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ENERGY USE, CONSERVATION AND EMISSIONS REDUCTIONS IN TAIWANESE COSMETICS INDUSTRY

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Abstract

This work performs an energy flow case study on the cosmetics industry in Taiwan. In addition, the energy-saving potential of these options is evaluated. It is found that the total potential energy saving amounts to around 2397.0 GJ. It represented a potential reduction of 179.8 tonnes in carbon dioxide emissions. This study establishes an energy flow analysis and energy-saving method for this case study, in addition to identifying potential energy-saving areas. The greatest energy-saving potential can result from improving equipment efficiency, which would potentially comprise around 92% of total energy conservation potential. This analysis serves as a benchmark for updating the cosmetics' products industry operation, and assisting energy users in performing energy management in order to enhance energy utilization efficiency.

Key words: cosmetics industry, energy conservation, Taiwan

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1. Introduction

The cosmetics industry has grown worldwide, especially in the United States, France, Germany, Italy, Japan and Taiwan. Unfortunately, the concentration of greenhouse gases (GHG) resulting from the manufacture of these products has also increased significantly. Increasing energy efficiency is crucial if greenhouse gas emissions are to be reduced. Numerous analytical studies have been undertaken on energy audits or energy conservation strategies for different industries, such as the iron and steel industry (Chan et al., 2010; Mohsen and Akash, 1998; Ross, 1987; Thollander et al., 2005; Zhang and Wang, 2008), cement industry (Anand et al., 2006; Hasanbeigi et al., 2010), textile industry (Hong et al., 2010; Palanichamy and Babu, 2005), petroleum/chemical industry (Leites et al., 2003; Neelis et al., 2007; Pollio and Uchida, 1999), pulp and paper industry (Hong et al., 2011; Persson and Berntsson, 2009), small and medium scale industries (Gruber and Brand, 1991; Priambodo and Kumar, 2001; Thollander et al., 2007) and other manufacturers (Chan et al., 2007; Fromme, 1996; Harris et al., 2000; Mukherjee, 2008; Worrell et al., 2009). In addition, many studies have analyzed carbon emission reduction options within the industry, e.g. (Gielen and Dril, 1999; Mauricio et al., 2010; Ru et al., 2010; Worrell et al., 1999; Wang et al., 2011). Carbon emissions can be reduced using both energy conservation technology (ECT) and energy structural adjustment (ESA) (Guo et al., 2011). However, few studies have focused on energy issues in the cosmetics industry.

In general, there are at least ten principal steps in cosmetics products production: raw material preparation, mixing, heating (70-90^o), grinding (depended on the products), degassing, filling (molds), cooling (0-5^o), mold releasing, finish and assembly. Increasing energy efficiency is the most

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direct means of reducing GHG emissions. If energy users are willing to adopt improved technologies, or if government incentives are implemented, emissions can be further reduced (Priambodo and Kumar, 2001). Taiwanese industries are primarily small and medium scale and, of late, energy management technology has been increasingly adopted. However, as industry usually focuses on production, new directions are required if energy savings are to be realized. Increased energy utilization efficiency would assist industry in satisfying energy audit requirements. According to the Energy Management Law of Taiwan, energy users must observe the regulations promulgated by the central authority for conducting an energy audit, set an energy conservation target and devise an action plan accordingly.

Therefore, it is important that energy consumption flows in the cosmetics industry, including energy supply, energy distribution, energy conversion and energy end-use are all analyzed. According to the analysis results of this study, an enormous potential for energy conservation exists. This paper analyzes the energy flow of the case study, offers an energy flow model for the cosmetics industry and identifies potential energy-saving opportunities.

2. Current status in cosmetics industry

A comprehensive analysis of the cosmetics and toiletries market offered by Euromonitor International in June 2007 covered 52 countries, with a global GDP of 95%. In recent years, the market size of Latin America and Asia, including: Argentina, Brazil, Chile, Thailand, Korea, Indonesia, China and Taiwan, has increased significantly. In particular, the market size of Brazil increased the fastest, making that country the fifth largest market for cosmetics; the market size of China showed the second fastest increase, reaching the eighth largest market.

The sales volume of cosmetics products in Western Europe, estimated at 17.8 million U.S. dollars (1 U.S. dollar equals 31.73 Taiwan Dollars in 2008), accounted for 30% of the world's cosmetics sales volume in 2008, with Japan and the United States accounting for 17% and 20%, respectively, as shown in Fig. 1. According to statistical data from Taiwan's Industrial Development Bureau, the sales volume of cosmetics products in 2001 reached 1.06 million NT dollars (Taiwan Dollars). However, in comparison with 2000, sales decreased by 7.02%; this was likely a result of the global economic slowdown.

The cosmetics industry was listed in the Challenge 2008-National Development Plan in 2003. The government of Taiwan designated one hundred million NT dollars to assist the cosmetics industry to upgrade product or package design levels and to build up its own brands, so that the product value of its cosmetics industry would exceed forty billion NT dollars in the future.

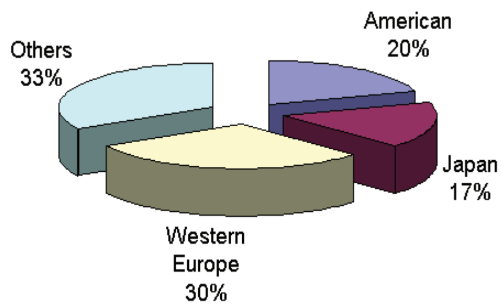

Fig. 1. Distribution of world cosmetics sales volume

3. Energy flow analysis methodology

Models, called energy footprints, showing the flow of energy supply, demand and losses for several US manufacturing industries, were created by the DOE (Ozalp and Hyman, 2006). There are five steps in carrying out an energy flow analysis, determining: energy supply, central energy generation/utilities, energy distribution, energy conversion and process energy use. The following steps explain how an energy flow analysis was applied in Taiwan's cosmetics factories:

Step 1: Energy supply

The energy supply is the sum total of fuel consumption: purchased electricity, steam, and biomass or byproduct fuels.

Step 2: Central energy generation/utilities

This value represents the energy, including the energy supply, mentioned in Step 1. Power generation means the energy produced onsite by fuel which actually enters the plant.

Step 3: Energy distribution

Energy distribution represents the energy which is distributed to the process energy systems. Energy distribution is obtained by subtracting the boiler and electricity generation losses in pipes, valves, traps, and electrical transmission lines from the central energy generation/utilities.

Step 4: Energy conversion

The available energy which can be used by motor-driven equipment, process heating and cooling units and other process equipment is called energy conversion, and is calculated by subtracting transmission losses and facilities energy from energy distribution systems.

Step 5: Process energy use

Process energy use is estimated by subtracting energy losses due to equipment inefficiency from energy conversion systems employed to process energy use systems.

According to these steps, an energy flow profile of a case study in the Taiwanese cosmetics industry was established, as shown in Fig. 2. The energy flow profile identifies where energy was lost as well as the areas with the potential for energy savings.

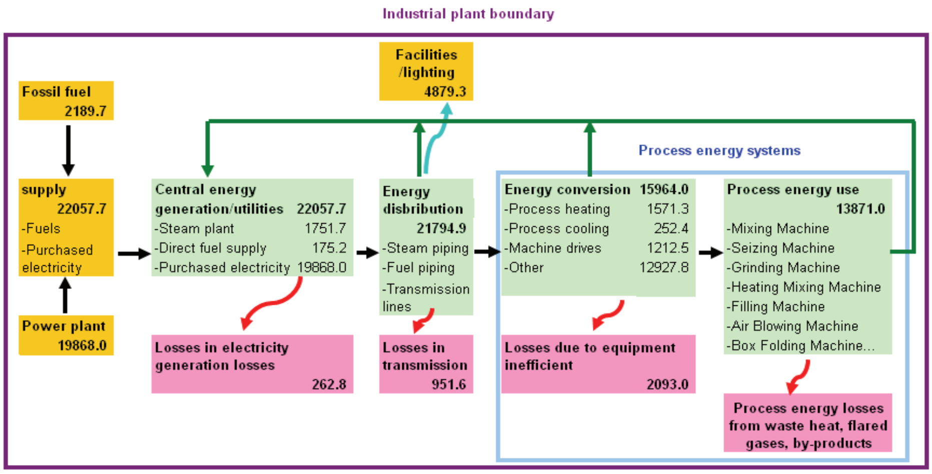

Fig. 2. Energy flow profile of this case study (Energy unit: GJ)

4. Results and discussion

4.1. Energy use and loss analysis

The energy use and loss of the case study in the Taiwanese cosmetics industry was analyzed, and the analysis results are described below. Primary energy, including purchased fuels and electricity, in addition to the energy losses associated with offsite power generation and energy supply systems, provide a perspective on the total energy use associated with cosmetics products. The energy inputs for this case are shown in Fig. 3. According to Fig. 3, over 90% of the energy used was contributed by purchased power, with boiler fuel comprising the energy source at 7.9%. The energy-use situation and distribution is according to the energy flow analysis methodology described in Section 3. The results of the energy loss analysis of this case study, as summarized in Table 1, show that the total energy losses including boiler losses, distribution losses and losses due to equipment inefficiency were 3307.4 GJ. The general energy flow and losses, as determined from the energy flow analysis, are illustrated in Fig. 4.

As Fig. 4 shows, on-site energy losses of overall energy utilization accounted for only 15% of the total, which was much less than that of other manufacturing industries, such as the pulp and paper industry (Hong et al., 2011). Equipment inefficiency accounted for 63.3%, boiler losses for 8.0% and distribution for 28.7% of on-site energy losses.

4.2. Energy conservation opportunities analysis

The energy flow analysis for this case included an evaluation of end-use and loss patterns to provide an in-depth understanding of the opportunities for energy conservation. According to the energy loss patterns, the energy conservation opportunities are as follows:

(1) Boiler loss:

(a) If inverters were added to the boiler blowers, electricity would be conserved.

(b) Controlling the discharged oxygen concentration and minimizing excess air, recycling cooling water and waste heat, and lowering the discharge temperature to below the original design setting, would effect energy savings.

(c) Periodic inspection and cleaning would improve the efficiency of the boiler.

(d) If the boiler equipment were upgraded, equipment efficiency would be improved.

(2) Energy distribution loss: Steam distribution losses due to heat transfer, ineffective steam traps, leaks etc., varied from 20% to 40% (Hooper and Gillette, 2002; Petek and Glavic, 1996; Siddhartha, 2000). If these parts were upgraded, energy consumption and production costs would be reduced. The suggested energy conservation methods are as follows:

(a) Installing insulation and conducting a survey of the steam distribution would reduce the leakage of steam.

(b) Weekly to monthly steam-trap testing intervals for high pressure (above 150 psig), monthly to quarterly for medium pressure (30~150 psig) and annually for low pressure (below 30 psig) equipment, is recommended. In addition, regular systematic inspection, testing and repair of steam traps should be carried out in order to reduce steam losses.

(3) Equipment inefficiency loss:

(a) Fan, Pump and Motor: Electricity would be saved if motors were switched to energy-efficient motor-driven systems.

Moreover, variable frequency drives, which allow operators to fine-tune processes while reducing costs for energy and equipment maintenance in the heating, ventilating and air-conditioning of buildings, would be an excellent choice for adjustable-speed-drive users (Jayamaha, 2006; Teitel et al., 2008). Electricity usage would be reduced if motors were combined with frequency controls.

(b) Air Compressor Systems: Three types in common use are: reciprocal type, screw type and centrifugal type. For most applications, flow and pressure considerations restrict the choice of compressor, with cost and efficiency being the determining factors (Falkner, 2009).

During the air compressor operation process, only 60% of the total energy input is applied to the manufacturing process, 30% energy loss is due to surges and leakage, and the other 10% wasted is caused by poor control.

When an air compressor system is converted to a system with electrically-powered tools, an air-free chiller can be installed and a screw-type air compressor used to replace the centrifugal type, thus raising the coefficient of utilization.

(c) Air Conditioning System: If the use of cooling water under low load were reduced and the cold water outlet temperature setting increased, energy would be saved.

4.3. Energy-saving potential evaluation

According to the Energy Management Law of Taiwan, energy users must observe the regulations promulgated by the central authority when conducting an energy audit; in addition, they must set an energy conservation target and create an action plan. According to the energy loss patterns discussed above, the potential energy-savings in this case study as determined by the evaluation are as follows:

(1) Boiler:

(a) Lowering the discharge temperature to below the original design setting and upgrading the equipment of the boiler and power generation system would increase equipment efficiency by 2%, equivalent to an energy saving of 45.2 GJ.

(b) Recycling the cooling water and waste heat would increase the efficiency of the boiler by about 1.2%, equivalent to an energy saving of 26.4 GJ.

(c) With periodic inspection and cleaning, the efficiency of the boiler would be increased by 1.0%, equivalent to an energy saving of 22.6 GJ.

(d) An energy saving of about 7.5 GJ (efficiency up 0.3%) could be realized by insulating the boiler and regulating its temperature.

(2) Energy distribution: If steam distribution losses due to heat transfer, ineffective steam traps, leaks, etc, were minimized, energy consumption would be reduced by 5-10%, equivalent to 94.2 GJ.

(3) Equipment inefficiency:

(a) Fan, Pump and Motor: If the motors of the fan and pump were switched to an energy-efficient motor-driven system, electricity usage would be reduced, with an energy consumption decrease of 20%, equivalent to an energy saving of 49.0 GJ.

(b) Lighting System: If daylight were used as an alternative light source, the energy consumed by lighting would be reduced (Kim and Kim, 2007). Moreover, replacing traditional fluorescent lighting with HF (high frequency) fluorescent lighting, or mercury lighting to high-pressure sodium or ceramic metal lamps, would save about 358.0 GJ.

(c) Electrical System: Total capacity could be decreased and still meet the demands of production since the requirements of energy users are generally over-estimated. Furthermore, the power factor could be improved on the low-voltage side. If these energy-saving measures were applied, there would be a decrease in energy consumption of 94.2 GJ.

(d) Refrigerators: A wide range of refrigerators are available, depending on style and use. Energy use per unit product is significantly influenced by the efficiency of the refrigerator.

Old equipment is considerably less efficient at around 0.8~1.1 kWh/RT (Refrigeration Ton) with appropriate chiller capacity. If old equipment were replaced with a high efficiency type (0.6~0.65 kWh/RT), the energy conservation potential would be over 25%, equivalent to an energy saving of 75.4 GJ.

(e) Air Conditioning System: Controlling the exhaust valve and increasing the cold water outlet temperature setting would save 1624.4 GJ.

In summary, the total energy-saving potential of this case study would be 2397.0 GJ, as listed in Table 3, representing an annual energy-saving potential of around 10.9% of energy use. According to Table 2, the greatest energy-saving potential would come from improving equipment efficiency, potentially comprising around 92% of the total energy conserved potential. Based on the CO_2 emission coefficients reported by Hong et al. (2010), it is estimated that the total CO_2 reduction potential was 179.8 tonnes, as listed in Table 2.

4.4. Actual energy reduction analysis

The cosmetics manufacturing process is divided into mixing, heating, grinding, degassing, filling and cooling. Heating process accounts for 12.5% of the total energy consumption and the other process accounts for 87.5%.

In this paper, the areas with the actual energy reduction for the case study are to be declared via the on-line Energy Declaration System (Hong et al., 2010) and summarized in Table 3. The carbon dioxide emissions reduction, investment costs, economic benefit, and payback period are also listed. This Table summarizes energy-saving measures and identifies the areas for making energy saving to provide an energy efficiency baseline.

Overall, five opportunities to reduce electricity usage could lead to total annual cost savings of 2.41 million NT dollars, with an investment costs of 2.7 million NT dollars. The actual energy reduction from the on-line Energy Declaration System was 1273.2 GJ, equivalent to a CO_2 reduction of 93.9 tonnes.

5. Conclusions

Taiwan must conform to the requirements of the Kyoto Protocol and preparations for doing so must be made. The Bureau of Energy of the Ministry of Economic Affairs has taken aggressive measures, with high financial and technical input, to help energy users enhance energy efficiency, reduce CO_2 emissions and promote energy savings in all industrial sectors.

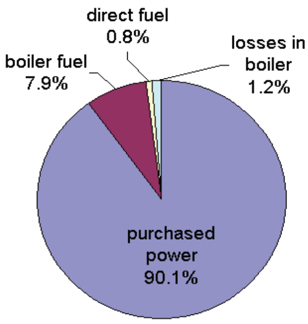

Fig. 3. Energy use distribution of this case study

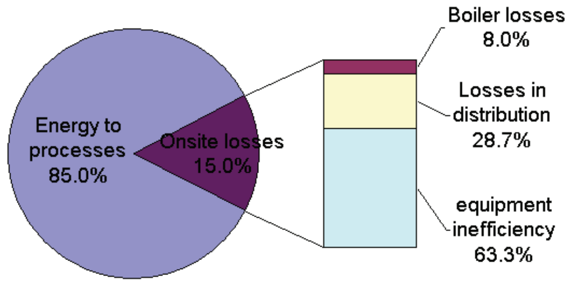

Fig. 4. Onsite energy loss profile of this case study

Table 1. Energy loss summary of this case study (Energy unit: GJ)

Boiler losses	262.8
Losses in distribution	951.6
Losses due to equipment inefficiency	2093.0
Total energy losses	**3307.4**

Table 2. Total energy saving potential for this case study

Energy saving items	*Energy saving potential (GJ)*	*CO_2 Reduction potential (Ton)*
Boiler	101.8	8.6
Distribution	94.2	8.8
Equipment inefficiency	2201.0	162.4
Summary	**2397.0**	**179.8**

Table 3. The areas with the actual energy reduction summary

Areas	*Actual Energy Reduction (GJ)*	*CO_2 Reduction (Ton)*	*Investment Costs (million NT dollars)*	*Economic Benefit [a] (million NT dollars/Year)*	*Payback period (Year)*
1. Variable frequency drives were applied to the circulation pump of refrigerators	578.2	42.6	0.7	1.2	0.6
2.Fluorescent lighting was replaced with high frequency fluorescent lighting; mercury lighting was changed to high-pressure sodium ceramic metal lamp	307.8	22.7	0.4	0.7	0.6
3.Traditional lighting system was replaced with high frequency (HF) fluorescent lighting	192.5	14.2	0.9	0.2	4.5
4.energy-efficient improvement for vacuum pump	72.9	5.4	0.3	0.16	1.9
5.Upgraded the air compressor system	121.7	9.0	0.4	0.15	2.7
Total	1273.2	93.9	2.7	2.41	-

[a] Economic benefit is defined as that saved due to a reduction in energy use; [b] Data source: The on-line Energy Declaration System website

This study has analyzed the energy flow of a cosmetics firm in Taiwan and determined an energy-saving potential of around 2397.0 GJ, equivalent to a CO_2 reduction of 179.8 tonnes. The greatest energy-saving potential would come from improving equipment efficiency, for a potential around 92% conservation potential in total energy. To achieve the energy conservation targets and improve the energy efficiency, we suggest that the government and enterprises should co-operate closely in the legal, financial and technical fields.

The following recommendations are suggested specifically: (a) the government should implement and support energy management and energy audits; (b) the government should improve the energy intensity, industrial structure; (c) the government should encourage enterprises to use clean fuels to reduce CO_2 emissions; (d) the government should encourage the development of new energy conservation technologies and the implementation of financing mechanisms to encourage enterprises' adoption for further reductions in GHG emission. It is expected that such policies or measures will promote industrial competitiveness and reduce the GHG effects to the environment.

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References

Anand S., Vrat P., Dahiya R.P., (2006), Application of a system dynamics approach for assessment and mitigation of CO_2 emissions from the cement industry, *Journal of Environmental Management*, **79**, 383-398.

Chan D.Y.L., Yang K.H., Hsu C.H., Chien M.H., Hong G.B., (2007), Current situation of energy conservation in high energy-consuming industries in Taiwan, *Energy Policy*, **35**, 202-209.

Chan D.Y.L., Yang K.H., Lee J.D., Hong G.B., (2010), The case study of furnace use and energy conservation in iron and steel industry, *Energy*, **35**, 1665-1670.

Falkner H., (2009), *Categorising the Efficiency of Industrial Air Compressors*, Energy Efficiency in Motor Driven Systems (EEMODS'09) Conference, France.

Fromme J.W., (1996), Energy conservation in the Russian manufacturing industry, *Energy Policy*, **24**, 245-252.

Gielen D.J., (1999), *Materialising dematerialisation. Integrated energy and materials system optimization for GHG emission reduction*, PhD Thesis, Delft University of Technology, The Netherlands.

Gruber E., (1991), Brand M. Promoting energy conservation in small and medium-sized companies, *Energy Policy*, **19**, 279-287.

Guo R., Cao X., Yang X., Li Y., Jiang D., Li F., (2010), The strategy of energy-related carbon emission reduction in Shanghai, *Energy Policy*, **38**, 633-638.

Guo X.D., Zhu L., Fan Y., Xie B.C., (2011), Evaluation of potential reductions in carbon emissions in Chinese provinces based on environmental DEA, *Energy Policy*, **39**, 2352-2360.

Harris J., Andersson J., Shafron W., (2000), Investment in energy efficiency: a survey of Australian firms, *Energy Policy*, **28**, 867-876.

Hasanbeigi A., Menke C., Therdyothin A., (2010), The use of conservation supply curves in energy policy and economic analysis: The case study of Thai cement industry, *Energy Policy*, **38**, 392-405.

Hong G.B., Ma C.M., Chen H.W., Chuang K.J., Chang C.T., Su T.L., (2011), Energy flow analysis in pulp and paper industry, *Energy*, **36**, 3063-3068.

Hong G.B., Su T.L., Lee J.D., Hsu T.C., Chen H.W., (2010), Energy conservation potential in Taiwanese textile industry, *Energy Policy*, **38**, 7048-7053.

Hooper F.A., Gillette R.D., (2002), *Steam trap performance assessment. How efficient is your steam distribution system*, Pacific Northwest National Laboratory, On line at: http://www.swopnet.com/engr/stm/steam_dist_eff.htm.

Jayamaha L., (2006), *Energy Efficiency Building Systems*, McGraw-Hill, New York.

Kim S.Y., Kim J.J., (2007), The impact of daylight fluctuation on a daylight dimming control system in a small office, *Energy and Buildings*, **39**, 935-944.

Leites I.L., Sama D.A., Lior N., (2003), The theory and practice of energy saving in the chemical industry: some methods for reducing thermodynamic irreversibility in chemical technology processes, *Energy*, **28**, 55-97.

Mauricio F.H.Jr., Fabrício D., Roberto S., (2010), Potential for reduction of CO_2 emissions and a low-carbon scenario for the Brazilian industrial sector, *Energy Policy*, **38**, 1946-1961.

Mohsen M.S., Akash B.A., (1998), Energy analysis of the steel making industry, *International Journal of Energy Research*, **22**, 1049-1054.

Mukherjee K., (2008), Energy use efficiency in the Indian manufacturing sector: An interstate analysis, *Energy Policy*, **36**, 662-672.

Neelis M., Patel M., Blok K., Haije W., Bach P., (2007), Approximation of theoretical energy-saving potentials for the petrochemical industry using energy balances for 68 key processes, *Energy*, **32**, 1104-1123.

Ozalp N., Hyman B., (2006), Energy end-use model of paper manufacturing in the US, *Applied Thermal Engineering*, **26**, 540-548.

Palanichamy C., Babu N.S., (2005), Second stage energy conservation experience with a textile industry, *Energy Policy*, **33**, 603-609.

Persson J., Berntsson T., (2009), Influence of seasonal variations on energy-saving opportunities in a pulp mill, *Energy*, **34**, 1705-1714.

Petek J., Glavic P., (1996), An integral approach to waste minimization in process industries, *Resources, Conservation and Recycling*, **17**, 169-188.

Pollio G., Uchida K., (1999), Management background, corporate governance and industrial restructuring: the Japanese upstream petroleum industry, *Energy Policy*, **27**, 813-832.

Priambodo A., Kumar S., (2001), Energy use and carbon dioxide emission of Indonesian small and medium scale industries, *Energy Conversion and Management*, **42**, 1335-1348.

Ross M., (1987), Industrial energy conservation and the steel industry of the United States, *Energy*, **12**, 1135-1152.

Siddhartha Bhatt M., (2000), Energy audit case studies I-steam systems, *Applied Thermal Engineering*, **20**, 285-296.

Teitel M., Zhao A.L.Y., Barak M., Eli Bar-lev., Shmuel D., (2008), Energy saving in agricultural buildings through fan motor control by variable frequency drives, *Energy and Buildings*, **40**, 953-960.

Thollander P., Karlsson M., Soderstrom M., Creutz D., (2005), Reducing industrial energy costs through energy-efficiency measures in a liberalized European electricity market: case study of a Swedish iron foundry, *Applied Energy*, **81**, 115-126.

Thollander P., Rohdin P., Danestig M., (2007), Energy policies for increased industrial energy efficiency: Evaluation of a local energy programme for manufacturing SMEs, *Energy Policy*, **35**, 5774-5783.

Wang R., Liu W., Xiao L., Liu J., Kao W., (2011), Path towards achieving of China's 2020 carbon emission reduction target-A discussion of low-carbon energy policies at province level, *Energy Policy*, **39**, 2740-2747.

Worrell E., Martin N., Price L., (1999), *Energy efficiency and carbon dioxide emissions reduction opportunities in the US iron and steel sector*, Technical Report LBNL-41724, Ernest Orlando Lawrence Berkeley National Laboratory, Berkeley, USA.

Worrell E., Bernstein L., Roy J., Price L., Harnisch J., (2009), Industrial energy efficiency and climate change mitigation, *Energy Efficiency*, **2**, 109-123.

Zhang J., Wang G., (2008), Energy saving technologies and productive efficiency in the Chinese iron and steel sector, *Energy*, **33**, 525-537.