ABSTRACT

There has been an immense necessity for lessening the reliance on fossil fuels for the generation of energy, especially in the developing countries. As these conventional energy means are not only rapidly diminishing from the earth but also causing the green house gases (GHG) emissions hence global climate change. The ever rising pressures of population and development in the developing countries, like South Asia have also been raising per capita energy consumption as well as unsustainable fossil fuels exploitation. The solution to these glitches is contingent in exploring the indigenous resources based renewable-alternate energy technologies like bioenergy in these developing Asian economies, including Pakistan, India, Bangladesh, Afghanistan and Srilanka etc.

This thesis addresses the design, implementation and operations of a medium commercial-industrial scale bioenergy plant in Pakistan that is based on effective anaerobic digestion (AD) technology and fed by indigenous bio-waste resources to develop a consistent, cost-effective and locally adaptable energy solution. There is a greater opportunity with aboriginal skills and resources that novel bioenergy technology can be integrated with prevailing small and medium enterprises (SMEs) infrastructure and setup while not only meeting the current energy demands but may also satisfy the future needs more productively. By employing the biomass derived bioenergy, there are a lot of prospects for saving fossil fuel based energy consumption in many rural and sub-urban areas of Pakistan. Bioenergy has been termed as climate neutral as it can effectively mitigate climate change effects by balancing carbon dioxide emissions.

This thesis highlights the first and unique industrial scale bioenergy plant in Pakistan along-with its functional capabilities using a multi-appraisal technique. This is a an anaerobic fixed dome multi-digester, continuous flow-mode plant design, which can digest various feedstock like cattle manure, vegetable-fruit wastes, poultry wastes and sugar molasses etc. This novel scheme also has the modern technological inclusions like temperatures controls, mechanical stirrers, microwave heating system biogas scrubbers, filtration, compression and storage systems. It has deliberated high output efficiencies and is yielding 75-125 m^3 of biogas per tonne of animal-cattle manure and/or vegetable-fruit wastes.

The primary valuation contained by this dissertation after the plant design, construction, setup and technology upgrades has scrutinized the design and financial cost-benefit aspects of the plant. As such all sorts of costs; like capital costs, operational and maintenance (O&M) costs and income-benefits using economic-financial modeling are well quantified and analyzed. The relevant indicators have rendered the project as highly viable. The later assessment has then evaluated the bioenergy productivities using locally accessible feedstock-substrates in various ratios of cow-buffalo manure and vegetable waste. The relevant drivers and seasonal limitations regarding bioenergy feedstock supply-chain were scrutinized so that these could be optimized as per regional conditions and variances.

Following the CHP (combined heat and power) generation scenarios for this novel AD bioenergy plant, the techno-economic impacts in-terms of socio-industrial and techno-economic implications have also been thoroughly deliberated, qualified and quantified. Last but not least the environmental life cycle assessment along-with and characterization of effluent slurry-digestate as bio-fertilizer has been gauged.

The research deliberations have demonstrated that this creative bioenergy plant design has prominent operational realization and is highly viable for an energy stressed country like Pakistan. Besides the primary benefits of energy generation and waste management there could be significant secondary benefits, regarding the utility and potential of digestate as highly enriched bio-fertilizer, which are yet outweighed. There are certain limitations, policy deficits and misleading conceptions among the stakeholders regarding the utilization of bioenergy on medium-large scale; however, the CHP pathway based on such novel AD system has been found quite acceptable and effective to exclude many of such limitations. Broadly such medium industrial bioenergy venture has shown encouraging socio-environmental, energy and financial paybacks.