

CONTENTS

1. Characteristics of Uttarakhand and its Implications for Renewable Energy	1
1.1. State of Uttarakhand	1
1.1.1. Introduction	1
1.1.2. Topography and Climate	2
1.1.3. Demography	3
1.1.4. Economic Activities	9
1.1.5. Energy Scenario	13
1.1.5.1. Electricity	13
1.1.5.2. Energy for Cooking and Lighting	13
1.1.5.3. Pattern of Household Expenditure on Energy (Fuels and Light)	22
1.2. Renewable Energy Resource Availability in Uttarakhand	23
1.2.1. Solar Radiation	23
1.2.2. Wind	25
1.2.3. Biomass	25
1.2.4. Hydro	25
1.3. Critical Areas for Development of Uttarakhand	26
1.3.1. Energy	26
1.3.2. Water	27
1.3.3. Agriculture	27
1.3.4. Tourism	28
1.3.5. Roads	28
1.4. Implications for Renewable Energy Applications in Uttarakhand	28
1.5. Potential and Diffusion of DRESs in Uttarakhand	32

CONTENTS (continued...)

1.6. Business Problem	33
1.7. Research Objective(s)	34
1.8. Organisation of the Thesis	35
2. Review of Barriers to the Dissemination of Decentralized Renewable Energy Systems	36
2.1. Introduction	36
2.2. Identification and Classification of Barriers to the Diffusion of DRESs	37
2.2.1. Technical Barriers	37
2.2.1.1. Resource Availability	39
2.2.1.2. Technology – Design, Installation and Performance	39
2.2.1.3. Skill Requirement for Design and Development, Manufacturing, Installation, Operation and Maintenance	41
2.2.1.4. Potential Remedial Measures	42
2.2.2. Economic Barriers	43
2.2.2.1. Cost	46
2.2.2.2. Market	48
2.2.2.2.1. Market Structure	48
2.2.2.2.2. Fuel/Energy Pricing	49
2.2.2.2.3. Incentives/Taxes/Duties	51
2.2.2.2.4. Purchasing Power and Spending Priorities	52
2.2.2.2.5. Financial Issues	52
2.2.2.2.6. Awareness and Risk Perception	53

CONTENTS (continued...)

2.2.2.3. Potential Remedial Measures	54
2.2.3. Institutional Barriers	59
2.2.3.1. Policy and Regulatory	60
2.2.3.2. Infrastructure	60
2.2.3.3. Administrative	63
2.2.3.4. Potential Remedial Measures	63
2.2.4. Socio-cultural Barriers	68
2.2.4.1. Societal Structure, Norms and Value System	68
2.2.4.2. Awareness and Risk Perception	70
2.2.4.3. Behavioral or Lifestyle Issues	71
2.2.4.4. Potential Remedial Measures	72
2.2.5. Environmental Barriers	74
2.2.5.1. Potential Remedial Measures	75
2.3. Concluding Remarks	76
3. Estimation of Potential of Decentralized Renewable Energy Systems in Uttarakhand	78
3.1. Introduction	78
3.2. Frameworks for Estimation of Potential of using DRESSs in Uttarakhand	78
3.2.1. Solar Energy based DRESSs	79
3.2.1.1. Domestic Solar Water Heaters	79
3.2.1.2. Solar Home Systems	81
3.2.1.3. Solar Lanterns	82
3.2.1.4. Dish Type (Paraboloid) Solar Cookers	84
3.2.1.5. Solar Dryers	85
3.2.1.6. Solar PV Pumps	86

CONTENTS (continued...)

3.2.2. Biomass based DRESs	87
3.2.2.1. Family Size Biogas Plants	87
3.2.2.2. Improved Biomass Cookstoves	89
3.3. Results and Discussion	89
3.3.1. Domestic Solar Water Heaters	89
3.3.2. Solar Home Systems	92
3.3.3. Solar Lanterns	94
3.3.4. Dish Type Solar Cookers	95
3.3.5. Solar Dryers	96
3.3.6. Solar PV Pumps	96
3.3.7. Family Size Biogas Plants	97
3.3.8. Improved Biomass Cookstoves	99
3.4. Concluding Remarks	100
4. Theory of Diffusion of Innovation and Expected Trend of Dissemination of Decentralized Renewable Energy Systems in Uttarakhand	102
4.1. Theory of Diffusion of Innovation	102
4.1.1. Innovation	102
4.1.2. Communication Channels	104
4.1.3. Time	104
4.1.4. Social System	111
4.2. Time-trend of Diffusion of DRESs in Uttarakhand	112
4.3. Technology Diffusion Models	119
4.4. Estimation of Time Required for the Cumulative Diffusion of DRESs to Reach their Estimated Utilization Potential	121
4.5. Concluding Remarks	124

CONTENTS (continued...)

5. Assessment of Barriers Faced by Decentralized Renewable Energy Systems Adopters and Non-Adopters in Uttarakhand	126
5.1. Introduction	126
5.2. Sample Design for Survey	126
5.3. Results of Survey	127
5.4. Concluding Remarks	136
6. Assessment of Financial Attractiveness of Decentralized Renewable Energy Systems in Uttarakhand	137
6.1. Introduction	137
6.2. Methodology	137
6.2.1. Expressions for Measures of Financial Performance	138
6.2.1.1. Discounted Payback Period	138
6.2.1.2. Net Present Value	139
6.2.1.3. Internal Rate of Return	139
6.2.1.4. Levelized Cost of Useful Energy	139
6.2.2. DRES Specific Expressions for Estimation of Monetary Value of Annual Benefits	140
6.2.2.1. Domestic Solar Water Heater	140
6.2.2.2. Family Size Biogas Plant	141
6.2.2.3. Improved Biomass Cookstove	142
6.2.2.4. Paraboloid (Dish) Type Solar Cooker	142
6.2.2.5. Solar Lantern	143
6.2.2.6. Solar Home System	144
6.2.2.7. Solar PV Pump	144
6.2.2.8. Solar Dryer	145
6.3. Results and Discussion	146

CONTENTS (continued...)

6.3.1. Domestic Solar Water Heater	148
6.3.2. Family Size Biogas Plant	153
6.3.3. Improved Biomass Cookstove	155
6.3.4. Dish Type (Parabolic) Solar Cooker	157
6.3.5. Solar Lantern	160
6.3.6. Solar Home System	163
6.3.7. Solar PV Pump	164
6.3.8. Solar Dryer	167
6.4. Concluding Remarks	170
7. Conclusions and Recommendations	172
7.1. Conclusions	172
7.2. Limitations of the Study and Recommendations for Further Work	176
References	177
Appendices	198
Appendix I	198
Appendix II	199