INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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Thesis Title:

Life Cycle and Techno-economic Assessments of Porous Radiant Burner and Proposed Organizational Design of the Entity Associated

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SHORT ABSTRACT

In 2005, the United Nations proposed sustainable development goals (SDG) with 17 objectives as a replacement for millennium development goals (MDGs), as MDGs could not be achieved to their fullest capacity. The third SDG which focuses on 'ensuring healthy lives and promoting well-being for all at all ages, is a broader goal when compared to the MDG, which concentrates only on maternity and child health. A lot is yet to be done to achieve the complete objective of the third SDG before 2030. Sustainable Development Goal (SDG) 7 is to ensure the usage of clean cooking fuel to 100% of households by 2030. An effort of developing a Porous Radiant Burner (PRB) at the Indian Institute of Technology Guwahati, Guwahati, India has been made considering these goals. In the present research work, different applications of PRB have been tested for sustainability.

The environmental sustainability of PRB has been tested by conducting a Life Cycle Assessment (LCA) of PRB when used for cooking and industrial applications. For cooking applications, LCA has been conducted to test the environmental sustainability of PRB when integrated with cook-stoves that are operated with Biogas and LPG fuels. As a part of the research to test the environmental sustainability of PRB when integrated with cook-stove and operated with biogas, the environmental impact of biogas operated Porous Radiant Burner (BGS_{PRB}) based domestic cook-stove is compared with that of a Conventional Burner (BGS_{CB}) based domestic cook-stove available in the Indian market. Also, the environmental impact of constructing a 3 m3 biogas plant which can generate up to 1 m3 biogas each day is analyzed. The comparison of the cook-stoves is done by conducting a "cradle-to-grave" LCA of eighteen midpoints and three endpoint levels under the ReCiPe method, with the help of the SimaPro database. The functional unit considered for the present study comprises a production unit and a consumption unit. The production unit is of 1 m3 biogas generation per day with a life span of 25 years. The consumption unit is the utilization of the

generated biogas by the cook-stoves which have a life span of 10 years. The environmental impact of the plant and the cook-stoves is assessed from the extraction of the raw material the construction and fabrication to its usage and discard. It is observed from the LCA of cook-stove that all the midpoint and endpoint impact categories are considerably driven by the operation phase of cook-stoves rather than the making. Some critical results reveal that the BGSPRB technology is potentially viable compared to the BGSCB technology in terms of all the endpoint impact categories. The BGSPRB technology has the potential of reducing the impacts on human health, ecosystem damage, and resource depletion in the ranges of 7.69E-09 DALY (Disability-Adjusted Life Year), 2.79E-11 species.yr and 2.67E-04 $, respectively. The impact of BGSPRB is lesser than BGSCB due to the efficient burning of the fuel. This thesis could serve as a source of scientific information for decision-making on environmental sustainability in biogas projects in India.

To test the environmental sustainability of PRB when integrated with cook-stove and operated with LPG, the environmental impact of a 1-3 kW LPG operated Porous Radiant Burner (PRBLPG) based domestic cook-stove is compared with that of a Conventional Burner (CBLPG) based domestic cook-stove of the same capacity. This study is also a “cradle-to-grave” LCA which includes eighteen midpoint and three endpoint levels of the ReCiPe method in the SimaPro database. The functional unit considered includes the fabrication and the operation phases of LPG cook-stoves (PRBLPG and CBLPG) with a life span of 10 years. Life Cycle Inventory (LCI) is considered for the quantitative representation of the embodied energy of the material required. Life Cycle Impact Assessment (LCIA) is performed for 1 kW and 3 kW power output. It is observed that all the midpoint and endpoint impact categories are considerably driven by the operation phases of cook-stoves than fabrication. Also, PRBLPG when compared to CBLPG cook-stove has the potential of reducing the impacts on human health (DALY), ecosystem damage (species.yr), and resource depletion ($) by 15%, each for 1 kW output. Whereas, the respective values for 3 kW power output are also reduced by 15% each for PRBLPG when compared to CBLPG cook-stove. This study could serve as a source of scientific information for decision-making on the environmental sustainability of cook-stoves.

In the present research, the environmental assessment of PRB is also conducted when it is used in industrial applications. PRB is integrated with a Small-scale Medical Waste Incinerator (SMWI), for the disposal of medical waste. For the LCA, the design of an SMWI equipped with an LPG-operated Porous Radiant Burner (PRBLPG) is presented as a solution for disposing of medical waste generated in remote areas. Based on simple mass and heat balance analysis, SMWI is designed to have primary and secondary chambers of volumes of 1 m3 and 0.754 m3, respectively. The proposed SMWI is evaluated for its environmental impact by performing an LCA and compared with an SMWI equipped with an Electric heater (SMWI-EH). The total primary energy required for the construction of SMWI is 48285.56 MJ. It is found that the damage caused by the operation of PRBLPG in SMWI is lesser when compared to that of an Electric heater. In SMWI-PRB, LPG consumption contributed to about 17488.27 kg CO2-eq in the global warming category, whereas in the case of SMWI-EH, electricity consumption contributed to about 243766.11 kg CO2-eq. The operation of SMWI-PRB showed a reduction of about 54% in the resource utilization category in comparison with SMWI-EH. The results obtained from the LCA study indicated that PRBLPG is a better option as an auxiliary heating device in SMWI than Electric heaters due to its environmental superiority.

The economic sustainability of PRB has been tested by conducting a Techno-economic Assessment (TEA) of PRB when used for domestic and commercial cooking applications. In this area of research, a Techno-economic Assessment of 1-3 kW and 5-7 kW PRB-based LPG cook-stoves operating in domestic households, and eateries and restaurants are conducted. Process flow study has been performed primarily to understand the technological process involved in the PRB and also to estimate the cost of manufacturing. The cost estimation has been done considering direct costs such as material costs and labor costs, and indirect costs such as factory costs, works costs and

administration costs. Sensitivity analysis has been performed considering the production capacity of 50, 250, and 500 cook-stoves each day. An economic feasibility study of PRB cook-stoves has been done by estimating the Pay Back Period, Net Present Value, and Internal Rate of Return. For a manufacturing capacity of 250 cook-stoves per day, PRB yields a 52.1% return on investment with a payback period of 1.1 years for 1-3 kW domestic cook-stove and a 51.4% return on the investment with a payback period of 0.25 years for small-scale eateries, 0.2 years for medium-scale eateries and 0.07 years for large-scale eateries with commercial cook-stoves. These results indicate high savings with PRB-based cook-stoves both for domestic usage and commercial usage making PRB highly viable economically.

Once the environmental and economic sustainability of PRB has been tested, study has been conducted to see the viability of PRB for its mass production and bringing it to public usage. For this, an Organizational Design has been proposed and a business model has been developed. An organizational design plays a major role in the effective and efficient functioning and management of all resources. To obtain an effective design, a proper analysis of the business model and the value chain has to be made and competencies have to be framed for various functional units and job roles. The present research proposes a business model for an entity to start with PRB cook-stoves manufacturing to portray the value these products propose to the end user. The business model in the present study is developed by taking the business canvas model into reference. The business model canvas majorly comprises of three sections viz., the value the entity provides to its customers, the procurement of the necessities to provide those values, and the customer base and how to reach it. In the present study, along with these three sections, two more sections have been added. One represents the environmental and societal benefits a product provides and the other represents the economic benefits provided to the consumers and manufacturers. Assessing the business model, an organogram is proposed with more of a mechanistic structure as well as a slight ting of organic structure; thereby work-flow has been analyzed. Each organization will have a unique design of its own depending on its type, the services it provides, its culture, communication, and the way it interacts with the external environment. In the present study, organizational design is proposed taking various aspects of the business model into consideration to provide the best output in the due course of the manufacturing of PRB cook-stoves. In the organogram, both the line and staff functions have been analyzed thoroughly and represented. A user study has been conducted for the production department based on the workflow analysis for various job roles and job positions and based on this, competency indicators have been proposed for job positions of the production department. The present study can be used for the recruitment, performance appraisal, and training modules for an entity in the PRB cook-stoves manufacturing business. This study can also be used as a reference to conduct user studies for other departments to propose respective competency indicators.