Analysing the Potential of Renewable Energy Use in the Textile Sector of Pakistan

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4 August 2015

A Major Paper submitted to the Faculty of Environmental Studies in partial fulfillment of the requirements for the degree of Master in Environmental Studies

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Abstract

Pakistan is an energy deficient country. The gap between energy supply and demand is growing continuously. Major factors behind its energy problems are: lack of infrastructure and planning; high dependence on imported fuels; chaotic law and order situation; and political instability. Pakistan's energy problems are resulting in lower economic and industrial growth.

This research reviews the energy profile of Pakistan, and investigates the potential and viability of renewable energy options for the Pakistan's textile industry. The textile sector is the backbone of Pakistan's economy. Renewable energy options such as wind, photovoltaic (PV), and solar thermal were investigated for this report. The research concludes that solar PV system is a financially viable option for replacing diesel sourced power generation. Finally, the research proposes a policy framework for the effective application and dissemination of renewable energy in Pakistan.

Acknowledgments

Deep appreciation is extended to my advisor/supervisor Dr. Jose Etcheverry for his guidance and support throughout my studies and major research paper. It could not have been possible for me to complete this intricate task without his mentoring. His effective coaching during studies and as an advisor enabled me to develop research skills along with in-depth understanding of climate change impacts. I am very thankful to him for his time and efforts and for being such a wonderful mentor.

I am also thankful to my family members for supporting and encouraging me through out this journey. Special thanks to my husband and sons (Rafay and Wasay) for extending their love, affection, and encouragement during this research.

I highly appreciate the collaboration of Cleaner Production Institute (CPI) for field survey assistance and access to their database. And last but not the least, I would like to offer my deep appreciation to Adnan Khan-Electrical Engineer of CPI for assisting me during the site surveys, data collection, and technical analysis of the research.

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List of Abbreviations

ADB	Asian Development Bank
AEDB	Alternative Energy Development Board
AE	Alternative Energy
AFOLU	Agriculture, Forestry and Other Land Use
APTPMA	All Pakistan Textile Processing Mills Association
ARE Policy	Alternate and Renewable Energy for Power Generation Policy
AR5	IPCC's fifth assessment report
Bcfd	Billion cubic feet per day
BOD	Biochemical oxygen demand
CNG	Compressed Natural Gas
COD	Chemical oxygen demand
CPI	Cleaner Production Institute
EAP	Environmental Action Programme
ECCP	European Climate Change Programme
EE	Energy Efficiency
EJ	Exajoules
ETS	Emissions Trading Scheme
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FIT's	Feed in Tariffs
GDP	Gross Domestic Product
GHG	Greenhouse gases
GJ	Gigajoule
GOP	Government of Pakistan
$GtCO_2$	Giga tons of carbon dioxide
GWEC	Global Wind Energy Council
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IPP's	Independent power producers
IRENA	The International Renewable Energy Agency
IUCN	International Union for Conservation of Nature
POS	Plan of study
PV	Photovoltaic
RD & D	Research, development & demonstration
REDD	Reducing Emissions from Deforestation and Forest Degradation
RE	Renewable energy
RET's	Renewable energy technologies
KP	Kyoto Protocol
KWh	Kilowatt-hour
LESCO	Lahore Electricity Supply Company
Mmcfd	Million meter cubic feet per day
MT	Million tons
MW	Megawatt
NAPRA	National Power Regulatory Authority
NG	Natural Gas
SLCP's	Short-lived climate pollutants

SNGPL	Sui Northern Gas Pipelines Limited
SRES	Special Report on Emissions Scenarios
TDS	Total dissolved solids
TOE	Ton of oil equivalent
TSS	Total suspended solids
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organization
WAPDA	Water And Power Development Authority (Pakistan)

Foreword

This paper connects well with my plan of study titled ‘analyzing climate change impacts, mitigation and adaptation strategies for Pakistan’. My research aims at evaluating a practical solution that helps to secure energy supply especially in the textile sector of Pakistan while minimizing the GHG emissions that cause climate change.

The learning objectives of my plan of study (POS) have been comprehensively achieved by the research. Initially, I achieved the learning objectives by taking the best available courses aligned with my POS. After my coursework was successfully completed this focused research was conducted to achieve the key learning objectives of my POS described below.

Component 1 of my POS is titled ‘Impacts of Climate on Physical Resources’. The two learning objectives of the component are as follows:

1.1 To learn about the physical impacts of climate change in Pakistan.

1.2 To identify the impacts of climate change on the physical resources of Pakistan.

Learning objectives 1.1 and 1.2 were covered in Chapter 2. The physical impacts of climate change on physical resources have been described and analysed in this Chapter. Component 2 of the POS titled ‘Socio Economic Impacts of Climate Change’. The key learning objective of component 2 was to learn about the socio-economic impacts of climate change on the vulnerable sectors of Pakistan. Chapter 2 describes and quantifies the vulnerability of socio-economic sectors linked to climate change impacts.

Component 3 'Mitigation and Adaptation Strategies to Manage Climate Change Impacts' targeted following four learning objectives:

3.1 To explore and learn about the best short, medium, and long-term mitigation and adaptation strategies for Pakistan

3.2 To study short, medium, and long-term mitigations and adaptation strategies for Pakistan;

3.3 To study local level adaptation based solutions to mitigate the impacts of climate change in Pakistan; and

3.4 To determine the potential of renewable energy solutions for industry in general and specifically in the textile sector of Pakistan.

Chapter 2 also covered learning objectives 3.1 and 3.2. These learning objectives were achieved by reviewing large set of literature published in Pakistan and at the international level. The major focus of the review was to assess the potential of renewable energy as mitigation for the climate change. In addition climate-resilient pathways and transformation were also critically studied in context of Pakistan. Chapter 3 focussed on the potential of renewable energy in Pakistan. Learning objective 3.3 is comprehensively covered in Chapter 3. This objective is achieved by determining the potential of renewable energy such as hydro, wind, solar (PV), solar thermal, and biomass in Pakistan. Learning objectives 3.3 is further achieved by assessing the potential of renewable energy as climate change mitigation for Pakistan. To achieve the same learning objective, the renewable policy framework of Pakistan was critically reviewed on the basis of local conditions. In the end major barriers responsible for limited application of renewable energy in Pakistan have been identified.

Chapter 4 Potential of Renewable Energy in Sarena Industry covers learning objective 3.4 to enhance my learning about the potential of renewable energy solutions for industry in general and more specifically in the textile sector of Pakistan, field research was conducted in Sarena in Pakistan. Their industrial production processes and energy management system were studied comprehensively. RETScreen software was used to analyse the potential of renewable energy sources as replacement to conventional energy sources (i.e. grid-based electricity, diesel, biomass and natural gas). Several recommendations for enhancing the policy framework of renewable energy in Pakistan have been developed on the basis of my comprehensive learning in line with my POS research goals.

Climate change is a global issue with respect to the scale of its impacts; however, the distribution and magnitude of impacts will differ in different continents and regions. Pakistan's contributions of GHG emissions at the global level are nominal. Whereas Pakistan is one of the most vulnerable countries that is exposed to climate change impacts. According to the 'Global

Climate Risk Index 2013', Pakistan is listed as the 3rd most affected country (1st is Thailand and Cambodia is 2nd) (Harmeling, S. & Eckstein, D., 2013).

Pakistan is located on marginal lands with high economic dependence on primary products. Its ever-increasing population with higher concentrations of low-income people and poor institutional capacity are additional compounding problems. These factors will increase the severity of anticipated climate change impacts in Pakistan.

Currently Pakistan is facing one of the worst energy crises in its history of 66 years. This acute electricity shortage is not only hampering economic growth but also causing public unrest in a country of 180 million citizens (Shabbir H. Kazmi, 2013).

The industrial sector of Pakistan is a major contributor towards the country's gross domestic product (GDP). The textile industry is the biggest export sector of Pakistan that is considered as the backbone of Pakistan's economy and a leading consumer of energy. The textile sector is hit hard due to the ongoing energy crisis.

Thus my research paper aims to understand the solutions of mitigation and adaptation to cope with climate change impacts and to investigate alternative energy solutions to address the ongoing energy crisis.

The outcomes of this research paper might be applicable for other industrial sectors of Pakistan. The research results presented in this paper might be useful for government policy makers, national and international financial institutions, and key stakeholders (end users, manufacturer’s and suppliers) of the renewable energy sector.

Chapter 1: Introduction

1.1 Objective of the study

This research paper is focused on analysing the potential of maximizing the use of renewable energy in the textile sector of Pakistan. Renewable energy options can satisfy energy needs and also mitigate the adverse impacts of climate change by reducing the CO_2 emissions caused by the burning of fossil fuels. This research is directly related to my POS area of concentration i.e. analyzing climate change impacts, mitigation and adaptation for Pakistan. The paper identifies physical and socio-economic impacts based on a literature review and fieldwork. The specific learning objectives of the research study are:

1. To understand the most promising short, medium, and long term GHG mitigation strategies available for Pakistan; and
2. To focus on specific local-level solutions that help satisfy energy requirements for the textile sector in a reliable and environmentally sound manner.

1.2 Research Context

According to the IPCC (2014), it is evident that climate change has adversely affected all continents and oceans of the world. Major adverse effects have already occurred on both natural and human systems and sectors including water resources (i.e. fresh water resources, terrestrial and freshwater ecosystems, coastal systems and low-lying areas, marine systems). Climate change will affect food security and food production systems, urban areas, rural areas, human health, human security compromising livelihoods and exacerbating poverty (IPCC, 2014a). The latest study by the IPCC warns that we are only 15 years away from surpassing the estimated safe threshold level of 2°C rise in global temperatures (Robert Savio, 2014).

Climate change is expected to occur at the global level with a variety of impacts, magnitude and diverse rates of change in continents, countries and regions. A few nations will likely experience more adverse effects than others. Some countries may benefit from climate change. However, developing countries are the most vulnerable to climate change. It is clear that disposed and low-income people worldwide will be affected the most and since women are over-represented in those two groups they will be affected more than men.

Another significant aspect worth highlighting is that about half of the total global population is below the age of 30; therefore young generations will be the ones who will suffer the most from climate change (Robert Savio, 2014).

One of the great challenges faced by the world in the near future will be to manage the energy crisis and climate change along with economic development. The energy sector is one of the vital drivers of economic development for all countries. Fossil fuel based energy is the most important source causing climate change and many environmental issues such as air pollution and health issues. Renewable energy is widely considered as an environmental friendly solution to fossil fuel based energy (KAS, 2007). Worldwide the energy system is experiencing transition and exploring new and environmental friendly alternatives other than the conventional energy sources. The renewable energy industry is growing at a surprisingly fast pace and speed over the last decade. It is now quite evident that, RE can play a positive role by helping to address economic, social and environmental goals simultaneously throughout society (IRENA, 2014c).

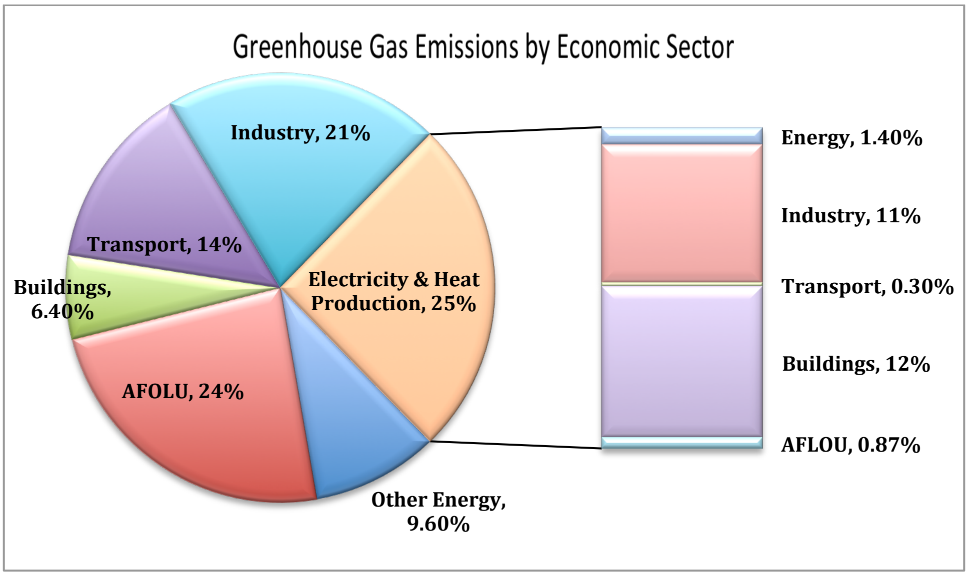
The economic benefits of RE can be felt throughout society, from new business generation and employment to the cost savings from fuel imports. In 2010, Spain cost saving from fossil fuel import was USD$ 2.8 billion and Germany avoided USD$ 13.5 billion of fossil fuel import by developing its RE sources for energy generation. Social benefits of RE includes poverty reduction due to the direct and indirect jobs generated from the economic activity of the RE industries in addition to upgrading of social well being by providing electricity to off grid regions. In 2013 alone the RE sector generated about 6.5 million direct and indirect jobs worldwide. RE benefits the environment by cutting down the GHG emissions from fossil fuel sourced energy generation and also helps to avoid ecological disasters (IRENA, 2014c).

This solution has become internationally recognized with the creation of the International Renewable Energy Agency, which now has more that 140 member nations including Pakistan.

Even if climate change was not an issue, there would still be enough valid reasons to develop renewable energy resources (Scheer, 2007). The strongest reason being the fact that fossil fuels are not renewable and will be depleted. For this reason alone, what we need is to start a new era referred by Amory Lovins as 'reinventing fire' (Lovins, 2011).

Emissions data for 2010 in Figure 1.1 shows the main contributors to global GHG emissions (IPCC, 2014).

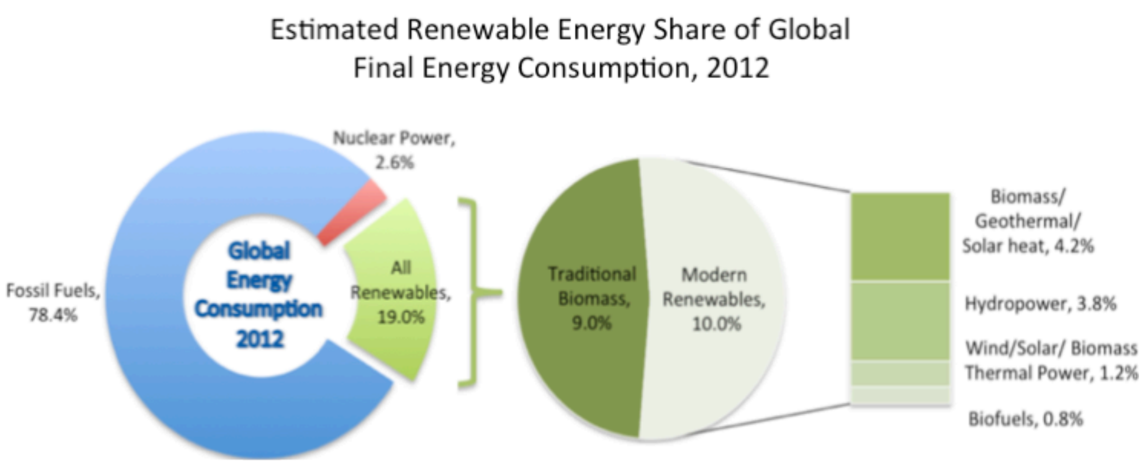
Figure 1.1: Global Greenhouse Gas Emissions by Economic Sector.
Source: (IPCC, 2014).



** AFLOU: The emissions data from Agriculture, Forestry and Other Land Use (AFOLU) includes land-based CO2 emissions from forest fires, peat fires and peat decay.*

Renewable Energy (RE) is a key strategy to reduce the energy related GHG emissions summarized in Figure 1. RE comprises a diverse class of technologies including biomass, direct solar energy, geothermal, hydropower, ocean energy and wind energy. Various types of RE can supply electricity, thermal energy and mechanical energy, to cater to society's multiple energy needs. A number of RE technologies such as photovoltaic (PV) and wind turbines are technically mature and are being used at a significant scale worldwide. Further technological advances in this field are being explored (IPCC, 2011). Figure 1.2 shows the share of renewable energy in the global energy consumption.

Figure 1.2: Estimated Renewable Energy Share of Global Final Energy Consumption.
Source: (IRENA, 2014a).



Due to constantly growing energy demand, investments in research, development & demonstration (RD & D) for renewable energy (RE) technologies have increased sharply particularly during the last decade. In

2011 RE accounted for 19% of the total global electricity generation (IEA, 2013a). Substantial cost reduction due to mass production and continuous performance improvements are proving RE options to be economically viable and a sustainable option to address global energy demand.

For developing nations, a combined strategy involving energy conservation, energy efficiency and renewable energies will serve as an environmentally, socially and economically sustainable energy path (Holm et al, 2010).

In the case of fossil fuel-importing countries, like Pakistan, the need for energy efficiency and renewable energy sources has become urgent. Renewable energy sources and energy efficiency should be supported for the following reasons (Ilhan Ozturk, 2014):

- *For energy supply security and diversification of energy sources;*
- *Reducing dependence on energy imports;*
- *To fight against climate change, reducing carbon dioxide emissions, creation of new jobs, contributing to local and regional development (contributing to economic and social cohesion).*

1.3 Overview of Research Study Area

Since its independence in 1947 from British India, Pakistan has been struggling with political instability, geographical conflicts and economic insecurity. The current population of Pakistan is estimated to be more than 196 million. Pakistan is the 7th most populous country globally (CIA, 2014).

Although Pakistan is blessed with a variety of landscapes and a wide range of natural resources to support its economy a series of geographical disputes and years of political instability have resulted in limited foreign investment, which in turn has affected economic growth within the country.

More recently, the September 2014 flash floods in Pakistan along with ongoing political unrest (sit-ins and protests by opposition parties) are adding additional stress to the unstable economy of Pakistan.

1.4 Pakistan's climate change risks and energy challenges

Pakistan is one of the most vulnerable countries to the effects of climate change due to multiple reasons such as: widespread poverty; a geographical location on marginal lands; a high dependence on all kinds of imported products; high population density; lack of institutional capacity; and an ongoing economic crises due to poor governance and political instability.

According to the 2013 Global Climate Risk Index, Pakistan is listed as the third most exposed country in the world (Thailand is ranked first and Cambodia second). That ranking provides a stern warning and highlights the serious level of exposure and vulnerability that Pakistan faces in relation to extreme climate events in the future (Harmeling, S. & Eckstein, D., 2013).

In 2010-2011, The Pakistani Ministry of Environment carried out a study titled 'National Economic, Environment and Development Study' (NEEDS) with the help of consultants and with the financial support from the Secretariat of the United Nations Framework Convention on Climate Change (UNFCCC). According to that report, water resources, agriculture, livestock, forestry, biodiversity, coastal zones, energy and industry are the sectors that will be most affected due to climate change (Khan and Malik, 2012).

In addition, Pakistan is currently facing one of the worst energy crises of its 66 years history as an independent nation. Acute electricity shortages are not only hampering economic growth but are also causing public unrest in a country of almost 200 million citizens (Shabbir, 2013). Pakistan's daily peak electricity production in 2012 was just 9,000 megawatts (MW) against a latent demand estimated at 15,000 MW (Ebrahim, 2012). Although Pakistan has an installed capacity of around 23,500 MW as of June 2012, the gap between supply and demand has reached 8,500 MW (Martin, 2013). That gap and gas shortages have caused production capacity in vital industries to drop by 50 percent, causing great economic losses (Shabbir, 2013). According to the Punjab government's 2012-2013 budget, more than 1,300 small to medium sized businesses were shut down and 330,000 thousand people lost their jobs resulting in a loss of $1 billion in the province of Punjab alone (Martin, 2013).

The gap between the demand and supply of natural gas is also widening resulting in an acute shortage especially in winters (used for heating purposes). Sui Northern Gas Pipelines Limited (SNGPL) serves about 4.4

million consumers including domestic, compressed natural gas (CNG) and industrial consumers. At present the overall shortage of natural gas is about 1,400 million meter cubic feet per day (mmcfd). The gap between supply and demand is around 2 billion cubic feet per day (bcfd) and under business as usual scenario would reach around 8.5 bcfd by 2028-29 according to the Oil and Gas Regulatory Authority (Ogra) of Pakistan. Punjab province with its industrial sector (60% of the total) contributes 65% towards the national GDP and is suffering the most due to this natural gas shortage. This shortage has left hundreds of workers jobless due to closures of small industrial units from all sectors. The textile industry experienced a drop of 4% in exports and 25% in its production (Ijaz, A., 2015).

The current energy crisis is due to the combination of various factors including rapid population increases, urban sprawl, energy mismanagement at all levels and a lack of foreign currency to import fuel (Martin, 2013). The national budgetary deficit for fiscal year 2012 was estimated to be about US $8.7 billion, which represents approx. 4% of Pakistan's Gross Domestic Product (GDP) (Govt. of Pakistan & USAID, 2013). Furthermore, energy mismanagement has escalated due to the absence of integrated energy policies/strategies and the unwillingness of political leaders in the past decades to address this emerging problem (Kugelman, 2013).

The current government of Pakistan was elected in mid-2013 and has formulated a new energy policy proposing short, medium and long term plans to address the energy crisis.

Short-term plans are limited and include borrowing from international financial agencies to pay off fuel companies, raise tariffs and addressing theft, loss and corruption issues. Most of the actions highlighted in the new energy policy are medium to long-term plans that will take years and decades to complete (Faiz, 2013). Importing electricity, exploring indigenous energy solutions (e.g. exploring the Thar coalfields), starting new hydropower projects/power plants and alternative energy sources are among other options considered by the government. A detailed energy generation and consumption profile of Pakistan is presented in Chapter 3.

In terms of RE development, the Quaid-i-Azam Solar Energy Project announced by the government is a positive step to resolve the energy crisis. This ten thousand acres solar park will have the electricity generation capacity of 1,000 MW or more in the future. The first phase of the project was supposed to be completed on an emergency basis and to produce 100 MW by the first quarter of 2014 (Martin, 2013). However, the project is still under construction and the first phase is not yet commissioned. A comprehensive overview of the RE sector of Pakistan is presented in Chapter 3.

1.5 Challenges of Pakistan's Industrial Sector

The industrial sector of Pakistan contributes 24.3% towards the country's GDP. The major industrial sectors of Pakistan are: textiles, leather, pulp and paper, cement, agriculture, fertilizer, steel, tobacco, edible oil, pharmaceuticals, construction materials, shrimp, sugar, food processing, chemicals and machinery (Govt. of Pakistan, 2014).

The contribution of the manufacturing industry to the GDP of Pakistan is 13.5%, out of which a major share (10.9 %) is contributed by large-scale manufacturing. The manufacturing sector employs 14.1 percent of Pakistan's labour force. The major problem faced by the manufacturing sector is the shortage of energy. In addition, the performance of the manufacturing sector is restricted due to old production technologies, poor production practices, and an unskilled labour force. The Global Competitiveness Report 2013-14 ranked Pakistan at 133 among 148 countries in the global competitiveness index. At present, Pakistan's industrial sector is operating at 33 percent of its capacity (Govt. of Pakistan, 2014).

1.6 Research Questions

The specific questions of the research are as follows:

1. What is the potential of using renewable energy in the textile sector of Pakistan?
2. What is the financial viability of using renewable energy in the textile sector of Pakistan?
3. What are the technological requirements for the adoption of renewable energy in the textile sector of Pakistan?

4. What is the business case for the adoption of renewable energy in the textile sector of Pakistan?
5. What are the environmental and social benefits of adopting renewable energy technologies in the textile industry in Pakistan?

1.7 Research Significance to Knowledge Mobilization in Pakistan

The research has been conducted in collaboration with the Cleaner Production Institute (CPI) of Pakistan. CPI is at present working with more than 300 industrial units and most of those units belong to the textile, leather, pulp & paper, and sugar sectors. These industrial units are very interested in understanding the potential of adopting renewable energy technologies.

Pakistan's energy crisis in the recent years has reduced the country's industrial production capacity and the increasing gap between power demand and supply has resulted in load shedding throughout the country. Load shedding hampers industrial activities and restrains economic growth. The Pakistani government is under great pressure to explore new strategies for energy generation and renewable energy represents a key solution.

At present, many industries in Pakistan are using biomass as an alternative fuel source for boilers. All the sugar mills are using bagasse as their main source of energy. The cement industry is using municipal and industrial waste for power generation. A few industries are using solar thermal sources for partially increasing the intake temperature of process water. Small numbers of industries are using wind energy for generating electricity for lighting purposes in the Karachi zone.

The textile industry is the backbone of Pakistan's economy and a leading consumer of energy. Textile companies are the largest industrial sector of Pakistan with respect to production, export and labour force employment. Pakistan is the 8th largest exporter of textile products among Asian countries and the 12th globally (Thomasson, 2012). Pakistan is the world's 4th largest producer of cotton with the 3rd largest spinning capacity in Asia. Its major international competitors are India, China, and Bangladesh (JCR-VIS, 2013). The textile sector contributes 8.5% of the country's GDP and 52% of Pakistan's exports. This sector employs 38% of the people involved in the manufacturing sector and accounts for 31% of the total investment in the country. Shortage of energy (gas and electricity) in the country is one of the major reasons behind the underperformance of the textile sector of Pakistan. Other major issues faced by the sector are the need to replace inefficient production machinery. The textile sector lost nearly 4 billion dollars in 2010 due to the ongoing energy crisis (Govt. of Pakistan, 2012 a).

The research presented here aims at providing ideas for increasing the use of RE in the textile sector of Pakistan to thereby help increase production and employment opportunities.

1.8 Research Methodology:

The research is based on an analysis of background data gathered as part of a comprehensive literature review and from analysis of empirical data obtained during fieldwork conducted in Pakistan during Dec 2013 – Jan 2014. The literature review focused on the application of renewable energy in the industrial sector and was conducted to identify the most salient renewable energy options for Pakistan. In terms of climate change, at the national level, major impact areas were identified on the basis of the literature review. Energy related information was gathered from government agencies and from international databases such as those developed by the International Energy Agency (IEA). The geographic potential of renewable energy generation (solar, wind, and hydro) of Pakistan was calculated using different sources such as Water and Power Development Authority of Pakistan (WAPDA), Alternate Energy Development Board (AEDB), United Nations Development Program – Global Environmental Facility (UNDP-GEF), Global Wind Energy Council (GWEC), Asian Development Bank (ADB), and Solar GIS. Case studies from leading RE countries were also analyzed to distill salient lessons for Pakistan.

Energy assessment survey and interviews with the management of Sarena Textile were conducted on the site (address: 22 km, Sheikhupura Road, Lahore) in the city of Lahore to obtain primary and secondary information related to actual production processes and representative energy use of the Pakistani textile sector. All energy intensive sub-production processes were analyzed as part of the overall production process of the textile mill and an energy audit of all production processes was also conducted. Detailed analysis was conducted for selected sub-production processes to determine the application potential of renewable energy as a substitute to conventional energy under financial, technical, and environmental criteria. Financial analysis has been conducted on the basis of a cost-benefit analysis and internal rates of return and to develop a business case. The focus of the technical analysis was to determine the availability of technology and capability of the industry's management to operate the proposed renewable energy solutions. Environmental analysis included determination of environmental benefits such as CO_2 emission reduction potential and improvements on employee and community health. Finally on the basis of the application of the proposed criteria, renewable energy technologies were assessed and the most promising options are identified and highlighted as recommendations to the Pakistani textile industry. An additional goal of the proposed research is to develop an assessment protocol that can be used to evaluate renewable energy potential in the textile sector of Pakistan. Key policy measures required to increase the penetration of renewable energy technologies in the textile sector of Pakistan are also analyzed as part of this research.

Chapter 2: Literature Review

This chapter summarizes a detailed review of the literature on climate change, including major global climate change impacts and specific impacts for Pakistan. The chapter also describes major climate change mitigation and adaptation strategies proposed and implemented throughout the world, and discusses in detail the potential of renewable energy as a most effective mitigation tool for climate change and as promising source of energy for developed and developing countries.

2.1 Background

There are many historical examples that illustrate that the current understanding of large-scale human impact on the environment is not a new phenomenon; for example, the ancient Greeks understood the relationship between deforestation and rainfall changes (Spencer, 2008). However, the modern history of observing and recognizing climate is almost two centuries old. Detailed observations and debates were registered in scientific journals centuries ago but were not available to common people as they are at present. Jean-Baptiste Joseph Fourier, a French Natural Philosopher, was one of the first scientists to write in the late 1700s and early 1800s about a greenhouse effect in Earth's atmosphere. A few decades later the prominent scientists James Hutton and Sir Charles Lyell presented the theory of 'uniformitarianism', which led to the modern science of geology. In 1896 almost three quarters of a century after Fourier, the Swedish chemist Svante

Arrhenius calculated and wrote about how global warming could occur due to the widespread use of coal and other carbon fuels (Christianson, 2000).

However, it took many more decades until environmental concerns became a mainstream issue (in the early 1970s), coinciding with the same period during which global temperatures had begun to rise. Scientists throughout the world started raising alarms about the threats of human induced climate change. Huge data sets were generated to understand the main causes of climate change. Computer models began to predict that high-speed rates of climate change that could cause impacts in the form of droughts, storms, rising sea levels, and other natural disasters. In the last two decades, the scientific communities of every major country have worked to establish consensus about climate change predictions, impacts, and responses. The IPCC report AR5, released in 2014, on the basis of scientific evidence, reported with high confidence that humans are causing climate change. The continuous warming of atmosphere and oceans, high rate of melting snow and ice and the sea level rise over many decades provide ample evidence to prove that the mega process of climate change has started (2014c).

Currently most of the scientists around the world agree that earth is warming up i.e. global warming has begun and the climate is changing. Many agree that this human-induced climate change may be one of the greatest threats facing the planet. Recent years show increasing temperatures in various regions, and/or increasing extremities in weather patterns in line with IPCC predictions.

It has been measured that out of the 14 hottest years, ever reported since record keeping began, the 13 hottest years have occurred in this century. The last 37 years were hotter than the average temperatures of the 20th century, and it is the 350th time in a row that April remained a hotter month than the last century's yearly average. The last decade was the warmest ever in recorded history (Gore, 2014).

In 1992 the United Nations Framework Convention on Climate Change (UNFCCC) was internationally signed with the objective to limit average temperature increases, resultant climate change and impacts. 195 countries have signed the UNFCCC, a convention that emphasizes that solutions to climate change will come from all disciplines and fields of research and development. However, the main international response to climate change has been to commit to reductions in greenhouse gas (GHG) emissions. In 1995, under the umbrella of the UNFCCC, countries agreed to sign the Kyoto Protocol (KP). The KP legally binds developed countries to GHG emission reduction targets. The KP first commitment period was 2008-2012. By 2010 governments had agreed to reduce emissions for limiting the global temperature increase below 2 degrees Celsius (UNFCCC, 2012).

The industrial and power sectors are the main sources of CO_2 emissions; they contribute more than 55% of the total current CO_2 emissions (IPCC 2014b). About 55-60% of the total anthropogenic radiative forcing is in the form of CO_2 emissions; the other 40-45% is accounted by other pollutants (black carbon, tropospheric ozone, methane, and hydro fluorocarbons). These pollutants are also referred as short-lived climate pollutants (SLCP's) due to their short atmospheric lifetime (i.e. days to a decade and a half) as compared to GHG's. Reducing CO_2 emissions only, to slow down the associated rate of climate change over the next decades is not enough; cutting down SLCP's emissions are also as important for mitigating climate change impacts. Incomplete combustion of fossil fuels, bio fuels, and biomass are the major sources of SLCPs. Reductions in SLCPs emissions can be achieved by using combustion efficient technologies, compliance to existing laws, and effective working of regulatory institutions (CCAC, 2013).

The future challenge for the development of mitigation measures will be addressing industrial equipment and appliances, heating and cooling systems, and vehicles which all can be replaced either by much more energy efficient technologies and approaches or by renewable energy sourced equipment and systems.

Both mitigation and adaptation are interconnected and complementary to each other for developing the future solutions for reducing the climate change impacts, only the timescale of outcomes are different from each other. The IPCC's fifth assessment report (AR5) with very high confidence states that *"Significant co-benefits, synergies and trade-offs exist between mitigation and adaptation"* (IPCC, 2014c). Mitigation and adaptation synergies may benefit resulting in achieving sustainable development goals, if right choices are made between the tradeoffs, otherwise the result may be undesirable. Land use change from food (agriculture) to biofuel plantation is an example to understand the complexity of the above-mentioned trade off. Reducing Emissions from Deforestation and Forest Degradation (REDD) programs that may lead to livelihood losses is yet another example (Asun, 2014).

The IPCC's fifth assessment report (AR5) states that even though many countries implemented climate change mitigation measures and policies, the largest increase in greenhouse gas emissions in absolute terms happened during the years 2000 to 2010. In 2010 anthropogenic greenhouse gas emissions reached 49 ± 4.5 GtCO_2 eq/yr. 78% of the total CO_2 emissions during 1970 to 2010 were contributed by the combustion of fossil fuels and by industrial processes, and they remained at the same level during 2000 to 2010. At the global level, the main drivers behind high CO_2 emissions were economic and population growth both mostly powered by fossil fuel combustion (IPCC, 2013).

The European Union and its member countries are leading in the UNFCCC in terms of implementation of climate solutions based on both hard approaches (e.g. reducing emissions by specific economic sectors) and soft actions (e.g. climate change policy development). The European Union (EU) and its 15 Member States ratified the Kyoto Protocol in May 2002 and agreed to enforce it by February 2005. Most EU Member States developed their own emission targets with the exception of Cyprus and Malta. The EU launched many programmes and strategies to mitigate climate change such as European Commission 1991, and European Climate Change Programme (ECCP). A major accomplishment of the ECCP was the development of the EU Emissions Trading Scheme (ETS). The ETS is the main tool of EU to achieve its targets under the Kyoto Protocol. Although its GHG mitigation results are, at best, mixed the ETS remains as an important effort to achieve carbon-pricing mechanisms (European Commission, 2012).

There is mixed opinion about the EU-ETS performance. During the short history of the ETS market, the scheme has experienced setbacks like cheap pricing, value added tax frauds and cyber thefts of permits (Chaffin, 2012).

The rejection of the proposed short-term price fix for the EU-ETS by the European Parliament in 2013 has cast doubts about the future of the ETS. However with all the ups and downs plaguing to EU-ETS progress, the carbon-pricing market is still emerging fast all around the world. More than 20 more carbon-pricing systems have been introduced worldwide since the EU-ETS in 2005. It is evident that the EU-ETS certainly needs major reforms but it is still a useful approach to mitigation (The Clean Revolution, 2013).

In addition climate change was also selected as one of the priorities in the Sixth Community Environmental Action Programme (EAP). EAP sets out the environmental policy and sustainable development framework for EU member states. EAP aims at achieving the EU KP targets and also to achieve the type of deeper emissions reductions recommended by the IPCC. Since 2002 climate change has been an integral part of EU environmental and sustainable development policies and provide valuable lessons for other nations. The EU aims at becoming energy efficient and low carbon economy by 2050. Those targets will result in a reduction of greenhouse gas emissions of 80-95% as compared to 1990 levels (European Commission, 2012).

The EU has approved to spend at least 20 % of its 2014-2020 period budget of €960 billion, on climate change actions. The EU is a prominent contributor in providing climate change finance to developing countries every year. During the period of 2010-12, EU provided over €7.3 billion in ‘fast start’ financing to the developing countries to cope with climate change (European Commission, 2015).

Consequently, there will be variance in adapting climate change by regions and countries and resultantly impacts will also vary by region and countries according to their circumstances and capacities (EPA, 2012).

2.2 Climate Change Impacts

The undeniable human induced warming of the climate system over the last century has already resulted in severe impacts to natural systems and human beings. The warming of the atmosphere and oceans, shrunken snow and ice, and sea level rise are the evidence of climate change. Further warming of climate may result in irreversible and long lasting impacts. Reducing and limiting GHG emissions along with adaptation and mitigation actions is the key to address the growing issue of climate change (IPCC, 2014c).

According to the IPCC recent report “Global mean sea level will continue to rise during the 21st century and the global sea level rise and changes in precipitation will not be uniform across regions”. Global water resources are going to be affected, both quality and quantity wise, due to the melting of snow and ice, and changing rainfall patterns. Due to the changing hydrological systems, already stressed out coastal systems and low-lying areas will be facing more problems such as flooding, submergence, and erosion during this century. A ±20% change in mean global sea level is estimated, affecting about 70% of the global coastlines. Number of people affected due to water scarcity and due to major river floods is predicted to rise due to continuing global warming. Many terrestrial, freshwater and marine species will increasingly experience the risk of extinction throughout and beyond this century. Worldwide food security including food production, availability and pricing will be also impacted by climate change (IPCC, 2014c).

The impacts due to climate change on freshwater resources in Asia will vary depending on the location due to the fact that Asia is the largest and most populous continent on the Earth with a diverse topography and broader range of climates. In Asia, ample water resources are predominantly very important due to the enormous population concentration and their high dependence on agriculture sector. Asia already is experiencing water scarcity, but due to population increase, heavy dependence on agriculture and improving standard of living in addition to climate change impacts, availability of adequate water resources will prove to be a big challenge for the region. Shrinking glaciers and melting snow may result in an increase in runoff in downstream rivers for few years in some regions of Asia but eventually will decrease over time causing water scarcity. Water management approaches such as increasing water storage capacity (dams, water reservoirs), improved irrigation technologies, altering cropping patterns, increasing efficiency to enhance water productivity and water recycling are needed to manage the issue of water scarcity in the region (Hijioka et al., 2014).

The next section briefly describes the climate change impacts expected to affect some of the most vulnerable sectors of Asia including Pakistan.

2.2.1 Freshwater Resources, Agriculture, Food and Fibre

Climate change can lead to changes in all components of the global freshwater system. An increase in temperature is expected to increase everywhere over land and during all seasons of the year while precipitation is expected to increase globally and in many river basins, but is expected to decrease in many others. (Kundzewicz *et al*., 2007).

The IPCC (2014) report states with high confidence that in parts of Asia rural poverty could increase due to climate change impacts particularly on rice production causing increases in food prices and on the cost of living. 58% of the population in Asia lives in rural areas and 81% of them are dependent on agriculture. In Central and South Asia, as the water demand for agriculture and hydroelectric power generation grows (due to population increase and economic development), the impacts of climate change are expected to furthermore intensify water shortage in the region which may cause political unrest between the neighbouring countries (U.S. Committee on Foreign Relations, 2011).

Pakistan with its diverse topography is spread into 18 habitats mostly arid and semi-arid zones, with an annual rainfall ranging from around 250mm to 125mm (Woods et al., 2000). Originating from the Himalayas the Indus River (1,800 miles), one of Asia's longest rivers, flows through India and Pakistan down into the Arabian Sea. Pakistan is already a water stressed country, therefore adequate availability of water resources is very critical for Pakistan because of its world's largest canal based irrigation system that is considered to be the blood lifeline for the country's economy (U.S. Committee on Foreign Relations, 2011). During the year 2013-14, only 107.47 million acre-feet **(**MAF) water became available out of the estimated 142 MAF resulting in decreased water availability for irrigation. This was mainly due to the reason that the groundwater extraction was effected owing to the rising prices of diesel and electricity (Govt. of Pakistan, 2014a). According to economic survey of Pakistan (Govt. of Pakistan, 2014a) and FAO 94% of the total water withdrawn is used for agriculture, 4% for municipalities and remaining 1% for industry (FAO, 2012).

According to IPCC (2014) report, food insecurity due to climate change will emerge as a problem in the next few decades and majority of the population affected will be those situated in South Asia (Hijioka et al., 2014).

Temperature increase due to climate change will impacts both positively and negatively on rainfed agriculture in semiarid areas (Ratnakumar et al., 2011 and Hijioka et al., 2014). The temperature rise in northern mountainous regions may support farmers to grow two crops (wheat and maize) in a year (Hussain & Mudasser, 2007 and Hijioka et al., 2014). Under SRES A2 and B2 senarios, the wheat yield is expected to rise by 50 % and 40 % repectively in the northern mountains, on the other hand, the wheat yield will probably decrease in sub-mountainous, semiarid, and arid areas by 2080s (Iqbal et al., 2009, and Hijioka et al., 2014). In Pakistan, these varied results are projected for the mountainous Swat district (960m above sea level) and Chitral district (1500m above sea level). The wheat yield is expected to decline in Swat district (by 7% and 24%) and increase in Chitral district (by 14% and 23%) with an increase of temperatures of 1.5°C and 3°C respectively (Hussain & Mudasser, 2007 and Hijioka et al., 2014).

Ninety percent (90 %) of the global rice is produced in Asia. In the case of rice, as the temperature rises the course of rice growth becomes faster therefore the duration of growth is reduced. According to Wassmann et al. (2009a,b), in various parts of Asia temperatures are already reaching dangerous levels leaving rice plantations at risk and more vulnerable due to heat stress. *These include Pakistan/North India (October), South India (April/August), East India/Bangladesh (March-June), Myanmar/Thailand/Laos/Cambodia (March-June), Vietnam (April/August), Philippines (April/June), Indonesia (August), and China (July/August)* (Hijioka et al., 2014).

The productivity of agricultural, forestry and fisheries systems is dependent on many climatic variables (e.g., temperature, radiation, and precipitation, water vapor pressure in the air and wind speed) (Easterling *et al*., 2007). Crops exhibit threshold responses to their climatic environment, which affect their growth, development and yield (Porter and Semenov, 2005). The reduced resilience in the agricultural sector is due to multiple stresses, such as limited availability of water resources, loss of biodiversity, and air pollution (FAO, 2003).

2.2.2 Coastal Systems and Low-Lying Areas

Asia is not only the largest continent in the world; it is the most diverse one also, and so its shoreline is also the longest, very diverse, unique and rich in nature. Almost half (45%) of the mangrove forest is situated along the tropical and sub tropical coastlines of Asia (Giri et al., 2011). Most of the global swamp forests are located in the low-lying areas of Southeast Asia. In addition 40% of the global coral reef area is also in Southeast Asia. Asia also leads in harvesting fisheries and aquaculture Hijioka et al., 2014).

Asia has experienced rising temperatures during the past century and the trend is expected to continue in the future. Both climatic and non-climatic factors are responsible for the rising strain on the coastal and marine ecosystems. Sea level rise is expected to continue and at higher rate than before (Hijioka et al., 2014).

Coastal flooding and erosion, saline water invasion in deltas/estuaries and alteration of wetlands are the main impacts of sea level rise (Mcleod et al., 2010 and Wong, 2014).

Pakistan is among the five South Asian countries that are most vulnerable to floods during the monsoon season (due to the storms surges originating in Bay of Bengal). Since 1950 Pakistan has experienced 21 major floods (Ali, 2013). The last major flood occurred in 2010 due to heavy monsoon rains which left one fifth of Pakistan underwater, 2,000 people dead and 20 million people directly affected. Although cyclones are not a frequent threat to Pakistan, they have caused damage on a large scale along coastal areas. Fourteen cyclones have been recorded since 1971 in Pakistan (SAARC-SDMC, 2009).

2.2.3 Human Health

The IPCC (2014) report states with high confidence that owing to frequent and intense heat waves, the prevalence of infectious diseases such as cholera, schistosomiasis, and diarrheal illnesses could increase and result in high mortality and morbidity rates in Asia. In addition, it is stated with medium confidence that the current geographical locations of diseases will also change from their present habitats in Asia (Hijioka et al., 2014).

Climate sensitive diseases outbreaks due to warming will impact the health of humans globally but would be a great challenge for developing nations especially in Asia (due to high concentration of population, poverty and lack of management and health facilities). Asia is primarily dependent on its agricultural sector for its livelihoods, 57.28% of the total population of Asia lives in a rural setup. According to human development indicators (UN DESA Statistics Division, 2009) after sub-Saharan Africa and southern Asia, Southeast Asia is the third worst performing nation. Poor urban communities in Asia will also be impacted by climate change, but in rural areas, where poverty is much higher than in urban communities, the impacts of climate change will be very serious (Hijioka et al., 2014).

According to the WHO (World Health Organization), outbreaks of diseases are common after floods and storms as a result of water borne (typhoid fever, cholera, leptospirosis and hepatitis) and vector borne (malaria, dengue and dengue haemorrhagic fever, yellow fever, and West Nile Fever) disease outbreaks. Pakistan is a frequent flood prone region. Therefore, Pakistan contaminated floodwaters often result in outbreaks due to the exposure to pathogenic agents and toxic substances in floodwaters (Sohan et al., 2008; Warraich et al., 2011 and Hijioka et al., 2014).

The increase in temperature and rainfall is associated with the outbreak of dengue fever in South and Southeast Asia (Su, 2008; Hii et al., 2009; Hsieh and Chen, 2009; Shang et al., 2010; Sriprom et al., 2010; Hashizume et al., 2012 and Hijioka et al., 2014). In 2011, the worst outbreak of dengue fever in Pakistan claimed 126 lives and more than 12,000 people were infected by the fever irrespective of their financial status (AFV, 2011).

2.2.4 Climate Change Impacts on Pakistan

In 2010-2011, The Ministry of Environment (Govt. of Pakistan) carried out the study 'National Economic, Environment and Development Study' (NEEDS) with the help of consultants and with the financial support from the Secretariat of United Nations Framework Convention on Climate Change (UNFCCC).

Table 2.1 below summarizes key impacts of climate change in the different sectors outlined in that report.

Table 2.1: Climate Change Impacts on Pakistan

(Adapted from Khan, Malik A.A., 2012).

Likely impacts on Water Resources
• *Enhanced melting of glaciers and reduction of snow cover leading to alterations in the seasonal flow pattern of the Indus River system.*
• *Increased flooding in the rivers for a few years followed by declining river flows.*
• *Increased chances of formation of glacial lakes with risk of GLOFs or glacial lake outburst flows.*
• *Higher frequency and intensity of extreme climate events coupled with erratic monsoon rains could cause high floods followed by droughts.*
• *Increased water demand due to high evaporation rates at elevated temperatures*
• *Increased chances of water stress of the shared water resource potentially leading to cross border conflict.*

Likely impacts on Agriculture and Livestock • *Reduced crop productivity and failure to timely respond to shifting crop calendars/rotations* • *Changing insect, pest and pathogen populations* • *Undermining of national food security* • *Changes in livestock productivity (meat and milk) due to temperature stress and other climate related diseases.*
Likely impacts on Forestry and Biodiversity • *Varying forest productivity as well as changes in growth/yield of tress with shifting of biomes.* • *Changes in composition of species as well as forest migrations due to changes in temperature and precipitation levels.* • *Pressure on forest resources due to weather extremes.* • *Increase in forest pests, insects, pathogens and disease due to increased temperatures.*
Likely impacts on Extreme Events and Coastal Zones: • *Increased frequency and intensity of cyclonic activity along the coastal zones.* • *Incidence of catastrophic Glacial Lake Outburst Flows (GLOFs) in the northern areas of the country.* • *Increased frequency and intensity of floods across the country.*
Likely impacts on Energy and Industry: • *Increased Changes in water availability and the timing of such water availability will impact hydropower generation and thermal power plant*

cooling. Likewise sedimentation built-up in existing dams will reduce hydropower generation capacity.

• Impacts of sea level rise on seashore energy infrastructure. Likewise potential hazards to infrastructure from floods.

• As predicted temperatures increase a reduction in thermal power efficiency is expected.

• Likelihood of increase in transmission/distribution lines losses due to temperature increases.

• Indirect impacts include greater reliance on fossil fuels or alternate energy as river flows exhibit cyclical changes due to glacier melt, rising temperature and changing precipitation patterns. Higher temperatures would also result in increased evapo-transpiration losses raising demand and cost of pumped water.

2.3 Climate Change Mitigation and Adaptation Strategies

The United Nations Framework Convention on Climate Change (UNFCCC) identifies mitigation and adaptation as responses to climate change i.e. mitigate by reducing greenhouse-gas emissions and adapt to the impacts of climate change. In their assessment reports, the IPCC defines climate change mitigation as:

"An anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases", and adaptation as *"adjustment in natural or human*

systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities"

Climate change projections suggest that impacts are expected to continue and amplify over the coming decades. Adaptation is therefore a necessary complement to ongoing research on impacts. As stated earlier, adaptive capacity can differ with respect to different countries, regions, and sectors (PRI, 2009).

With respect to the time frame and distribution of benefits, mitigation and adaptation strategies are different from each other (IPCC, 2007). Mitigation strategies create benefits at a global scale, while adaptation strategies tend to yield results on local and regional scales. On timescales, the benefits of adaptation are visible in the shorter term, whereas mitigation measures take decades to become effective (Know Climate Change, 2013). Furthermore mitigation can only be proactive, while adaptation can be both reactive and proactive (IPCC, 2007).

Both mitigation and adaptation strategies are complementary for reducing climate change impacts. For example, effective implementation of mitigation measures will reduce climate impacts; therefore will also lesser the need to adapt. Likewise, effective adaptation will reduce demand for mitigation (Know Climate Change, 2013).

According to (Müller, 2002) developing countries have to play a significant role in making global climate change policies successful by effectively implementing mitigation and adaption measures and policies. Muller says, " the chief victim of climate change is not 'Nature', but people" and that climate change is considered as a sustainable development problem but not in the case of developing countries, for them it is a problem of unsustainable development i.e. failing to survive (Müller, 2002). Climate change policies and development are interconnected to each other i.e. effective climate change policies results in sustainable development. Likewise absence of these policies will lower quality of life (Cosbey, 2009).

Most developing countries are the least contributors to GHG emissions but are most vulnerable to climate change. Therefore, developed nations who are the main contributors towards climate change, on the basis of equity and fairness, bear great responsibility to assist and support developing countries to cope and adapt to climate change (Cosbey, 2009).

Furthermore; according to the IEA's 'World Energy Outlook 2008' report, 87% of the total global energy demand will grow in the non-OECD countries during 2007-2030 resulting in a 97% global increase in energy related CO_2 emissions, another reason to invest towards the diversification of energy mix in these developing countries (Cosbey, 2009).

In recognition to the importance of their role in the implementation of global climate change policies, developing countries are responding positively by dovetailing climate change policies in the overall international sustainable development policy framework (IPCC, 2007a).

2.4 Renewable Energy as Mitigation

The energy sector is one of the vital drivers of economic development for all countries. Studies have projected that climate change impacts are expected to continue and increase with time (PRI, 2009). Renewable energy is considered as an environmental friendly strategy to replace fossil fuel (KAS, 2007). Renewable Energy (RE) comprises a diverse class of technologies including bio energy, direct solar energy, geothermal, hydropower, ocean energy and wind energy. Various types of RE can supply electricity, thermal energy and mechanical energy, to cater all type of energy needs. Several RE technologies such as solar PV's and wind turbines are technically mature and are being used at significant scale. Further technological advances in this field are being explored (IPCC, 2011).

Technologies like solar PV's, solar water heaters, wind pumps, improved cooking stoves, biomass briquettes, and biogas offer good potential for developing countries like Pakistan. In addition exploitation of renewable energy potential will help developing countries to reduce dependence and energy import bills.

The International Renewable Energy Agency (IRENA) states that the cost of renewable sourced energy generation is almost at par, and in some cases and regions below par, with fossil fuel fired power generation. Renewables are even more financially viable and competitive against energy produced by fossil fuel fired plants if the external cost (i.e. the cost of CO_2 emissions and damage to human health) is also added to the total cost of power generation. If these externalities are added, the price of power generation by fossil fuel is estimated to be between USD 0.07 and 0.19/kWh. In comparison, renewable sourced energy cost is dropping rapidly day by day. The cost of renewable power generation in China, North America and South America is at par with fossil fuel power generation. In Middle Eastern countries e.g. Dubai and UAE, the cost of solar powered energy generation has fallen to 0.06USD/kWh. The wind energy generation cost is around USD 0.09/kWh in Africa, USD 0.07/kWh in North America and drops as low as USD 0.06/kWh in China and Asia. In Europe and many other countries the onshore wind power is delivering at USD 0.05 per kilowatt-hour (kWh) is proving to be highly competitive against the current cost of USD 0.045 to 0.14/kWh for fossil-fuel power plants (IRENA, 2015).

It is heartening that in about 79 (including India and Bangladesh) countries the cost of fossil fuel based energy generation is almost equal to solar-based energy generation. Africa and Bangladesh are one of the leading developing regions that have opted for a very fast growth of solar PV generation. Solar PV development has exceeded all past predictions by many times. The two largest economies i.e. USA and China are implementing very large PV based projects. China is targeting to generate 70 gigawatts of PV generation by 2017. Al Gore in “The Turning Point: New Hope for the Climate” predicts that by 2020 solar energy will become competitive with electricity from other sources in the regions of about 80% of the world population (Gore, 2014). Wind energy is also catching-up in terms of cost of generation with solar energy. USA is taking the lead in wind energy generation. The present installed capacity of electricity from wind surpassed many times the projections made in 2000 (Gore, 2014). Germany, at one point in May 2014, set a new record of generating 74 percent of its total electricity demand through renewable energy sources. Germany is targeting to generate 100% of its electricity from renewable sources by 2050 (Kroh, 2014).

Throughout the world, renewable energy solutions are now considered to be an essential part of national energy policy (irrespective of the fact of being developed or developing countries).

Although the renewable energy sector is transitioning towards achieving the goal of becoming more and more competitive with respect to traditional energy sources, long term policy frameworks and market design is seriously needed to boost investment and for scaling up this sector (IEA, 2014b).

Many large businesses throughout the world have developed and implemented sustainability plans and incorporation of renewable energy in their energy systems, is one of the key elements of these plans. Consumers especially in the developed world are also putting pressure on large corporations to do responsible business. Early experiences of corporations are positive with respect to the application of renewable energy as cost and resource efficient solutions (Gore, 2014).

The IRENA study (Renewable Energy in Manufacturing*:* A technology roadmap for REmap 2030) identifies that renewable energy can be best applied on industrial heating systems, such as for conversion of biomass into oil or crops into plastics, paper, and food. Industrial heating systems are mostly comprised of equipment or devices that use kilns, ovens, and piping systems to transfer heat for industrial processing. It is projected that by 2030 about 80% of the total final consumption in the manufacturing industry will be used as process energy. The major energy using sectors will be: metal industry, chemical and petrochemical industry, and non-metallic minerals mainly, cement (IRENA, 2014b).

The manufacturing industry consumes about a third of global energy demand (IEA, 2012). Electricity represents about 20% of total energy consumption of the manufacturing industry. Sixty seven percent (67%) of global energy is used by the countries in transition or developing nations (like Pakistan), and China is the biggest user (30% of global energy demand in manufacturing). IRENA, (2014b) projects that by 2030, energy demand will grow by 45%. The high level of energy consumption of the manufacturing industry at present, and in the future, makes it imperative for factories throughout the world to use energy more rationally by adopting best energy use practices and by installing energy efficient technologies, especially in industrial heating systems (UNIDO, 2010).

In the presence of many alternate approaches for reducing carbon emissions, the combined application of renewable energy along with energy efficiency approaches are offering the best potential for carbon reductions. Ample cost effective alternatives exist for the application of renewable energy in the process heat generation of many manufacturing industries. If the world is serious about achieving the goal of doubling its total renewable energy share by 2030, then effective policies need to be implemented to mobilize concomitant economic resources and social support.

A pivotal IRENA study (IRENA, 2014b) proposes the following six priority areas for the application of renewable energy in the manufacturing sector:

i) Energy intensive industries should incorporate renewable energy both in existing and new industries;
ii) Small and medium enterprises should adopt renewable energy options through an iterative process of learning by doing;
iii) Optimizing the use of biomass as a substitute source of energy in the manufacturing industry;
iv) Less energy intensive industries like textile and food sectors should effectively exploit energy through solar thermal heating systems;
v) Deployment of renewable energy alternatives in the electrification of industry and power sectors is imperative; and
vi) The adoption of national and sub-national renewable energy friendly policies must become a political priority.

Another pivotal UNIDO study titled "Renewable Energy in Industrial Application" advocates that solar thermal systems be incorporated to work effectively in industrial sectors such as textiles and leather manufacturing where process heat temperatures requirements are below 400^{o}C. The installation of heat pumps in those industries complimented by renewable energy generation to power them is one good example of industrial innovation.

At a different scale innovative examples for the application of renewable energy are emerging in form of comprehensive solutions for reduction in carbon emissions, two such examples are presented in Box-2.1.

Box 2.1: Innovative Examples of Renewable Energy Application

Masdar City: Masdar City is becoming the first carbon neutral eco-city of the world. The Middle-East is a land of extreme heat and solar insolation. The city is been built in Abu Dhabi. It is important to note that the United Arab Emirates is one of the leading producers of fossil fuels. Masdar is being powered by solar and wind power technologies. The total cost of the project is between US$ 15 to US$ 30 billion. The city designers have used designs based on advanced solar architecture to minimize heat gains and to create an oasis ambiance. The goal is that all inhabitants of the city should enjoy clean air, breezes, shade, and dissipated heat (AE, 2010).

Grameen Shakti (Bangladesh): is another example of successful implementation of renewable energy that can be replicated in other developing countries like Pakistan.

The aim of this World Bank financed project of small scale Program of Activities (POA) is to provide micro-finance for installing solar home systems in the Bangladesh in collaboration with Grameen Shakti (The World Bank, 2015).

This initiative has received multiple awards including The Ashden Award (2006), International Microfinance Award (2009) and SolarWorld Einstein Award (2010). The project has sold more than one million solar home systems, 590,000 improved cooking stoves and 24,000 biogas plants by the end of 2012, hence improving the lives of around 8 million people and reducing emissions by 1 million tonnes of CO_2 e/year (Ashden, 2015).

This project is reducing national dependency on fossil fuel imports and is yielding tangible climate change and community related benefits (The World Bank, 2015).

The literature review presented in this chapter aims at providing evidence that renewable energy can advance economic, environmental, and social criteria established under the concept and definition of sustainable development. Renewable energy is here to stay and is gaining ground due to its growing cost-competitiveness against fossil fuels, technological durability, increased social demand, convenience, and as a major mitigation solution for climate change. Furthermore, key industrial technologies like heat pumps that can be powered by renewable energy have already been developed and are able to replace conventional heating and cooling equipment used in the manufacturing sector. Cost reductions and technological development in the renewable energy sector are providing strong incentives to large corporations and business to shift from conventional sources of energy. Supportive policies are essential to accelerate the process of industrial adoption of RE.

Pakistan's needs a comprehensive policy approach towards renewable energy to address its prolonged and ongoing energy crisis.

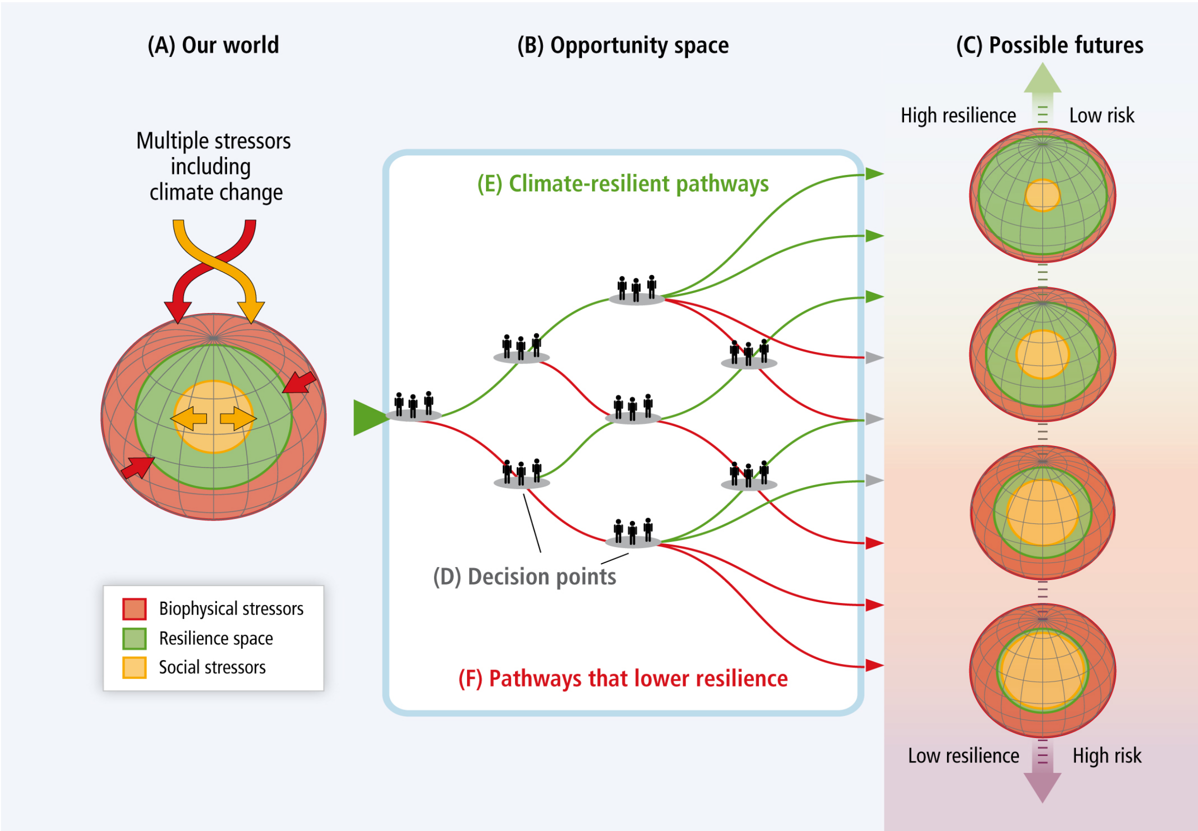
2.5 Climate-resilient Pathways and Transformation

Figure 2.1 presents the climate-resilient pathways developed by the IPCC's AR5. These pathways predict the trajectories for sustainable development and integrate adaptation and mitigation decisions to manage climate change impacts. The goal of decision-makers should be achieving high resilience and low risk future. The major stressors are: climate change, climate variability, land-use change, degradation of ecosystems, poverty and inequality, and cultural factors. Pakistan is also exposed to these stressors by climate change. The opportunity space illustrated in the figure 2.1 shows that the world can adopt different pathways or the combination of pathways to reach different levels of resilience and risks. At the operational level, resilience and exposure to risk depends on decisions taken at different strategic points along the pathways. If the world, follows the green lines in the opportunity space then it will achieve higher resilience and low risk, and if the world decides to follow the red lines then the world is bound to end up in a regime of low resilience with high risks (IPCC, 2014).

In the context of Pakistan and of this research, one of the major factors for Pakistan's resilience is the adoption of clean energy supplies to manage the stressors of poverty and inequality, degradation of ecosystems, and climate variability. Supply of clean energy (such as renewable energy) depends on national and provincial energy policies, and decisions taken by energy consumers. As figure 2.1 indicates if such efforts are pursued with vigour and determination resilience will increase and social and environmental stressors will decrease.

Figure 2.1 Opportunity space and climate-resilient pathways.

Source: (IPCC, 2014)



Chapter 3: Potential of Renewable Energy in Pakistan

3.1 Pakistan: The Study Area

Pakistan is a country within South Asia, situated between the Arabian Sea and the great mountain ranges of the Himalayas, the Karakorams and the Hindukush (WAPDA, 2011). Pakistan's bordering countries are Iran in the west, Afghanistan in the west and northwest, China in the north and northwest, India in the east and southeast and the Arabian Sea in the south. The country has an area of 796,095 sq. km, excluding the section of Kashmir under its control (GCISC, 2009) with a population of 183.30 million as of 2013 (Pakistan Census Organization, 2013). Pakistan is located in the vast valley of the mighty Indus River, and its tributaries run throughout the whole country as bloodlines. Northern Pakistan inherited one of the highest lands of the world. The three great mountain ranges: Himalayas, Karakorum's and the Hindukush meet in a very complex system of mountains, separated by narrow river gorges (GCISC, 2009).

Pakistan has a great variety of landscapes that include the majestic high mountain ranges of the sub-Continental north known as the Himalayas, the Karakorams and the Hindu Kush, the vast and rich irrigated plains of the Indus Basin covering vast regions of the Punjab and Sindh, the blunt deserts of Cholistan (Punjab) and Thar (Sindh), the inter-mountain valleys of Khyber Pakhtunkawa (KP Province) and the awe-inspiring rugged plateaus of Baluchistan and the meeting point of the Hindu Kush, and the Karakorams in the Northern areas. These are some of the most varied features of Pakistan's landscape (UNEP, 1998).

According to the Pakistan Energy Yearbook of 2011, the primary sources of energy were gas (47.6%), followed by oil (32.0%), hydro-electricity (11.8%), coal (6.7%), nuclear electricity (1.3%), LPG (0.5%), and imported electricity (0.1%). Final energy consumption during 2010-11 was 38.8 million TOE. Figures 3.1 and 3.2 present the use of energy by major sectors, and Figure 3.3 presents energy generation by source. During 2010-11, 94,385 GWh of electricity was produced, which includes 62.7% from thermal generation, 33.7% from hydroelectric generation and 3.6% from nuclear generation (Government of Pakistan, 2012a).

Figure 3.1: Total Energy Consumption (TOE) by Source and Sectors
(Source: Pakistan Energy Yearbook, 2011)

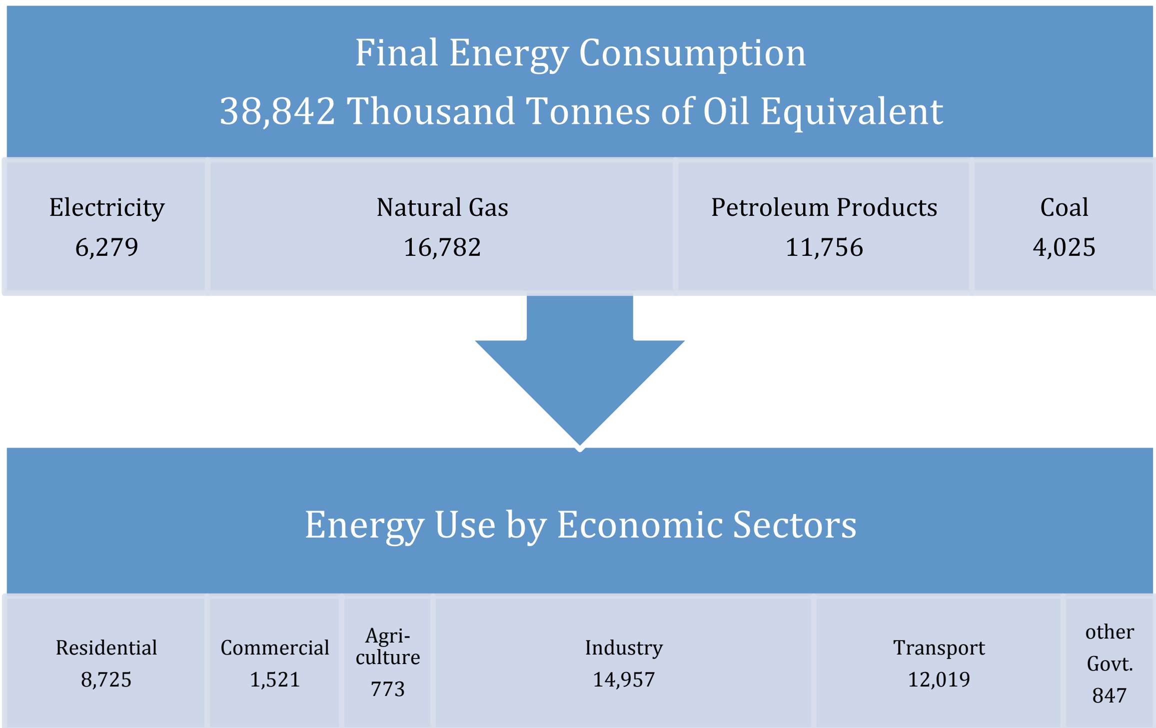
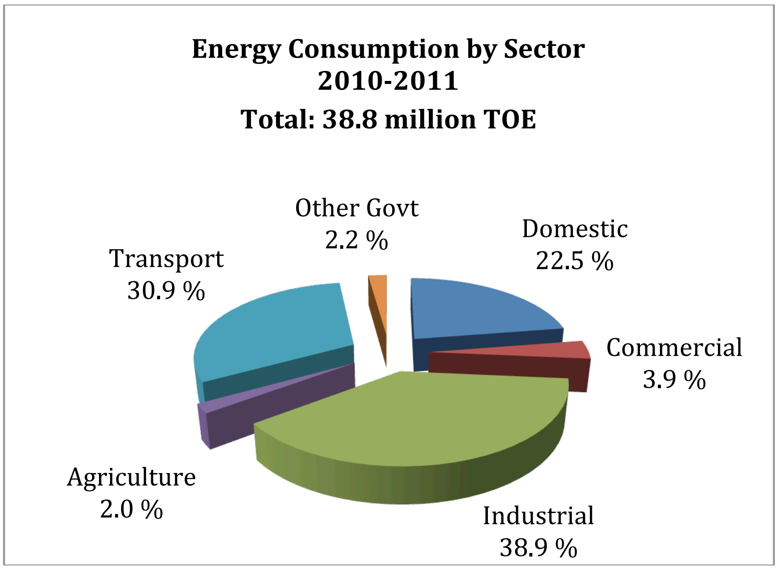
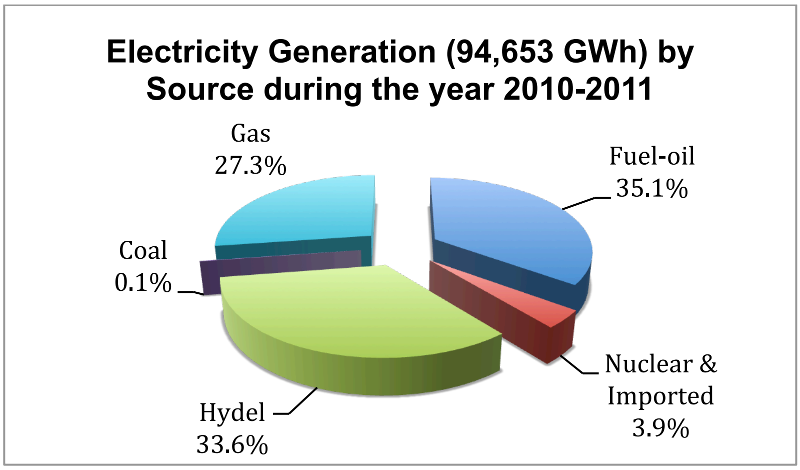


Figure 3.2: Energy Consumption by Sector (2010-2011)
(Source: Pakistan Energy Yearbook, 2011)



Source: Pakistan Energy Yearbook (2011)

Figure 3.3: Sources of Electricity Generation (2010-2011)
(Source: Pakistan Energy Yearbook, 2011)



Pakistan's current electricity production capacity is 9,000 megawatts (MW) against a daily demand of 15,000 MW (Ebrahim, Z., 2012). The gap between supply and demand at one point hit 7,500 MW, nearly 40 percent of national demand in the year 2012 (Mirza, 2013). The increasing gap between electricity demand and supply has resulted in load shedding throughout the country all year long. At present all the cities in Pakistan are experiencing load shedding of at least eight hours a day. Rural areas experience routine blackouts of 14-18 hours on a daily basis. In the summer season the electricity gap widens resulting in prolonged periods of load shedding of 15 to 20 hours, triggering countrywide protests. The long hours of power outages have seriously hampered industrial activity and restrain economic growth.

Many factors are involved in Pakistan's deep and complex energy crisis. Governance issues, weak political will, limited and weak disintegrated energy strategies, insufficient revenue available for importing fuel for energy generation and infrastructure, low efficiency rates, widespread electricity theft and lack of coordination among stakeholders, etc. are only a few of the many reasons behind the country's dysfunctional energy sector.

3.2 Renewable Energy Potential in Pakistan

For developing nations, a combined strategy involving energy conservation, energy efficiency and renewable energies will serve as an environmentally, socially and economically sustainable energy path. Developing nations may not be rich in fossil fuel resources, but most of them are located in areas with high renewable energy resources (hydro, wind, and solar). The transition to renewable energy resources from conventional fuels will be beneficial for developing countries as foreign exchange spending to buy imported energy (fuel) will be reduced. In addition, the sustainable energy path would help minimize conflicts over limited resources (Holm, et al, 2010).

Pakistan is fortunate enough to have renewable energy resources in abundance but unfortunately the country has not been able to exploit them, except for large hydroelectric projects (Govt. of Pakistan, 2006). The Alternative Energy Development Board (AEDB) has targeted to generate at least 5% of total electricity generation from renewable sources by 2030. Research by AEDB in collaboration with international experts and agencies (i.e. The United States National Renewable Energy Laboratories, GIT from Germany and Risoe National Laboratory from Denmark) has identified Pakistan's RE potential (PRES, 2011). The next sections summarize AEDB's research findings.

3.2.1 Hydro

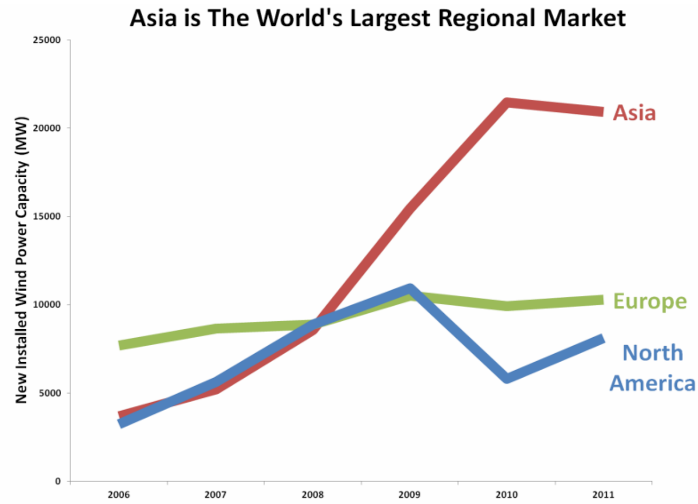
The total hydroelectric potential in Pakistan has not been yet investigated in detail, but it is roughly estimated to be 60,000 MW. This includes hydropower plants of all sizes, including schemes on mountainous streams in the north and plants on rivers and canals in the southern plains (Govt. of Pakistan, 2006). Pakistan has harnessed only 11% of this potential. The total installed hydroelectric generation capacity by 2010 was about 6,720 MW. Hydroelectric generation by location in 2010 was: 3,849 MW in the province of Khyber Pakhtunkhwa (versus a potential of 24,736 MW); 1,699 in the province of Punjab (versus a potential of 7,291), 1,039 in Azad Jammu and Kashmir (versus a potential of 6,450); and 133 MW in Gilgit-Baltistan region (versus a potential of 21,725 MW) (BBIP, 2011).

At present, the Northern Areas of Pakistan are not served by electricity grids due to their remoteness and difficult topography. Northern Areas offer ample potential for electricity generation through mini/micro hydropower plants. Presently about 300 such plants are already under operation in the area (Asif, 2009). The Alternate Energy Development Board (AEDB) aims at implementing an additional 103-mini/micro hydro power plants in the Chitral and Gilgit-Baltistan regions, with the collaboration of Agha Khan Rural Support Programme (AKRSP). For this, The United Nations Development Programme in collaboration with the Global Environmental Facility (UNDP-GEF) will contribute US$ 1.00 Million under the Productive Use of Renewable Energy (PURE) project (AEDB, 2014).

3.2.2 Wind

In the last five years worldwide wind energy generation grew by 26%. It is predicted that in the next five years, if past growth trends persist, wind energy generation will grow at 16% per annum. Total global contributions of the Asia region are more than those provided by North America and Europe. China and India are the leading countries in the region plus it is expected that from 2012 to 2020 the total investment for wind energy generation will be about US$ 50 billion. Asia as region offers the world largest market for wind energy (see Figure 3.4) (ADB, 2012).

Figure 3.4: The Global Trend of Installed Wind Power Capacity by Region.
Source: Global Wind Energy Outlook, various issues, Global Wind Energy Council (GWEC) (ADB, 2012).



It is expected that if Asia maintains current growth trends in the future then the region is bound to generate more wind energy than all the combined wind energy generation of North America and Europe (ADB, 2012). Figure 3.5 shows that even though Asia has shown exponential growth of wind energy generation, it has only realized a fraction of its potential. The estimated potential of wind energy generation for Asia Pacific region is about 5,300 GW. It is estimated that if the trend continue then Asia will be generating about 8 times the present level of generation in the next 10 to 20 years (ADB, 2012).

Figure 3.5: Potential of Wind Resources in Asian Countries.
Source: Global Wind Energy Outlook, various issues, Global Wind Energy Council (GWEC) (ADB, 2012).

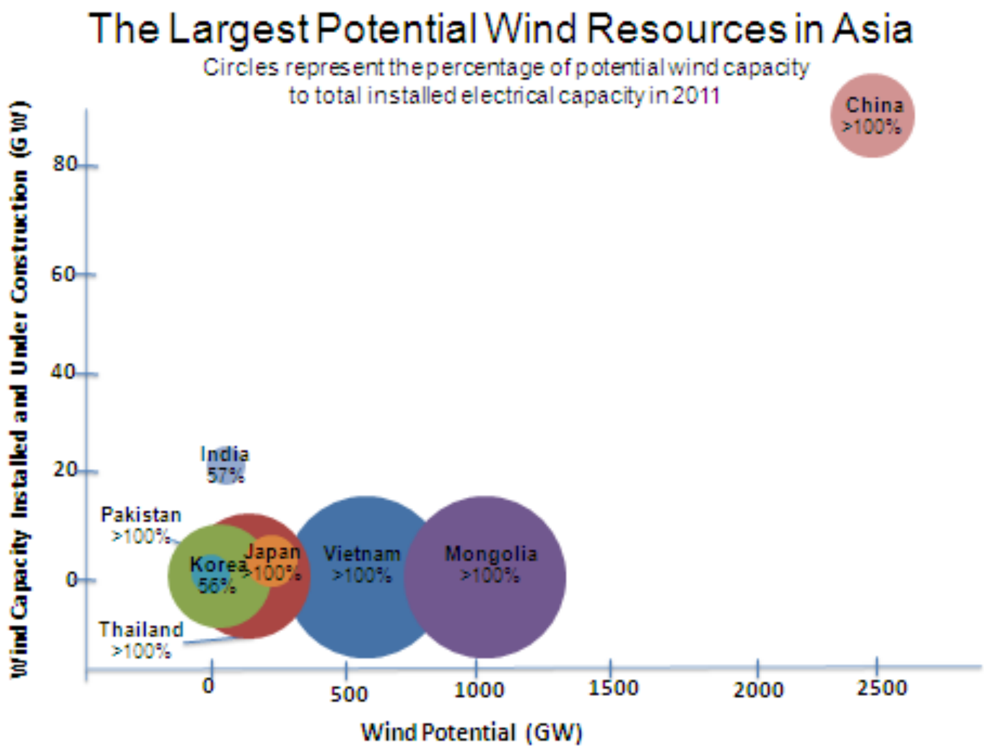
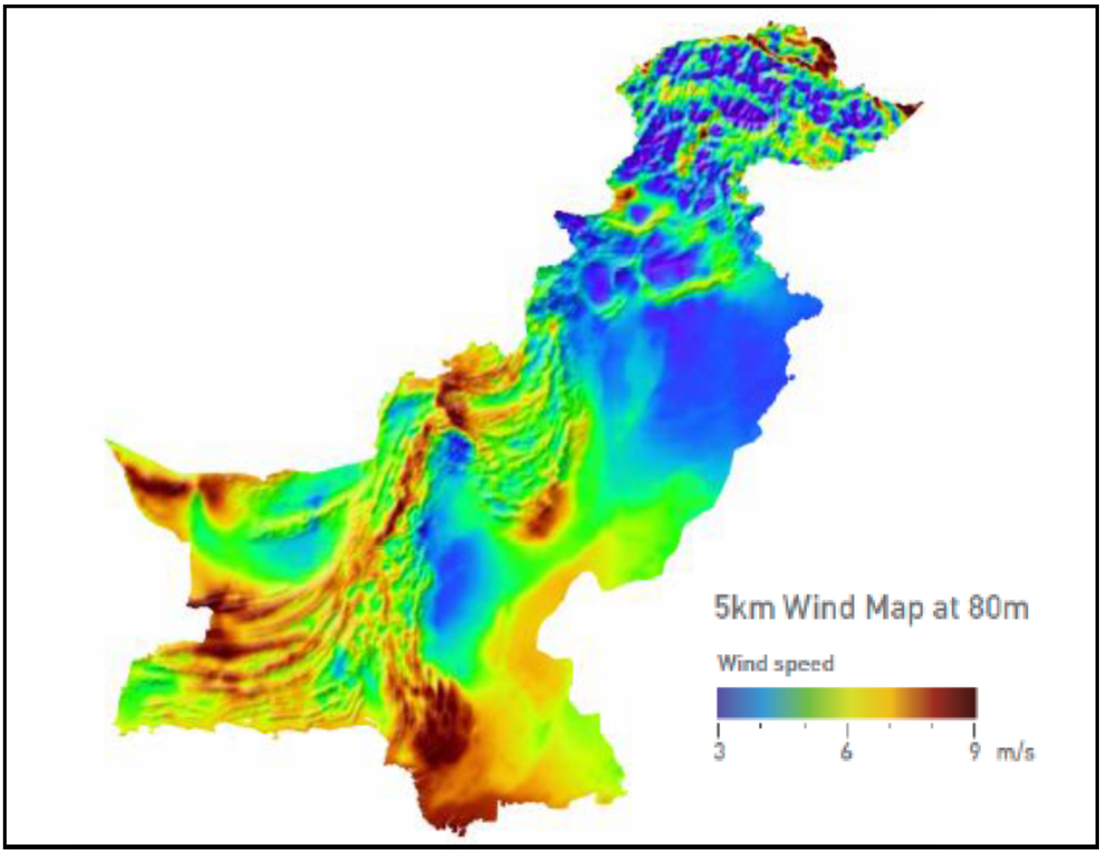


Figure 3.6 shows that Pakistan offers has one of the highest wind energy potentials in Asia. Many locations in Pakistan are suitable for harnessing wind energy, especially in southern Sindh and coastal Baluchistan. The monthly average wind speed at some sites along Keti Bandar- Gharo exceeds 7-8 m/s (Govt. of Pakistan, 2006). Figure 3.6 presents the wind resource map of Pakistan. Total wind energy generation potential of this corridor is estimated in the range of 40,000-50,000 MW (TBL, 2008) and 350,000 MW countrywide (Oxford Analytica Daily Brief Service, 2012).

Figure 3.6: Wind Potential of Pakistan
Source: Wind Energy Future in Asia (ADB, 2012).



At present, Pakistan's total installed wind energy generation is 6 MW. According to AEDB, about 556 MW of wind energy generation projects are in the pipeline. Table 3.1 presents a list of wind energy projects installed or expected.

Table 3.1: Wind Projects in Pakistan
Source: Alternate Energy Development Board

Name/Location	Capacity (MW)	Project Cost (USD Million)	FIT (USD/ kWh)	Status
1. ZorluEnerji Wind Power Project Phase 1 (Jhampir, Thatta); Total 50 MW capacity	6	121.99	0.1211	Year Operational: 2010
2. Dawood Power Ltd., Bhambore	50	120.34	0.1187	Acquired land, FS, generation license

3. Arabian Sea Wind Energy Pvt. Ltd., Lakha	50	142.23	0.1192	Acquired land, FS
4. FFC Energy Ltd., Jhampir	50	143.00	0.1611	Acquired land, FS, EPA (Under construction, expected operation: 2012)
5. Green Power (Pvt) Ltd, Kuttikun		108.80	0.1028	Acquired land, FS, generation license, EPA
6. TenagaGenerasi Ltd., Kuttikun	50			Acquired land, FS, generation license
7. Lucky Energy (Pvt) Ltd., Jhampir	50	132.35		Acquired land, FS
8. Metro Power Co. (Pvt), Jhampir	50			Acquired land
9. Gul Ahmed Energy Ltd, Jhampir	50			Acquired land
10. CWE, Jhampir	50			Acquired land
11. New Park Energy Ltd, Gharo			0.0950	Acquired land, FS, generation license
12. Master Wind Energy Ltd, Jhampir				Acquired land, FS
13. Zephyr Power Ltd., Bhambore				Acquired land, FS
14. Beacon Energy Ltd., Kuttikun		130.00	0.1250	Acquired land, FS, EPA
15. HOM Energy (Private) Ltd, Jhampir				Acquired land
16. Sachal Energy Development Pvt Ltd, Jhampir				Acquired land
17. Wind Eagle Ltd. (Technology Plc Ltd), Jhampir				Acquired land
18. Sapphire Wind Power Company (Pvt) Ltd, Jhampir				Acquired land, FS

3.2.3 Solar: Photovoltaic (PV) and Solar thermal

Almost all of Pakistan receives a strong amount of solar irradiance throughout the year, especially Baluchistan province, Sindh province, and southern Punjab province, receives a solar irradiation of over 2 MWh/m^2 and 3,000 hours of sunshine a year, which is at the highest end of global insolation averages (Govt. of Pakistan, 2006). Pakistan, owing to its geographical location, topography and climatic conditions ranks amongst the richest countries for solar energy generation potential (Shaikh, et al, 2013).

It is estimated that 19 Mega Joules per Square Meter of solar energy is shining in Pakistan. The conditions in Pakistan are highly suitable for the application of solar photovoltaic, solar water heating, solar desalination, and solar thermal technologies (Shaikh, et al, 2013). Figure 6 illustrates Pakistan's solar radiation map, which shows that solar radiation is spatially available throughout the country. According to the Alternative Energy Development Board (AEDB), Pakistan has a potential of generating 2.4 million MW from solar (Oxford Analytica Daily Brief Service, 2012).

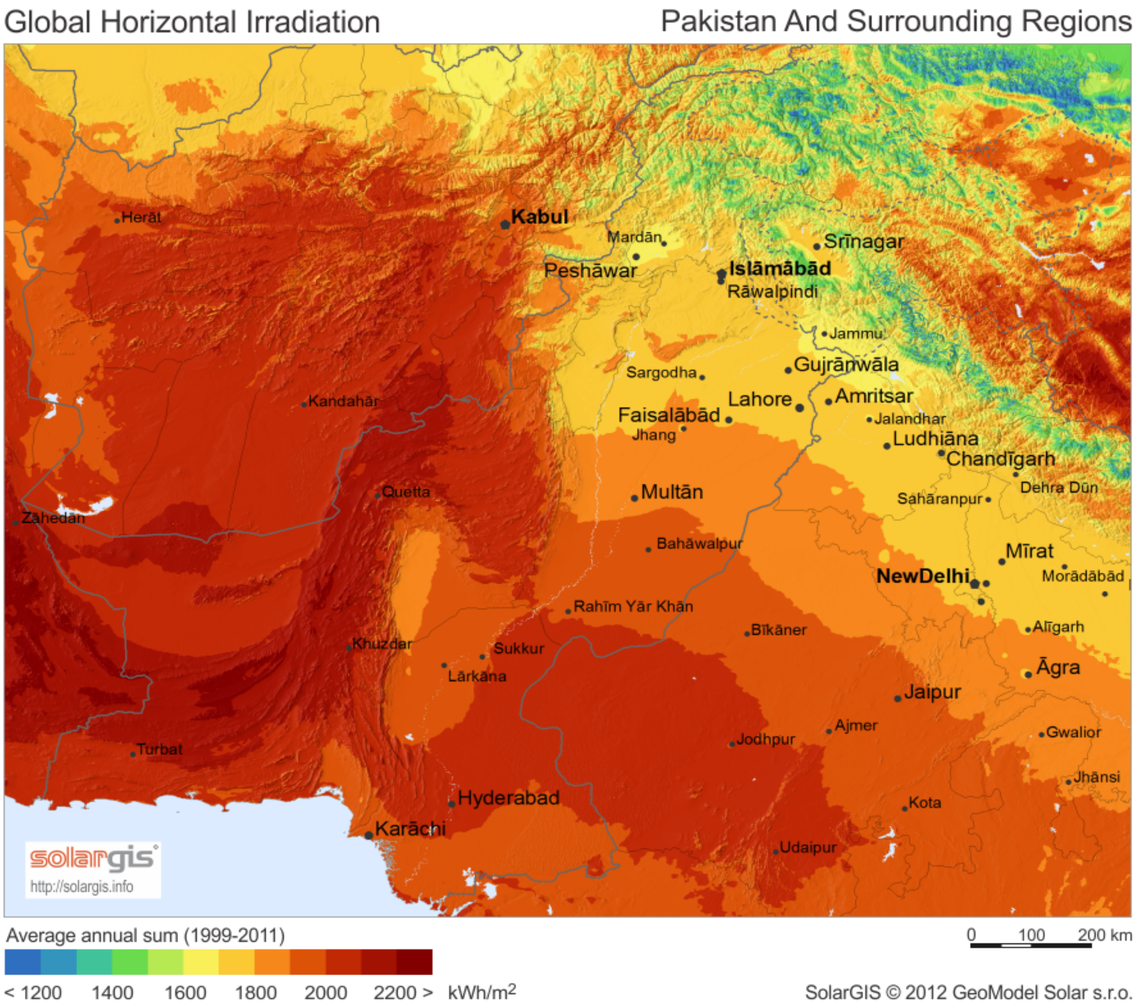
Spatially the population of Pakistan is well spread throughout the country. Sparsely located villages in the remote areas of the provinces of Khyber Pakhtunkhawa and Baluchistan with no electricity are the common landscapes of these provinces. Rural development programs such as the Agha Khan Rural Support Program, the National Rural Support Program, and Pakistan's Poverty Alleviation Fund have started installing PV units in mosques, schools, and streets. Considering the limited availability of grid electricity and the serious shortfall of electricity to grid connected users, off-grid applications of PV show very good potential in the country.

Recently the governments of Pakistan and Germany have signed two agreements for electricity generation through solar and wind energies.

Solar thermal technologies also offer huge potential. Solar thermal technologies are simple in application, and relatively cost effective. Major applications of solar energy in Pakistan are in the form of domestic cooking, heating and cooling of buildings, industrial steam generation, water heating, and dry industrial production processes (Pillai and Banerjee 2009). Many solar-based appliances and technologies are now entering into the Pakistani market including: solar dryers for domestic and industrial applications, solar cookers, solar water pumps, solar water heating equipment. The corporate sector has also developed many innovative applications for solar power. For example, telecom power, solar powered lighting, solar powered traffic signals etc. Solar thermal is highly relevant for industrial process (particularly processes that require water from 40^{o}C to 80^{o}C). The textile industry is one most relevant sectors for such applications. At present, Pakistan’s textile sector is facing a very serious shortage of energy and expensive energy costs. These two factors are making the textile industry non-competitive in the international market. Pakistan’s textile sector can easily use solar-based energy generation for space and water heating and for drying processes (Bhutto, et, al, 2012).

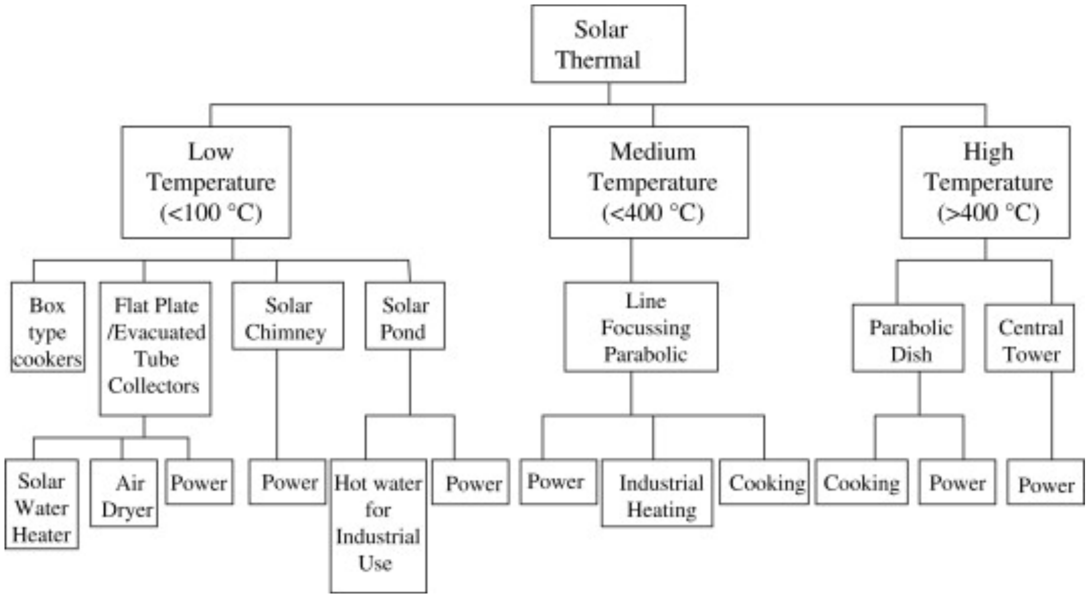
Figure 3.7: Solar Radiation Map of Pakistan

Source: http://solargis.info/doc/_pics/freemaps/1000px/ghi/SolarGIS-Solar-map-Pakistan-and-surrounding-regions-en.png



Application of solar power sourced desalination projects can provide safe water for drinking and for agriculture in the saline water logged areas of Pakistan. Solar water pumping for drinking and for irrigation can also contribute to Pakistan's rural development. Figure 3.8 summarizes the applications of solar energy in Pakistan.

Figure 3.8: Application of Solar Energy in Pakistan
Source: (Bhutto, et, al, 2012).



3.2.4 Biomass Sources

In 2012, the share of bioenergy (biomass energy) in the global primary energy supply was approximately around 10% (50 EJ) and the developing countries were the main consumer. Bioenergy electricity accounts for about 1.5 % (370 TWh) of the total global electricity generation. This generation capacity is expected to grow at an average of (+7 %) annually from 370 TWh in 2012 to 560 TWh in 2018 (IEA, 2015).

Pakistan produces a large amount of biomass from its agriculture and livestock sector. That biomass is usually available in the form of crop or animal residues (e.g. rice husks, and dung), which are currently used as fuel for cooking and for household heating. In addition, municipal solid waste is produced by a large urban population and could be used to produce methane gas for electricity generation and heating/cooling (Govt. of Pakistan, 2006). Owing to the limited availability of commercial energy in the rural areas of Pakistan there is high dependence on fuel wood, animal dung and crop residues. The current techniques of conversion of biomass into energy sources in rural areas are very inefficient, and most of the energy potential is generally wasted (Bhutto, Bazmi, and Zahedi, 2012). These techniques need to be replaced by efficient bio-energy technologies (Chaudhry, et al, 2008).

In Pakistan, waste from livestock and residues of sugarcane crop are abundantly available for producing biogas that can be further used for power generation (Zuberi, et al, 2013). Table 3.2 presents the biomass generation potential by crops in Pakistan. The largest amount of biomass is generated by sugarcane crops in Pakistan. Pakistan is ranked as the world's 5th largest producer of sugarcane. The average annual production of sugarcane in Pakistan is about 50 million tons. The average residual sugarcane bagasse is about 10 million tons. This large amount of bagasse can be used for power generation (Amjid, et al, 2011). There are about 80 sugar mills in Pakistan; these mills can generate about 3,000 MW through bagasse. At present, Pakistani sugar mills are generating only 700 MW of electricity using bagasse (PBIT, 2010).

In the year 2012, the livestock population of Pakistan reached about 167.5 million (Govt. of Pakistan, 2012b). Table 3.3 presents the livestock population of Pakistan by species of livestock. The population of cattle and buffaloes is estimated to be 70 million, and these animals produce 696 million kg of dung per year. If half of that dung is used to generate biogas and the biogas is then used for power generation, the resultant computed power generation potential would be about 4,800 to 5,500 MW (Sheikh, 2009).

Table 3.2: Production of Different Crops and their Respective Residue Availability in Pakistan

Sources: Greener energy: Issues and challenges for Pakistan—Biomass energy prospective (Bhutto, A. W., Bazmi, A. A., & Zahedi, G., 2012).

Name of the Crop	Annual Production (thousand MT)*	Type of Residue	Crop to Residue Ratio (residue/kg crop)**	Total available residue (thousand MT)
Rice	6883	Husks	0.20	1376.6
		Stalks	1.50	10,324.5
		Straw	1.50	10,324.5
Cotton	3000	Boll shell	1.10	3,300.0
		Husk	1.10	3,300.0
		Stalks[a]	3.80	11,802.8
Wheat	23,864	Pod	0.30	7,159.2
		Stalks	1.50	35,796.0
Sugar-cane	49,373	Bagasse	0.33	16,293.1
		Top and leaves	0.05	2,715.5
Maize	296	Cobs	0.30	88.8
		Stalks	2.00	592.0
Bajra	470	Cobs	0.33	151.2
		Husks	0.30	141.0
		Stalks	2.00	940.0
Barley	82	Stalks	1.30	106.6
Dry chilly	187.7	Stalks	1.50	281.6

Note a-Tons/hectare
* GOP Pakistan Economic Survey 2009–10.
** Biomass conversion to energy in India—a critique (J. Singh, S. Gu., 2010).

The total biomass potential to generate power can be estimated at about 8,000 MW (3,000 MW from bagasse and 5,000 from livestock dung). This is a sizeable potential considering the present shortage of electricity is about

7,500 MW in Pakistan (Zuberi, et al, 2013). The other sources of biogas generation are residues from the paper industry, poultry waste, and organic domestic waste (Govt. of Pakistan, 2012c).

Table 3.3: Livestock Population in Pakistan by Species (Units in Millions)

Source: Economic Survey of Pakistan 2011-2012

Species	2009-10	2010-11	2011-12
Cattle	34.3	35.6	36.9
Buffalo	30.8	31.7	32.7
Sheep	27.8	28.1	28.4
Goat	59.9	61.5	63.1
Camels	1.0	1.0	1.0
Horses	0.4	0.4	0.4
Donkeys	4.6	4.7	4.8
Mules	0.2	0.2	0.2
Totals	**159.0**	**163.2**	**167.5**

3.3 Potential of Renewable Energy as a Climate Change Mitigation Strategy for Pakistan

About 55-60% of the total anthropogenic radiative forcing is in the form of CO_2 emissions, the other 40-45% accounts for other pollutants (black carbon, tropospheric ozone, methane, and hydro fluorocarbons). These pollutants are also referred as short-lived climate pollutants (SLCP's) due to their short atmospheric lifetime (i.e. days to a decade and a half) as compared to GHG's. Reducing CO_2 emissions only, to slow down the associated rate of climate change over the next decades is not enough; cutting down SLCP's emissions is also as important for mitigating climate change impacts (CCAC, 2013).

Cumulative anthropogenic CO_2 emissions (2010) from the energy supply (35 %) and industrial (21%) sectors accounts for more than 55% of total current global CO_2 emissions (see Figure 1.1) (IPCC 2014b). According to IEA data cumulative CO_2 emissions from electricity and heat production (42%) and industry (20%) accounts for 62% of the total CO_2 emissions (IEA, 2014).

The future challenge for mitigation measures development will be that, energy sourced industrial equipment and appliances, heating and cooling systems, and vehicles need to be replaced either by much more energy efficient solutions and/or by equipment and systems powered through renewable energy.

The incomplete combustion of fossil fuels, biofuels, and biomass are the major sources of SLCPs. Reductions in SLCPs emissions can be achieved by using combustion efficient technologies, compliance with existing laws, and effective working of regulatory institutions (CCAC, 2013).

The energy sector is one of the vital drivers of economic development for all countries. Studies have projected that climate change impacts are expected to continue and increase with time (PRI, 2009).

According to the International Energy Agency (IEA), Global carbon-dioxide (CO_2) emissions from fossil-fuel combustion reached a record high of 31.7 gigatonnes (Gt) in 2012. Coal accounted for 44% of total energy-related CO_2 emissions in 2011, followed by oil (35%), natural gas (20%), and others (1%) (IEA, 2014). The growth in emissions from the global energy system is shifting towards Asia (IEA, 2013b).

Two thirds of global GHG emissions come from the energy sector. Therefore, the future trends of the energy sector will determine whether or not climate change reduction targets are attained. Economic growth, energy demand and energy related CO_2 emissions are all tightly interlinked; however, through the implementation of effective policies and relevant technologies they can be unbundled (IEA, 2013c).

According to the International Energy Agency (IEA), Pakistan's total CO_2 emissions from fuel consumption increased from 134.64 million tonnes of CO_2 in 2010 to 136.3 million tonnes of CO_2 in 2011. Tables 3.4 and 3.5 provide a detailed overview of those figures.

Table 3.4: CO_2 Emission of Pakistan
Source: IEA CO_2 Emissions from Fuel Consumption Highlights -2013, Edition (IEA, 2013d)

Pakistan (2011)			
Total CO_2 Emissions	CO_2 Emissions: Sectoral Approach (million tonnes of CO_2)		
	Coal/Peat	Oil	Natural Gas
136.3	15.8	61.3	59.2

Table 3.5: Sector-wise CO_2 Emission of Pakistan
Source: IEA CO_2 Emissions from Fuel Consumption Highlights -2013, Edition (IEA, 2013d)

Pakistan (2011)							
Total CO_2 emissions from fuel consumption	Electricity and heat production	Other energy industry own use	Manufacturing industries and construction	Transport:	of which: road	Other sectors	of which: residen tial
CO_2 emissions by sector (Million tones of CO_2)							
136.3	39.0	1.2	42.2	32.7	36.1	17.4	14.5
Per capita emissions by sector (Kg CO_2 / capita)							
771	220	7	239	205	189	100	82

3.4 Renewable Policy Framework of Pakistan

The Government of Pakistan's (GOP) announced the "Alternate and Renewable Energy for Power Generation" (ARE Policy) for the first time in 2006. The ARE 2006 policy was initially planned to be revised by a long-term policy in the year 2008, however the policy was replaced with a new ARE policy in 2011. The ARE 2011 policy targets to provide "At least 5% of the total energy supplies through alternative and renewable energy by 2030." (GOP, 2011).

Following are the categories that fall under the ARE 2011 policy:

- Alternative Fuel (Biogas, Biofuels, Fuel from Waste, Hydrogen)
- Renewable Energy (Geothermal, Hydro, Marine, Solar, Wind, Energy from Waste)
- ARE-Fossil Fuel Hybrid Systems

The most salient features of Pakistan's ARE 2011 policy include: (GOP, 2011).

- Alternative Energy Development Board- Pakistan (AEDB) has established "one-window" office operations that facilitate from land acquisition to project implementation for the investors.

- Feed in Tariffs (FIT's) /Guaranteed electricity purchase: Under this section, it will be mandatory for the power supply companies to purchase all the electricity offered by renewable energy projects. Any RE power project with a capacity of 1MW or greater may offer its surplus electricity to the national grid. The sale of power by independent power producers (IPP's) to the grid system will be executed through contracts including security packages and having validity period of not less than 20 years.
- Simplified Generation Licensing Methodology and Procedure: will be offered to the small IPP's producing up to 5 MW of electricity.
- Electricity banking and Wheeling: Under the electricity banking option IPP's may provide electricity to the utility company/grid at one location and receive the same amount at another location and at different time from the grid for self-use without paying wheeling charges. The excess electricity if provided from the IPP's shall be adjusted in the next month on a rolling basis.

  While under wheeling the IPP's through direct bilateral sales contract may sell all or part of electricity directly to end users/ customers and the remaining electricity to the utility/grid for general supply. This allows IPP's to provide electricity to the grid at any specific location and receive the same amount of electricity from the grid at any other location upon paying wheeling charges.

- Net metering: The consumer based ARE Distributed Generators (ARE-DG's) may sell full or ay excess electricity generated to the grid which will be balanced (netted) against the electricity provided by the grid. For this reason net metering services will be provided by the utility company/grid which includes unidirectional meters for recording amounts of electricity received and supplied to the grid by the IPP's or bidirectional meters for recording net electricity transfer's.

- Fiscal Incentives: For all new or expansion of existing RE projects (small hydro, wind, and solar), exemption from income tax, no customs duty or sales tax on machinery and equipment will be applicable.
- Financial Incentives: IPP's are permitted to issue corporate registered bonds.

  The State Bank of Pakistan has offered financing options for RE power projects having installation capacity up to 20 MW using renewable energy sources (wind, hydel, biogas, biofuels, bagasse cogeneration, solar power and geothermal as fuel). The maximum time period limit will be 10 years with a grace period of 2 years and maximum borrowing limit of US$ 30 million for a single RE project (State Bank of Pakistan, 2014).

- Carbon credits: As Pakistan is a signatory to the Kyoto Protocol, RE projects under CDM shall apply for carbon credits with the help of AEDB facilitation. No duty or income tax will be applicable on the revenue generated from selling carbon credits by IPP's.

3.5 Major Barriers

Pakistan's ARE policy 2011 could not be implemented successfully due to many barriers. RE investors in Pakistan still face significant social, economic, technical, regulatory, information and institutional barriers that preclude widespread RE implementation. The major barriers in the implementation of ARE policy are summarized below:

Cumbersome tariff determination process by the National Power Regulatory Authority (NAPRA): Tariff determination for power is the mandate of NAPRA. Many local and international investors reported that tariff determination process is cumbersome. In that regard the most prominent case is power generation by sugar mills. As mentioned earlier, sugar mills offer the potential of 3,000 MW but are generating only 700 MW. NAPRA and the Pakistan Sugar Mills Association could not resolve the issue of tariffs in the last five years. Owing to that reason most of the sugar mills are not generating surplus power for the national grid. Similar tariff settlement issues are pending for many nationally and internationally financed windmill projects.

Limited political will of previous governments: Pakistan remained politically unstable in last two decades. Perpetual dictatorial governments substantially decreased the importance of strategic institutions like AEDB in the country. The political governments of the past remained aloof about the importance of RE for Pakistan. The present political government has taken few strategic steps to resolve the energy crises of Pakistan, and taken RE as one of the important sources of energy. For example, the present government has started the implementation of a 1,000 MW solar park in collaboration with local and international investors. It is expected that in the next five years RE will get a respectable share in the energy generation of Pakistan.

Law enforcement and security issues: Security issues in Pakistan are well documented and wisely known. This is one of the most important barriers to foreign direct investment in Pakistan. The government of Pakistan has started an operation against terrorism in Pakistan. The law and order and security situation has improved in the last year. Specifically to RE, Chinese and Turkish companies are already showing serious interest in the 1,000 MW solar parks in Punjab. Many Chinese and Turkish companies are in the process of developing of 100-200 MW projects. The success of the 1000 MW solar park will certainly increase the confidence of international investors in the RE sector of Pakistan.

Lack of institutional capacity: AEDB has done a good work of preparing ARE policy. However, the policy environment needs institutional strengthening to engage the private sector. More than 100 letters of intent were issued for RE projects in the last ten years yet only a few of them reached maturity. AEDB needs to perform more like a corporate entity rather than a typical bureaucratic government organization.

The International Finance Corporation (IFC) has conducted many awareness seminars with Pakistan's State Bank and other private sector banks of Pakistan on RE investments. These banks are not yet primed for RE projects investments. Much more effort is needed to engage the banking sector of Pakistan in line with RE commercial investments.

Low dissemination of RE technologies: The general perception in Pakistan is that RE is expensive and it is not competitive with existing sources of energy. One of the most important reasons behind that perception is the lack of research and dissemination of RE successful case studies in Pakistan and other countries.

Low level of private sector and community involvement: Large numbers of villages in Northern Areas and in the Baluchistan province of Pakistan are not served by the national electric grid. ARE policy also promotes off-grid application of RE in these areas. A few attempts at smaller scale RE development were made by NGOs like the Agha Khan Rural Support Program in the Northern (micro hydels) and Coastal Areas (solar panels and wind mills) of Pakistan with 80% contributions of Pakistan's Poverty Alleviation Fund (financed by the Government of Pakistan and the World Bank Group and other international financing institutions) and 20% contributions by the beneficiary communities. In these projects, the communities were involved and trained in the implementation and operations of RE projects. There is a need to scale up these pilot projects in most areas of Pakistan.

RE product development: The Open market operates through well-matured products. In Pakistan, RE product development is at its infancy. In many cases, product development involves customization of internationally tested products adapted to local conditions. This is the function of local RE technology companies. However, these companies are selling international RE products in the market without customization. Owing to this reason their market outreach is limited. In the last three years, a few technology companies have developed customized RE products for the industrial and residential markets.

Pakistan can develop its RE potential by reinforcing its energy policy framework, mainstreaming RE into its national planning priorities, establishing more attractive legal and financial instruments, expanding engagement with the private sector and local communities, fostering research and development of local RE products, and investing in the dissemination of RE products. In addition, RE generation can be substantially increased by developing a more organized market to attract international investors for wind, solar, biomass, and hydroelectric projects. Mainstreaming of RE in the energy sector of Pakistan will help Pakistan to save foreign exchange, reduce its pollution and carbon footprints, increase local energy security, and to achieve more environmentally-friendly economic development throughout the country.

Chapter 4: Potential of Renewable Energy in Sarena Industry

4.1 Introduction

This chapter applies the information provided in Chapter 3 and data from a field survey conducted during January 2014 (which was analyzed using RETScreen software). “RETScreen is a Clean Energy Management Software system for energy efficiency, renewable energy and cogeneration project feasibility analysis as well as ongoing energy performance analysis” (RETScreen International, 2014). The RETScreen Clean Energy Project Analysis Software is a windows-based software tool available online worldwide in multiple (36) languages and can be downloaded free of cost from www.retscreen.net.

A field survey was conducted in a textile factory named Sarena Dyeing and Finishing (located in Lahore, Pakistan, see figure 4.1 for the site map and figure 4.2 for site plan) to assess the potential of using energy efficiency and renewable energy strategies in the Pakistani textile sector. Sarena industry has been selected for conducting a detailed assessment because it is one of the most progressive, environmentally conscious and representative industry of the textile sector in Pakistan. Sarena is already facing serious long-term energy crises, and is ready to explore and adopt financially viable alternate energy options.

Figure 4.1: Site Map of Sarena Dyeing and Finishing
Source: www.google.com/maps

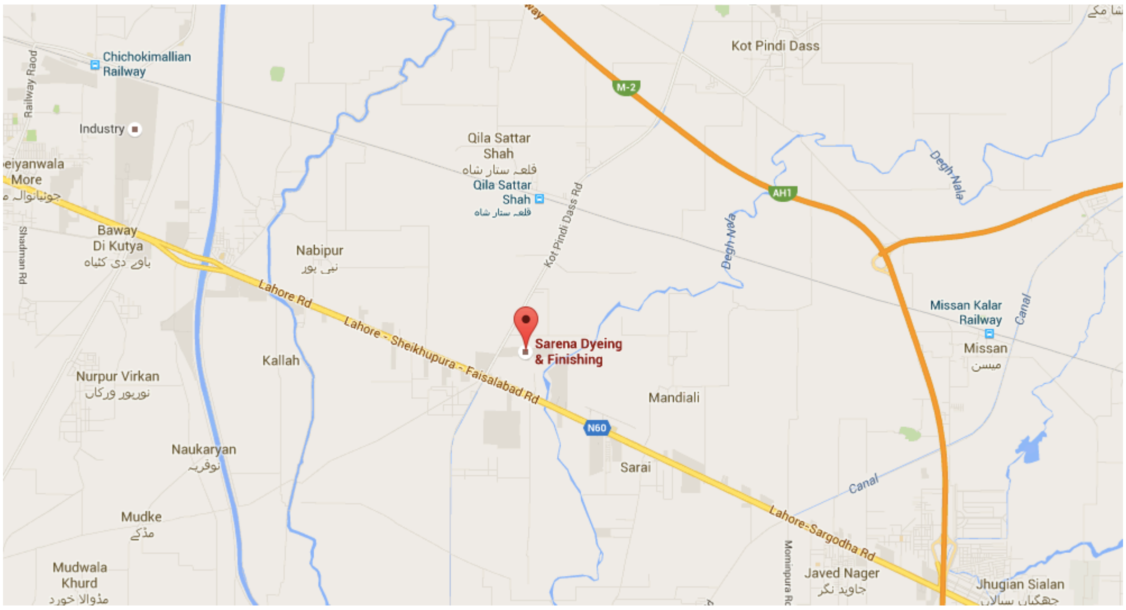


Figure 4.2: Site Plan of Sarena Dyeing and Finishing
Source: Sarena Dyeing and Finishing Database

To prepare for fieldwork, secondary information was collected regarding production processes, total industrial energy use and energy use by sub-production processes. Then an in-person survey was conducted in the facilities of Sarena Industry to assess their physical and working conditions. The person in charge of facilitating the site visit provided a PowerPoint presentation showing facts and figures of the facility. Then afterwards all the departments of the industry were visited on foot, the person in charge briefed me on all details about equipment, machinery and processes. Pictures and notes were taken during the survey. The person in charge of each department were also interviewed and participated in specific questions related to their departments. Then primary information regarding production processes, raw material consumption and utilities consumption data was collected between the three visits over a period of 15 days. (Please see pictures of the selected facility and website in Figure: 4.3).

After data gathering in the field, RETScreen was used to quantify the potentials of energy efficiency measures and renewable energy options for Sarena industry.

4.2 Profile of Sarena Industry

Sarena Industries and Embroidery Mills (Pvt) Ltd. is a large sized woven textile processing industry. Sarena processes the grey woven fabric to produce printed and dyed finished fabric. The average annual production of the industry was 24,355,782 meters dyed finished fabric in 2013. Sarena has ISO 9001 and Oeko Tex 100 certifications (and its quality testing laboratory is ISO 17025 certified). Sarena management is planning to get ISO 14001 certification in the future. Sarena started its operation in 2000 at its current location (address: 22 km, Sheikhupura Road, Lahore). Sarena is a member of the All Pakistan Textile Processing Mills Association (APTPMA).

Figure 4.3: Physical and Virtual Facilities of Selected Research Facility
Source: Photo credits: Tabassum, F. and web image reproduced from: http://sarenapk.com/

Sarena Dyeing and Finishing website : http://www.sarenapk.com

Sarena Dyeing & Finishing: Administration Block

 Steam Turbine	 Site for extension for treatment plant
 Storage shed: Bagasse	 Bagasse
 Finishing Area	 Storage: Grey fabric
 Bleaching process	 Folding after bleaching

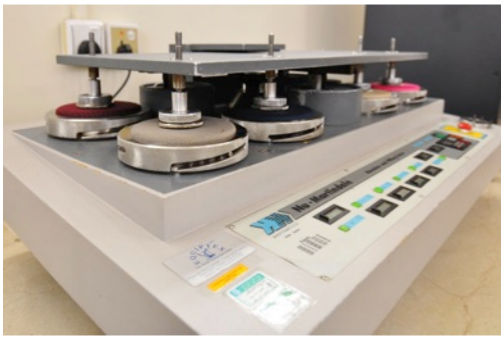

Printing: Flat bed printing machine


Finishing: Stenter machine


Laboratory: Quality control


Laboratory: Quality control


Laboratory: Quality testing machine


Laboratory: Quality testing machine

The Sarena mill works 24 hours a day for 350 days a year, in two shifts of 12 hours. In total there are 444 workers employed in the mill. All the workers are employed on a permanent basis. The finished products of Sarena industry are dyed and printed finished fabric. The major production facilities of the mill include:

- **Pretreatment** (singeing, desizing, scouring, bleaching and mercerization):

Pretreatment processes aim to prepare fabric for the dyeing and printing processes. Grey fabric quality and quantity is evaluated, after inspection following treatments is done.

Singeing: First step of the pretreatment is the singeing. First the brushing of the fabric is carried and unwanted fibers adhered on the surface of fabric are removed by abrasive action. Then it is passed over series of burners where the loose hairy fibers protruding from the surface of the fabric are burnt, which makes it smooth and clean.

Desizing: Before the conversion of yarn into the grey fabric in the weaving mill, yarn undergoes a sizing treatment. In this treatment, coating of chemicals mostly starch, oil and waxes on its surface provides strength and lubrication so that it could resist wear and tear while moving on the weaving machine.

Scouring: After desizing, fabric is subjected to scouring treatment, which is employed to remove oil, grease and dirt that are attached to the fiber either naturally or acquired during the sizing process.

Bleaching: Coloring matters are also the natural impurities in the cotton fiber. The primary objective of bleaching is to remove the colored and undesired impurities to avoid unwanted shade or tint on the white, dyed or finished fabric.

Drying: After bleaching, fabric is dried on the drum dryers. The objective of drying is to evaporate the water soaked by the fabric during washing processes.

Mercerization: The purpose of mercerization is to give strength, improve luster and increase absorption of the fabric for dyes in the subsequent processes for cotton fabric.

- **Dyeing department**

  Dyeing process is employed to impart the desired shade on the fabric. In Sarena industry, pad batch, pad steam, pad thermosol, soft flows and open jiggers machines are used for the dyeing. Reactive dyeing is carried out in cold or hot state.

- **Printing**

  Printing is a process to impart desired pattern & shade to the fabric. The printing process can be divided into three activities: preparation of coloring paste in color kitchen: screen development and stripping, and fabric printing.

- **Finishing department** (Chemical and Mechanical)

  The objective of the finishing operations is to bring textile product into presentable form. Two types of fabric finishing processes include chemical and mechanical. The extent of finishing depends on the fabric quality and end product finish demands.

- **Packing and dispatching**

  Finished fabric is folded at the folding machines. The folded fabric is packed in different packing materials like polyethylene bags and fabric to avoid dust. The finished fabric is finally stored in a finished product storage area before shipment.

A detailed description of all above-mentioned processes is provided in Annex 1 and a process flow summary is provided in Figure 4.5).

The area of the facility is about 43,494 m^2 of which about 45% is a roofed area. Most of the machines are well maintained (please see Figure 4.4 below) which indicates that regular and preventive maintenance is carried out in the industry.

Figure 4.4: Equipment's/ machinery maintenance of Selected Research Facility

Source: Photo credits: Tabassum, F.

Waukesha natural gas generator

Printing: Rotary printing machine

Mercerization: Mercerizing equipment

Grey woven fabric undergoes a series of processes to produce dyed, printed and finished products. Major raw materials for the textile processing are grey fabric and chemicals. Different varieties of grey fabric arrive at the mill for further processing. Some fabrics are made from pure cotton or polyester yarns, whereas others are blended fabrics of polyester and cotton mixed in different proportions. Each fabric quality and type requires different treatment processes. Therefore, each process recipe, chemicals, water consumption and process control parameters varies from fabric to fabric which implies that raw materials and energy demands of each product and sub-process are different from each other.

The Sarena mill produces three types of finished textile products: white (bleached); dyed; and printed fabrics. The total annual production of the mill is 24,355,782 meters of fabric (with a total weight of 10,649,566 kg).

The Sarena production processes can be broadly categorized as: pretreatment, dyeing, printing and fabric finishing (a detailed description of all these processes is provided in Annex 1 and a process flow summary is provided in Figure 4.5 below).

Figure 4.5: Process Flow Diagram

Inputs	Process	Outputs
	Fabric Reception	Rejected
	Accepted	
Energy, Water	Singeing	Energy, fluff waste
Water, Enzyme, Common Salt, Caustic soda, Detergent, heat	Desizing	Wastewater (BOD, COD, pH, TDS & TSS), heat
Water, heat	Washing	Wastewater (pH, TDS, TSS), heat
Water, Caustic Soda, Sequestering agent, Detergent, heat	Scouring	Wastewater (BOD, COD, pH, TDS, TSS, O&G), heat
Water	Washing	Wastewater (BOD, COD, pH, TDS, TSS, O&G), heat
Water, Hydrogen Per Oxide , Stabilizer, Caustic soda, Detergent	Bleaching	Wastewater (pH, TDS, Surfactants)
Water, heat	Washing	Wastewater (pH, TDS, Surfactants) , heat
Water, Acetic Acid	Neutralization	Wastewater (pH)
Water, Caustic Soda, wetting agent	Mercerization	Wastewater (BOD, COD, pH, TDS & TSS), heat
Water, heat	Washing	Wastewater (high pH)
Heat, water	Drying	Wastewater, heat
Water, heat, Dyes and Auxiliaries	Dyeing	Wastewater (BOD, COD, pH, TDS, TSS, Color, surfactants, Cr, Cu), heat
Water, heat	Washing	Wastewater (BOD, COD, pH, TDS, TSS, color, surfactants, Cr, Cu), heat)
Printing chemicals (dyes, pigments and auxiliaries), water	Printing	Wastewater (BOD, COD, pH, TDS, TSS, Color)
Finishing chemicals, Water, heat	Finishing	Wastewater (COD, TSS, TDS)

4.3 Energy Profile

4.3.1 Sarena Electricity Demand

Electricity: the major sources of electricity in Sarena Mill are self-generation and supply from the Lahore Electricity Supply Company (LESCO). At Sarena Mill self-generation includes three generators: a 900 kW natural gas generator; a 1850 kW diesel generator and one 1000 kW biomass steam turbine. Total annual demand in 2013 was 12,197,212 kWh. More than 85% of that demand was supplied by self-generation and the rest from LESCO. Electricity supplied by the LESCO costs about 19.075 CAN cents/kWh whereas a unit rate of self-generation costs varies according to the fuel used.

Table 4.1: Amount of Energy Shares by Sources

Fuel	KWh/year	KWh-%	Hrs/ day	Hrs/year	Unit Price (PKRs/KWh)	Unit Price (CAN cents/ KWh)
Gas	4,755,000	39.0	9.4	3,415	6.00	7.5
LESCO	1,508,295	12.4	3.0	1,083	15.26	19.075
Biomass	4,919,164	40.3	9.7	3,533	960/ton or 3-4 Rs/Kwh	960/ton or 3.75-5 cents/Kwh
Diesel	1,014,753	8.3	2.0	729	28.00	35.00
Total	**12,197,212**	**100.0**	**24.0**	**8,760**	**8.25**	**10.3125**

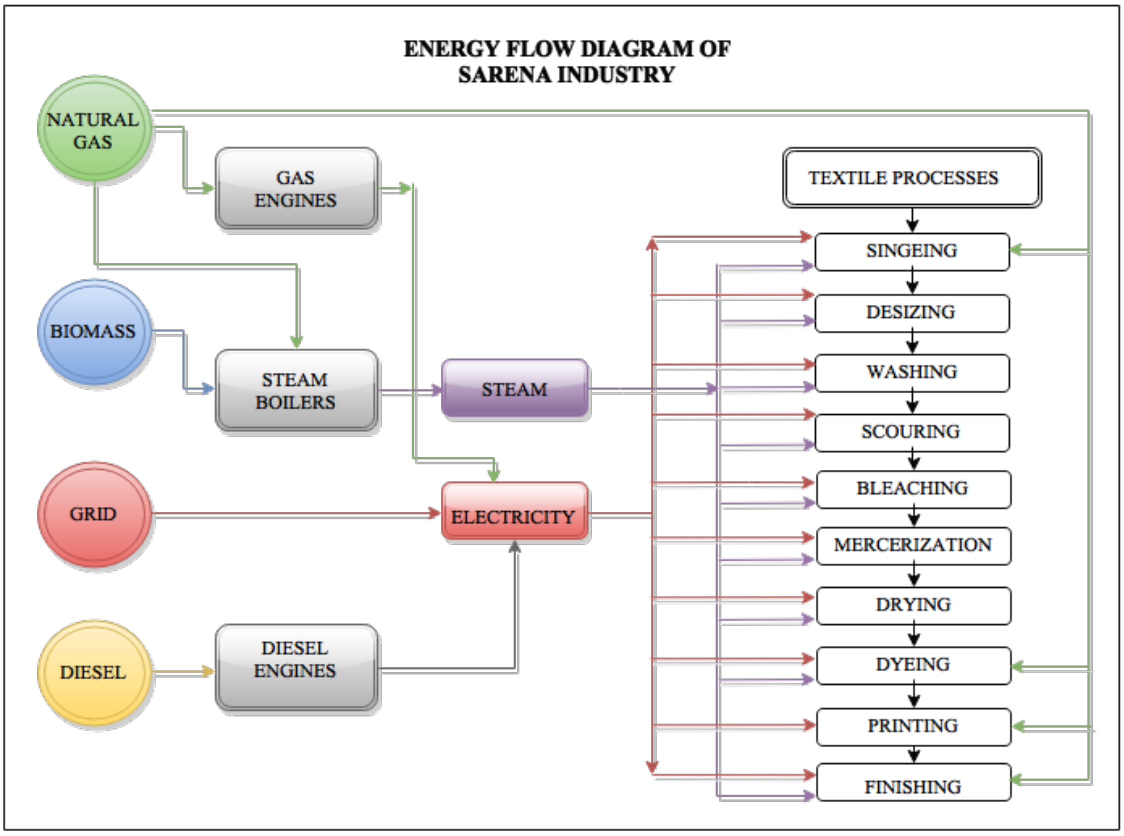
- Unit cost of kWh produced by the power plant is inclusive of salaries, maintenance costs, electrical duty etc.
- Unite rate calculated @ 1 PKRs.= 80 CAN $

Natural Gas: Natural gas is supplied by the Sui Northern Gas Pipelines Limited (SNGPL). It is used in Steam boilers (2), Thermal oil heater (1), Singeing machine (1), Gas generators (2), Stenters (4), and Thermosol (2). About 82% of the total gas is consumed in the production process whereas

18% is used by the generators (Waukesha and Caterpillar) to produce electricity.

Steam: Steam is another important medium of supplying heat energy to the different processes. It is either employed directly to heat water or indirectly through coils or jackets. Direct injection of steam is irrecoverable whereas indirect steam gets condensed after the heat transfer to the other media of contact and can be reused or recycled. There are three steam boilers. The fuel used in two boilers is natural gas. The third one is the waste heat boiler. Reported heating surfaces of steam boilers are 2,312 ft^2 and 1,500 ft^2. The boilers capacities are 10 tons/hr and 6 ton/hr, respectively. The waste heat boiler has a heating surface of 2,300 ft^2 with capacity of 0.5 tons/hr. All the three steam boilers operate 24 hours a day. Steam is mainly used in desizing, scouring, hot washings, bleaching, drying and calendering. Steam condensate from most of the plant equipment is returned to the boiler feed water tank, which is 65-70% of the overall steam (275-300 ton/day) consumed. An economizer is installed at both boilers. Steam condensate and makeup water is mixed in the feed water storage tank. This mixed water is pumped into the economizer and heated up to 12^{o}C above the inlet temperature. This heated water is then fed to the boilers.

Figure 4.6: Energy Flow Diagram



4.3.2 Product Energy Demand

Specific demand of electricity and gas per kilogram of product is given in Table 4.2. Optimum utility demand values are also provided (which are based on demand data from various local and international textile industries).

Table 4.2 Product Energy Demand
Source: Data collected during field surveys, and Cleaner Production Institute database.

Energy	Actual Demand (Per kg of fabric)	Optimum Consumption (Per kg of fabric)
Natural gas (m^3)	0.87	0.5-1.0
Electricity (kWh)	0.64	0.5-1.0
Steam (kg)	10.00	5-8
Water (litres)	125	70-100

4.4 Sarena Energy Analyses

In this section I explore the contributions that energy efficiency and the application of renewable energy could provide to the Sarena industry. The objective of conducting energy efficiency analysis is to analyze all possibilities of energy efficiency to enable the industry to achieve a higher level of energy efficiency production and management. In the last part of this section I analyze the potential of using renewable energy in the Sarena industry. For both sections, RETScreen software has been used to facilitate the analysis.

4.4.1 Energy Efficiency Analysis

Energy Efficiency (EE) as a concept revolves around the goal to reduce the total amount of energy required to provide products and services. High-energy expenses are often seen as one of the major factors decreasing business competitiveness. Throughout the world industries and institutions have substantially reduced their energy costs by applying innovative designs and state-of-the-art energy efficient technologies.

Based on the energy demand data obtained from Sarena mill and consultation with Sarena management during fieldwork, the following efficiency measures were identified as promising:

- Replacement of T8 tube lights by T5 tube lights;
- Replacement of water turbines by energy efficient electric turbines;

- Replacement of stanter fans;
- Replacement of current electric motors by more efficient units

Tables 4.3 and 4.4 present the summary of the results of RETScreen Analysis for energy efficiency that are possible in Sarena industry. Figure 4.7 presents the overall graphical presentation of the RETScreen analysis (the detailed RETSreen Analysis is included in Appendix 2).

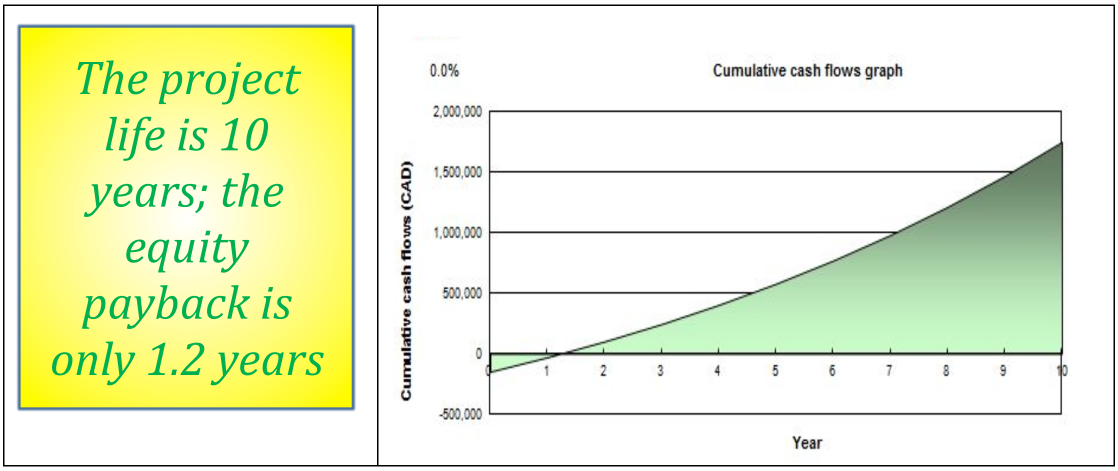
Table 4.3: Summary of Energy Efficiency Analysis

Proposed Energy Efficiency Measures	Number of Units	Fuel Saved Electricity GJ	Initial Cost CAN $	Fuel Cost Savings CAN $	Pay-back Yrs.
Replacement of T8 tube lights by T5 tube lights.	1,174	1,222	29,350	34,956	0.8
Replacement of stanter fans.	35	1,673	16,625	47,866	0.3
Replacement of 11 kW standard efficiency motors by efficient motors.	51	401	30,600	11,480	2.7
Replacement of 7.5 kW standard efficiency motors by efficient motors.	70	317	43,750	9,056	4.8
Replacement of 22 kW standard efficiency motors by efficient motors.	4	29	7500	844	8.9
Replacement of 45 kW standard efficiency motors by efficient motors.	5	125	21875	3,567	6.1

Table 4.4 Comparative Analysis of Base and Proposed Cases

Fuel Type	Base Case			Proposed Case		Fuel Cost Savings		
Electricity	Fuel rate CAN $	Fuel consumption	Fuel cost CAN $	Fuel consumption	Fuel cost CAN $	Fuel saved	Fuel cost savings CAN $	
Fuel unit MWh	8,250.0	9,586.4	987,404	8,540.1	879,635	1,046.3	107,769	
Fuel consump-tion	Electricity GJ			Electricity GJ		Fuel Saved GJ	Fuel saved %	
	34,511			370,745		3,767	10.9	
Emission Analysis	GHG Emission tCO^2			GHG Emission tCO^2		Net Annual GHG Emission Reduction tCO^2		
	4,0171.0			3,626.7		444.3		
Financial Analysis	Initial costs	Fuel cost		Fuel cost		Pre-Tax IRR equity %	Simple Pay-back Time yrs.	Equity Pay-back yrs.
	149,700	987,404		879,653		88.9	1.4	1.2

Figure 4.7: Summary of RETScreen Efficiency Analysis for Sarena Mill



Tables 4.3 and 4.4 shows that the energy efficiency measures offer very attractive payback periods with moderate levels of investment versus large energy savings. The replacement of motors with more efficient motors offers longer payback periods and might not be as attractive to Sarena. Figure 4.7 shows that if the Sarena mill implements all the proposed measures it can achieve cash breakeven within 15 months, and then for the next eight and half years the industry can achieve large financial gains.

4.4.2 Renewable Energy Solutions

As Table 4.1 illustrates the energy supply chain of Sarena industry is from multiple sources. Biomass and natural gas represent about 79.3% of the current electricity demand used at the mill. Sarena management operates its electricity generation systems in this descending order of priority:

(i) Gas-LESCO-Biomass, (ii) LESCO-Biomass-Diesel, and (iii) Gas-Biomass-Diesel to achieve the lowest costs to satisfy its electricity demand. Diesel is the most expensive source of electricity and industries like Sarena use it in the case of non-availability of natural gas or grid electricity. Sarena is operating at average energy rate of 10.3125 (CDN cents/kWh). It is important to note that there is a hidden subsidy in the price of natural gas and an indirect subsidy in grid electricity provided the government of Pakistan. The presence of these subsidies makes renewable sources of energy less attractive for industry in Pakistan.

Table 4.1 presents the quantities and shares of energy sources in the supply chain of the energy to the industry. Current natural gas (NG) and electricity sources are facing serious shortfalls, and there is no sign of improvement for these supplies in the future. This situation implies that for any increase in electricity demand by the industry (e.g. for expansion purposes), the mill owners have to secure their own supply.

Availability of biomass in the market is showing its limitation due to competition among multiple consumers of biomass. It is assumed that industry will not shift to diesel due to its high prices. These arguments imply that Sarena mill is willing to consider the potential of solar photovoltaic (PV), solar thermal, and wind. Initial RETScreen feasibility analysis indicates that wind energy is an expensive proposition for Sarena mill due to poor wind resources and high capital cost. Solar thermal potential does show promise particularly for the preheating of intake water for steam turbines and other production process. Detailed analysis of wind and solar thermal energy as alternate energy sources were beyond the scope of this research. Application of solar thermal in the industry of Pakistan is non-existent. RE vendors informed that solar thermal systems were marketed to both household and industry sectors. The industry sector did not show any interest due to large area requirement and limited contribution in the energy system of the industry. Detailed research on solar thermal potential is beyond the scope of this paper and although promising it needs to be investigated during future studies. To summarize, my analysis focuses only on the potential use of solar PV in Sarena mill.

Case A: Diesel based energy generation Vs Photovoltaic system

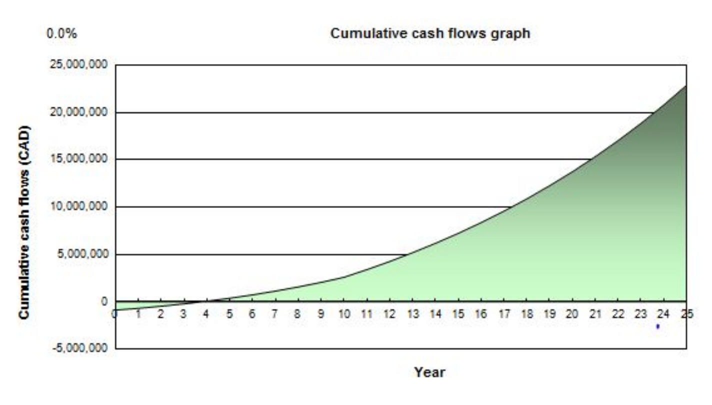
Table 4.5 provides a summary of the RETScreen analysis conducted to evaluate RE use in Sarena mill to replace electricity produced from diesel generators (for all the detailed calculations please see Appendix III).

Table 4.5: RETScreen RE Solutions Analysis for Sarena Mill Diesel Vs PV system

<table>
<tr><th>Parameters/Variables</th><th>Measurement Units</th><th colspan="2">Values/Remarks</th></tr>
<tr><td colspan="4">Base Case</td></tr>
<tr><td>Grid type</td><td>-</td><td colspan="2">Off-Grid</td></tr>
<tr><td>Technology</td><td>-</td><td colspan="2">Reciprocating engine</td></tr>
<tr><td>Fuel rate</td><td>CAN $/KWh</td><td colspan="2">1.275</td></tr>
<tr><td>Capacity</td><td>KW</td><td colspan="2">1400</td></tr>
<tr><td>Annual O&M cost</td><td>CAN$</td><td colspan="2">25,000</td></tr>
<tr><td>Electricity rate</td><td>CAN $/KWh</td><td colspan="2">0.376</td></tr>
<tr><td>Total electricity cost</td><td>CAN $</td><td colspan="2">384,099</td></tr>
<tr><td>Load characteristics</td><td>-</td><td colspan="2">Method-1</td></tr>
<tr><td>Electricity–daily-AC</td><td>KWh</td><td colspan="2">2,800</td></tr>
<tr><td>Electricity-annual-AC</td><td>MWh</td><td colspan="2">1,022</td></tr>
<tr><td>GHG Emission factor for Pakistan (all fuel types)</td><td>tCO_2/MWh</td><td colspan="2">0.425</td></tr>
<tr><td>GHG emissions</td><td>tCO_2</td><td colspan="2">756.1</td></tr>
<tr><td colspan="4">Proposed Case</td></tr>
<tr><td>Grid Type</td><td>-</td><td colspan="2">Grid tight</td></tr>
<tr><td>Technology</td><td>-</td><td colspan="2">PV solar panel</td></tr>
<tr><td>Electricity-daily-AC</td><td>KWh</td><td colspan="2">2,800</td></tr>
<tr><td>Electricity-annual-AC</td><td>MWh</td><td colspan="2">1,022</td></tr>
<tr><td>Solar tracking mode</td><td>-</td><td colspan="2">Fixed</td></tr>
<tr><td>Slope</td><td>Degree</td><td colspan="2">45</td></tr>
<tr><td>Annual solar radiation Lahore</td><td>KWh/m^2/annum</td><td>Solar radiation-horizontal</td><td>Solar radiation-tilted</td></tr>
<tr><td></td><td>-</td><td>4.68</td><td>4.91</td></tr>
<tr><td>Manufacturer</td><td>-</td><td colspan="2">JA Solar</td></tr>
<tr><td>Model</td><td>-</td><td colspan="2">Poly-Si- JAP6-60-250W</td></tr>
<tr><td>Total power capacity</td><td>KW</td><td colspan="2">1,400</td></tr>
<tr><td>Incremental cost of PV system</td><td>CAN$</td><td colspan="2">2,038,750</td></tr>
<tr><td>Solar collector area</td><td>M.sq.</td><td colspan="2">9,156.3 (5,600 units)</td></tr>
<tr><td>Capacity factor</td><td>%</td><td colspan="2">18.9</td></tr>
</table>

Emissions Analysis		
GHG Emission factor for Pakistan (all fuel types)	tCO_2/MWh	0.425
GHG emissions	tCO_2	0
Net annual GHG emission reduction	tCO_2	756.1
Financial Analysis		
Inflation Rate	%	7.0
Project Life	Yrs	25
Dept. Ratio	%	60
Dept. interest rate	%	11
Dept. term	Yrs.	10
Total Initial Incremental Cost	CAN $	2,163,750
Dept. payments-10 years	CAN $	220,445
Total Annual Savings and Income	CAN $	384,099
Simple Payback	Yrs	5.6
Equity Payback	Yrs	3.7
Cost of electricity (PV system)	CAD $/KWh	2.33

The project life is 25 years; the equity payback is only 3.7 years



Case B: Grid electricity Vs Photovoltaic system

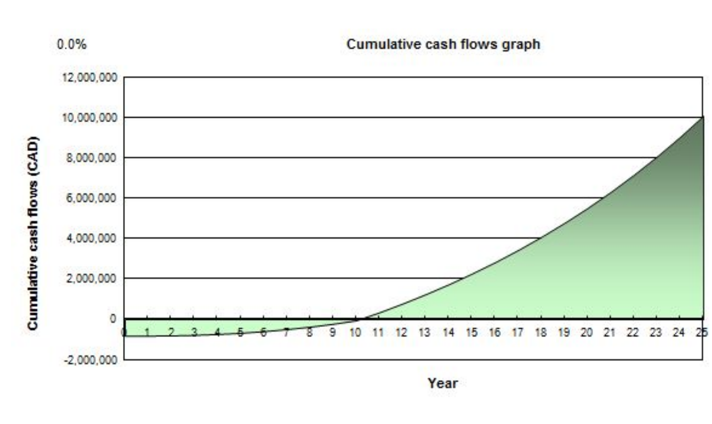
Table 4.6 provides a summary of the RETScreen analysis conducted to evaluate RE use in Sarena mill to replace grid electricity (for detailed calculations see Appendix IV).

Table 4.6: RETScreen RE Solutions Analysis for Sarena Mill Grid Vs PV system

<table>
<tr><th>Parameters/Variables</th><th>Measurement Units</th><th colspan="2">Values/Remarks</th></tr>
<tr><th colspan="4">Base Case</th></tr>
<tr><td>Grid type</td><td>-</td><td colspan="2">Grid electricity</td></tr>
<tr><td>Technology</td><td>-</td><td colspan="2">-</td></tr>
<tr><td>Fuel rate</td><td>CAN $/KWh</td><td colspan="2">0.188</td></tr>
<tr><td>Capacity</td><td>KW</td><td colspan="2">1400</td></tr>
<tr><td>Annual O&M cost</td><td>CAN$</td><td colspan="2">0</td></tr>
<tr><td>Electricity rate</td><td>CAN $/KWh</td><td colspan="2">0.188</td></tr>
<tr><td>Total electricity cost</td><td>CAN $</td><td colspan="2">191,625</td></tr>
<tr><td>Load characteristics</td><td>-</td><td colspan="2">Method-1</td></tr>
<tr><td>Electricity–daily-AC</td><td>KWh</td><td colspan="2">2,800</td></tr>
<tr><td>Electricity-annual-AC</td><td>MWh</td><td colspan="2">1,022</td></tr>
<tr><td>GHG Emission factor for Pakistan (all fuel types)</td><td>tCO_2/MWh</td><td colspan="2">0.425</td></tr>
<tr><td>GHG emissions</td><td>tCO_2</td><td colspan="2">200.6</td></tr>
<tr><th colspan="4">Proposed Case</th></tr>
<tr><td>Grid Type</td><td>-</td><td colspan="2">Grid tight</td></tr>
<tr><td>Technology</td><td>-</td><td colspan="2">PV solar panel</td></tr>
<tr><td>Electricity-daily-AC</td><td>KWh</td><td colspan="2">2,800</td></tr>
<tr><td>Electricity-annual-AC</td><td>MWh</td><td colspan="2">1,022</td></tr>
<tr><td>Solar tracking mode</td><td>-</td><td colspan="2">Fixed</td></tr>
<tr><td>Slope</td><td>Degree</td><td colspan="2">45</td></tr>
<tr><td>Annual solar radiation Lahore</td><td>$KWh/m^2/annum$</td><td>Solar radiation-horizontal</td><td>Solar radiation-tilted</td></tr>
<tr><td></td><td>-</td><td>4.68</td><td>4.91</td></tr>
<tr><td>Manufacturer</td><td>-</td><td colspan="2">JA Solar</td></tr>
<tr><td>Model</td><td>-</td><td colspan="2">Poly-Si- JAP6-60-250W</td></tr>
<tr><td>Total power capacity</td><td>KW</td><td colspan="2">1,400</td></tr>
<tr><td>Incremental cost of PV system</td><td>CAN$</td><td colspan="2">2,038,750</td></tr>
<tr><td>Solar collector area</td><td>M.sq.</td><td colspan="2">9,156.3 (5,600 units)</td></tr>
<tr><td>Capacity factor</td><td>%</td><td colspan="2">18.9</td></tr>
<tr><th colspan="4">Emissions Analysis</th></tr>
<tr><td>GHG Emission factor for Pakistan (all fuel types)</td><td>tCO_2/MWh</td><td colspan="2">0.425</td></tr>
<tr><td>GHG emissions</td><td>tCO_2</td><td colspan="2">0</td></tr>
<tr><td>Net annual GHG emission reduction</td><td>tCO_2</td><td colspan="2">200.6</td></tr>
<tr><th colspan="4">Financial Analysis</th></tr>
<tr><td>Inflation Rate</td><td>%</td><td colspan="2">7.0</td></tr>
<tr><td>Project Life</td><td>Yrs</td><td colspan="2">25</td></tr>
<tr><td>Dept. Ratio</td><td>%</td><td colspan="2">60</td></tr>
<tr><td>Dept. interest rate</td><td>%</td><td colspan="2">11</td></tr>
<tr><td>Dept. term</td><td>Yrs.</td><td colspan="2">10</td></tr>
<tr><td>Total Initial Incremental Cost</td><td>CAN $</td><td colspan="2">2,038,750</td></tr>
</table>

Dept. payments-10 years	CAN $	207,710
Total Annual Savings and Income	CAN $	191.625
Simple Payback	Yrs	10.6
Equity Payback	Yrs	10.1
Cost of electricity (PV system)	CAD $/KWh	2.19

The project life is 25 years; the equity payback is 10.1 years



Case C: Natural gas based energy generation Vs Photovoltaic system

RETScreen analysis conducted to evaluate the viability of PV system to replace the natural gas based generation showed an equity payback time of more than 18 years against the project life of 25 years, hence not a financially viable option.

Case D: Biomass based energy generation Vs Photovoltaic system

RETScreen analysis conducted to evaluate the viability of PV system to replace the biomass based generation showed an equity payback time in negative (-ve) i.e. more than the project life of 25 years, hence not a financially viable option.

4.5 Summary:

The RETScreen analysis is summarized in Tables 4.5 and 4.6. It is concluded from these tables that PV system is only financially viable against diesel based electricity generation. Simple payback period for a PV system to meet 1400 kW worth of electrical demand at the Sarena Mill is 3.7 years to replace diesel based electricity generation. This payback period is particularly attractive as electricity from other low-cost sources (natural gas, LESCO, and biomass) will not be available in future. As stated above, the availability of NG and grid electricity cannot be increased in the near future (at least in the next five years), and biomass supply is facing problems. Under these circumstances, it is concluded that energy from solar PV solar systems to replace diesel based electricity generation represents a good business case.

Chapter 5: Conclusions, Recommendation and Limitations

5.1 Conclusions

Worldwide experience establishes that advances in renewable technologies (for example: electric cars, heat pumps, PV solar panels, solar thermal, biomass, and wind turbines etc.) have made renewable energy (RE) generation economically viable, environmental friendly, and socially acceptable. It is rightly argued that adoption of RE as an a solution to fossil fuel based energy that will help the world to substantially reduce carbon emissions and enable the climate to stabilize at safe levels in the next 50-60 years. Many successful business cases of RE application demonstrate that RE can be adopted under current market factors in a wide variety of countries. Consequently, many large and medium businesses are adopting RE as part of their sustainability efforts.

Energy efficiency plays an important role in reducing carbon emissions. Energy saved is considered as a replacement of energy generation. Energy efficiency helps address the “Energy Trilemma” i.e. energy security, environmental sustainability and energy equity. Therefore, improving energy efficiency will allow energy savings and reduction in the environmental impacts of energy production, and reduce the energy dependency of Pakistan.

The combination of energy efficiency (EE) and widespread RE development has become an essential energy policy element in developing and developed countries. The integrated package of EE and RE serves as the most efficient path for energy management at all levels of the system (consumers to large energy suppliers). Sustainable development of energy deficit countries depends on how well the countries integrate EE and RE to achieve energy security.

Pakistan is a country facing severe energy supply deficits and yet it also uses energy very inefficiently. Energy waste is due to widespread use of old and second-hand production machinery that is further hampered by poor maintenance and poor energy management systems and practices. The industrial sector in Pakistan can easily improve its energy efficiency by 10-15% by simply replacing the most inefficient production machinery and appliances, proper maintenance, and adopting best energy management practices. The energy efficiency analysis performed at the Sarena textile mill, conducted under this study, establishes that EE measures offer very attractive payback periods. Furthermore, the adoption of the EE summarized in this report will reduce 444.3 tCO_2 of emissions annually in the Sarena mill. While photovoltaic systems (PV) replacing the diesel based energy will reduce another 756.1 tCO_2 of emissions annually. There is an urgent need to promote and replicate the experiences of EE and RE throughout the industrial sector of Pakistan. The national and provincial governments in collaboration with market actors like the Pakistani Cleaner Production Centers and key industry associations like All Pakistan Textile Mills Association (APTMA) and All Pakistan Textile Processing Mills Association, can help disseminate the message to larger audiences in a short period. These associations can be mobilized and engaged through policy guidelines, direction demonstration of RE technologies through pilot projects, dissemination of financial viability case studies, and strengthening of RE vendor market.

Pakistan has reasonably high geographic potential for all types of RE, but seriously lags behind in exploiting its potential (particularly when compared with comparable countries such as Turkey, India, and China). The main barriers hindering Pakistan from developing its RE resources include cumbersome tariff determination process by the National Power Regulatory Authority (NAPRA); limited political will of previous governments; law enforcement and security issues; lack of institutional capacity; low dissemination of RE technologies; and low level of private sector and communities involvement. Pakistan can increase its installed RE capacity by revisiting its energy policy, mainstreaming RE in the energy policy, establishing legal and financial instruments, effective engagement of private sector and communities, research and development of local RE products, and investing in the dissemination of RE products. In addition RE generation can be substantially increased by offering a favourable investment environment to international investors for the large-scale wind, solar, biomass, and hydroelectric projects.

This study has investigated the case of a textile industry to determine the potential of using RE in its current operation. It is concluded that almost 50% (biomass + PV system) of the current electricity requirements of that textile industry can be met through RE in the province of Punjab. These results are promising for other industries and communities located in that important/populous province…

- Energy from biomass is the most attractive option. The unit cost of energy from biomass is even lower than the gas. In Pakistan the technology of biomass fed steam boilers is well established. Most of the boiler manufacturers have developed the capability of building and assembling biomass fed boilers. In the recent past, many large and medium industries have shifted to biomass fed boilers. The major problem faced by biomass fed boilers is the combustion efficiency. There is need to import high efficiency biomass fed boilers technology in Pakistan.

- Solar PV is a viable option under the long-term strategy for sustainable energy supply chain for the textile industry. In Sarena industry, electricity load of 1400 MW generated from diesel generator can be shifted to PV solar panels. In this case the simple payback period of PV solar panels investment is computed as 3.7 years. This study concludes that if subsidies on gas and grid electricity are removed, and the shortfall of gas and grid electricity remains at the present level then it can be stated with confidence that energy from PV solar panels establishes it rationality and justification as a good business case. Installation of PV solar panels of the capacity of 1400 KW will reduce 756.1 tCO_2. PV solar panels market is improving in Pakistan. Many small companies have emerged in the last three years for the supply and installation of PV solar panels at small scale. There is a need that

Pakistani companies should start collaborating with international companies for extending services for industry grade PV solar panel systems.

- Preliminary investigations were conducted for wind energy option. The initial results showed that at present the wind energy is not a viable proposition in Punjab, due to poor wind resources, as compared to other RE options.

5.2 Policy Framework for Renewable Energy

Pakistan's renewable energy policies should be based on the goal of providing energy security to all Pakistanis as well as local economic benefits and environmental protection. The government should promote and facilitate the implementation of financially viable RE technologies.

Following are the proposed policy statements and description of RE policy framework:

- **Enact RE policy/law/legislation for increasing the share of RE in national energy mix:** At present, according to the Pakistan Renewable Development Policy-2011, at least 5% of the total installed capacity will be produced through RE sources, by 2030 (Govt. of Pakistan, 2011). This policy should be backed by legislation and it should be enforced on the industry consumers. Integrate RETs options in all government development programs.

- **The framework should be supported by effective legislation and regulatory mechanisms and actions, so to ensure an increase of RE share in the country's total energy mix:** The Alternate Energy Development Board (AEDB) should be strengthened to provide leadership, guidance, monitoring and other general services for the RE sector, including research and development. AEDB should be financially well funded and technically sound. India's Ministry of Non-conventional Energy Sources (MNES) particularly concentrates on renewable energy matters in the country and is a good example of the above. AEDB should enable government to implement following measures:

    - Remove subsidies and add external costs to fossil fuel rates so to level the playing field for RET's against other conventional fuels:
    - Provide incentives to the private sector to invest in RE sector by introducing a system of tariffs, give financial incentives (financial incentives includes tax breaks, lower duty and duty free on importing capital equipment, material, and components to manufacture and maintain RET's) in RE sector. This will increase and encourage uptake of RET's by the parties.
    - Micro finance institutions should be created to provide funds/loans for small scale and medium scale RE projects by individuals or small groups/NGO's/entrepreneurs including women. Grameen Bank established in 1976 in Bangladesh is one of the best example of micro financing. Since the establishment of the bank more than

six million people have been awarded loans, an estimated 5.7 billion dollars (Stefan Lovgren, 2006).

- Develop mechanism to attract investments from international agencies for the development of the RE sector.
- Development of legal and financial mechanisms for the developments of RET's.

- **Research, Development, Demonstration and Dissemination of RET's:** Establishment of network of institutions for assisting and supporting stakeholders in development, management and maintenance of RET's projects. The mandate of these institutions should include the following:

I. Providing financial and technical information for acquiring RET's.
II. Activities related to research and development.
III. Attracting international investment for development of RET's.
IV. Collaborate with international research institutions/organizations to share and transfer their knowledge and experiences.
V. Provide training services (manufacturing, installing, service and repair) to generate skilled and professional manpower in RE sector.
VI. Promoting RET's through private and public demonstrations (via workshops, conferences, seminars) starting from low cost small scale RE technologies.

- **Increase public awareness and commercial promotion of RET's:** Integrate renewable energy information in the educational curriculum to enhance public awareness. Increase public awareness through media campaigns. Presentations/ short trainings programs in industries, universities, colleges, etc. Engage communities through community participation;

- **Engage communities through community participation:** Engage communities as stakeholder to accelerate progress. The community participation approach for development is the best participatory approach, which really works, especially in developing countries. Millions of lives in developing nations have been changed through community-based projects around the world. Also involve women as community participants in RE projects as renewable energy technicians, entrepreneurs and end users. This will not only help in promoting RET's but also help towards women empowerment, which is seriously needed especially in developing nations. "Solar Mama's" a project Barefoot College (India), focuses on training village women to become solar energy engineer, so to help them bring electricity to their communities through small household level solar equipment.

5.3 Limitations of the study

The major limitation of the study is that the field survey was conducted only for one textile unit. The textile sector in Pakistan is very large and diversified. Textile mills are using different combinations for their energy supply chains. In addition, Pakistan's industry sector is comprised of more than twenty sub-industry sectors. Owing to these limitations, the results of the study cannot be generalized to the entire textile sector or to other industrial sectors of Pakistan. Nevertheless, some of the findings on how to increase the adoption of conservation, efficiency and renewable energy solutions in Pakistan (particularly PV system, biomass, and energy efficiency) show promise to other regions and industrial sectors in the country.

Finally, due to time and resource constraints, I was not able to gather data regarding transportation requirements nor about downstream energy requirements (i.e. regarding the Mills product distribution). That energy use merits further additional research and may yield interesting findings for example about the viability of electric vehicles.

Nevertheless, the research provides an interesting and detailed analysis that should be replicated in other parts of Pakistan and Asia.

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ANNEXURE I

Informed Consent Form

Informed Consent Form

Date:

Name of Participant:

Study Name: **Potential of renewable energy in the textile sector of Pakistan**

Researchers: Firdous Tabassum

Address: Canada 29 Nobbs Drive, Ajax, ONT, L1T4M1, Canada.
Pakistan 152/II C-Block Model Town, Lahore, Pakistan

Contact: Canada (289)-660-0125, (647)-779-5044,
Pakistan 03214757941, 042-35866826

Purpose of the Research This research is part of my MES Major Research Paper at York University Toronto. The title of my MES Major Research Paper is 'Potential of renewable energy in the textile sector of Pakistan'. The purpose of this study is to investigate and develop viable renewable energy solution for industry in general and specifically for the textile sector of Pakistan.

What You Will Be Asked to Do in the Research: You will asked to provide data related to processes and energy consumption including detailed energy consumption at sub production process level. You will be asked to provide information data verbally and/or via hard/soft copy. Data collection process will take 10-15 days.

Risks and Discomforts: We do not foresee any risks or discomfort from your participation in the research. You have the right to not answer any questions.

Benefits of the Research and Benefits to You: The results of this research will identify viable renewable energy based solution packages on the basis of basic research in the key perspective of international knowledge and experience. The positive outcome of the research will benefit all the industries in general and specifically the textile sector of Pakistan.

Voluntary Participation: Your participation in the study is completely voluntary and you may choose to stop participating at any time. Your decision not to volunteer will not influence the nature of your relationship with York University either now, or in the future.

Withdrawal from the Study: You can stop participating in the study at any time, for any reason, if you so decide. Your decision to stop participating, or to refuse to answer particular questions, will not affect your relationship with the researchers, York University, or any other group associated with this project. In the event you withdraw from the study, all associated data collected will be immediately destroyed wherever possible.

Confidentiality: Unless you choose otherwise, all information you supply during the research will be held in confidence and unless you specifically indicate your consent, your name will not appear in any report or publication of the research. Handwritten notes will be taken during the interview. Hard copy and/or soft copy about the information will be needed. Your data will be safely stored in a locked facility with the researcher and only research staff will have access to this information. The data will be stored safely for a minimum of two years with the researcher after the study. The data will be destroyed after two years. Confidentiality will be provided to the fullest extent possible by law.

Questions About the Research? If you have questions about the research in general or about your role in the study, please feel free to contact Dr. Jose Etcheverry either by telephone at (416)736-2100, extension 22695 or by e-mail (rejose@yorku.ca). This research has been reviewed and approved by the FES Research Committee, on behalf of York University, and conforms to the standards of the Canadian Tri-Council Research Ethics guidelines. If you have any questions about this process or about your rights as a participant in the study, please contact the Sr. Manager & Policy Advisor for the Office of Research Ethics, 5th Floor, Research Tower, York University (telephone 416-736-5914 or e-mail ore@yorku.ca).

Legal Rights and Signatures:

I, Asif Masood, consent to participate in *Potential of renewable energy in the textile sector of Pakistan* conducted by *Firdous Tabassum*. I have understood the nature of the project and wish to participate. I am not waiving any of my legal rights by signing this form. My signature below indicates my consent.

Signature ____________________ **Date** 7-01-2014
Participant

Signature ____________________ **Date** 7-01-2014
Principal Investigator

Use this section if imagery (photographs or video) will be taken of participants and used in teaching or dissemination of research.

I, Asif Masood, agree to allow video and/or [digital images or photographs] in which I appear to be used in teaching, scientific presentations and/or publications with the understanding that I will not be identified by name. I am aware that I may withdraw this consent at any time without penalty.

Signature ____________________ **Date** 7-01-2014
Participant

Details of Production Process

Pretreatment Processes: Pretreatment processes aim to prepare fabric for the dyeing and printing processes. In the mill, pretreatment processes include brushing, singeing, desizing, scouring, bleaching and mercerization. Numbers of washing steps are also included in the pretreatment processes.

Grey Fabric Inspection: Three types of grey fabric are received by the industry, including 100% cotton, Polyester-Cotton (PC) or Lycra-Cotton. Grey fabric quality and quantity is evaluated. Normally appearance, stains, weaving faults are checked. In quality test, blend, construction, GSM and width are checked. The average width and GSM (gm/m^2) of the fabrics are 1.65 m and 265, respectively.

Singeing: First step of the pretreatment is the singeing. First the brushing of the fabric is carried and unwanted fibers adhered on the surface of fabric are removed by abrasive action. Then it is passed over series of burners where the loose hairy fibers protruding from the surface of the fabric are burnt, which makes it smooth and clean. The total width of the flame zone of the burners, over which fabric is allowed to pass, is about 2 meter, which can be adjusted manually according to the width of the fabric. The production capacity of the singeing machine is 85,000 meter per 24 hours a day. The waste material produced in the brushing machine is sucked and collected in the bags. Water is sprinkled on the exhaust of the singeing machine, containing burnt fluff. There four rollers on which fabric passes, become hot during the process and require cooling otherwise fabric can be burnt. The cooling water is circulated inside the rollers to keep them cool. This warm water, after acquiring rollers' heat, is wasted currently.

Desizing: Before the conversion of yarn into the grey fabric in the weaving mill, yarn undergoes a sizing treatment. In this treatment, coating of chemicals mostly starch, oil and waxes on its surface provides strength and lubrication so that it could resist wear and tear while moving on the weaving machine. These chemicals remain on the surface of the grey fabric, after weaving and need to be removed prior to further processing. If these chemicals are not removed, desired bleaching, dyeing and printing quality cannot be achieved as this coating hinders penetration of chemicals, dyes, pigments and finishing chemicals due to their hydrophobic properties. Purpose of the desizing is to remove starch from the fabric, which is the major constituent of sizing chemicals. Enzymatic desizing is carried out in the open width continuous machine. Enzymes react with water insoluble starch and convert it into water soluble intermediate products of starch. Initially, the desizing chemicals comprising of enzymes, detergent and sequestering agent are mixed with water in the two stock tanks (1,000 liter each) to prepare the desizing chemical solution. This solution is supplied into the desizing saturator at a fixed flow rate. The fabric, in open width form, is dipped and passed through this saturator at a temperature of 60-70^{o}C and it was reported that pH of the desizing bath is not required to maintained. Some of the water and chemicals are soaked by the fabric. The makeup chemical solution is pumped into the saturator from the stock tank, at constant intervals. The chemical soaked fabric is allowed to stay for 12 hours so that enzymetic reactions are completed and insoluble starch is converted into soluble starch intermediate products. After it, fabric is washed three times with hot water at 95^{o}C temperature in the wash boxes to remove water soluble starch products. Table-1 presents the washing sequence at desizing stage.

Table-1

Wash Box #	**Temp (^{o}C)**	**Water In *from***	**Water Out *to***
1	90	Discharge of 2nd wash box	Drain through heat exchanger
2	90	Discharge of 3rd wash box	1st wash box
3	90	Hot water from heat exchanger	2nd wash box

The temperature and pH are the process control parameters for the desizing process. It was reported that temperature is checked regularly and recorded in the daily log sheet. Steam supply in the saturators and the wash boxes to heat up the water and chemical solution is controlled through automatic shut off valves which are temperature sensitive.

Scouring: After desizing, fabric is subjected to scouring treatment, which is employed to remove oil, grease and dirt that are attached to the fiber either naturally or acquired during the sizing process. Chemical processes responsible to remove these impurities in the scouring are the saponification of fats into water-soluble soap and water miscible glycerin and emulsification of unsaponifiable oils and waxes. Fabric is dipped into the scouring saturator. Scouring chemical solution comprising of chemicals like caustic soda, wetting agents and sequestering agents is prepared in the stock tanks. This solution is pumped into the saturator at the fixed flow rate. The scouring temperature is maintained at about in the rage of 50-60^{o}C. After saturator, fabric is passed through the steamer where scouring reaction is allowed to be completed at about 102^{o}C temperature. Stay time of the fabric inside the steamer is 22 minutes. After steamer, fabric is washed with hot water at about 90^{o}C temperature by passing through five wash boxes. Countercurrent washing sequence is employed in these wash boxes. Table-2 presents the washing sequence at scouring stage.

Table-2

Wash Box #	**Temp (^{o}C)**	**Water In *from***	**Water Out *to***
1	80-90	2nd wash box	Drain through heat exanger
2	80-90	3rd wash box	1st wash box
3	80-90	4th wash box	2nd wash box
4	80-90	5th wash box	3nd wash box
5	80-90	Hot water from heat exchanger	4nd wash box

Bleaching: Coloring matters are also the natural impurities in the cotton fiber. The primary objective of bleaching is to remove the colored and undesired impurities to avoid unwanted shade or tint on the white, dyed or finished fabric. Bleaching chemical used in the mill is hydrogen per oxide. Bleaching chemical solution comprising of hydrogen peroxide (50%), caustic soda- 48 ^{o}Bé (Baume'), stabilizer, detergents and sequestering agents is prepared in the stock tanks and pumped into the bleaching saturator (35 liters capacity) at a fixed flow rate. The temperature of the saturator is kept at 25-30^{o}C. After saturator, fabric is steamed inside the steamer at about 102^{o}C temperature for the completion of bleaching reaction. Fabric remains inside the steamer for about 22 minutes. After steamer, it is passed through five wash boxes for washing and neutralization with acetic acid. The countercurrent washing sequence is presented in Table-3.

Table-3

Wash Box #	**Temp (^{o}C)**	**Water In *from***	**Water Out *to***
1	80-90	2nd wash box	Drain through heat exchanger
2	80-90	3rd wash box	1st wash box
3	80-90	4th wash box	2nd wash box
4	80-90	Hot water from heat exchanger	3rd wash box
5	Normal	Fresh water and acid	Drain

Drying: After bleaching, fabric is dried on the drum dryers. The objective of drying is to evaporate the water soaked by the fabric during washing processes. Drum dryer consists of series of jacketed steel cylinders, mounted vertically, one over the other. Each cylinder is rotated by electric motor and pulleys. Steam is injected inside the jackets of these cylinders to heat up the outer surface. The fabric is wrapped around the rotating cylinder surface while passing through the dryer and gets dried. All the steam condensate from the cylinder jackets is collected and used as boiler feed water. Fabric after drying is cooled down by passing over cooling drums. The water is circulated through these cooling drums, which after acquiring fabric heat, is wasted.

Mercerization: The purpose of mercerization is to give strength, improve luster and increase absorption of the fabric for dyes in the subsequent processes for cotton fabric. In this process, fabric is treated with caustic soda (NaOH) solution. Caustic soda reacts with the cellulose, swells it and imparts above properties. Cold mercerization is carried out in the mill. Fabric is allowed to dip into the saturator containing caustic soda of 25-28^{o}Bé concentration. After passing through this saturator which consists of three chambers, fabric is squeezed and enters into the stabilizing zone where it is treated with caustic soda of 12-20^{o}Bé concentration. Fabric is stretched in the stretching frames and passed through the second stabilizing zone where fabric is treated with caustic soda of 8-12^{o}Bé. Temperature of the stabilizing chambers is maintained at 70-80^{o}C. Fabric is squeezed and then washed in the eight wash boxes. The countercurrent washing sequence is presented in Table-4.

Table-4

Wash Box #	**Temp (^oC)**	**Water In *from***	**Water Out *to***
1	80-90	2nd wash box	Drain
2	80-90	3rd wash box	1st wash box
3	80-90	4th wash box	2nd wash box
4	80-90	5th wash box	3rd wash box
5	80-90	6th wash box	4th wash box
6	80-90	7th wash box	5th wash box
7	80-90	8th wash box	6th wash box
8	80-90	Hot water from power house	7th wash box

Process control parameters for the mercerization are temperature of the caustic soda impregnation bath, concentration of the caustic soda, percent stretch, degree of singeing and quality of the fabric. For process controls in the mercerization, the (Baume') degree of the liquid caustic soda is checked regularly. The concentration is adjusted according to the fabric quality. The daily production of the mercerization machine is 70,000-74,000 meters in 24 hours.

Dyeing Process: Dyeing process is employed to impart the desired shade on the fabric. In Sarena industry, pad batch, pad steam, pad thermosol, soft flows and open jiggers machines are used for the dyeing. Fabric is colored with variety of water soluble and insoluble dyes. Choice of the dyes and process depends upon the fabric type and desired quality of the finished product. Reactive, vat, sulfur and disperse dyes are used for dyeing cotton and polyester fabrics. Reactive dyes are water soluble, anionic dyes and form covalent bonds with the fabric. Reactive dyeing is carried out in cold or hot state. The dyeing steps are similar except for the difference in the state of the dyeing and washing baths i.e. cold or hot. Reactive dyeing is carried out in two steps. In the first step, dye is transferred from aqueous medium to the fabric surface (exhaustion), whereas in the second step dye present on the fabric surface is allowed to react and fix on the fabric under alkaline condition. Vat dyes are water insoluble dyes which are reduced to water soluble leuco form and after exhaustion, they are oxidized back to their original insoluble form. Disperse dyes are low water soluble dyes and are applied as a dispersion of finely ground powder in the dye bath. High pressure and temperature is used to fix the dyes on the fabric. Sulfur dyes are water insoluble which are reduced to soluble form and after exhaustion, they are oxidized back to their original insoluble form. Table-5 presents the steps involved during the dying process.

Table-5

Type of Dye	**Dyeing Steps**
Reactive	Pad dry cure/washing
	Pad dry silicate develop
	Pad dry salt develop
Vat	Pad dry/pad steam develop
Pigment	Pad dry cure

Sulfur	Pad steam
Disperse	Pad dry cure
	Pad steam develop

In Sarena industry open jigger and Jet machine are used for dyeing cotton and polyester fabrics, respectively. Cotton dyeing with reactive dyes was being carried out in the open jiggers. Average dyeing capacity of each jigger is about 2,000 meters per day. Reactive dyeing is carried out in two steps. In the first step dye is transferred from aqueous medium to the fabric surface (exhaustion), whereas in the second step dye present on the fabric surface is allowed to react and fix on the fabric under alkaline conditions. Initially fabric is washed with hot water at 70^oC, while loading on the Jigger. This hot water is drained and a continuous cold wash is applied to the fabric, where water is added at one end and overflow is continuously drained. Dye bath is prepared in the jiggers by adding desired dye quantity in the required amount of fresh water. Fabric runs in this cold dye bath for two hours, then sodium chloride (NaCl) is added in this bath and process runs for one hour. Later soda ash (Na_2CO_3) is added in this bath and process is carried out at high temperature and alkaline conditions. After fabric gets required shade, dye bath is drained and the fabric undergoes a continuous wash process. The Jigger is then filled with water and dilute acetic acid solution to neutralize the effect of alkali. A continuous wash is also applied after this neutralization process. Later fabric runs in the jigger in the presence of fixing chemicals followed by a continuous wash. Finally fabric is unloaded and transferred to the drum dryer for drying before any subsequent processing. Dyeing is a very sensitive process and requires very good process controls. The quality of the water to prepare dye bath, is important for good dyeing results. In Sarena industry raw ground water is used to prepare dye baths, which may cause excessive use of dyes and auxiliary chemicals with impaired fabric dyeing quality. The major process controls in dyeing process are the bath temperature and pH. For the alkaline bath the temperature and pH are reported to be at 60-70^oC and 10-11, respectively. During the neutralization process the pH of the bath is reported to be around 3 to 4. Different types of the dyes are padded on the fabric in thermosol and pad steam machines. After that fabric is passed through steamer of the pad steam where dyes are fixed. After fixation, steam fabric is passed though washing chambers of the pad steam where hot and cold washing are carried out. Sequence of washings is presented in Table-6.

Table-6

Wash Box #	**Temp (^oC)**	**Water In *from***	**Water Out *to***
1	80	Fresh water	Drain
2	80	Detergent wash	Heat exchanger
3	80	4rd wash box	2nd wash box
4	80	5th wash box	3rd wash box
5	80	Heat exchanger	4th wash box

Printing: Printing is a process to impart desired pattern & shade to the fabric. Printing process can be divided into three activities: preparation of coloring paste in color kitchen: screen development and stripping, and fabric printing. Printing paste is prepared in two steps in color kitchen, which is manually controlled. In the first step, chemicals like thickeners, binders, fixing agents and anti foaming agents are dissolved in water using agitators in the drums. In the second step, this paste is transferred to the other drums, mixed with dyes, and transported to the printing machine. In Sarena industry printing is carried out at Flat Bed printing machine. Screens, used in the flat belt printing machine, which are made in such a manner that synthetic wire mesh fabric is fastened across a square or rectangular wooden frame. The screen gaps, other than the desired pattern, are coated or filled using chemical film. Only mesh holes of the desired design are left open. Separate screen is required for each color in the design pattern. In Flat Bed printing, the fabric is placed in open width on a flat moving belt. Screen is placed on the fabric surface and printing paste is manually transferred on the screen. The paste is then spread on the whole surface of the screen by a moving scraper. Pattern on the screen is printed on the fabric due to intimate contact between fabric and screen. Printing paste formation is a sensitive process. If colored traces are present in the paste drum the required shade and tone of the new paste cannot be achieved. Special care is taken during washing of the paste drums. Large quantity of colored wastewater is discharged from the color kitchen during the drums washing to assure that no trace of the paste is left. After printing, fabric undergoes steam aging (reactive dyes), washing (all except pigments) and curing (only pigments). In steam aging process the fabric is exposed to hot mist to improve dye fixation and better luster. In Sarena Industry there is one closed rectangular tank in the steam ager, which is filled with water. Water is heated by indirect steam application through the coils to produce the hot mist. The fabric travels inside the closed steam ager body at a controlled speed and exposed to this mist. After this, soaper washing is conducted. The purpose of washing is to remove unfixed dyes from the fabric. In Sarena industry, the washing and soaping of the dyed and printed fabric is performed in the soaper washing machine. Soaper machine consists of one battery of six wash boxes. Fabric is passed through these six wash boxes. Each wash box is maintained at certain cold or hot water conditions as per requirement. Soaper washing have counter current washing system and all these wash boxes are also interconnected through pipelines having valves to use water of one wash box in the other one. Heat exchanger is also installed at this machine to recover the energy from hot wastewater. After washing, fabric is dried in the drum dryer and transferred to the finishing section. Washing sequence of soaper washing machines is presented in Table-7.

Table-7

Wash Box #	**Temp (°C)**	**Water In *from***	**Water Out *to***
1	70	2nd wash box	Drain through heat exchanger
2	70	3rd wash box	1st wash box
3	73	4th wash box	2nd wash box
4	70	5th wash box	3rd wash box
5	72	6th wash box	4th wash box

6	50	Hot water from heat exchanger	5^{th} wash box

Curing: In curing process heat is provided to the fabric to keep it at a high temperature to enhance the pigment fixation. In Sarena industry the curing is done for the fabric printed with pigments only. This process is carried out in the Ager attached with the printing machine. The resin present in the finishing chemicals is not in its most stable and durable form, so the fabric is heated up to about 150^{o}C temperature, for a few minutes; treatment is termed as curing. It hardens the resin and makes it insoluble and a firm bond is formed between the finish chemicals and the fabric. The higher temperature in the curing machines is achieved by the circulation of hot therm oil at a temperature of 130-145^{o}C.

Finishing: The objective of the finishing operations is to bring textile product into presentable form. Two types of fabric finishing processes include chemical and mechanical. The extent of finishing depends on the fabric quality and end product finish demands. Finishing is generally employed for the adjustment of fabric width, to remove cross and bowing faults, to control shrinkage, improve surface appearance and to make it more uniform, soft, and lustrous. Chemical finishing is carried out in the stenters. There are four stenters in the Sarena industry. It is comprised of two parts, the first part is a chemical bath in which fabric is immersed and padded, where as the second part is a dryer. In the dryer, fabric is passed on a moving belt to dry the applied chemicals and to adjust the fabric width. The main process controls of stenter are its temperature, fabric moisture contents, and fabric speed. In mechanical finishing fabric appearance is improved and certain surface effects are produced. Peaching, Raising, Sanforizing and Calender machines are used for this purpose. The average daily production of each stenter is 65,000-70,000 meters. The three peaching machines collectively produce about 42,000 meters per day whereas sanforizing and curing machine production is about 80,000 meters and 90,000 meters per day respectively. Finished fabric is folded at the folding machines. The folded fabric is packed in different packing materials like polyethylene bags and fabric to avoid dust. The finished fabric is finally stored in a finished product storage area before shipment.

ANNEXURE-II

RETScreen Analysis Worksheet for Energy Efficiency

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Clean Energy Project Analysis Software

Project information

See project database

Project name	Potential of Energy Efficiency in Sarena textile Industry
Project location	Sheikhupura, Lahore, Pakistan
Prepared for	MRP: Potential of RE in Textile sector of Pakistan
Prepared by	Firdous Tabassum
Project type	Energy efficiency measures
Facility type	Industrial
Analysis type	Method 1
Heating value reference	Lower heating value (LHV)
Show settings	☑
Language - Langue	English - Anglais
User manual	English - Anglais
Currency	Canada
Units	Metric units

Site reference conditions

Select climate data location

Climate data location	Lahore Airport
Show data	☐

RETScreen Energy Model - Energy efficiency measures project

Fuels & schedules ☑ Show data

Fuel	Fuel type 1	Fuel type 2	Fuel type 3	Fuel type 4	Fuel type 5	Fuel type 6
Fuel type	Electricity	Electricity	Diesel (#2 oil) - L	Natural gas - kWh	Biomass	
Fuel consumption - unit	MWh	MWh	L	kWh	t	
Fuel rate - unit	CAD/kWh	CAD/kWh	CAD/L	CAD/kWh	CAD/t	
Fuel rate	0.103	0.191	1.275	0.075	12.000	

Schedule	Unit		Schedule 1	Schedule 2	Schedule 3	Schedule 4	Schedule 5	Schedule 6
Description			24/7	3	2	9.4	9.7	
				Occupied	Occupied	Occupied	Occupied	Occupied
Temperature - space heating	°C		24.0					
Temperature - space cooling	°C							
				Unoccupied	Unoccupied	Unoccupied	Unoccupied	
Temperature - unoccupied	+/-°C							
				Occupied	Occupied	Occupied	Occupied	
Occupancy rate - daily			h/d	h/d	h/d	h/d	h/d	
Monday			24	3.0	2.0	9.4	9.7	
Tuesday			24	3.0	2.0	9.4	9.7	
Wednesday			24	3.0	2.0	9.4	9.7	
Thursday			24	3.0	2.0	9.4	9.7	
Friday			24	3.0	2.0	9.4	9.7	
Saturday			24	3.0	2.0	9.4	9.7	
Sunday			24	3.0	2.0	9.4	9.7	
Occupancy rate - annual	h/yr		8,760	1,095	730	3,431	3,541	
	%		100%	13%	8%	39%	40%	
Heating/cooling changeover temperature	°C	16.0						
Length of heating season	d	45						
Length of cooling season	d	320						

Facility characteristics ☑ Show data

Show:	Heating	Cooling	Electricity	Incremental initial costs	Fuel cost savings	Incremental O&M savings	Simple payback	Include measure?
Fuel saved	GJ	GJ	GJ	CAD	CAD	CAD	yr	☐
Heating system								
Cooling system								
Building envelope								
Ventilation								
Lights								
Replacement of T8 Tube Lights by T5 (Admin Bloc	-	-	96	2,300	2,739	0	0.8	☑
Replacement of T8 Tube Lights by T5 (Production	-	-	1,126	27,050	32,217	0	0.8	☑
Electrical equipment								
Hot water								
Pumps								
Fans								
Replacement of 35 Stanter Fans	-	-	1,673	16,625	47,866	0	0.3	☑
Motors								
Replacement of 51, 11 kW standard efficiency mo	-	-	401	30,600	11,480	0	2.7	☑
Repalcement of 70, 7.5 kW standard efficiency m	-	-	317	43,750	9,056	0	4.8	☑
Repalcement of 4, 22 kW standard efficiency mot	-	-	29	7,500	844	0	8.9	☑
Repalcement of 5, 45 kW standard efficiency mot	-	-	125	21,875	3,567	0	6.1	☑
Process electricity								
Process heat								
Process steam								
Steam losses								
Heat recovery								
Compressed air								
Refrigeration								
Other								
Total	0	0	3,767	149,700	107,769	0	1.39	

Summary ☑ Show data

	Fuel		Base case		Proposed case		Fuel cost savings	
Fuel type	**Fuel consumption - unit**	**Fuel rate**	**Fuel consumption**	**Fuel cost**	**Fuel consumption**	**Fuel cost**	**Fuel saved**	**Fuel cost savings**
Electricity	MWh	CAD 103.000	9,586.4	CAD 987,404	8,540.1	CAD 879,635	1,046.3	CAD 107,769

Project verification

Fuel type	Fuel consumption - unit	Fuel consumption - historical	Fuel consumption Base case	Fuel consumption - variance
Electricity	MWh		9,586.4	

Fuel consumption	Heating GJ	Cooling GJ	Electricity GJ	Total GJ
Fuel consumption - base case			34,511	34,511
Fuel consumption - proposed case			30,745	30,745
Fuel saved			3,767	3,767
Fuel saved - %			10.9%	10.9%

☐ Show data

See benchmark database

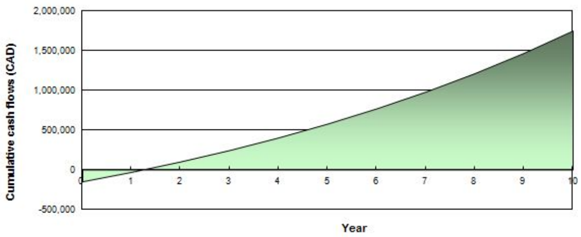
Benchmark

Energy unit	GJ	
Reference unit	m²	

Financial Analysis

Financial parameters			
Inflation rate	%	10.0%	
Project life	yr	10	
Debt ratio	%	0%	
Initial costs			
Energy efficiency measures	CAD	149,700	100.0%
Other	CAD		0.0%
Total initial costs	CAD	149,700	100.0%
Incentives and grants	CAD		0.0%
Annual costs and debt payments			
O&M (savings) costs	CAD	0	
Fuel cost - proposed case	CAD	879,635	
Other	CAD		
Total annual costs	CAD	879,635	
Annual savings and income			
Fuel cost - base case	CAD	987,404	
Other	CAD		
Total annual savings and income	CAD	987,404	
Financial viability			
Pre-tax IRR - assets	%	88.8%	
Simple payback	yr	1.4	
Equity payback	yr	1.2	

Cumulative cash flows graph



ANNEXURE-III

RETScreen Analysis Worksheet for Photovoltaic System
Diesel generation Vs PV system

Project information — See project database

Project name	Sarena Industry :Solar Vs Diesel in CAN $
Project location	Lahore, Pakistan
Prepared for	MRP: Potential of RE in Textile sector of Pakistan
Prepared by	Firdous Tabassum
Project type	Power
Facility type	Industrial
Analysis type	Method 1
Heating value reference	Lower heating value (LHV)
Show settings	☑
Language - Langue	English - Anglais
User manual	English - Anglais
Currency	Canada
Units	Metric units

Site reference conditions — Select climate data location

Climate data location	Lahore Airport
Show data	☐

RETScreen Energy Model - Power project

Power project

Base case power system

Grid type		Off-grid
Technology		Reciprocating engine
Fuel type		Diesel (#2 oil) - L
Fuel rate	CAD/L	1.275
Capacity	kW	1,400.00
Heat rate	kJ/kWh	10,000
Annual O&M cost	CAD	25,000
Electricity rate - base case	CAD/kWh	0.376
Total electricity cost	CAD	384,099

Load characteristics

⦿ Method 1
○ Method 2

	Unit	Base case	Proposed case
Electricity - daily - DC	kWh		
Electricity - daily - AC	kWh	2,800.000	2,800.000
Intermittent resource-load correlation			Zero

☐ **Percent of month used**

		Base case	Proposed case	Energy saved	Incremental initial costs
Electricity - annual - DC	MWh	0.000	0.000		
Electricity - annual - AC	MWh	1,022.000	1,022.000	0%	CAD 125,000
Peak load - annual	kW				

Proposed case power system

				Incremental initial costs
Inverter				
Capacity	kW	280.0	Peak load - annual - AC	
Efficiency	%	80%		
Miscellaneous losses	%	20%		
Battery				
Days of autonomy	d			
Technology		Photovoltaic		
Resource assessment				
Solar tracking mode		Fixed		
Slope	°	45.0		
Azimuth	°			

☑ Show data

Month	Daily solar radiation - horizontal kWh/m²/d	Daily solar radiation - tilted kWh/m²/d	Electricity delivered to load MWh
January	2.79	4.08	36.61
February	3.81	4.85	39.64
March	4.97	5.50	52.68
April	5.68	5.32	60.65
May	6.30	5.22	71.36
June	6.17	4.86	71.82
July	5.56	4.52	70.52
August	5.27	4.69	64.38
September	5.10	5.25	54.51
October	4.33	5.38	46.45
November	3.39	4.98	37.23
December	2.78	4.35	34.91
Annual	**4.68**	**4.91**	**640.73**

Annual solar radiation - horizontal	MWh/m²	1.71
Annual solar radiation - tilted	MWh/m²	1.79

Photovoltaic					
Type		poly-Si			
Power capacity	kW	1,400.00		CAD 2,038,750	*See product database*
Manufacturer		JA Solar			
Model		poly-Si - JAP6-60-250W	5600 unit(s)		
Efficiency	%	15.3%			
Nominal operating cell temperature	°C	45			
Temperature coefficient	% / °C	0.40%			
Solar collector area	m²	9,156.3			
Control method		Maximum power point tracker			
Miscellaneous losses	%				
Summary					
Capacity factor	%	18.9%			
Electricity delivered to load	MWh	640.73	62.7%		
Peak load power system					
Technology		Grid electricity			
Fuel rate	CAD/kWh				
Charger efficiency	%				
Suggested capacity	kW	0.0			
Capacity	kW				*See product database*
Electricity delivered to load	MWh	0.0	0.0%		

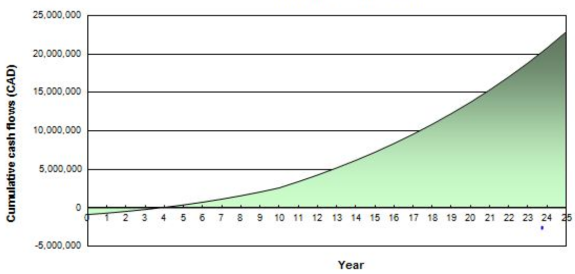
☑ Emission Analysis

GHG emission					
Base case	tCO2	756.1			
Proposed case	tCO2	0.0			
Gross annual GHG emission reduction	tCO2	756.1			
GHG credits transaction fee	%				
Net annual GHG emission reduction	tCO2	756.1	is equivalent to	138	Cars & light trucks not used
GHG reduction income					
GHG reduction credit rate	CAD/tCO2				

Financial Analysis

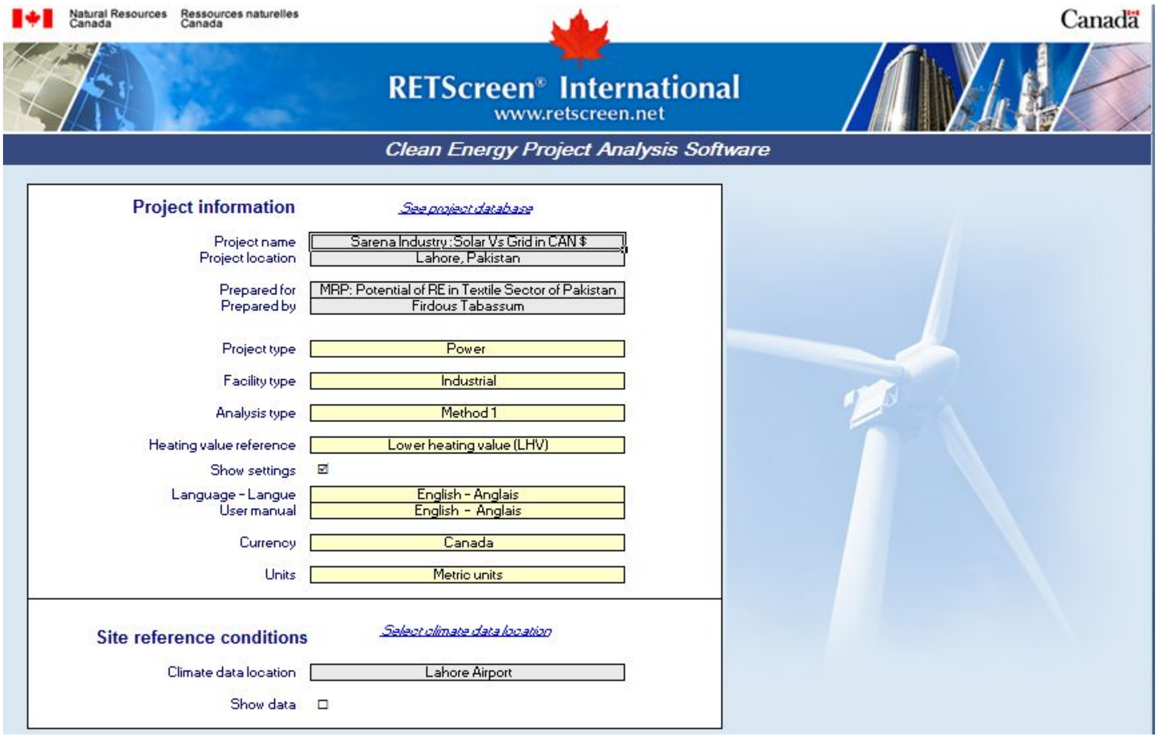
Financial parameters			
Inflation rate	%	7.0%	
Project life	yr	25	
Debt ratio	%	60%	
Debt interest rate	%	11.00%	
Debt term	yr	10	
Initial costs			
Power system	CAD	2,163,750	100.0%
Other	CAD		0.0%
Total initial costs	CAD	2,163,750	100.0%
Incentives and grants	CAD		0.0%
Annual costs and debt payments			
O&M (savings) costs	CAD		
Fuel cost - proposed case	CAD	0	
Debt payments - 10 yrs	CAD	220,445	
Other	CAD		
Total annual costs	CAD	220,445	
Annual savings and income			
Fuel cost - base case	CAD	384,099	
Other	CAD		
Total annual savings and income	CAD	384,099	
Financial viability			
Pre-tax IRR - equity	%	35.0%	
Pre-tax IRR - assets	%	19.4%	
Simple payback	yr	5.6	
Equity payback	yr	3.7	

Cumulative cash flows graph



ANNEXURE-IV

RETScreen Analysis Worksheet for Photovoltaic System
Grid electicity Vs PV system



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Canada

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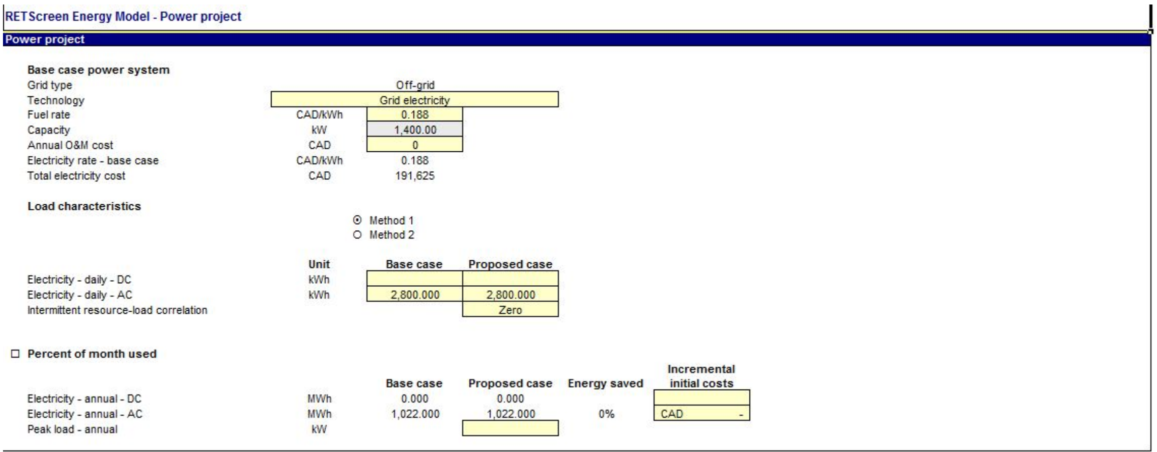
Clean Energy Project Analysis Software

Project information — See project database

Project name	Sarena Industry: Solar Vs Grid in CAN $
Project location	Lahore, Pakistan
Prepared for	MRP: Potential of RE in Textile Sector of Pakistan
Prepared by	Firdous Tabassum
Project type	Power
Facility type	Industrial
Analysis type	Method 1
Heating value reference	Lower heating value (LHV)
Show settings	☑
Language - Langue	English - Anglais
User manual	English - Anglais
Currency	Canada
Units	Metric units

Site reference conditions — Select climate data location

Climate data location	Lahore Airport
Show data	☐



RETScreen Energy Model - Power project

Power project

Base case power system

Grid type		Off-grid
Technology		Grid electricity
Fuel rate	CAD/kWh	0.188
Capacity	kW	1,400.00
Annual O&M cost	CAD	0
Electricity rate - base case	CAD/kWh	0.188
Total electricity cost	CAD	191,625

Load characteristics

⦿ Method 1
○ Method 2

	Unit	Base case	Proposed case
Electricity - daily - DC	kWh		
Electricity - daily - AC	kWh	2,800.000	2,800.000
Intermittent resource-load correlation			Zero

☐ **Percent of month used**

		Base case	Proposed case	Energy saved	Incremental initial costs
Electricity - annual - DC	MWh	0.000	0.000		
Electricity - annual - AC	MWh	1,022.000	1,022.000	0%	CAD -
Peak load - annual	kW				

Proposed case power system

	Unit	Value		Incremental initial costs
Inverter				
Capacity	kW	280.0	Peak load - annual - AC	
Efficiency	%	80%		
Miscellaneous losses	%	20%		
Battery				
Days of autonomy	d			
Technology		Photovoltaic		
Resource assessment				
Solar tracking mode		Fixed		
Slope	°	45.0		
Azimuth	°			

☑ Show data

Month	Daily solar radiation - horizontal kWh/m²/d	Daily solar radiation - tilted kWh/m²/d	Electricity delivered to load MWh
January	2.79	4.08	36.61
February	3.81	4.85	39.64
March	4.97	5.50	52.68
April	5.68	5.32	60.65
May	6.30	5.22	71.36
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November	3.39	4.98	37.23
December	2.78	4.35	34.91
Annual	**4.68**	**4.91**	**640.73**

	Unit	Value			
Annual solar radiation - horizontal	MWh/m²	1.71			
Annual solar radiation - tilted	MWh/m²	1.79			
Photovoltaic					
Type		poly-Si			
Power capacity	kW	1,400.00		CAD 2,038,750	See product database
Manufacturer		JA Solar			
Model		poly-Si - JAP6-60-250W	5600 unit(s)		
Efficiency	%	15.3%			
Nominal operating cell temperature	°C	45			
Temperature coefficient	% / °C	0.40%			
Solar collector area	m²	9,156.3			
Control method		Maximum power point tracker			
Miscellaneous losses	%				
Summary					
Capacity factor	%	18.9%			
Electricity delivered to load	MWh	640.73	62.7%		
Peak load power system					
Technology		Grid electricity			
Fuel rate	CAD/kWh				
Charger efficiency	%				
Suggested capacity	kW	0.0			
Capacity	kW				See product database
Electricity delivered to load	MWh	0.0	0.0%		

☑ Emission Analysis

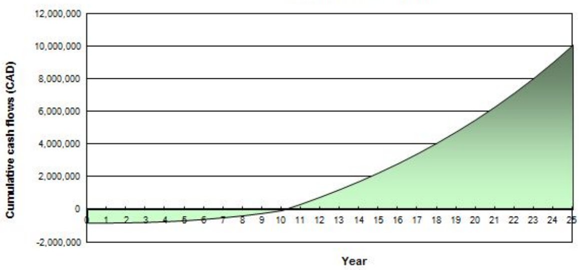
Base case electricity system (Baseline) Country - region	Fuel type	GHG emission factor (excl. T&D) tCO2/MWh	T&D losses %	GHG emission factor tCO2/MWh
Canada	All types	0.196		0.196

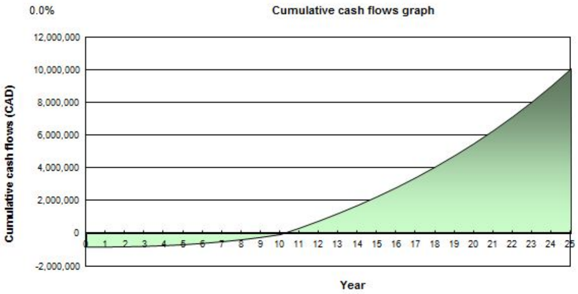
GHG emission	Unit	Value			
Base case	tCO2	200.6			
Proposed case	tCO2	0.0			
Gross annual GHG emission reduction	tCO2	200.6			
GHG credits transaction fee	%				
Net annual GHG emission reduction	tCO2	200.6	is equivalent to	36.7	Cars & light trucks not used
GHG reduction income					
GHG reduction credit rate	CAD/tCO2				

Financial Analysis

	Unit	Value	
Financial parameters			
Inflation rate	%	7.0%	
Project life	yr	25	
Debt ratio	%	60%	
Debt interest rate	%	11.00%	
Debt term	yr	10	
Initial costs			
Power system	CAD	2,038,750	100.0%
Other	CAD		0.0%
Total initial costs	CAD	2,038,750	100.0%
Incentives and grants	CAD		0.0%
Annual costs and debt payments			
O&M (savings) costs	CAD		
Fuel cost - proposed case	CAD	0	
Debt payments - 10 yrs	CAD	207,710	
Other	CAD		
Total annual costs	CAD	207,710	
Annual savings and income			
Fuel cost - base case	CAD	191,625	
Other	CAD		
Total annual savings and income	CAD	191,625	
Financial viability			
Pre-tax IRR - equity	%	17.5%	
Pre-tax IRR - assets	%	10.3%	
Simple payback	yr	10.6	
Equity payback	yr	10.1	

Cumulative cash flows graph




0.0%
Cumulative cash flows graph
Cumulative cash flows (CAD)
12,000,000
10,000,000
8,000,000
6,000,000
4,000,000
2,000,000
0
-2,000,000
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Year