

Draft

# Development and Climate

## An Assessment for India

A Report by  
Indian Institute of Management, Ahmedabad

### Project Team

P.R. Shukla  
Rajesh Nair  
Manmohan Kapshe  
Amit Garg  
S. Balasubramaniam  
Deepa Menon  
K.K. Sharma

### Sponsor

UNEP Collaborating Centre on Energy and Environment (UCCEE)  
Roskilde, Denmark

May 2003

## Table of Contents

|   |              |
|---|--------------|
| <b>Executive Summary</b>  | <b>I-VII</b> |
| <br>  |              |
| <b>Chapter 1: National Development Plans and Sustainable Development</b>            |              |
| <br>  |              |
| <b>1.1 Introduction</b>   | <b>1</b>     |
| <b>1.2 Indian Policies linking Sustainable Development with Climate Change</b>      | <b>3</b>     |
| <i>1.2.1 The Energy Sector</i>  | 3            |
| <i>1.2.2 Petroleum and Natural Gas</i>  | 4            |
| <i>1.2.3 Coal</i>   | 5            |
| <i>1.2.4 The Power Sector</i>   | 7            |
| <i>1.2.5 Energy conservation</i>  | 8            |
| <i>1.2.6 Development of Hydel projects</i>  | 9            |
| <i>1.2.7 Rural Electrification</i>  | 10           |
| <i>1.2.8 The Transportation Sector</i>  | 13           |
| <i>1.2.9 The Forestry Sector</i>  | 15           |
| <i>1.2.10 Agriculture and Land Management</i>                                       | 17           |
| <i>1.2.11 Biodiversity and Wildlife Conservation</i>                                | 18           |
| <i>1.2.12 Desertification, Drought plans and Disaster Management Plan</i>           | 18           |
| <i>1.2.13 Population Policy</i>   | 19           |
| <b>1.3 Conclusion</b>   | <b>19</b>    |
| <br>  |              |
| <b>Chapter 2: The Methodology: An Integrated Modeling Approach</b>                  |              |
| <br>  |              |
| <b>2.1 The Integrated Modeling Framework</b>  | <b>26</b>    |
| <b>2.2 Bottom-Up Model Integration</b>  | <b>29</b>    |
| <i>2.2.1 End-Use Demand Projection Model</i>  | 29           |
| <i>2.2.2 AIM/ENDUSE Model</i>   | 30           |
| <i>2.2.3 MARKAL Model</i>   | 30           |
| <i>2.2.4 Stochastic MARKAL Model</i>  | 31           |
| <b>2.3 Top-Down Models and Linkages</b>   | <b>31</b>    |
| <b>2.4 Other models</b>   | <b>32</b>    |
| <i>2.4.1 Inventory Estimation Model</i>   | 32           |
| <i>2.4.2 Geographical Information System (GIS) Based Energy and Emissions Model</i> | 32           |
| <i>2.4.3 Power Sector Linear Programming (LP) Model</i>                             | 33           |
| <i>2.4.4 Health Impact Model</i>  | 33           |

## **Chapter 3: Construction of Emission Scenarios for India**

|  |    |
|--|----|
| <b>3.1 Introduction</b>                          | 35 |
| <b>3.2 Scenario- building exercises in India</b> | 35 |
| <b>3.3 The Methodology</b>                       | 37 |
| <b>3.4 Scenario description</b>                  | 39 |
| 3.4.1 <i>Scenario Storylines</i>                 | 39 |
| 3.4.2 <i>Quantification of Scenarios</i>         | 48 |
| <b>3.5 Conclusion</b>                            | 49 |

## **Chapter 4: India's Emission Projections**

|  |    |
|--|----|
| <b>4.1 Introduction</b>  | 51 |
| <b>4.2 The Methodology</b>   | 52 |
| 4.2.1 <i>Model inputs</i>  | 54 |
| 4.2.2 <i>Technology specification in the models</i>                          | 56 |
| 4.2.3 <i>End-use Demand Projections</i>                                      | 57 |
| 4.2.4 <i>Integrated analysis using MARKAL Model</i>                          | 58 |
| <b>4.3 Future Projections</b>  | 58 |
| 4.3.1 <i>Aggregate Energy Consumption</i>                                    | 58 |
| 4.3.2 <i>Projections for consumption of Coal, Gas, Oil, Renewable Energy</i> | 59 |
| 4.3.3 <i>Total Electricity capacity and generation</i>                       | 60 |
| 4.3.4 <i>Aggregate and per capita carbon emissions (MT)</i>                  | 61 |
| <b>4.4 Conclusion</b>  | 62 |

## **Chapter 5: Climate Change Impacts on Infrastructure**

|                                      |    |
|--------------------------------------|----|
| <b>5.1 Introduction</b>              | 65 |
| <b>5.2 Case of Konkan Railway</b>    | 67 |
| <b>5.3 Impact Matrix</b>             | 68 |
| <b>5.4 Results and Analysis</b>      | 70 |
| 5.4.1 <i>Current stresses</i>        | 70 |
| 5.4.2 <i>Regional Climate Change</i> | 71 |
| 5.4.3 <i>Potential Impacts</i>       | 72 |
| <b>5.5 Conclusions</b>               | 74 |

## **Chapter 6: Climate Change Impact on Energy and Environment**

|   |    |
|---|----|
| <b>6.1 Introduction</b>                                   | 77 |
| <b>6.2 ANSWER-MARKAL Model Specification</b>              | 77 |
| <b>6.3 Scenario Description</b>                           | 78 |
| <b>6.4 Direct Impacts on Energy Use</b>                   | 80 |
| <b>6.5 Factors Causing Indirect Impacts on Energy Use</b> | 80 |
| 6.5.1 <i>Supply Side Impacts</i>                          | 81 |
| <b>6.6 Scenario Drivers and Model Parameters</b>          | 81 |
| <b>6.7 Results and Analysis</b>                           | 82 |

|                                  |    |
|----------------------------------|----|
| 6.7.1 <i>Power Generation</i>    | 82 |
| 6.7.2 <i>Impact on Emissions</i> | 84 |
| <b>6.8 Conclusions</b>           | 85 |

## **Chapter 7: The Food-Water-Energy-GHG Nexus**

|  |    |
|--|----|
| <b>7.1 Introduction</b>  | 87 |
| <b>7.2 Global warming and climate change impacts for India</b> | 88 |
| 7.2.1 <i>Food Security</i>                                     | 88 |
| 7.2.2 <i>Agriculture</i>                                       | 88 |
| 7.2.3 <i>Infrastructure</i>                                    | 89 |
| 7.2.4 <i>Mountainous regions and glaciers</i>                  | 90 |
| 7.2.5 <i>Forests</i>   | 90 |
| 7.2.6 <i>Coastal regions and natural ecosystems</i>            | 90 |
| 7.2.7 <i>Power</i>   | 91 |
| <b>7.3 Objective of the Study</b>                              | 91 |
| <b>7.4 Findings of the study</b>                               | 93 |
| <b>7.5 The GHG –Model</b>                                      | 95 |
| 7.5.1 <i>Equation for impact on GHG Emission</i>               | 95 |
| 7.5.2 <i>Data Analysis</i>                                     | 97 |
| <b>7.6 Conclusion</b>  | 98 |

## **Chapter 8: Regional Energy Cooperation in South Asia: Benefits of Integrating the Primary Energy and Electricity Markets**

|  |     |
|--|-----|
| <b>8.1 The Context</b>                                 | 99  |
| <b>8.2 Argument for Cooperation</b>                    | 100 |
| <b>8.3 The Methodology</b>                             | 102 |
| <b>8.4 Status of current cooperation in the region</b> | 103 |
| <b>8.5 Existing barriers to regional cooperation</b>   | 104 |
| 8.5.1 <i>Political barriers to cooperation</i>         | 104 |
| 8.5.2 <i>Institutional and public policy</i>           | 105 |
| 8.5.3 <i>Technical barriers</i>                        | 106 |
| 8.5.4 <i>Investment and financial barriers</i>         | 107 |
| <b>8.6 The South Asian Regional Analysis</b>           | 107 |
| <b>8.7 Conclusion</b>                                  | 114 |

## **Chapter 9: Air Quality, Development and Climate Change: The Nexus**

|   |     |
|---|-----|
| <b>9.1 Introduction</b>   | 117 |
| <b>9.2 Nexus between air quality and climate change</b>                                     | 118 |
| <b>9.3 Linking development, air quality and climate change:<br/>CNG conversion in Delhi</b> | 123 |
| 9.3.1 <i>Vehicular pollution control measures</i>   | 124 |
| 9.3.2 <i>CNG experience: The transition process</i>   | 125 |

|   |     |
|---|-----|
| 9.3.3 <i>Linkages of CNG experience in Delhi<br/>with development and climate change benefits</i> | 127 |
| <b>9.4 Disjoint between air quality improvement and<br/>climate change policies in future</b>     | 128 |
| <b>9.5 Framework for air quality improvement and<br/>climate change mitigation</b>                | 132 |
| <b>9.6 Conclusions</b>  | 134 |
| <br>  |     |
| <b>Chapter 10: Conclusion</b>   | 137 |
| <b>References</b>   | 141 |