Proceedings of IOE Graduate Conference, 2017
Volume: 5 ISSN: 2350-8914 (Online), 2350-8906 (Print)

Energy Efficiency Improvement Potential of Dairy Development Corporation: Kathmandu Valley Milk Supply Scheme

Sudhir Bahadur Joshi, Laxman Poudel

Department of Mechanical Engineering, Pulchowk Campus, Institute of Engineering, Tribhuvan University, Nepal
Corresponding Email: sudhirjoshi198@gmail.com, p12_laxman@yahoo.com

Abstract
Industries in Nepal are facing dire condition due to energy scarcity. The demand for dairy products is increasing and with it the energy consumption and GHG emissions related to dairy processing. This paper explores the effects of introducing different technological interventions in Dairy Development Corporation (DDC) under different economic scenarios. The study uses double logarithmic regression model to forecast the production volume and LEAP framework to analyze the energy consumption and GHG emissions under different scenarios. The study indicate that the demand for milk, ghee and fresh milk increases but for butter it decreases. The final energy demand increases from 22.09 TJ in base year 2017 by 189.43% to 63.94 TJ in base case, by 151.15% to 55.49 TJ in medium economic growth and by 245.44% to 76.31 TJ in high economic growth scenarios respectively in the final year of analysis, 2030. The contribution of electricity, diesel and wood increase from 7.85 TJ, 14.37 TJ and 0.14 TJ respectively in base year to 21.39 TJ, 42.39 TJ and 0.15 TJ in the final year of analysis in base case scenario. The related GHG emissions would be 7,209.97 MT, 6,602.49 MT and 8,078.40 MT of non-biogenic CO_2. With the intervention of efficient boiler, the energy consumption would decrease to 59.03 TJ and 51.81 TJ and the GHG emissions would decrease by 90.02% and 90.31%. In the normal and medium economic growth conditions respectively. With the intervention of efficient motors, the final energy consumption would reach 61.70 TJ and 53.56 TJ under normal and medium economic growth conditions respectively. Hence, investment in implementation of energy efficient technologies in dairy industry should be promoted.

Keywords
Energy Efficiency – LEAP Framework – Scenario analysis

1. Introduction

The lack of energy has retarded the growth of the industrial sector. Dairy industry is such a sector that has a potential for growth but is facing problems due to energy crisis. Dairy industry links the agriculture and the industry sector. The improvement of dairy industries can help in the uplifting the economic condition of the farmers as well as the whole country.

Mondal et al. (2010) used the LEAP framework for industrial sector electricity demand projection of Bangladesh from 2005 to 2035 [1]. Pokharel (2007) used the econometric models for fuels and consumption sector to forecast medium-range energy demand projections till 2012 for Nepal [2]. The sectorial end use energy demand under different national economic growth scenario up to year 2030 using LEAP was studied by Bhattarai (2015) [3]. Yadav (2014) forecasted the energy demand and GHG emission for Dharan Industrial sector up to year 2030 using LEAP [4]. Geary (2010) developed a processing-sector model that estimates the product yield, net milk value, and component values of milk based on milk quantity, composition, product portfolio, and product values [5]. Xu and Flapper (2009) reviewed the energy usage in global fluid-milk markets to identify baseline information that allows comparisons of energy performance of individual plants and systems [6]. Xu and Flapper (2011) analyzed production and energy data on butter, concentrated milk, milk and whey powder processing across various countries and plants [7]. The viability of reduction of fuel consumed in dairy industries of Nepal by using solar thermal systems to heat the boiler feed water was studied by Khaiju (2010) and Kumar(2013) [8, 9]. Singh (2013) studied the effect of introducing different energy efficient technologies in the Nepalese cement industry from 2015 to 2030 using LEAP [10]. Studies related to industrial sector in Nepal is rare. Shakya (2014) analyzed the energy efficiency improving potential in different economic sectors of Nepal using bottom up cost minimization energy system model based on MARKet ALlocation model (MARKAL) framework [11]. The technical potential of improving the energy efficiency in the five economic sectors, viz. industrial, residential, commercial, transport and agricultural sectors of the country were estimated by the study. It showed that the implementation of various energy efficiency improving strategic options in all the five economic sectors can reduce the total final energy consumption by 13.3% and GHG emissions by 14.7% in 2020 compared to the base case scenario.

This study analyzes the potential of reducing the final energy use and the GHG emission of Kathmandu Milk Supply Scheme of Dairy Development Corporation by implementing energy efficient technologies.

1.1 Demand for Dairy Products

The demand for dairy products has been studies worldwide since the early 80's. The demand for dairy products depends on the economic, geographic as well as demographic factors. Sharma (2002) showed that nearly 66% of urban and 23% of rural households purchased milk [12]. The lower share in rural area reflects the fact that many rural households keep dairy animals. Manandhar (2014) showed that the daily demand for milk was 8.2 million liters and the daily supply was 4.26 million liters [13]. The demand for dairy products is increasing at a rate of 8% per annum but the production is increasing at only 3%.

1.2 Energy Use and GHG emission in Dairy Industries

The demand for energy depends on the processes or devices that use the energy. The energy requirements in industries is broadly classified as motive energy requirement and thermal energy requirement. The motive energy, used in electric motors that drive other equipment, is supplied by electricity. In addition to machine drives, the primary uses of electricity in the dairy processing industry are for process cooling, cold storage as well as lighting. The thermal energy needs are mainly met by steam generated in boiler by combustion of fuels, petroleum as well as biomass [14]. Thermal energy accounts for around 80% of the energy consumed in dairy industries and the remaining 20% is accounted by electricity [7]. The figures range from 0.15 to 2.5 GJ for electricity and 0.18 to 1.5 GJ for thermal energy per ton of milk for European dairy industries. The annual emissions from the plants were estimated to be between 50 and 100 g CO_2 per kg milk. The baseline study conducted in 9 dairy industries by NEEP (2012) found the electrical energy intensity varied from 0.132 to 0.815 GJ/t, average Specific Energy Consumption (SEC) being 0.269 GJ/t of electricity and thermal energy intensity varied from 0.174 to 2.841 GJ/t, average being 0.859 GJ/t [15]. The CO_2 emission was found to be 79.64 kg/t of processed milk. The large variation in thermal energy consumption between the two studies is because the thermal energy use is higher for processes like drying and evaporation which is used for production of powdered milk and condensed milk, which are not made in Nepal.

1.2.1 Energy Use in DDC

From the survey it was found that DDC:KMSS used around 954 kl of diesel and around 3.43 TJ of electricity from national grid annually. 141 kl of diesel was used in generators for electricity generation and remaining was used for steam generation in boiler. So, the total electricity consumption amounts to around 7.85 TJ.

1.2.2 GHG emissions in DDC

The annual GHG emissions from DDC due to combustion of diesel for steam generation in boilers and power generation in generators was calculated to be 1,201.72 MT.

1.3 Energy Efficiency Opportunities

Improving energy efficiency of the processes in dairy industries is cost effective and profitable with added benefit of reduced GHG emissions[16]. Energy can be saved by installing new equipment with higher energy efficiency or renovating old equipment. Some of the energy efficiency techniques relevant to dairy industries is discussed below

- Improvement in motor loading
- Replacement of old motors by energy efficient motors
- Improvement in insulation of the pipelines and storage area
- Installation of capacitor banks
- Improvement in combustion efficiency in boilers
- Installation of economizer for waste heat recovery
- Minimization of steam leakages
- Condensate recovery

2. Methodology

2.1 Description of modeling approach

A double logarithmic regression model was developed in spreadsheet for forecasting the production. The results of the regression analysis were used in LEAP for forecasting the final energy use and the GHG emissions under different scenarios. Simulation was done for the period of 14 years from 2017 to 2030. The energy end use demand was categorized into products, lighting, comfort, office equipment and Cleaning In Place (CIP). The products include fluid milk, butter, ghee and fresh milk. The energy use in products was further classified into thermal, motive and refrigeration needs. The electrical energy use was divided into existing and efficient technology and the thermal energy was divided into diesel and biomass for scenario analysis.

2.2 Model Development

Double-logarithmic multiple regression model was used to examine the major determinants of aggregate dairy consumption. Population, GDP, Industrial GDP and food expenditure share of GDP were used as independent variables to develop the regression equation. Annual production was assumed to be dependent on one or more of the independent variables. Demographic data were collected from [17] and economic data from [18] and data related to production and energy consumption were collected through site visits. The collected data were used to develop econometric models for the projection of milk production using regression analysis in spreadsheet. The production volume of individual products was analyzed separately. Some products were found to be dependent on GDP only while others were found to be dependent on population and industrial GDP. The equations used for forecasting are given below.

$$\begin{aligned} log(Fluid) = 65.06 - 0.72 \times log(Food) \\ - 4.72 \times log(Population) \\ + 3.65 \times log(GDP) \end{aligned} \tag{1}$$

$$log(Ghee) = 8.21 + 0.56 \times log(GDP) \tag{2}$$

$$log(Freshmilk) = 10.19 + 0.11 \times log(GDP) \tag{3}$$

$$log(Butter) = 7.39 + 0.87 \times log(GDP) \tag{4}$$

Where, *Fluid*, *Ghee*, *Freshmilk* and *Butter* are the annual production volume of fluid milk, ghee, fresh milk and butter respectively. *GDP* is the National GDP in constant 2000 prices, *Food* if the food expenditure share of GDP and *Population* is the total population of the Kathmandu Valley.

The energy demand was calculated as the product of economic activity and specific energy consumption) for the activity as shown in equation below:

$$Energy\ Demand_i = SEC_i \times Total\ Production_i \tag{5}$$

Where, Energy $Demand_i$ is the annual energy demand for product i, SEC_i is the specific energy consumption for product i and Total $Production_i$ is the annual production of product i.

The SEC for each product was calculated for a year based on the ratings of equipment and hours of operation and assumed to remain same in all scenarios. The equation for specific energy consumption for each product is given below:

$$SEC = \frac{\sum_{i=1}^{n} E_i}{P} \tag{6}$$

Table 1: Specific Energy Consumption for different processes

S.N.	Process	Electrical SEC	Thermal SEC
1	Fluid milk	263.00 kWh/kl	0.6 MJ/kl
2	Butter	43.56 kWh/t	88 MJ/t
3	Ghee	1.53 kWh/kl	1359 MJ/kl
4	Fresh milk	0.45 kWh/kl	167 MJ/kl
5	CIP		
i	Tanker	2.68 kWh/kl	119 MJ/kl
ii	Equipment	3.85 kWh/kl	179 MJ/kl

Where, E_i is the actual energy usage of process step i, P is the total actual volume or mass of product and n is the number of process steps to be aggregated. The electrical and thermal SEC for the products obtained from calculation are shown in Table1.

2.3 Description of Scenarios

The study considered seven scenarios : the base case, two economic growth scenarios and two technology intervention scenarios under each economic growth scenario.

Business-As-Usual Scenario
"Business-as-usual" (BAU) scenario, which assumes that the economy develops at the present condition with no technological or policy intervention is the base case scenario. This is the reference scenario with which the alternative scenarios are compared. In this case, the real GDP (at constant 2000/2001 prices) is assumed to grow at an annual compounded growth rate (ACGR) of 4.3% throughout the period of analysis.

Economic Growth Scenario
The economic growth scenario considered two different economic development paths, viz. medium GDP growth and high GDP growth. GDP is considered to grow at 5.6% and 6.5% in the Medium growth (MED) and High growth (HIG) scenarios respectively. The share of technology in the economic growth scenario is assumed to remain same as in the base case scenario.

Technology Intervention Scenario
Technology Intervention scenario considered the effects of implementing the efficient technologies for improving energy efficiency and controlling environmental pollution at normal and medium economic growth scenarios. The scenario considers that the plant will operate at current level of BAT by 2030. The share of efficient technologies is assumed to reach 33% by 2020, 66% by 2025 and 100% by 2030. In the efficient motor scenarios (MOT and MMO), standard motors are assumed to be replaced by efficient motors and in the efficient boiler scenarios (BOI and MBO), diesel boiler is assumed to be replaced by biomass boiler.

3. Results and Discussion

3.1 Projection of Production demand

The demand for fluid milk would increase from 46.55 million liters in base year 2017 to 138.47 million liters in BAU, to 119.88 million liters in MED and to 165.68 million liters in HIG scenarios respectively. The demand for butter would decrease from 251.34 thousand kg to 55.03 thousand kg in BAU, to 60.73 thousand kg in MED, and to 48.68 thousand kg in HIG scenarios respectively. The demand for ghee would increase from 148.14 kiloliters in base year to 225.48 kiloliters, 219.42 kiloliters and 233.26 kiloliters in BAU, MED and HIG scenarios respectively. The demand for fresh milk, which was 54.21 in the base year would increase to 58.65 kiloliters in BAU, 58.34 kiloliters in MED and to 59.03 kiloliters in HIG scenarios respectively. The details of the simulation are provided in Table 2

3.2 Final Energy Demand

The final energy demand in the base year 2017 is 22.09 TJ. The growth of final energy demand in different scenarios are shown in Figure1 and are discussed below:

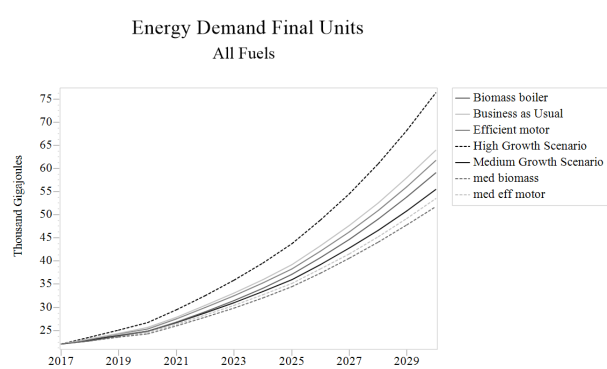

Figure 1: Final Energy Demand

Business-As-Usual Analysis

Table 2: Production Forecast

S.N.	Product	Scenarios	2017	2020	2025	2030	Ann. Avg Growth (%) 2017-30
1		BAU	46.55	54.35	84.20	138.47	8.75%
2	Fluid milk	MED	46.55	52.57	77.05	119.88	7.55%
3		HIG	46.55	56.65	94.03	165.68	10.26%
4		BAU	251.34	177.03	98.70	55.03	-11.03%
5	Butter	MED	251.34	181.10	104.87	60.73	-10.35%
6		HIG	251.34	172.08	91.52	48.68	-11.86%
7		BAU	148.14	163.22	191.84	225.48	3.28%
8	Ghee	MED	148.14	162.20	188.65	219.42	3.07%
9		HIG	148.14	164.50	195.89	233.26	3.55%
10		BAU	54.21	55.13	56.86	58.65	0.61%
11	Freshmilk	MED	54.21	55.07	56.68	58.34	0.57%
12		HIG	54.21	55.22	57.09	59.03	0.66%

The final energy use is estimated to rise at an annual average growth rate (AAGR) of 8.52% during 2017-2030. As a result, the final energy consumption is found to increase from 22.09 TJ in 2017 to 59.49 TJ in 2030. The share of fuel being 7.58 TJ supplied by electricity and 14.37 TJ supplied by diesel and 0.14 TJ supplied by wood in the base year. The fuel share in 2030 would be 21.40 TJ from electricity, 42.39 TJ from diesel and 0.15 TJ from wood as shown in Figure2.

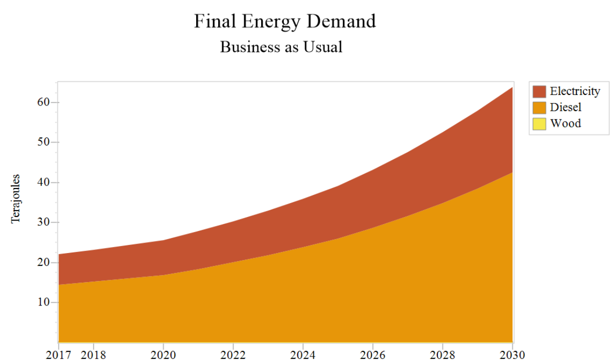

Figure 2: Final Energy Demand in BAU Scenario

Economic Growth Scenario

In the medium economic growth scenario, the final energy demand would increase at AAGR of 7.34% as shown in Figure 3. The share of fuel in the final year would be 18.60 TJ from electricity, 36.74 TJ from diesel and 0.15 TJ from wood. As shown in Figure4, the final energy demand would increase at AAGR of 10.01% in the high economic growth scenario. The share of fuel in the final year would be 25.50 TJ from electricity, 50.67 TJ from diesel and 0.15 TJ from wood.

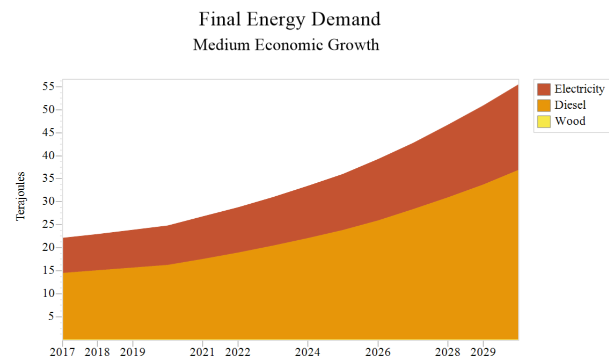

Figure 3: Final Energy Demand in Medium Economic Growth Scenario

Technology Intervention Scenario

In the efficient boiler scenario, the final energy consumption in 2030 would reach 59.70 TJ under normal economic growth condition and 51.81 TJ under medium economic growth condition. As seen in Figures 5 and 6, the fuel share of electricity, wood and diesel in the final year would be 21.40 TJ 0.15 TJ and 38.15 TJ under normal economic growth and 18.60 TJ, 0.15 TJ and 33.06 TJ under medium economic growth condition respectively.

The final energy consumption for efficient motor

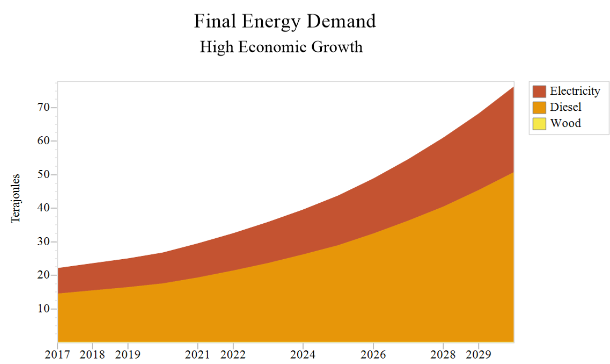

Figure 4: Final Energy Demand in High Economic Growth Scenario

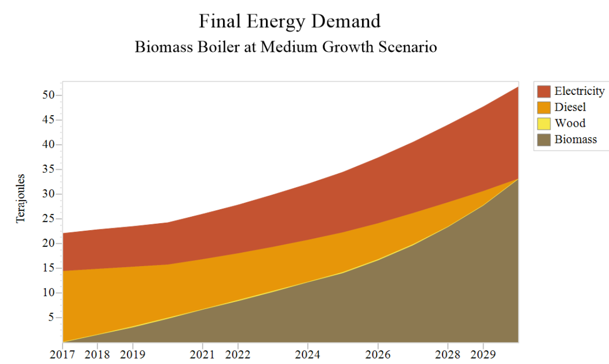

Figure 6: Final Energy Demand in Efficient Biomass in Medium Economic Growth Scenario

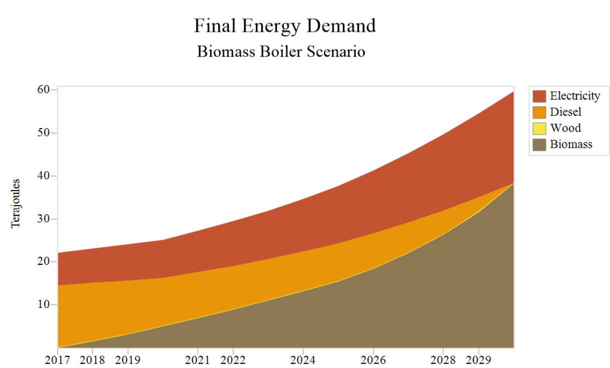

Figure 5: Final Energy Demand in Efficient Biomass in Normal Economic Growth Scenario

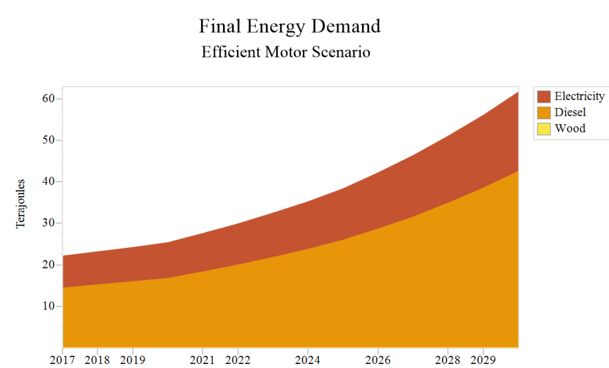

Figure 7: Final Energy Demand in Efficient Motor in Normal Economic Growth Scenario

scenario in normal economic growth and medium economic growth are shown in Figures 7and 8 respectively. The final energy consumption would reach 61.70 TJ under normal growth condition and under medium economic growth condition, it would reach 53.56 TJ. The fuel share under normal economic growth condition would be 19.16 TJ from electricity, 42.39 TJ from diesel and 0.15 TJ from wood. Under medium economic growth condition, the fuel share would be 16.67 TJ for electricity, 36.74 TJ from diesel and 0.15 TJ from wood.

3.3 GHG emission

The GHG emission increases without efficient biomass boiler intervention. It increases from 1042.65 MT in base year and reaches 3075.67 MT, 2665.32 MT and 3676.31 MT Under the BAU, MED and HIG scenarios respectively. Under the intervention of efficient biomass boiler, the GHG emission decreases and reaches zero in the final year of analysis. The emission decreases at an AAGR of 90.20% in the normal growth scenario and 90.31% in the medium growth scenario as shown in Table 3. The reduction in cumulative emission from 2017 to 2030 in normal growth scenario would be 4715.01 MT compared to BAU and in medium growth it would be 4794.99 MT.

4. Conclusion

From the study, it is found that production of dairy products would continue to increase in future except for butter. With the increase in production, the energy consumption and the GHG emissions would also increase. The major conclusions are:

- The demand for fluid milk would increase at the highest rate annually ranging from 7.55% in

Table 3: GHG Emission Forecast (MT)

Scenarios	2017	2020	2025	2030	Cumulative	Ann. Avg Growth (%) 2017-30
BAU	1,042.65	1,215.58	1,876.07	3,075.67	7,209.97	8.68%
MED	1,042.65	1,176.30	1,718.22	2,665.32	6,602.50	7.49%
HIG	1,042.65	1,266.33	2,093.11	3,676.31	8,078.40	10.18%
BOI	1,042.65	814.44	637.86	-	2,494.95	-90.20%
MOT	1,042.65	1,215.58	1,876.07	3,075.67	7,209.97	8.68%
MBO	1,042.65	788.12	584.19	-	2,414.97	-90.31%
MMO	1,042.65	1,176.30	1,718.22	2,665.32	6,602.50	7.49%

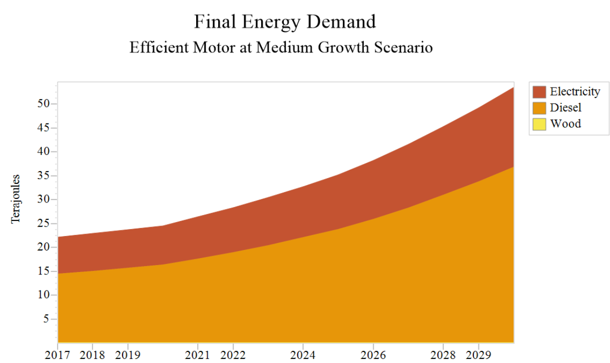

Figure 8: Final Energy Demand in Efficient Motor in Medium Economic Growth Scenario

medium growth scenario, to 10.26% in high economic growth scenario. The demand for ghee and fresh milk would increase annually at rates of 3.28±.20% and 0.61 ±.05% while for butter, the demand would decrease at rate of -11.03±.70%

- The final energy consumption for production of dairy products would increase annually at rates ranging from 7.34% to 10.01% reaching upto 76.31 TJ in high economic growth scenario.
- Intervention of energy efficient motors and efficient boiler can save upto 14.61 TJ and 24.5 TJ of energy respectively compared to high economic growth scenario.
- Intervention of biomass boiler can reduce the cumulative GHG emission by 3676.31 MT compared to high economic growth scenario.

There is an opportunity to save huge amount of energy as well as GHG emissions by implementing energy efficient technologies in the dairy industries of Nepal. So, investment in implementation of energy efficient technologies should be promoted.

Acknowledgments

Authors gratefully acknowledge the support from Dairy Development Corporation: Kathmandu Milk Supply Scheme and Dr. Shree Raj Shakya.

References

[1] Manfred Denich Md. Alam Hossain Mondal, Wulf Boie. Future demand scenarios of bangladesh power sector. *Energy Policy*, 38:7416–7426, Nov 2010.

[2] Shaligram Pokharel. An econometric analysis of energy consumption in nepal. *Energy Policy*, 35:350–361, Jan 2007.

[3] Nawraj Bhattarai and Iswor Bajracharya. Industrial sector's energy demand projections and analysis of nepal for sustainable national energy planning process of the country. *Journal of the Institute of Engineering*, pages 50–66, 2015.

[4] Ram D Yadav and Rajendra Shrestha. Energy demand and green house gas emission forecast and scenario analysis of dharan industrial sector, nepal. In *Proceedings of IOE Graduate Conference*, pages 316–323. Institute of Engineering, 2014.

[5] Dorian J Garrick Una Geary, Nicolas Lopez-Villalobos and Shalloo Laurence. Development and application of a processing model for the irish dairy industry. *Journal of Dairy Science*, 93:5091–5100, 2010.

[6] Tengfang Xu and Joris Flapper. Energy use and implications for efficiency strategies in global fluid-milk processing industry. *Energy Policy*, 37:5334–5341, Dec 2009.

[7] Tengfang Xu and Joris Flapper. Reduce energy use and greenhouse gas emissions from global dairy processing facilities. *Energy Policy*, 39:234–247, 2011.

[8] Prakash Khaiju. Replacement viability of thermal energy requirement by solar thermal energy system for industries (case study of dairy industries). Master's thesis, Institute of Engineering, Tribhuvan University, 2010.

[9] Ramendra Kumar. Study on diesel fuel consumption reduciton in dairy industries by application of solar thermal energy. Master's thesis, Institute of Engineering, Tribhuvan University, 2013.

[10] Pradeep Singh. Study in the effect of implementing best available technology in cement industries of nepal. Master's thesis, Institute of Engineering, Tribhuvan University, 2013.

[11] Shree Raj Shakya. *Energy efficiency improvement potential of Nepal*. Energy System Planning and Analysis. Centre for ENergy Studies (CES), 2014.

[12] Bikash Sharma and Kamal Banskota. *Smallholder dairy in mixed farming systems of the Hindu Kush-Himalayas*, chapter Smallholder dairy farming in Nepal: Characteristics, constraints, and development opportunities. ICIMOD, 2002.

[13] Narayan Manandhar. The milky way, 2014.

[14] Eric Masanet Adrian Brush and Ernst Worrell. Energy efficient improvement and cost saving opportunities for the diary processing industry. Report, AdrianErnest Orlando Lawrence Berkeley National Laboratory, Oct 2011.

[15] NEEP/GIZ. Baseline study of selected sector industries to assess the potentials for more efficient use of energy, 2012.

[16] IPPC. Reference document on best available techniques in the food, drink and milk industries, 2006.

[17] Central Bureau of Statistics. National population and housing census 2011, 2011.

[18] Ministry of Finanace. Economic survey 2014, 2014.