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論 文 要 旨

THESIS SUMMARY

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TRANSDISCIPLINARY SCIENCE & ENGINEERING
ENVIRONMENT AND SOCIETY
GLOBAL ENGINEERING FOR DEVELOPMENT
系
コース

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申請学位（専攻分野）：
Academic Degree Requested
博士 Doctor of (ENGINEERING)

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要旨（英文 800 語程度）

Thesis Summary（approx.800 English Words ）

The exploitation of organic and waste feedstocks is a much-needed lifeline to cope with prevalent issues of inadequate energy supply, limited energy diversification, poor waste management and sustainability in Zimbabwe. The promotion of sustainable coal-alternative fuel production from waste requires, as an initial step, the quantification of the available amounts. Hydrothermal carbonization (HTC) can offer a solution to Zimbabwe's woes as it involves the artificial coalification of biomass by direct injection of steam in a pressurized vessel to produce an upgraded hydrochar with characteristics similar to coal. HTC is preferred amongst other thermal conversion technologies as it is versatile and capable of handling high moisture feed. A gap exists in the literature on the assessment of large-scale HTC systems, holistic evaluations (economic and environmental assessments) of potential technologies in Zimbabwe.

The objective of this research is to quantify the available feedstocks, namely municipal solid waste (MSW), Brewer's spent grains (BSG) sewage sludge, animal dung, crop and forestry residues. This is discussed in chapter 2 following the introduction in chapter 1. More specifically, the purpose is to investigate present MSW generation in Zimbabwe, its characteristics as a fuel source, and the impact of coal-alternative solid fuel production from MSW using HTC on greenhouse gases

(GHG) and other air pollutant emissions. This forms chapter 3. Related to MSW-derived fuel, an economic assessment of the proposed HTC-MSW system was conducted to determine factors that would consolidate the venture to achieve a certain level of return. The effectiveness of different investment strategies, namely, a government or private sector-run operation will be tested. Using a modified purchased equipment cost method involving probability models and Monte Carlo simulations, the economic viability was evaluated assuming a project life of 20 years. This makes up chapter 4. A further objective is to quantify the avoided leachate flow from Zimbabwe's landfills when HTC is introduced using probability models and a stochastic water balance method supported by Monte Carlo iterations as elaborated in chapter 5. Owing to its unique nature as both a source of food and energy, the research seeks to determine the least impactful usage of BSG in chapter 6. Demand for food security and energy are likely to lead to competing interests and uses of BSG. Therein lies the fundamental dilemma that constitutes the central issue, which of the two options flour or coal-alternative fuel production from BSG will have the least impact on the environment?

Results indicate the following at a 90% confidence interval: 2.55-5.50 million Mg/yr. of crop residue and 2.99-4.99 million Mg/yr. of dung is generated. The total exploitable energy was estimated at an annual mean of 26.6 and 16.9 million GJ for crop residue and dung respectively. At a 90% confidence level, between 3,067-179,110 Mg/yr of dry sewage sludge is generated. Results confirm that greenhouse gas emissions from unsanitary MSW landfills and coal-fired power plants can be abated by HTC. Roughly 1051.7 ± 270.7 Gg/year of MSW are generated and a yield of 289.3 Gg/year of hydrochar is possible. This can substitute between 6.1 and 9.0% of coal used in thermal power plants with coal consumptions rates of 3,200–4,700 Gg/year. Under the best scenario, slight reductions in overall direct emissions from the co-burning

route; 4.2% for SO_X, 4.5% for CH_4, 3.1% for CO_2, 2.2% in Global Warming Potential (GWP) and a 18.0% rise for NO_X can be expected. The diversion of MSW from landfills can significantly reduce the methane potential of household waste from 62.2 to 15.8 Gg CH_4/year under this scenario. Roughly 2.2 million m^3/yr. of leachate can be avoided if HTC is introduced. From the economic analysis, generation of a positive NPV is not possible for the private sector. Risk analysis indicates a very low probability of success (18%) for a positive NPV. The calculated 90% confidence interval indicates that the TCI would be US$ 76.4–93.4 million with an ROI ranging from -0.8–18.2% and IRR of 7.9%. Under the government-run system, there is a 55% probability of a positive NPV assuming a zero corporate tax rate and full waiver on import duties. At a 90% confidence level ROI will be 5.4–29.0% and IRR of 5.2–22.9% (mean 14.6%). TCI for the HTC plants and MSW collection system is about US$ 74.9 million or about US$54.11 – 66.95 per Mg of MSW treated. Flour production can be expected to have a lower GWP compared to biochar production. The GWP of BSG conversion to biochar is more than 1,400 million CO_{2eq} for a 20-year time horizon which is 3.90 times higher than the alternative, BSG milling to flour. A socio-economic study is recommended for future studies as it can compare the cost and monetized benefits of new policies and adoption of HTC. This study can serve as a foundation for such studies.