neural Networks for modeling and predicting boiler's operating performance. . *Energy***,** 1-8.

Lanzi, E. 2013. Impacts of innovation: Lessons from the empirical evidence. *Encyclopedia of Energy, Natural Resource and Environmental Economics***,** 82-88.

Leisching, A., Geigenmueller, A. & Lohmann, S. 2014. On the role of alliance management capability, organizational compatibility, and interaction quality in interorganizational technology transfer. *Journal of Business Research,* 67**,** 1049-1057.

Liu, C. H., Lin, S. J. & Lewis, C. 2010. Evaluation of thermal power plant operational performance in Taiwan by data envelopment analysis. *Energy Policy,* 38**,** 1049-1058.

Lulu, M., Seyoun, G. & Swift, F. W. 1996. A decision model for technology transfer *Computers ind. Engng,* 31**,** 37-40.

Olanrewaju, O. A. & Jimoh, A.-G. A. 2014. Impacts of Independent Research and Development, Foreign Technology and Domestic Technology Transfer Driven Activities *In:* REITER, S. (ed.) *Energy Consumption - impacts of human activity, current and future challenges, environmental and socio-economic effects.* New York: Nova.

Olden, J. D., Joy, M. K. & Death, R. G. 2004. An accurate comparison of methods for quantifying variable importance in artificial neural networks using simulated data. *Ecological Modelling,* 178**,** 389-397.

Sagar, A. D. & Zwaan, B. C. C. V. D. 2006. Technological innovation in the energy sector: R&D, deployment, and learning-by-doing. *Energy Policy,* 34**,** 2601-2608.

Soriano, F. H. & Mulatero, F. 2011. EU Research and Innovation (R&I) in renewable energies: The role of the Strategic Energy Technology Plan (SET-Plan). *Energy Policy* 39**,** 3582-3590.

Tyagi, P., Yadav, S. P. & Singh, S. P. 2009. Relative performance of academic departments using DEA with sensitivity analysis. *Evaluation and Program Planning,* 32**,** 168-177.

Watanabe, C. MITI's efforts to mitigate global warming by substituting technology for energy. IIASA's International Workshop on Assessment of Mitigation. Impacts and Adaptation to Climate Change, 1993 Vienna.

William, W. C., Jose, L. R. & Sirvent, I. 2007. Choosing weights from alternative optimal solutions of dual multiplier models in DEA. *European Journal of Operational Research,* 180**,** 443-458.

William, W. C., Lawrence, M. S. & Tone, K. 2006. Introduction to Data Envelopment Analysis and its uses with DEA-Solver Software and References. New York: Springer.

Worrell, E., Berkel, R. V., Fengqi, Z., Menje, C., Schaeffer, R. & Williams, R. O. 2001. Technology transfer of energy efficient technologies in industry: a review of trends and policy issues. *Energy Policy,* 29.

Biographies

Dr. Oludolapo Akanni Olanrewaju is currently a Post-doctoral student in Industrial Engineering and Operations Management at University of Johannesburg's (UJ) Faculty of Engineering and the Built Environment (FEBE). As an established researcher in the field of energy, his specializations include applications of Data Management and Analysis, Optimization, and Artificial Intelligence on energy systems with general research interests in energy and greenhouse gas potentials. Dr. Olanrewaju has presented at numerous conferences and published more than 20 papers in peer-reviewed journals and conferences, and 1 book chapter. He holds a BSc Honours in Electrical Engineering from the University of Ibadan in 2004. Upon graduating with his MSc in Industrial Engineering from the University of Ibadan in 2008, he was employed as an ad-hoc engineer by the same University he graduated from. He completed his doctoral studies at Tshwane University of Technology in South Africa.

Professor Charles Mbohwa is the Vice-Dean Postgraduate Studies, Research and Innovation at University of Johannesburg's (UJ) Faculty of Engineering and the Built Environment (FEBE). As an established researcher and professor in the field of sustainability engineering and energy, his specialisations include sustainable engineering, energy systems, life cycle assessment and bio-energy/fuel feasibility and sustainability with general research interests in renewable energies and sustainability issues. Professor Mbohwa has presented at numerous conferences and published more than 350 papers in peer-reviewed journals and conferences, 10 book chapters and three books. Upon graduating with his BSc Honours in Mechanical Engineering from the University of Zimbabwe in 1986, he was employed as a mechanical engineer by the National Railways of Zimbabwe. He holds a Masters in Operations Management and Manufacturing Systems from University of Nottingham and completed his doctoral studies at Tokyo Metropolitan Institute of Technology in Japan. Prof Mbohwa was a Fulbright Scholar visiting the Supply Chain and Logistics Institute at the School of Industrial and Systems Engineering, Georgia Institute of Technology, a Japan Foundation Fellow, is a Fellow of the Zimbabwean Institution of Engineers and is a registered mechanical engineer with the Engineering Council of Zimbabwe.