

TABLE OF CONTENTS

| CONTENTS | | Page No. |
|--|---|-----------------|
| Acknowledgment | | I |
| Abstract | | II - VI |
| Table of Contents | | VII-X |
| List of Tables | | XI-XII |
| List of Figures | | XIII-XIV |
| List of Abbreviations | | XV-XVII |
| CHAPTER 1: INTRODUCTION | | 1-30 |
| 1.1 | Importance of clean cooking fuels and its status in India | 1-2 |
| 1.2 | Biogas as a clean cooking fuel with multiple benefits | 3-7 |
| 1.3 | Implementation and management of HBS in India | 8-9 |
| 1.4 | Global status of biogas development: a comparison with recent trends in India | 9-12 |
| 1.5 | Management of biogas system | 12-17 |
| 1.6 | Potential of biogas as a rural entrepreneurship | 17-18 |
| 1.7 | Problem Statement | 19-20 |
| 1.7.1 | Preamble | 19 |
| 1.7.2 | Motivation | 19 |
| 1.7.3 | Research Gap | 20 |
| 1.8 | Objectives of the research | 19 |
| 1.9 | Organization of the Thesis | 20-22 |
| References: | | 22-30 |
| CHAPTER 2: REVIEW OF LITERATURE | | 31-57 |
| 2.1 | Introduction | 31 |
| 2.2 | Assessing multifaceted benefits of the biogas system | 31-34 |
| 2.3 | Status of research on biogas production | 34-40 |
| 2.3.1 | Factors influencing the production of biogas | 34-38 |
| 2.3.2 | Research advancement in biogas production | 38-40 |
| 2.4 | Challenges in the management of a Household Biogas System (HBS) | 41-44 |

| | | |
|--|--|--------------|
| 2.4.1 | Managerial issues concerning design and construction | 41 |
| 2.4.2 | Managerial issues concerning feedstock | 41 |
| 2.4.3 | Managerial issues concerning operation (biogas equipment) | 42 |
| 2.4.4 | Lack of technical knowledge | 42-44 |
| 2.5 | Status of biomass-based rural entrepreneurship and its relevance to SDG | 45-46 |
| 2.6 | Technology advancement for management of household biogas system | 46 |
| 2.6.1 | IoT and Sustainability | 46-47 |
| 2.6.2 | IoT and anaerobic digestion | 47-48 |
| 2.7 | Summary | 48-49 |
| | References | 49-57 |
| CHAPTER 3: STATUS OF HOUSEHOLD BIOGAS SYSTEMS: COMPREHENSIVE ANALYSIS OF USERS' RESPONSES | | 58-83 |
| 3.1 | Introduction | 58 |
| 3.2 | Materials and Methods | 58-63 |
| 3.2.1 | Data Source | 58-59 |
| 3.2.2 | Selection of study area | 60-61 |
| 3.2.3 | System description | 61-63 |
| 3.3 | Results and Discussions | 63-80 |
| 3.3.1 | Status of installation of household biogas system (HBS) | 63-65 |
| 3.3.2 | Comparative preferences for cooking fuels and status of biogas | 65-68 |
| 3.3.3 | Biogas system operational experiences | 68-75 |
| 3.3.3.1 | Technical issues during the operation of the biogas system | 68-70 |
| 3.3.3.2 | Availability of feedstock for biogas production | 71-72 |
| 3.3.3.3 | Storage, handling, and pretreatment of feedstock for biogas production | 72-73 |
| 3.3.3.4 | Current slurry management system and its potential impact | 73-74 |
| 3.3.3.5 | Capacity building (training) on HBS: need assessment | 74-75 |
| 3.3.4 | Economic concern while using the biogas system | 75-78 |
| 3.3.5 | Technological upgradation: need assessment based on user perception | 78-79 |
| 3.4 | Summary | 79-80 |

| | |
|------------|-------|
| References | 80-83 |
|------------|-------|

| | | |
|-------------------|--|--------|
| CHAPTER 4: | IoT FOR MANAGEMENT OF HOUSEHOLD BIOGAS SYSTEM: A FEASIBILITY ANALYSIS | 84-104 |
|-------------------|--|--------|

| | | |
|------------|--|---------|
| 4.1 | Introduction | 84 |
| 4.2 | Materials and Method | 84-90 |
| | <i>Conceptualization of IoT in biogas system</i> | 85-86 |
| | <i>Testing of e-platform for Data Acquisition and Communication System</i> | 87 |
| | <i>Integration of Hardware component of IoT into HBS</i> | 87-90 |
| | <i>Data access and verification</i> | 90 |
| 4.3 | Results and Discussion | 90-101 |
| 4.3.1 | Testing of e-platform for Data Acquisition and Communication System | 90-97 |
| 4.3.2 | Integration of Hardware component of IoT into HBS | 98 |
| 4.3.3 | Data access and verification: Critical challenges for IoT applications | 98-101 |
| 4.4 | Summary including limitations | 102-103 |
| References | | 103-104 |

| | | |
|-------------------|--|---------|
| CHAPTER 5: | POTENTIAL OF HOUSEHOLD BIOGAS SYSTEM AS VIABLE RURAL ENTREPRENEURSHIP AND ITS PROSPECT TO DECARBONIZE THE RURAL INDIAN COOKING SECTOR | 105-132 |
|-------------------|--|---------|

| | | |
|-------|---|---------|
| 5.1 | Introduction | 105-107 |
| 5.1.1 | Status of entrepreneurship in rural India and the prospect of HBS | 105-106 |
| 5.1.2 | SDG target through rural entrepreneurship | 106 |
| 5.1.3 | Decarbonising potential of HBS | 106-107 |
| 5.2 | Materials and Methods | 107-116 |
| 5.2.1 | Comparative Analysis of Entrepreneurial Potential | 107-115 |
| 5.2.2 | Potential Contribution of HBS towards SDGs | 115 |
| 5.2.3 | Decarbonizing Potential of HBS for Rural Cooking Sector | 115-116 |
| 5.3 | Results and Discussion | 116-126 |

| | | |
|---|---|-----------------|
| 5.3.1 | Cost-benefit analysis: Fixed cost, levelized fixed cost, running cost, and income-to-cost ratio | 116-118 |
| 5.3.2 | Net present value (NPV) analysis | 118-120 |
| 5.3.3 | SDG targets through rural entrepreneurship | 120-124 |
| 5.3.4 | Annual decarbonization potential of three villages surveyed | 125-126 |
| 5.4 | Summary | 126-127 |
| | References | 127-132 |
| CHAPTER 6: SUMMARY AND CONCLUSIONS | | 133- 164 |
| 6.1 | Status of Household Biogas Systems: Comprehensive analysis of users' responses | 133-136 |
| 6.2 | IoT for management of household biogas system: a feasibility analysis | 137-139 |
| 6.3 | Potential of household biogas system as viable rural entrepreneurship and its prospect to decarbonize the rural Indian cooking sector | 139-142 |
| 6.4 | Conclusion and Suggestions for future work | 142-143 |
| Appendices | | |
| Appendix 1A | Different models of biogas plants in India | 144-145 |
| Appendix 3 A | Percentage of different cooking fuels used by the rural households in all the districts in Assam (<i>Data sourced from the District Census Handbook of Villages and Town Wise Primary Census Abstract (PCA), Directorate of Census Operations Assam of Census 2011 for all the districts of Assam as per 2011 Census</i>) | 146 |
| Appendix 3 B | Description of parameters for Table 3.2 | 147 |
| Appendix 3 C | Description of parameters and assumptions used for Table 3.3 | 148 |
| Appendix 3 D | Questionnaire used to interview the participants | 149-161 |
| Appendix 5A | Indian standards for the quality of feeds and feedstocks for different enterprises | 162 |
| Appendix 5B | NPV of the five enterprises for 10 years | 163 |
| | List of Publications | 164 |