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Science and Technology – Drivers for a Common Future

Proceedings of the 2nd German-Indian Conference on Research for Sustainability: Energy and Land Use

RESEARCH

Igniting ideas!

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Proceedings of the 2nd German-Indian Conference on Research for Sustainability

Sustainable | Solutions
Science for Sustainability

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Sustainability Science Generates Better Solutions

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At the Earth Summit in Rio de Janeiro (1992), the United Nations declared its commitment to the vision of sustainable development. Over 170 signatory states committed to translate this vision into practice by adopting Agenda 21, a global action programme to achieve sustainable development worldwide. Science and technology play a crucial role in meeting the pressing challenges of sustainable development and internationally coordinated research agendas are essential to finding sustainable solutions to the global challenges of our time. Sustainability science as a new approach addresses the triad out of economy, ecology, and sociology right from the beginning to generate better (sustainable) solutions (see Figure).

Recognizing the considerable potential for collaboration in developing cost-effective and innovative technologies, Germany and India have entered into a research policy dialogue process that aims to strengthen bilateral science and technology cooperation. Similar dialogues between Germany and Brazil, South Africa, China and Russia have also been initiated. The Dialogue on Science for Sustainability (D4S) project rests on an assessment that Germany and emerging economies, such as India, face a challenge in combining economic growth with social justice and acceptable ecological levels, i.e. generating sustainable solutions to some pressing challenges. The Governments of both countries have agreed that

Triad of sustainability research

the time is ripe for a partnership based on mutual interests in a sustainable future, at first bilaterally and gradually multilaterally.

The IHDP[1] Open Meeting in April 2009 addressed the following questions. Can we achieve sustainability through technological innovation? Is it possible to identify an agenda for action necessary for the transition towards sustainability? How do we transform the economic basis of our society into a sustainable one? What role does the current economic crisis play in shaping a possible sustainability transition?

It is time for us to face these challenges and to act. Education is crucial to integrate the principles, values and practices of sustainable development through learning in order to address the social, economic, cultural and environmental problems we face nowadays.

Climate change, demography and economic development call for sustainable solutions. Land use and energy are two essential aspects of

[1]IHDP – International Human Dimensions Programme on Global Environmental Change

the challenge of sustainable development and were the focus of the 2nd German-Indian Conference on Research for Sustainability. The conference goal was to define common strategic areas between India and Germany in research and development in these two fields and build future D4S networks.

During the sessions, problems such as desertification, population pressure and energy were highlighted as the major issues for India. The aim of these sessions was to contribute to the exchange of experience and to the identification of challenges and common interest. At the end of the conference, new bilateral and international research and development projects related to sustainability and ecological innovation were generated.

Dialogue for Sustainability (D4S)...

...so that we can leave our kids and their kids a world worth living!

Innovation alliances for the better use of scientific and technological knowledge were also created.

These proceedings are the outcome of the aforesaid German-Indian conference and shed light on the D4S project. The conference addressed key issues and challenges related to energy and land use research, identified cooperation in specific areas between the two countries and initiated future project plans. Contributions that have dealt with the topics of energy and land use are also included in this publication. The organizers would like to sincerely thank everyone who contributed to the conference and these proceedings. All presentations and results as well as this publication are available for download at URL: www.dialogue4s.de.

Summary of Outcomes

The 2nd German-Indian Conference in the framework of the Dialogue on Science for Sustainability, "Science for Sustainability – Driver for a Sustainable Future", took place on 27 and 28 April 2009 in Bonn, Germany. Sustainability is an integrated concept and guiding principle in international politics in a time of global change, global challenges, and global responsibility. Sustainability means ensuring equity between generations, quality of life and social cohesion. Informed decisions that are sustainable in economic, environmental as well as social terms and coordinated effort are essential to the preservation of our vital natural resources. New technologies and new concepts for decision-making are indispensable to meeting present and future challenges. By combining their expertise in science and technology related to sustainability research, Germany and India can be drivers for substantial contributions towards the generation of sustainable solutions.

The Federal Ministry of Education and Research (BMBF), Germany and the Department of Science and Technology (DST) of the Government of India have emphasized the prominent role that science and technology play in sustainable development and confirmed their support for the development of an internationally coordinated research agenda as part of the Heiligendamm dialogue process as requested by the G8+5 in 2007.

International Dialogue on Science for Sustainability (D4S)

Internationally coordinated research agendas are essential to finding sustainable solutions to the global challenges of our time. For this reason, the German Federal Ministry of Education and Research (BMBF) has launched a series of dialogues on science and technology for sustainability policy with five key emerging economies: India, Brazil, China, Russia, and South Africa. Bilateral events under the slogan "Sustainable Solutions – Science for Sustainability" are being held to promote international cooperation in research and development and to establish the foundations for long-term, strategic partnerships in sustainability research.

The D4S Process between Germany and India

Within the framework of science and technology cooperation between Germany and India (signed in 1974), Dr. Annette Schavan, German Federal

Dr. Annette Schavan, Federal Minister of Education and Research (BMBF, Germany) and Shri Kapil Sibal, Minister for Science and Technology and Earth Sciences of the Government of India signing a Joint Declaration of Intent of "Research cooperation on Science for Sustainability" on 9 September 2008 in New Delhi

Minister of Education and Research and Shri Kapil Sibal, Minister for Science and Technology and Earth Sciences of the Government of India signed a Joint Declaration of Intent on "Research Cooperation on Science for Sustainability" on 9 September 2008 in New Delhi. The 1st German-Indian Conference on Research for Sustainability was held in New Delhi on the same day.

Science and technology play a key role in meeting the global challenges of sustainable development and resource efficiency. Recognizing the considerable potential for collaboration in developing cost-effective and innovative technologies between Germany and India, the German Federal Ministry of Education and Research (BMBF) and the Department of Science and Technology (DST) of the Government of India convened the 2nd German-Indian Conference on Research for Sustainability in Bonn, Germany on 27 and 28 April 2009. The conference was held in the "United Nations" City of Bonn back-to-back with the International Human Dimensions Programme (IHDP) Open Meeting 2009, and was hosted by the United Nations University (UNU). Both events highlighted the urgency of further defining "sustainability" in its diverse dimensions: ecological, social, economic and cultural. In his keynote address to the IHDP Open Meeting, the German State Secretary for Education and Research, Prof. Dr. Frieder Meyer-Krahmer, stressed three key issues:

1. **Sustainable solutions to global challenges require the inclusion of social sciences and humanities. New technologies, albeit crucial, cannot be considered in isolation from the dynamic and complex socio-cultural context in which they are embedded.**
2. **New impulses for a more efficient and sustainable technology transfer are required.**
3. **Future research has to be organized in inter- and trans-disciplinary and international collaboration. BMBF strongly supports this approach.**

These statements were taken up by the 2nd German-Indian Conference on Research for Sustainability.

Results and Recommendations

The 2nd German-Indian Conference on Research for Sustainability focused on land use and energy. About 60 German and Indian stakeholders from government, public and private institutions discussed how research and technological development could effectively contribute to enduring, socially equitable and ecologically sustainable economic development. The conference goal was to define common strategic areas between India and Germany in the fields of energy and land use research and development and strengthen networks between scientists in the two countries. The expectation is that these will contribute to the planning of bilateral and international research related to sustainability and ecological innovation and generate research, development and innovation alliances for the better use of scientific and technological knowledge.

The key outcomes of the meeting can be summarized as follows:

- **Dialogue on key issues related to the thematic foci of the conference, namely energy and land use research and development, including identification of each country's priorities and research funding schemes.**
- **Identification of specific areas for enhanced cooperation between the two countries.**
- **Initiation of discussion on concrete Indo-German research and development project proposals.**

Two parallel sessions on the thematic areas prioritized for the conference – energy and land use, respectively – were organized to enable specialized exchange of expertise, discussion and networking opportunities.

Two expert coordinators (one from India and one from Germany) were nominated for each focus area. The coordinators supported preparations for the conference by ensuring the scientific coherence of content and advising on the selection of speakers. During the conference, they chaired and reported on the results of their respective sessions.

Results and Recommendations in the Field of Energy Research

Dr. Leena Srivastava, Executive Director, The Energy and Resources Institute (TERI), India and Prof. (em.) Dr. Karl Strauss, Technical University of Dortmund, Germany served as the scientific coordinators and chairs of the sessions on energy. Dr. Srivastava replaced Prof. H.S. Mukunda, Indian Institute of Science, who was unable to participate at the last minute.

The following thematic areas were emphasized as priorities for joint energy research:

- **Analysis and design of integrated energy systems to cover energy demand in a sustainable manner,**
- **Renewable energy and rural energy access,**
- **Energy efficiency and waste minimization, including waste energy,**
- **Policy innovations for reducing private energy consumption,**
- **Linkage between energy pathways and societal interactions, including the impact of choice of energy on social dynamics, and**
- **Fuel cell technology.**

The coordinators emphasized that although successful demonstration projects have been developed in India already, there is still a need to scale them up, and that this is an area where cooperation with Germany could be particularly fruitful. The participants concurred that a genuine partnership between Germany and India could not be reduced to technology transfer. Thus, it was recommended that tools for enabling and expanding Indo-German sustainability research networks and activities that go beyond face-to-face meetings be set up. It was proposed to link this initiative to the already existing intergovernmental “German-Indian Energy Forum”.

Results and Recommendations in the Field of Land Use Research

Prof. Dr. Harald Kächele, Leibniz-Centre for Agricultural Landscape Research (ZALF), Müncheberg, Germany and Prof. P.S. Ramakrishnan, School of Environmental Sciences, Jawaharlal Nehru University (JNU), New Delhi, India, served as the scientific coordinators and chairs of the sessions on land use. Prof. P.S. Ramakrishnan was also nominated by the Department of Science and Technology (DST) of the Government of India to officially represent its interests.

The coordinators noted the following:

- **The research presented during the land use sessions was problem-oriented, inter-disciplinary and/or trans-disciplinary and integrated the human dimension.**
- **Scientists were interested in capacity building, with several German institutions offering training and Masters-level courses with a focus on India.**
- **While the conference provided a fairly good overview of Germany's land use research landscape, the same could not be said of India's land use research landscape. This was due to a lack of adequate representation of Indian expertise in this area at the sessions. The participants recommended**
  - that the discussions on land use continue, as this vast thematic area was characterized by a high level of fragmentation and, thus, required more time;
  - that technology-oriented research be integrated into a systemic approach; and
  - that future research be organized around thematic and regional clusters.

Under the crosscutting issues of climate change and globalization of economies, five thematic clusters were identified for detailed and more specific consideration:

- **Cluster 1: Land Use Change and Governance**
- **Cluster 2: Biodiversity, Sustainable Forest Management and Agriculture**

- **Cluster 3: Land Use and Water Interaction, Integrated Water Resource Management**
- **Cluster 4: Food and Livelihood Security**
- **Cluster 5: Soil and Land Degradation**

Two regional clusters were identified:

- **Cluster 1: Fragile Regions (Semi Arid Areas and Mountain Regions including the north-eastern hill areas)**
- **Cluster 2: Interface between Urban and Peri-urban Areas**

The recommendations generated at these sessions will be provided to the Intergovernmental Joint Working Group on Science for Sustainability under the Indo-German Joint Committee for Science and Technology for directing future joint activities, including funding for "Science for Sustainability" R&D projects, e.g. under the Indo-German Science and Technology Centre (IGSTC) programme.

Outlook

Proceedings of the conference will be prepared and disseminated. A new website, www.dialogue4S.de, was set up to enable active networking of stakeholders, especially researchers working in science for sustainability in both countries.

The Joint Working Group on Science for Sustainability has already agreed to continue this German-Indian dialogue with the 3rd German-Indian Conference on Science for Sustainability, which will focus on water and waste management, in early 2010.

With regard to the funding of joint R&D projects in the above-mentioned fields of sustainability, among other things, BMBF and DST have just started the Indo-German Science and Technology Centre Programme (€ 10 million from each side) for joint Indo-German research and development projects (so-called "2+2" projects). Furthermore, a new BMBF funding scheme for international cooperation with Brazil, China, India, Russia and South Africa in the field of environmental technology research for sustainability is in preparation. Details will need to be discussed in due course.

German Federal Minister for Education and Research, Prof. Dr. Annette Schavan, has signed similar agreements with Brazil, China and South Africa (with one with Russia to follow soon). Similar topics were jointly identified as priority areas. BMBF proposes to jointly organize a conference together with all these countries in 2010 to merge the bilateral activities and discuss how best to set a global research agenda, which might then become reality during the so-called Carnegie Meeting of research ministers due to take place in Germany in 2011.

Foreword

Prof. Dr. -Ing. Dr. h.c. Janos J. Bogardi
Vice-Rector a.i., United Nations University, Bonn, Germany

D4S stands for Dialogue on Science for Sustainability. The importance of sustainability is acknowledged globally but local perceptions vary. What does sustainability mean to you? What does it mean in social context? How does it relate to norms and values? What should be sustainable, for how long and where? We all recall the famous "first definition" of sustainable development by the Brundtland Commission: "development, which meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987). Many more definitions have appeared since, pointing to the complexity of the issue.

The definition of sustainability is inherently a definition of values and of the future of a society. The difficulty of defining this concept is clearest when we compare different attempts to measure sustainability. This underscores the urgent need for a basic common understanding and terminology in order to avoid the degeneration of emerging sustainability science into the construction of an interdisciplinary Tower of Babel. Practice cannot wait for the settlement of theoretical debates.

D4S, "Sustainable Solutions – Science for Sustainability," is a groundbreaking project that focuses on establishing bilateral science policy dialogues between Germany and the world's five key emerging economies, namely Brazil, Russia, India, China and South Africa. The dialogues evolved from the

Chairmen of the Conference: Prof. P. S. Ramakrishnan (Jawaharlal Nehru University), Prof. Dr. -Ing. Dr. h.c. Janos J. Bogardi (Vice-Rector a.i., United Nations University, Bonn) and Dr. Wolf Junker (BMBF), (from left to right)

realization that the challenges we face in the 21st century disregard national borders. Thus, the time is ripe for a global research agenda. The initiative demonstrates the countries' commitment to Agenda 21 and supports the promotion of fundamental political, social, economic and industrial change towards the goal of sustainability.

The Dialogue on Science for Sustainability is first about defining a joint vision and second about defining a joint research agenda and making progress towards this objective. While the first step must happen in the sphere of policy, the second step happens in the sphere of science. Yet, neither policy nor science alone can create the solutions needed. Only together can we address the complexity of pressing global issues and provide adequate responses to them. Only together, through forging new partnerships and filling knowledge gaps, can we make progress.

The United Nations University (UNU) is dedicated to the generation and transfer of knowledge, and the strengthening of individual and institutional capacities in furtherance of the purposes and principles of the Charter of the United Nations. The mission of UNU is to contribute, through research

Participants of the 2nd German-Indian Conference on Research for Sustainability

and capacity building, to efforts to resolve the pressing global problems that are a concern of the United Nations, its Peoples and Member States. In order to provide innovative solutions, policy-relevant science must go beyond traditional boundaries. By creating bridges between research and policy as well as by supporting thematic networking of scientific institutions worldwide, UNU contributes to building global coherence in research for sustainability and provides an international platform for this Dialogue.

I am, therefore, very pleased to present the proceedings of the 2nd German-Indian Conference on Research for Sustainability, which is an example of vital cross-border discussion. The publication addresses a broad range of issues related to land use and energy research in India and Germany and attempts to extend understanding of how research contributes to social, environmental, economic and institutional sustainability.

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Introducing Germany and India – Drivers for a Sustainable Future

Dr. Wolf Junker, Federal Ministry of Education and Research, Bonn, Germany

Sustainability is a guiding principle in German politics and I believe more and more so in Indian politics, too. Advanced, dynamic and developed economies in particular must take decisions that are sustainable in economic, environmental and social terms if our vital natural resources, e.g. energy and land use – the two topics of this conference, are to be preserved.

Sustainability means ensuring equity between generations, quality of life, social cohesion and international responsibility. Present and future challenges are so ambitious that they can only be mastered with new technologies and discoveries, and new concepts for decision-making. I am confident that by combining their expertise in science and technology, Germany and India can make a substantial contribution towards generating sustainable solutions. The German Federal Ministry of Education and Research (BMBF) and the Department of Science and Technology (DST) of the Government of India have emphasized the prominent role which research and development play in sustainable development and confirmed their support for the development of an internationally coordinated research agenda as part of the Heiligendamm dialogue process as requested by the G8+5 in 2007.

Dialogue on Science for Sustainability (D4S)

Internationally coordinated research agendas are a must when it comes to finding sustainable solutions to the global challenges of our time.

Heiligendamm Process (G8+5) (2007) and Gleneagles Dialogue on Climate Change, Clean Energy and Sustainable Development (2008) call for a global research agenda to address global challenges by joining resources

For this reason, the German Federal Ministry of Education and Research (BMBF) has launched a series of dialogues on “Science for Sustainability” with key emerging economies, namely India, Brazil, China, Russia and South Africa. Bilateral events are being held under the slogan “Sustainable Solutions – Science for Sustainability.” Their objective is to establish the foundations for long-term, strategic partnerships in sustainability research and increase bilateral cooperation in sustainability-related research and development projects and the dissemination of results. In the long term, global challenges need to be tackled by setting a global agenda for research cooperation to find sustainable solutions.

The 2nd German-Indian Conference on Research for Sustainability marks the continuation of the German-Indian Dialogue on Science for Sustainability (D4S, for short), which was recently launched by Federal Minister Dr.

Annette Schavan (BMBF) and Shri Kapil Sibal, Minister for Science and Technology and Earth Sciences of the Government of India by the signing of a Joint Declaration of Intent and the holding of the 1st German-Indian Conference on Research for Sustainability in New Delhi on 9 September 2008.

Science and technology play a key role in meeting the global challenges of sustainable development and resource efficiency. Recognizing the considerable potential for collaboration in developing cost-effective and innovative technologies between Germany and India, the German Federal Ministry of Education and Research (BMBF) and the Department of Science and Technology (DST) of the Government of India have now convened this 2nd German-Indian Conference on Research for Sustainability. The conference is being held in the "United Nations" City of Bonn today and tomorrow back-to-back with the 2009 Open Meeting of the International Human Dimensions Programme on Global Environmental Change (IHDP). Most of us attended the IHDP opening session this morning. Both events deal with sustainability; while the IHDP meeting focuses more on the human dimension, our conference here focuses more on the research aspect.

In his opening keynote address to the IHDP Open Meeting this morning, BMBF State Secretary Prof. Meyer-Krahmer stressed three key issues:

- **In order to find sustainable solutions to global challenges, besides new technologies, we need to include perspectives from social sciences and the humanities.**
- **It will also require new impulses for more efficient and sustainable technology transfer.**
- **Future research has to be organised more than it has been in the past in inter- and trans-disciplinary and international collaboration. BMBF strongly supports this approach.**

The 2nd German-Indian Conference on Research for Sustainability will focus on land use and energy, enquiring as to what sustainable solutions science and research, respectively, have to offer in response to global and future challenges in these fields. About 60 stakeholders from government, public and private institutions have come together here to discuss, today and tomorrow, how research and technological development can effectively contribute to enduring, socially equitable and ecologically sustainable economic development.

The conference goal is to define common areas between India and Germany in the fields of energy and land use research and development and build future networks between scientists in the two countries. These are expected to contribute to the planning of bilateral and international research related to sustainability and ecological innovation and to generate research, development and innovation alliances for the better use of scientific and technological knowledge. There are plans to continue this dialogue early next year with another bilateral conference, focusing on water and waste management research.

Envisaged Outcomes

The envisaged outcomes of this meeting are:

1. **Dialogue on key issues related to the thematic foci of the conference, namely energy and land use research and development;**
2. **Identification of specific areas for enhanced research cooperation between the two countries; and**
3. **Initiation of discussion on concrete Indo-German research and development project proposals.**

BMBF and DST have a very strong record of cooperation in science and technology since 1974. Recommendations generated from this meeting will provide input and guidance for the Joint Working Group on Science for Sustainability under the Indo-German Joint Committee for Science and Technology for directing future joint activities, including funding for “Science for Sustainability” R&D projects, e.g. under the Indo-German

From left to right: PD Dr. Lothar Mennicken (International Bureau of BMBF), Hartmut Grübel (BMBF), Prof. P. S. Ramakrishnan (Jawaharlal Nehru University), Prof. Dr. -Ing. Dr. h.c. Janos J. Bogardi (United Nations University) and Dr. Wolf Junker (BMBF), are defining common areas in the field of “energy” and “land use” research and development and to build future networks between the scientists in both countries.

Science and Technology Centre programme, which is open for so called “2+2 R&D projects”. My colleague, Dr. Stienen, will provide more details on BMBF/DST S&T funding programmes later.

A Word of Thanks

I thank the organizers: first of all, United Nations University – Vice Rectorate in Europe, Prof. Janos Bogardi and his team; second, the International Bureau of the BMBF; and, last but not least, the Department of Science and Technology (DST) for their effort in bringing us here together. I thank all of you for coming and wish you a successful second conference and fruitful discussions on research for sustainability.

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Bilateral Cooperation in Science and Technology between the Governments of Germany and India

Dr. Christian Stienen, Federal Ministry of Education and Research, Bonn, Germany

The basis for long-lasting cooperation in science and technology between India and Germany lies in the governmental agreement of 1974, as well as the collaborative foundation of the Indian Institute of Technology (IIT) Madras in 1958. Ever since, cooperation has been continually developed and deepened.

Today the German Federal Ministry of Education and Research works in close cooperation with the Indian Department of Science and Technology (DST), Department of Biotechnology (DBT), Council of Scientific and Industrial Research (CSIR), Indian Council of Medical Research (ICMR) and Department of Atomic Energy (DAE) in selected technology fields. These include biotechnology, health research, information technology, environmental technology, sustainability research, material science, space research, energy research, production technology and disaster and security research. Besides a regular exchange of students and scientists, there is an increasing number of bilateral research projects and university-level cooperation between the two countries. And, in a newer trend, more and more companies have become engaged in research projects with academic institutions. India is one of the most important strategic partners of the BMBF in Asia. A variety of specific concerted programs to support research cooperation between the two states exist. The mobility funding programs allow visits as well as short-term residencies in research institutions.

As part of the ongoing campaign "India and Germany – Strategic Partners for Innovation" the BMBF has selected 20 projects by companies, research institutions and universities to highlight Germany's innovation potential with the aim of stimulating more mutually beneficial R&D collaborations between German and Indian research institutions and companies. The campaign was launched on 9 September 2008 with a kick-off event in New Delhi, which was attended by the research ministers and high-ranking representatives from both countries. Other sector-specific events organized by German research and technology establishments will give interested partners in India the opportunity to establish contacts with German research establishments and technology companies before the "Techno Germa" in New Delhi in March 2010. Currently, workshops, multiplier events, partnering events, lectures and presentations at conferences and meetings are being organized. They are aimed at scientists at universities and research institutions, scientists and decision-makers at R&D-oriented companies, junior scientists, multipliers and investors.

The Indo-German Science and Technology Centre (IGSTC) is the biggest and most expensive project ever within the Indo-German collaboration. Both governments will spend up to 2 million Euros per annum each until 2012. IGSTC is aimed especially at intensifying research projects between industry and academia. Therefore, the participation of at least one German and one Indian research institution as well as one German and one Indian industry partner is a prerequisite for funding. Research projects in the area of applied research and development within the fields of biotechnology, health research, production and energy technology as well as environmental technology will be executed within the IGSTC. It is expected that the selected projects will produce new insights and exploitable research results in the above-mentioned fields. More than 45 grant proposals have been submitted in response to the first call, underlining the great interest in, as well as the solid basis of, Indo-German cooperation in science and technology.

The mid-term goal of both governments, and which is at the centre of their respective international commitments nowadays, is to tackle global challenges – specifically, global challenges with regard to security, nutrition, peace and the welfare of people. Within this framework, Germany and India, their governments, their researchers and their entrepreneurs

Both research ministers, Prof. Dr. A. Schavan (l.) and S. K. Sibal (r.), jointly inaugurated the Indo-German Science and Technology Centre (IGSTC) in Delhi on 9th September 2008. The IGSTC intends to primarily provide support for "2+2 technology projects" (with the participation of science and industry on both sides) on the basis of invitations for projects in various fields of research. The Centre will focus on natural, life and engineering sciences.

are seeking ever closer cooperation with each other and with other countries capable of meeting these challenges. The German government is accommodating these aims with the High-Tech Strategy for Germany and the Internationalization Strategy. This conference is but a small part of the endeavour, but a very important one.

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Foreword of the Department of Science and Technology, Government of India

Dr. T. Ramasami, Secretary to the Government of India,
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India and Germany signed a Declaration of Intent on 9th September 2008 in Delhi for engaging each other on a dialogue on a Dialogue on Science for Sustainability. The declaration was signed by Science Ministers of both countries. Following the declaration 4 thematic areas viz. Land-use, Energy, Water and Waste Management for further discussions were identified. Two meetings have been held in New Delhi and Bonn to discuss follow-up actions on the selected thematic areas and the 3rd is planned in Delhi in February 2010.

View into the conference hall: Dr. B. C. Nagaraja, Dr. Divya Sharma, Thomas Kutter and Prof. Dr. Harald Kaechele (from right to left to be seen in the forefront)

Scientists and experts from both sides met in a most cordial atmosphere to identify the strengths and opportunities for collaborative work and exchanged information and knowledge on the state-of-the-art in the two countries. The discussions of the meeting have now been documented. This publication will be of immense use to both practitioners and policy makers. I am sure that stakeholders would put the publication to use and enhance the dialogue process to enable India and Germany embarks on a voyage of togetherness and Sustainability at a time when the global attention is on Sustainability Science.

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Energy

Challenges for R&D in the Indian Energy Sector

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With over 15 per cent of the world's population and its high rates of economic growth, India is likely to become a significant consumer of global energy resources. While nearly 50 per cent of India's population does not have access to clean, modern energy forms, at least 20 per cent of its population can be classified as middle class and this percentage will increase in the coming years. This fast-growing, new middle class with increased disposable incomes and easier access to appliances will demand more energy for a more comfortable life style, while millions of poor people in rural areas still wait for access to electricity.

The shortage of energy in India (approximately 10 per cent, and at peak times about 15 per cent, in 2007/08) is one of the biggest challenges for the country's development. Model calculations done by The Energy and Resources Institute (TERI) indicate that by 2031 electricity supply in India has to increase six-fold (from 150 to 900 GW) to meet demand. This would mean a five- to six-fold increase in consumption of fossil energy resources compared to today, if the growth pattern does not change significantly.

India lacks sufficient domestic energy resources and must import about 30 per cent of its growing energy requirements. It is not only experiencing an electricity shortage but is also increasingly dependent on oil imports to meet demand. In addition to pursuing domestic oil and gas exploration

View into the conference hall at the United Nations University, Bonn

and production projects, India is also stepping up its (liquefied) natural gas imports.

Coal accounts for more than half of India's total energy consumption (53 per cent, EIA International Energy Annual 2006) followed by oil, which comprises 31 per cent of total energy consumption. Natural gas and hydroelectric power account for 8 and 6 per cent of consumption, respectively. Although nuclear power comprises a very small percentage of total energy consumption at this time (1 per cent), it is expected to increase following recent international civil nuclear energy cooperation deals. The efforts of the Indian government in the field of energy research and technology, although great, are not nearly adequate. R&D expenditure in the field of energy currently only makes up about 8 per cent of India's overall spending on research and technology, with a large share going to nuclear energy. Within the Government of India, the following ministries and departments are in charge of energy research, policy, development, production and dissemination of energy technologies in India:

- **Ministry of Power (MoP),**
- **Ministry of New and Renewable Energy Resources (MNRE),**
- **Department of Atomic Energy (DAE),**
- **Ministry of Coal,**
- **Ministry of Petroleum and Natural Gas,**
- **Ministry of Science and Technology/Department of Science and Technology (DST) and others.**

In particular, the Department of Atomic Energy (DAE) and the Department of Science and Technology (DST) fund energy research in India.

Thermal Power

With coal still the most abundant and cheapest conventional energy form, India would need to build a large number of new thermal (coal) power plants and also upgrade old thermal power plants through technology transfer to enhance energy efficiency and extend lifetime. This sector needs large investments both from the public and private sector, including international investments.

Renewable Energies

In June 2007 renewable energy (>10 GW capacity) accounted for approximately 7 per cent of India's total energy production. This share is to be increased to 10 per cent of energy production by 2010 and 20 per cent by 2020. The greatest progress so far has been made in the use of wind power, which now amounts to approximately 70 per cent of India's renewable energy. India has become the world's third largest producer of wind power and the fourth largest exporter of wind turbines. The Indian company SUZLON Energy bought a majority stake (86.5 per cent) in the former Germany-based wind power company Repower Systems, Hamburg on 1 June 2007. At the time, this was the third largest cross-border takeover by an Indian company of all time.

Small hydroelectric power plants (up to 25 MW) contribute a further 20 per cent, while combined heat and power generation and biomass (mainly wood firing) are responsible for another 20 per cent (2007) of India's renewable energy production. The Indian government supports this development through financial incentives as well as training and information programmes.

In addition, there is a (small) solar energy programme. With only 2 MW, the contribution of solar energy to India's renewable energy production is very small. MNRE provides financial support for several pilot projects in the area of photovoltaic. However, there is room for improvement when it comes to transferring the findings from these pilot projects to practical application. Indian companies are second only to the U.S. in the production of solar cells.

MNRE has also launched a pilot programme to support energy generation from biomass.

Nuclear Energy

India is also working on developing its civil nuclear energy programme so as to become independent from other countries. In fact, India's research and development activities in the area of nuclear energy use have the ultimate aim of making the entire fuel cycle – from uranium mining to nuclear waste management – independent from other countries. There are two major atomic research centres in India: BARC and IGCAR.

Fusion Energy

Nuclear fusion has the potential to solve the world's energy problems in the long run, but a lot of research and development has to be done in order to be able to manage this high technology energy resource. Fusion energy will not be broadly available within the next 20 to 30 years. However, India contributes to the large fusion experiment, ITER, in France. Together with the European Union (including Switzerland), Japan, Russia, People's Republic of China, South Korea and the USA, India is a full partner country contributing to build and operate ITER, a very large pan-European experimental facility to develop electricity generation from nuclear fusion. From Germany BMBF is involved as well.

Indo-German Collaboration

The governments of Germany and India have agreed to engage in a dialogue on energy as part of their strategic partnership. The Indo-German Energy Forum (IGEF) was created in 2006 by German Chancellor Angela Merkel and Indian Prime Minister Manmohan Singh. It aims at promoting cooperation in energy security, energy efficiency and renewable energy; investment in energy projects; and collaborative research and development. Participating actors include the Indian and German governments, public institutions and the private sector.

The Indian government is represented by the Ministry of Power (MoP) and Ministry for New and Renewable Energies (MNRE) and the German government by the Federal Ministries of Economics and Technology (BMWI), Economic Cooperation and Development (BMZ), Environment, Nature Conservation and Nuclear Safety (BMU) and Education and Research (BMBF). The Department of Science and Technology (DST) is associated, too. The private sector is invited to participate in, and should clearly benefit out of, the IGEF. The clear objective is to develop joint cooperation projects between German and Indian institutions, or yet more desirably between the private sectors of both countries. The Indo-German Symposium on Energy Efficiency held in New Delhi in May 2008 generated an additional momentum for the bilateral political dialogue on energy; a second symposium is scheduled for November 2009.

Efficiency enhancement in fossil fuels-based power plants: under Indo-German Financial Cooperation (funded by BMZ), KfW Bank has launched the Energy Efficiency Programme, which aims at demonstrating the benefits of energy efficient rehabilitation and modernisation/lifetime extension in selected power stations. Together with Anna University in Chennai, the Helmholtz Association of German Research Centres carried out a workshop on “Major Aspects of Energy Research in India and Germany: The Challenges for the Future” on 20 and 21 June 2007. A recent workshop focused on R&D cooperation in fuel cell technology between both countries. The recently established Cluster Network Germany-India (www.CNGI.de) is a research initiation project funded by the German Ministry for Research and Education (BMBF). It aims at strengthening Indo-German ties in the research areas of renewable energy and energy efficiency. In response to a recent joint call for proposals under the Indo-German Science and Technology Centre (IGSTC), several Indo-German R&D project proposals in energy research were submitted. Following the recommendation of the G8+5 summit in Heiligendamm (2007), BMBF initiated the “Dialogue for Sustainability (D4S)” with Brazil, Russia, India, China and South Africa (BRICS) to strengthen the contribution of R&D for finding sustainable solutions to challenges in priority areas. Under the umbrella of the Indo-

German Science and Technology Committee (BMBF and DST), an Indo-German Joint Working Group on Science for Sustainability was established in May 2008. The first conference on the topic was organized in New Delhi in September 2008 and identified energy as one of four priority areas for joint research and development (R&D) initiatives for enhanced cooperation.

Some areas in which further cooperation and collaboration can effectively take place between our two countries include:

- **Demonstration projects and sharing of experiences on solar rooftop installations;**
- **Design and impact evaluation of economic and financial instruments for promoting energy efficiency;**
- **Simulation tool for concentrating solar power technologies;**
- **CDM project on concentrating solar PV technology;**
- **Cost-Optimised Energy Management for Stand-Alone Photovoltaic Hybrid Systems;**
- **Applied optics in the context of solar devices and seasonal shading; and**
- **Mini grids: socio-technical integration.**

Conclusion

Meeting the fast-growing energy demand in India in a sustainable way, i.e. in a way that contributes to economic development, is ecologically acceptable and socially just, is a major challenge. Germany and India should continue exchanging experiences and step up cooperation in R&D to find sustainable solutions.

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Energy Research Funding by the Federal Ministry of Education and Research (BMBF)

Karl Wollin, Federal Ministry of Education and Research, Bonn, Germany

Energy research supports energy and climate policy. Sustainable energy supply is a strategic goal to the Federal Government of Germany. The objective is to ensure energy security at affordable prices, compatible with climate and environmental protection requirements.

Therefore, the German Government established an **Integrated Energy and Climate Programme** in 2007. This integrated Programme comprises:

- **Realization of European climate protection goals by 2020,**
- **Legislative initiatives and incentive programs,**
- **Energy research and innovation is an important program element,**
- **Recognition that energy research helps in the achievement of energy and climate goals more efficiently, faster and less expensively,**
- **Recognition that energy research supports competitiveness and export.**

In Germany, five federal ministries fund energy research:

- **Federal Ministry of Economics and Technology (BMWi),**
- **Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU),**
- **Federal Ministry of Food, Agriculture and Consumer Protection (BMELV),**
- **Federal Ministry of Transport, Building and Urban Affairs (BMVBS) and**

- **Federal Ministry of Education and Research (BMBF).**

BMWi: General Principles of Energy Research Policy, Energy Research Program of Fed. Gov., International Energy Research Policy, Coordination Platform on Energy Research Policy; Institutional Funding: Efficient Energy Conversion, Renewable Energy; project funding applied research, development and demonstration;

BMU and BMELV: project funding applied research, development and demonstration in renewable energy (BMU) and Bioenergy (BMELV), respectively;

BMVBS: project funding: efficient use of energy (building and transportation sector)

BMBF: funding energy research through institutional and project funding (basic energy research) in the areas of

- **Efficient Energy Conversion,**
- **Renewable Energy,**
- **Nuclear Safety, and**
- **Fusion.**

Energy Research Funding Programmes by BMBF

BMBF funds energy research on various levels and with various instruments:

- **Institutional funding of German National Research Centres: Helmholtz Association, Fraunhofer Society, Max Planck, Society, and Leibniz Association,**
- **Project funding with priority on research alliances of research centres and universities and on strategic alliances of science and industry**
- **Funding of young scientists e. g. creating working groups led by post-docs,**

- **Transfer of research results via seminars, workshops, conferences, summer schools.**

BMBF funds fundamental, long-term research work: Basic Energy Research 2020+.

BMBF funding resources for energy research are

- **200 Mio. €/a institutional funding (Helmholtz association),**
- **55 Mio. €/a for projects in basic energy research,**
- **70 Mio. €/a for energy-relevant projects in other programs.**

Priorities of BMBF

Next generation solar technology

- **Electricity generation by thin-film solar cells based on inorganic materials**
  - New materials, cell structures and hybrid structures
  - Improvement in the understanding of physical processes in the solar cell
  - New methods for structural and functional analysis and simulation
- **Hydrogen production by photocatalytic water splitting**
  - Further development of natural photosynthesis
  - Improvement of semi-artificial systems
  - Creation and optimization of artificial systems
- **Innovation alliance "Organic Photovoltaic"**
  - Development of new or improved solar cells based on organic materials
  - Combination of basic research, application-oriented materials research and process technology
  - Solar energy converters in the small power range with 10 per cent efficiency and a life-time of 2 -3 years shall be available at low production costs on a medium term basis

- **Regional cluster "Solar Valley Mitteldeutschland"**
  - Cooperation between regional solar industry, research and educational institutions
  - Development of next generation solar cells based on very thin silicon wafers
  - Maintain competitiveness of German photovoltaic technology by reduction of production costs
  - Special regional initiatives for the education of young researchers and engineers

Bioenergy: Biomass Production and Conversion

"BioEnergy 2021" – a call for research on energetic use of biomass

- **Use of specific energy plants as well as biological waste,**
- **Combined use of biomass for energy and raw material purposes (bio-refinery),**
- **Improvement of efficiency of biomass conversion,**
- **Goal: internationally competitive use of biomass in Germany.**

Efficient generation, transport, storage and consumption of energy

- **Innovation alliance "Lithium-Ion-Battery": development of high-capacity and safe Lithium-based batteries**
  - Stationary and mobile fields of application e. g. combination of regenerative electricity generation with local energy storage; cars with electric or hybrid drive "National Development Plan for Mobility by Electric Cars"

Competition "Energy-efficient City"

- **The city as a complex energy system**

The shortage of energy in India is one of the biggest challenges for the country's development. The governments of Germany and India have agreed to engage in a dialogue on energy as part of their strategic partnership. At the conference the participants discussed e. g. how to promote cooperation in energy security, energy efficiency and renewable energy, investment in energy projects and collaborative research and development.

- **Reduction of energy consumption and CO_2 emission by a certain percentage; (the Federal Government's goal is 40 per cent CO_2 emission reduction by 2020)**
- **Development of innovative strategies, technologies, instruments and new services**
- **Conversion of a "normal city" into an "energy-efficient city"**
- **Networking in energy systems**
- **Development of new financing tools**
- **Overcoming barriers (financial, structural, legal, etc.)**
- **Cost-benefit consideration of municipal perspective**

Various BMBF programs are relevant for energy efficiency

- **Materials Research Program: light weight materials; components for fuel cell development; heat insulation materials; high temperature-resistant materials (power generation)**
- **Electronics and electronic systems programs: energy efficient drive systems; energy saving chips and**

electronic systems (e.g. servers and personal computers); electronics for application in automobiles
- **Optical technologies: OLED R&D program**
- **Microsystems: R&D program on micro FCs and energy independent microsystems**
- **Production systems and technologies: R&D program on energy and material efficient production technology**
- **Social sciences: research programme "New Ways to Sustainable Consumption"**

National Innovation Program on Hydrogen and Fuel Cell (FC) Technology

- **Coordinated by BMVBS, in cooperation with BMWI and BMBF**
- **Research, development and demonstration**
- **500 Mio €, 10-year-program**
- **R&D to increase durability and reduce costs**
- **FC application in transportation, industry, home and special markets**
- **H_2 production**

Low CO_2 power stations and carbon capture and storage (CCS)

- **BMWI: R&D on modern high efficiency power stations including carbon capture**
- **BMBF: R&D on carbon capture and storage (CCS) and usage of CO_2**
  - Exploration, selection and evaluation of storage sites,
  - Interaction of CO_2 with the reservoir medium and overlying rock. Acceptance by the public is essential!
  - CO_2 as a raw material for industry
- **Fundamental R&D on nuclear safety and waste**
  - Reactor safety, especially modelling and simulation
  - Characterization and treatment of radioactive waste, partitioning and transmutation of long-lived radioactive waste
  - Radiation research: radiation protection research, medical radiation biology, radiation and environment,

- Participation in international committees and research platforms,
- International integration of young scientists.

International cooperation in fusion research

- **Cooperation in the large international fusion experiment, ITER, within the EURATOM agreement (together with India and other international partner countries)**
- **BMBF supports multilateral cooperation in projects of the International Energy Agency (IEA) and European Commission**
- **Basic energy research in the European Research Area in the framework of ERANET INNER (Innovative Energy Research)**
- **Individual cooperation contacts with research institutions**

Outlook

The wide spectrum of topics covered by German energy research offers many opportunities for an enhancement of bilateral Indo-German cooperation in the energy sector. Basic energy research as well as application-oriented projects could be defined in the course of bilateral workshops and experts' visits.

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Indo-German Energy Forum – History, Objectives and Outlook

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The Indo-German Energy Forum (IGEF) was founded on 26 April 2006 at the initiative of German Federal Chancellor Angela Merkel and Indian Prime Minister Manmohan Singh. On the German side the Federal Ministry for Economics and Technology (BMWi) has the co-ordination function. Its counterpart on the Indian side is the Ministry of Power (MoP).

Objectives

According to the agreed Terms of Reference at the first meeting, among other things, the IGEF aims to promote cooperation in the areas of energy security, energy efficiency (EE), renewable energies (RE), investment in energy projects and collaborative research and development. The private sector is invited to participate in the initiative and should clearly benefit from it. The concrete objective is to identify and develop joint cooperation projects between German and Indian governmental and non-governmental institutions or, yet more desirably, between the private sectors of both countries.

At the second meeting of the IGEF in December 2007, a decision on the establishment of three ad-hoc sub-groups was taken:

- **Sub-Group 1 for in-depth study in the area of "efficiency enhancement in fossil fuels based power plants" led by the Ministry of Power (MoP) of India and by the German Ministry for Economics and Technology.**

Interior view of the Indo-German “Science Express” 2007/08

- **Sub-Group 2 for further cooperation in the field of “decentralized power generation based on biomass and other renewable energies” led by the Ministry of New and Renewable Energy (MNRE) of India and by the German Ministry for Economics and Technology (BMWi) and Ministry for Environment, Nature Conservation & Nuclear Safety (BMU).**
- **Sub-Group 3 on “CDM projects in the Kyoto framework” led by the Indian Ministry of Power (MoP) and by the German Ministry for Environment, Nature Conservation & Nuclear Safety (BMU).**

Meetings of all three sub-groups took place over the course of 2008. Sub-Group 1 established two task forces involving German and Indian energy associations and utilities in order to pursue the following two concrete projects:

- **"Harmonisation of tendering procedures for rehabilitation and modernisation contracts in the Indian power sector"**
  There is a significant and growing market for rehabilitation and modernisation (R+M) of thermal power stations. Establishing a standard tendering procedure will most likely result in time and money savings and increase planning reliability. This will make R+M projects more attractive not only for consulting companies and suppliers of equipment but also for financing institutions. The two sides have, therefore, expressed interest in assessing options for harmonizing tendering procedures and in developing model terms of reference, tender documents and procedures based on the best practices adopted in India and worldwide.

- **Establishment of an Indo-German "Excellence Enhancement Centre (EEC)"**
  It is intended to establish an organization that is a legal entity in accordance with Indian law and located in India. The institutional framework of the EEC will be comparable with industry associations in Europe and have permanent staff to organize its day-to-day work. It will be based on voluntary membership of power generation companies, equipment suppliers, research bodies and training institutions. The technical work of the EEC will be done primarily by committees that consist of representatives of EEC members. The activities of the Centre shall focus on three fields: technology, personal skills and processes in power plants.

Sub-Groups 2 and 3 met for the first time in November 2008. The following areas of cooperation were identified and subsequently outlined in a road map:

- **Business models to promote renewable energies in rural areas;**
- **New installation of large-scale renewable energies technologies;**
- **Consultancy support for photovoltaic panel installations on Indian governmental buildings;**
- **Programmatic CDM as a mechanism to promote technology transfer;**
- **Energy Service Companies (ESCO);**

- **An excellence enhancement centre as a networking platform in the industrial sector;**
- **Energy efficiency programmes on the demand side.**

As mainly activities related to energy efficiency are addressed in Sub-Group 3, there is broad agreement among partners to rename it Sub-Group "Energy Efficiency including CDM."

Next Steps

Due to the fact that IGEF is, according to the agreed Terms of Reference, mandated to also address energy research issues, the Federal Ministry for Education and Research (BMBF) has proposed that a fourth sub-group cover research cooperation. BMBF has already contacted the Indian Department of Science and Technology (DST) in this regard. Organizational details and possible areas for cooperation need to be discussed by BMBF, DST and other involved German and Indian Ministries in the coming month.

It is the German intention to convene the third meeting of the IGEF before the end of the year 2009 in order to take stock of the work done so far in the existing sub-groups and task forces. An even more important aim should be to come to a political agreement on topics and projects for future cooperation, especially in the area of SG two to four and to mandate the relevant sub-groups to specify the cooperation.

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Energy and Resource Efficiency and Effectiveness in Industrial Manufacturing

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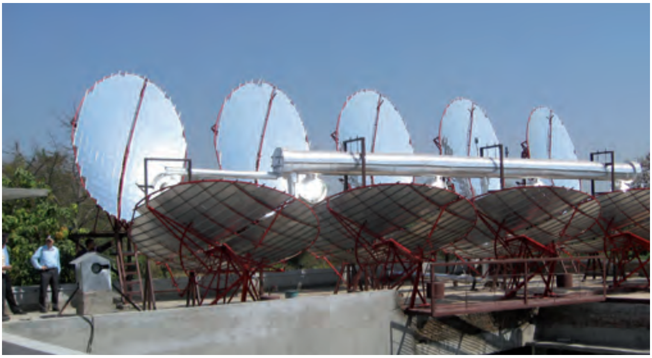
Nowadays the target system of production companies is more and more influenced by originally environmentally driven aspects. Issues like rising energy and resource prices, shortage of strategically relevant natural resources, stronger regulations or rising public awareness regarding resource consumption and climate change are just some examples that incorporate a very strong economic relevance for the company. As a consequence, the efficient and effective use of energy and raw materials is a key challenge for the manufacturing companies trying to cope with these challenges.

Due to their nature, the production process is critically important for economic success and environmental as well as social impact. Production can be defined as a combination of production factors, such as labour, material, energy, and technical equipment for the purpose of value creation in the form of products. To be able to evaluate realistically the impact and to avoid problem shifting, a holistic perspective on all input and output flows of production processes (besides the raw material input) is necessary (e. g. Herrmann et. al, 2007a). This includes a detailed coverage of energy (e. g. electricity, compressed air, steam), auxiliary material/media inputs (e. g. coolants) and emissions (e. g. special material waste, heat).

It is important to consider that consumption as well as emission of energy and media are not static but rather highly dynamic depending on the



Solar systems for steam and/or electricity generation

actual state of the machine or process respectively. On a production plant level, with diverse production machines involved, this leads to cumulative demand or emission profiles. Within a manufacturing site, it is the task of the technical building services (TBS) to provide dynamically demanded energy and media and to ensure the needed production conditions in terms of temperature, moisture and purity of the air. In order to do that TBS also needs energy in form of electricity, gas oil. Altogether, this underlines the role of the production plant as a complex control system with dynamic interdependencies between different internal and external influencing variables (e. g. local climate). To cope with its influencing factors and strong interdependencies simulation is necessarily needed and applicable for deriving measures for improvement on a realistic base (e. g. Herrmann et. al, 2007a and 2008). In recent research coupled simulation approaches of production, TBS and also building shell are proposed in order to maximize energy efficiency from a holistic perspective (Hesselbach et. al, 2008).

Besides increasing the efficiency in manufacturing sites, another research challenge is the development of appropriate systems to provide necessary energy while respecting the described requirements. Having in mind global challenges, renewable and decentralized energy systems are a promising approach towards zero emission manufacturing sites. Especially for developing countries this enables to bring value creation

Jatropha Curcas seeds can be used for oil production

and welfare into rural regions without "compromising the ability of future generations to meet their own needs" (Brundtland). Examples are wind systems (electricity) or solar concentration systems for the simultaneous supply with process heat (steam) and electricity. Against the background of the difficult requirements of production plants and (dis-)advantages of different renewable energy supply systems (e. g. storability, dependence from daytime/season/weather conditions), integrated solutions (e. g. combinations of technologies) have to be found.

In addition to the energy supply for manufacturing sites through renewable energy generation systems, another future challenge lies with the substitution of fossil resources through the cultivation of biogenous alternatives. As an example, the substitution of mineral oil by biogenous oils as an alternative coolant resource for metal working processes is considered. Machining processes (e. g. grinding) generally transform raw materials into products using coolants. These fluids are used in more than 1 million machine tools in Germany. Predominantly, mineral oil is the oil basis in cutting fluids with over 72.000 t/a in Germany. While it is easy to simply exchange mineral oil through alternative oils (e. g. palm oil), the technological, economical, ecological and social impacts of biogenous alternatives have to be thoroughly observed for shifts of benefits or detriments in all life cycle phases from raw material cultivation and extraction, to use as well as disposal. This also includes regional and global aspects as raw material availability (e. g. jatropha cultivation in African and Indian decentralized farming networks). Based on these exigencies, several biogenous oils have been analyzed as potential substitutes for mineral oil coolants – starting from palm oil, rapeseed oil to jatropha oil as well as glycerol (Herrmann et. al. 2007b). Further alternatives have been found in used cooking oil and technical animal fat, which imply a cascading use of materials (Dettmer 2006). Subsequently, ecological, social and economic benefits of these alternatives have been substantiated through Life Cycle Analysis. Through integrated consideration of all aspects of a sustainable development, beneficial biogenous materials can be derived for companies in the metal processing industry.

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Science for Affordable and Sustainable Energy for India

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The subject is discussed under (a) cooking energy (b) distributed electricity generation (c) transport fuels with focus on India.

India is characterized by enormous differences in quality of life and what is intended to be addressed here is for the larger section (≈ 60 to 70 % households) at the lower spectrum in the quality of life. For ensuring a stable social equilibrium, the minority that enjoys a good quality of life should ensure a minimum quality of life for those with limited affordability. The science that needs to be used as a tool here aims at making new technology accessible and affordable. Many of the issues described here are common to most oil importing developing or emerging nations.

Cooking Energy

India has about 200 million households (average size ≈ 5), of which 140 million households (hh) depend on about 250 million metric tonnes (mmt) of firewood and 120 mmt of agro-residues at considerable inefficiency (2.5 t/hh/yr of firewood and 5.5 t/hh/yr of agro-residues) and poor indoor air quality. The total magnitude of cooking energy in India is about 50 million tonnes oil equivalent – a number that is comparable to the amount of high-speed diesel use.

Domestic stove and prepared fuels that use agro-residues

Development and introduction of (a) new science based affordable devices for domestic cooking that are efficient - with utilization efficiencies about 80 % of those with liquid petroleum gas (LPG) and with low emissions, and (b) prepared fuels that use agro-residues is an important area. Large-scale commercialization would imply limiting the use of solid bio-fuels to less than 100 mmt. Some technology developments and commercialization have been done; more needs to be done with sensitivity to efficiency and emissions. The key point is that unless air for combustion is supplied in a controlled manner, it is neither possible to obtain high efficiencies nor can the emissions be reduced. This requires the availability of electricity – typically, a 2 W fan can power a 2.5 kW stove (nominal power of a LPG stove). In this strategy, kitchen with good indoor air quality is ensured without compromise on the green house gas emissions to the environment; donor agencies across the world involved in mitigation of cooking problems are to recognize that free-convective based combustion systems for cooking cannot meet this obligation.

Distributed Electricity Generation

This subject is far more debated in India than across the world. The principal issue in India is that random political short-sightedness has led to "free electricity" for the farmers leading to a series of problems over three decades – electricity boards that cannot function in a "profit center" mode, excessive underground water pumping leading to lowering of the water table, and inadequate power supply even for those who can afford in the villages. Among solutions, thought over for overcoming these situations is the possibility of distributed electricity generation at power levels of tens of kWe to a MWe. Many field experiments on biomass-based power generation systems have been conducted in India under the aegis of the Ministry of New and Renewable Energy (MNRE) at low power levels (5 to 10 kWe class). These experiences show the need for commercially sustainable power levels of 250 to 1000 kWe that can be operated either in a stand-alone mode to supply electricity to the villages or to the grid when the power off-take from the villages is small. Professional operation of these biomass based power plants and separation of the activities of generation, distribution and tariff collection form ingredients for sustained operation. It is also important that the state electricity boards be partners in this process. Of course, the political system should function as stabilizing element.

The power generation technologies using biomass gasification with air as the gasification medium have made enormous strides in India because of substantive research, development, and field experiments over the last three decades. This is an area where south-to-north technology transfer is a good possibility. Current developments involve incremental improvements contributing to reduced maintenance cycle and greater user-friendliness in operation.

Research and development into using oxygen-steam gasification technologies for hydrogen and liquid hydrocarbon production has just begun. This may be an area for cooperation between institutions in India and Germany.


1 kWe gasification based power generation system


100 kWe gasification system for power

First Generation Transportation Fuels

The greatest economic issue that remains to be adequately recognized by the Indian government is that one can derive multiple benefits by producing its own oil for transportation from growing oil-seed bearing trees in the wastelands that constitute about 33+ million hectares. This land has been identified by the national remote sensing agency (NRSA) of the Space department of GoI through a systematic and serious effort in 2005. These maps have been integrated into a more detailed land use map by the Indian Institute of Science in a major multi-group and multi-institutional effort National Biomass Resource Atlas project (NBRAP) under the aegis of MNRE and made available for internet access both in the form of tables of data on various aspects of land use and GIS-based maps.

While the idea of growing non-edible oil trees and benefiting from it have been known for some time and explored in India in various ways, systematic exploitation at relevant scale has yet to begin. This requires a public-private partnership (PPP) in which oil produced is bought by a national agency in a sustained mode, land for growing such trees is given to profit-making industries on a lease basis, local authorities and population participate in it as employees with assured income. Such a strategy that is not in conflict with food production should be treated as a tree-culture industry to help production at scales that would make a difference to the economy of the country that uses 50 mmt of high-speed diesel for transportation annually. The multiple benefits include more than 60 million new wide-ranging job opportunities, environmental protection, better quality of life for the underprivileged apart from preventing out-go of financial resources.

While much has been discussed, the fact that such an operation will also generate solid residues that need to be disposed has not been discussed adequately. It is suggested here that this strategy is integrated with that of distributed power generation to close the loop between availability and demand.

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Work on Biomass Energy at Indian Institute of Science

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At the Indian Institute of Science, the work on biomass-based energy is being carried out in two centers: (a) the Centre for Sustainable Technologies that concentrates on biomethanation of solid and liquid wastes, fixed biomass combustion devices for cooking and other semi-industrial applications, and (b) the Combustion, Gasification and Propulsion Laboratory (CGPL), a part of Aerospace engineering that is concerned with thermo-chemical conversion processes and technologies into which about 450 man-year effort has been put in over the last twenty five years.

This report is concerned with the work at CGPL. In a rather unique venture of IISc, this laboratory deals with research, development, testing, training and technology transfer activities all under a single roof with its five faculty and researchers supported by ten engineers and thirty support staff. The commercial activities of technology protection and transfer are dealt with under a society called Advanced Bioresidue Energy Technology Society (ABETS). As a result, five different technologies have been developed and transferred. These are

1. **Downdraft gasifier for industrial high-grade heat and with a power pack for electricity generation,**
2. **Downdraft gasifier for high quality charcoal generation,**
3. **Reversed downdraft gasification concept for cooking and industrial heat,**

4. **Hydrogen sulfide scrubbing technology for gases from distillery effluents and others,**
5. **Technology for generating precipitated silica from rice husk ash/char.**

The fundamental studies and the field experience in implementing the technologies in several environments both rural and urban, societal and industrial has led to a broad understanding of the issues all the way from research to practical implementation. This has allowed the laboratory to conduct much-sought training programs on biomass utilization – principles and technology periodically. It has conducted a dozen training programs and workshops for national and international participants. The thirty international participants include those from Austria, Brazil, Cuba, Thailand, China, Myanmar, Zambia, Kenya and South Africa.

General Combustion Studies

Fundamental studies on combustion have been performed on premixed and diffusion flames on a number of configurations at low and high speeds to clarify the flame structure. Studies were extended to biomass combustion recognizing the feature that this was far more complex due to shape, size, moisture and ash content effects. It was uncovered that the gasification process is likely to help manage these effects towards higher efficiency and low emissions.

Gasification Studies

These studies were performed both on individual particles and in reactors with packed bed of particles as both char particles as well as biomass, both natural and briquetted. Laboratory studies – experiments and modelling led to quantitative evaluation of effects of oxygen, nitrogen, carbon dioxide and water vapour on the gasification rates on the size. Exploration of classical downdraft reactors (suitable for cold clean gas generation for electricity or high grade heat) as well as reverse downdraft systems (suitable for domestic stoves) to determine the gas composition including tar and particulates as well as gasification efficiency, flame propagation in packed bed reactors led to important results of fundamental and applicational value. Most of these have been published in refereed journals and international conferences of significance (they can be accessed at http://cgpl.iisc.ernet.in under the head of publications).

Gasification Technology

The gasification technology developed at IISc is unique in the world – a fuel-flex, open top, staged air entry (reburn) downdraft system that converts any solid bio-fuel of specified size range and with minimum moisture to clean gaseous fuel. It can use a wide range of fuels, both solid as well as fine. The fine sized fuels like sawdust and rice husk need to be briquetted to size. The system elements – reactor, cooling and cleaning systems – have been conceptually evolved based on principles of fluid mechanics with additional aspects of chemical thermodynamics in the case of reactor to minimize the complexity in system design. Adding sensing and control systems is expected to aid in reducing or eliminating dependence on operators.

The technologies involving a host of aspects – ceramic materials for the corrosive hot environment (both oxidizing and reducing in different zones that change with time), staged air entry design for large throughput systems, dry char/ash extraction through a screw with a high temperature valve, and vapor absorption chiller to provide cold water for final stage of cleaning and a special effluent treatment system for recycling the cooling water.

While all the aspects noted above used the know-how available within the laboratory, the power pack consisting of engine – alternator combination depended on engine manufacturers. For producer gas (gas from air gasification system identified above), there are no standard engines across the world; adaptation of natural gas based engine through the design of a different carburetor for air-to-fuel gas ratio control is required. Getting a suitable engine for making adaptations was accomplished after much effort with Cummins, India and they now market producer gas based engines. M/s Jenbacher, Austria is another major industry that has consented to provide engines for IISc gasification technology. There is a choice for the elements involved in the cooling, cleaning section and the safety and control system and the elements are chosen to meet somewhat different requirements between rural low power application (≈ 50 kWe) with manual operation and MWe level, 24x7 class automated operational system. In fact, a whole range of technology options from 1 to 1,000 kWe electrical systems and 1 kg/h to 1200 kg/h thermal systems to work with a wide range of fuels including urban solid waste is available from the knowledge base of the laboratory.

The same reactor design with no cooling, but some hot gas clean up is used for specific thermal applications like Aluminium melting, etc. Further, the same reactor design is adopted to generate high throughput charcoal; other system elements required for smooth start-up, shut-down are added to the standard system.

The technology (patented in India and several countries of interest) has been transferred to ten licensees in India and overseas (Japan, Switzerland and Brazil). More than hundred systems have been built – about equal numbers for electrical and thermal applications in various capacities up to 1.2 MWe (1200 kg/h biomass throughput, 1 kg/kWh nominal).

The reverse downdraft design was adopted to build a portable domestic stove that promises very high efficiency in domestic cooking applications. These stoves use high-density pellet fuel that is produced and supplied thus main-streaming the solid bio-fuel. This technology is also transferred to a global industry.

Hydrogen Sulfide Scrubbing Technology

Distillery industries have a statutory need for doing anaerobic treatment of the effluents that are too high in BOD and COD (bacterial and chemical oxygen demand). This leads to a gas rich in methane. However, the gas also carries 3 to 5 % hydrogen sulfide that is tolerated by power generation systems to no more than 0.1 % because of its extreme corrosive nature. IISc has developed a technology for extracting sulfur selectively so that the gas produced is "sweet". An iron chelate-based chemical solution is sprayed to mix it with the "sour" gas. The hydrogen sulfide is converted into elemental sulfur. The reacted iron is then regenerated into active form by bubbling air through the solution. After a number of laboratory studies, plants of 10 to 1,000 m^3/h of gas with 3 to 5 % hydrogen sulfide have been built. This gas used for power generation by using standard reciprocating gas engines. This technology has been transferred to two licensees and several plants have been built at MWe power level (≈ 2 kWe per m^3/h of gas).

Precipitated Silica from Rice Husk Char/Ash

Rice husk has 20 % ash and the ash itself has 95 % silica. Rice husk burns in combustion systems leaving char with about 10 % carbon since it takes a long time for further oxidation to occur. This waste material is an environmental problem as its disposal creates nuisance. An economically meaningful low temperature (≈ 95 °C) ambient pressure technology for converting rice husk char/ash to precipitated silica has been developed. This uses sodium hydroxide for selectively converting silica in the ash into sodium silicate. This mix is filtered to eliminate the carbon/ash. Carbon dioxide is bubbled through the sodium silicate solution to produce silica and sodium carbonate. This is further regenerated into sodium hydroxide by reacting it with lime. The process has gone through pilot scale studies in which about hundred 50 kg batches have been produced and the properties evaluated both in the laboratory as well as selected industrial users. It is awaiting large scale commercialization.

Biomass Atlas of India

In order to support distributed power generation from bio-residues on a national scale, a GIS based atlas containing biomass generation and surplus biomass that can be used for power generation has been developed. This was a multi-institutional effort with IISc as the focal group to collect the data and embed them into the map. The data can be seen as a map or in the form of tables. The data presentation can be used to extract the data on a taluk, district or national level residue-wise. It can be used by entrepreneurs for first cut estimate of the data or planners and administrators to help regulate the use. One of the principles followed in the data management is that societal uses for fodder and domestic cooking are considered unavailable for power generation. Thus even though about 500 million tonnes of waste from about 250 million tonnes of agro-produce is a resource, only about 100 million tonnes are estimated to be available for power generation.

This database is internet-enabled and can be accessed at http://cgpl.iisc.ernet.in under biomass atlas.

New Research and Development

Based on the knowledge base of the laboratory, projects on biomass based hydrogen and liquid hydrocarbons have been initiated. The first process uses the classical IISc gasification technology with air as the oxidizing fluid replaced by oxygen-steam mixtures. Optimization of the composition of the mixture and operational procedure is expected to lead to near tar-free gas with high hydrogen ≈ 50 % or more. This gas will be used in the next process, known for a long time as Fischer–Tropsch process to generate liquid hydrocarbons. This process is called 2nd generation process for liquid bio-fuels.

Acknowledgements

All the projects identified above have been funded by the Ministry of New and Renewable Energy (MNRE), Government of India. The laboratory has received over 2.5 million Euros over the last twenty-five years from MNRE for half a dozen projects on topics identified above. Other funding from testing agencies has also been received.

Supported by MNRE, Indian Institute of Science has now a centre termed Advanced Bioenergy Research Centre located at CGPL to be a focal group on biomass based energy activities in the country.

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Recovery of Energy from Wastes

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Tannery is an important industrial sector in India. The sector has export earnings potential and provides employment opportunities. At the same time, however, tanning is an extremely polluting industry characterized by high organic and inorganic loads. During leather processing, about 30 m^3 of wastewater and about 0.5 tonnes of solid waste will be generated per tonne of raw hide/skin.

Presently, the effluents generated from the tannery cluster are treated by primary treatment, anaerobic lagoon followed by extended aeration process or two-stage extended aeration process to reduce the organic load to meet the standards prescribed by the regulatory authority. In open anaerobic lagoon, effluent undergoes anaerobic degradation process leading to the generation of methane and hydrogen sulfide.

Methane is one of the important greenhouse gases (GHGs), as it has 21 times more global warming potential than CO_2. In Tamil Nadu, about 12 Common Effluent Treatment Plants (CETPs) are operating ranging from 600 m^3/day to 4,000 m^3/day. In total, about 20,000 m^3/day of effluent with average COD of 4,000 mg/L is generated. About 10,000 tonnes per day of methane i. e., equivalent to 210,000 tonnes of CO_2 is released into the atmosphere. In order to reduce the emission of methane, efforts are made to convert the open anaerobic into closed anaerobic system and also burn the methane generated which will reduce the GHG effect by 20 times. Hence, all the new CETPs designed and implemented will have only

Pilot UASB Reactor at CLRI, Chennai

closed anaerobic systems like Upflow anaerobic sludge blanket (UASB) to minimize the global warming effect. Similarly, the solid waste (fleshings, trimmings, primary sludge, etc.) generated from tanneries also contain considerable portions of organics leading to generation of methane when disposed in an unscientific manner. Efforts are also made to convert the fleshing and sludges from CETPs into energy through anaerobic digestion process. Similarly, waste generated from other agro-based industries such as distillery, slaughterhouse, poultry, starch, dairy, etc. has a huge potential for energy generation from wastes. In addition, studies have demonstrated a synergistic effect in biogas production during anaerobic treatment by mixing wastes generated from different industrial sectors.

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Gas Hydrate and CCS Research: An Interface between CH-Exploration Industry, Science and Climate Change

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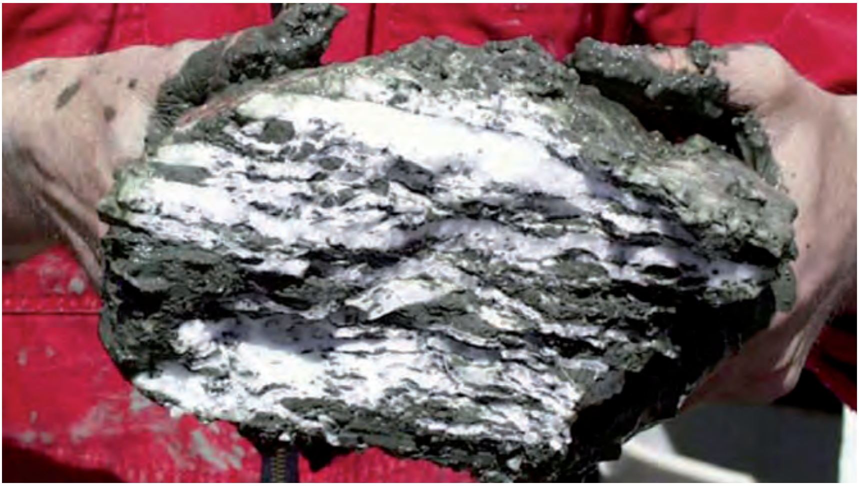
In the current discussion about still growing energy demands, decreasing carbon resources and climate change it has become obvious that alternate energy resources are in great demand in the future. With the extended installation of sun- and wind-driven power generators, flexible power plants are required to compensate variations in production. Here, gas-driven power plants provide the best performance, while their CO_2 emission is only 50 % of a similar coal plant. In terms of fossil carbon energy supply, natural gas is the most environment friendly source.

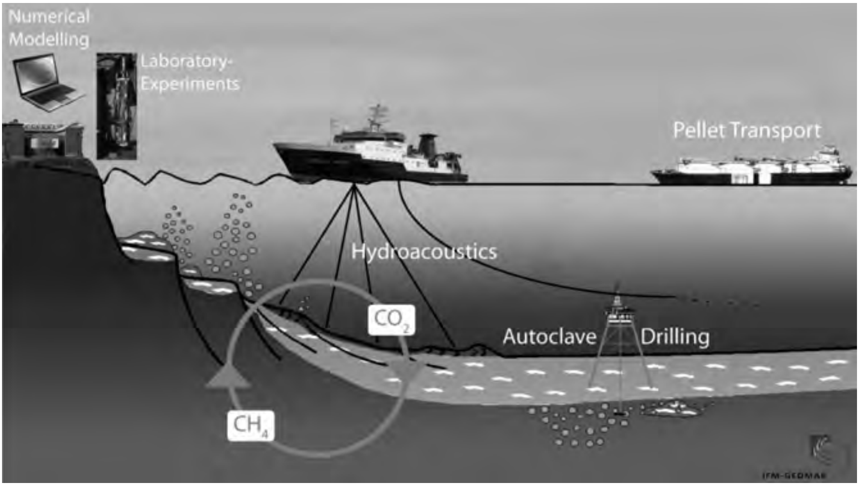
Moreover, it turned out that the anthropogenic effect on climate change by CO_2 emissions cannot be reduced to large extends in short time. Consequently, efforts to collect existing gases and store them elsewhere are necessary to decrease the input of CO_2 into the atmosphere.

Land deposits for CO_2 are, on first sight, easy to find and offer easiest access for storing CO_2. However, storage safety, influence of other pore fluids and in particular possible interaction of economic activity within the storage area may not be easily assessed. Within this context, marine gas hydrates offer a two-fold chance to gain access for new gas reservoirs and CO_2 storage sites. Gas hydrates (GH) are a cage structure formed by water molecules, which incorporate natural gas (mainly methane) in a solid matrix. GH is present in marine sediments at about 700 m water depth where temperature and pressure provide the gas hydrate stability field. Increasing temperature or



Methane hydrate

decreasing pressure in the reservoir will immediately result in dissolution of the hydrate and provide free gas. Injecting liquid CO_2 into methane hydrate deposits will decompose the methane hydrates and form CO_2 hydrates in the pore space. CO_2 storage as a solid hydrate in the marine subsurface provides the most secure sequestration technique (immobile, away from urban communities). Due to higher temperature stability of CO_2 hydrates, diffusion of CO_2 by leakage and/or dissolution may be prevented. Through the release of methane in the associated process, this kind of sequestration can be combined with methane exploitation, which improves the economic balance of the procedure and makes it easier to obtain acceptance. The volume of CO_2 stored is 2 to 5 times higher than the released volume of methane, i. e., more CO_2 is stored than subsequently produced by the combustion of the methane leading to an overall positive carbon dioxide balance. The German network project SUGAR develops, in an integrated approach, new technologies for the entire potential hydrate exploitation chain extending from the exploration of new CO_2 deposits to the CO_2 and methane transport in suitable ships.



Submarine gas hydrate deposits: exploration, exploitation and transport

Until today, gas hydrates were recovered in more than 20 locations worldwide. At about 100 locations, their presence was inferred indirectly by geophysical, geochemical or geological observations. Analyses of gas hydrate deposits have shown that the content of gas hydrates in sediments is very variable. Finely distributed hydrates, which fill only a few per cent of the pore space, are widely spread but economically of small significance, because they can only be removed at high energy and cost expenses. Massive hydrate deposits, in which the sediment pore space is filled to a large degree with hydrate, form mostly in sandy sediment horizons, which are fed by migrating methane gas. New studies show that economically interesting hydrate deposits are formed mainly by methane gas bubbles, which are produced through microbial decomposition of organic material at great sediment depth (approx. 1-5 km). These bubbles rise to the surface where they freeze out as hydrate (Haeckel et al. 2004; Wallmann et al. 2006). The highest hydrate concentrations are found in thick sediment layers at continental slopes in medium water depths of approx. 400 – 2,000 m (Buffett and Archer 2004). These methane hydrate deposits offer ideal conditions for the sequestration of CO_2 through the substitution of the contained methane.

Among the most prominent findings of massive hydrate layers are the recent findings in the Krishna-Godavari Basin (KGB) and the Andaman Island (AI). While calculations from the drill logs assume up to 60-80 % of GH saturation in the KGB the AI seems to host the thickest GHSZ of the world. Such reservoir conditions provide the most promising environment for future field tests of the proposed methane production with an integrated CO_2 sequestration. The SUGAR network program and project partners are interested in joint cooperation with Indian scientists and industry partners to further develop this technology.

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Globalising Western Lifestyles, Energy Consumption and Policy Innovations

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Energy consumption and economic growth are closely interrelated. Thus, for almost two centuries, extensive energy consumption and accordingly high levels of greenhouse gas emissions (GHG) have been a core feature of the most industrialized countries. Today, the emerging economies are about to catch up, although in a very specific way. In the countries that have been the historical forerunners of industrialization per capita consumption of energy is still on a top level but, meanwhile, considerable progress could be achieved in increasing energy efficiency. In comparison, even in developing countries that perform best in economic respect, due to the still enormous weight of the rural and urban poor, per capita consumption of energy keeps to be modest.

However, steep increases in per capita energy consumption unfold in metropolitan areas in general and in the social realm of the new middle classes in particular. As a consequence, GHG emissions are also on the rise and this process is assumed to keep on increasing (cf. OECD 2008). In other words: until recently, access to energy used to be the most relevant challenge in the Global South, particularly in rural areas. The ongoing rise of the “new consumers” with their Western lifestyle, are estimated to comprise more than a billion persons in developing countries by 2030 (Bussolo et al. 2007), is about to make excessive energy consumption an also relevant issue of strategies towards a more sustainable future in developing countries, particularly in urban areas.

It is widely agreed that the transport sector belongs to the most significant and growing contributors to GHG emissions. They are projected to be by 80 % higher than current levels by 2030, emerging economies accounting for the most dynamic increase (International Transport Forum 2008). Steep increase is also expected for domestic appliances such as heating/cooling and all kind of sophisticated electrical devices (Desgupta 2004, 117 passim). Regarding the aim of making development more sustainable this is clearly counter-productive.

In search of potentials for mitigation in “developing countries like India there exists enormous scope of energy conservation by up-grading technology, equipment and appliances in a wide range of areas” (Desgupta 2004, 188). Here, cooperation with countries such as Germany provides significant potential for progress. India can even take a lead in adopting and adjusting cutting edge technologies to the specific conditions and needs of developing countries without stepping into the costly pitfalls most industrialized countries went through.

However, in Germany as well as in any other western countries there is ample evidence that technological innovations, aiming at increasing energy efficiency, can realize their potential only within the framework of supportive policy innovations. These have to consider the whole bandwidth of fields: from innovation, production and the systems of provision to the realm of consumption and, last but not least, the various domains and institutions of the political-administrative process of regulation.

The Conceptual Framework

As Rajendra K. Pachauri stated with respect to transportation as a key area of GHG emissions, policy innovations to be developed and put in place should "...include among others carbon-price regulations, standards, and taxes as well as a change in land use, in lifestyles and consumption patterns" (International Transport Forum 2008). As a consequence, the need for developing equipment and suitable technical solutions goes along with an increasing need to develop medium term strategies that focus on

- **Raising both actor-specific and more general awareness and acceptance of the need to save energy.**
- **Setting up conducive regulatory frameworks (including incentives aiming at changes in behavioural patterns).**

These are exactly the fields to which in the Global North social science has paid most attention during the last 30 years. This applies to economy and political science as well as to sociology, psychology and geography.

Therefore, an Indo-German network of experts from (i) social science in close contact with (ii) experts from public administration and industry should concentrate on three points:

1. **Identifying common ground and differences in private energy consumption between Germany and India: In spite of obvious similarities in dominant trends in energy consumption in India and Germany there are equally obvious differences with respect to institutional systems, welfare state regulations, cultural traditions, etc. Hence, identifying specific Indian needs and priorities should be the first step in setting up a framework for cooperation.**
2. **Against this background there should be a screening of 30 years of European (and further) efforts to reduce energy consumption, considering the state of the art in questions to be asked and outcomes to be considered. This will allow for focusing on those findings that, offhand or after due**

adaptation, could be relevant for India and which, subsequently, should be at the focus of Indo-German cooperation.

3. **The aim of such cooperation should be to develop concepts for tailored Indian policies reducing energy consumption in a limited number of fields, mainly motoring and housing.**

How to make the Concept operative?

Considering the limited experience that has been made so far in Indo-German social science cooperation related to problems of sustainable development, a two-step strategy seems to be appropriate:

Step 1: Setting up a small working group comprising not more than three to four persons from each country. This group should be able to identify two to three fields of action which (i) are seen as relevant on either side and where (ii) there is sufficient competence and experience to built on in either country (= see above point 1). This can be done within the next six months.

Step 2: Setting up two or three project groups, which will concentrate on one topic each (see above points 2-3), during the next three years. Its members don't need to be identical with the members of the working group of step no. 1. In any case, they should comprise more persons.

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Sustainable Climate Change Adaptation and Mitigation Options in the Future Megacity of Hyderabad/India: Scenario Development and Leverage Points on Influence Networks

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In this paper we highlight our ongoing work on adaptation to and mitigation of climate change within the BMBF-funded research network "Climate and Energy in a Complex Transition Process towards Sustainable Hyderabad – Mitigation and Adaptation Strategies by Changing Institutions, Governance Structures, Lifestyles and Consumption Patterns". Starting a complex transition towards more climate friendly and climate resilient city structures in a developing country's future megacity involves an assessment of the potential future climate in Hyderabad, the impacts of climatic changes on various subsystems, and an understanding of the emission pathways. It needs an integration of impact assessment, adaptation options and mitigation efforts on various levels (households, lifestyles, policy levels) to hinder maladaptations and find trade-offs between actions.

Our assessment of Hyderabad's future climate statistically analyses the currently available, but rather coarse AOGCMs outputs (IPCC, AR4:

exemplary A2 and B1 global CO_2-emission scenario) for the central south Indian region and combines them in a statistical downscaling process to receive a finer resolution of projections specified on the urban region of Hyderabad. Climate projections depend themselves on global development scenarios, e. g. social, technological, population and economic development, on the convergence between developing and developed countries, consumption choices, etc. Our analysis shows that a massive reduction of the global CO_2 emissions (B1 instead of A2) will certainly "buy" some time for Hyderabad to adapt to more intensive rainfalls (in the second instead of the first half of the 21st century) but will not spare the city to prepare for about a doubling of strong rain events. This is even worsened by the result that the subset of extreme events greater than 160 mm/day (like, e. g. in August 2000) will increase over-proportionally. For the total annual precipitation in the region around Hyderabad we have to expect changes between -4 % to +17 %, but the influence of the differences in the AOGCMs is currently still larger than the influence of the global emission scenarios. Regarding heat waves, the average number of days per year with night temperatures above 27 °C will approximately triple until 2050 relatively independent from the emission scenario but in 2100 A2-emissions will lead to an increase of almost 560 % (±50) of the current number while under B1-emissions we expect only 240 % (±50). The frequency of heat waves longer than one week will double to triple until 2050 and increase further until 2100. The mean annual temperature will develop monotonously in time and with a stronger trend in the high emission scenario up to +5 °C, which would definitely alter the natural water balance towards increased dryness, even under a (very uncertain) increase in total rainfall. Here a global emission reduction along the B1 scenario would ease impacts and the adaptation pressure.

The impacts of climate change on Hyderabad are serious. Extreme flood and drought events severely reduce the availability of quality water to the population, agriculture and industry by either contaminating existing water resources or generating severe surface and ground water scarcity. Depleting local groundwater resources may push the dependence of Hyderabad on external sources of water to rather unsustainable levels. Climate extremes adversely impact transport and communication

Old town of Hyderabad - Street view

infrastructure making them inaccessible, dysfunctional and damaged, unreliable or uncomfortable to use (Shukla et al., 2003). Impacts of climate change on the health risk can be the direct exposure to heat with the increased occurrence of heat waves and exposure to flooding with a potential increase in serious precipitation events. Flooding can also lead to contamination of freshwater with bacteria, chemicals or other hazardous substances (Young et al., 2004) and its consumption can result in diarrheal diseases, cholera and intoxication. The situation is particularly severe in areas of Hyderabad where sewage flows in open ditches close to water distribution pipes and where people live in industrial areas close to factories. Climate-sensitive diseases like Malaria, Dengue and Chikungunya might increase due to favourable climatic conditions of temperature, humidity and breeding places of water. In particular, Dengue cases have reached alarming levels in Hyderabad; while the trend of Dengue is going down in the state as a whole, it is going up in the city.

Although Hyderabad's contribution to global CO_2 emissions is small, these large impacts of climate change on the region put investments in mitigation options into another perspective. Hyderabad has to prepare for climate change without putting further stress on the atmospheric CO_2 content, and can thereby act as a role model for other cities in developing countries. For a more detailed view on the influences of climate on urban subsystems (climate impacts) and CO_2 emission sources in Hyderabad, we developed influence networks for three issue areas: transport and other infrastructures, water provision, food security and health (Reckien et al. 2009). Among others (see further down), they are used to educate and build capacities and as communication tool with stakeholders (Reusswig et al. 2009a).

Understanding urban processes is only part of achieving strategic goals, like climate change mitigation and sustainable adaptation options. Any strategic action involves target setting. To do so, we focus on a stakeholder-oriented scenario process that tries to map two contrasting scenarios for the future development of the greater Hyderabad municipality and functionally related adjacent regions: (1) A so-called 'worst case scenario', including ongoing nonmitigated global climate change with medium to severe negative local impacts and a couple of partly dependent, partly independent trajectories of relevant parts of the urban system (local economic growth, environmental goods and services, equity, governance, civil society). (2) A so-called 'sustainability scenario', including an ongoing, but slightly dampened global climate change, and with qualitatively different pathways of the urban systems parameters mentioned (Reusswig et al. 2009b). Such a scenario process involves the local actors, policy makers and lay people, to discuss and influence their future.

Finding targets and overcoming involved conflicts are challenging tasks. A well-planned stakeholder participation process is therefore vital for its success; it fosters discussions, helps to disseminate knowledge and builds capacities. Our influence networks can help to visualise the interrelated problems, supports in target setting and helps prioritizing adaptation and mitigation options. Influence networks are therefore a support tool for policy and plan making too. Putting leverage points, e. g. measures of adaptation and mitigation on different influence levels makes consequences and ranges of influence clearer. The effectiveness and efficiency of measures can be discussed; regional, local or state-wide policy options can be reasoned, e. g. against the National Climate Action Plan, or the plan's appropriateness can be assessed against the city's particular background.

Future work involves the development of a quantitative urban assessment tool for Hyderabad (CATHY– Climate Assessment Tool for Hyderabad) supporting decision-making in terms of its spatial resolution and particular social targets (e. g. slum population). Moreover, we plan to conduct so-called socio-technical experiments in representative target households to evaluate options and conditions of change from a higher to a lower carbon-intensive pathway.

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Life Cycle Assessment of Wind Energy Converter

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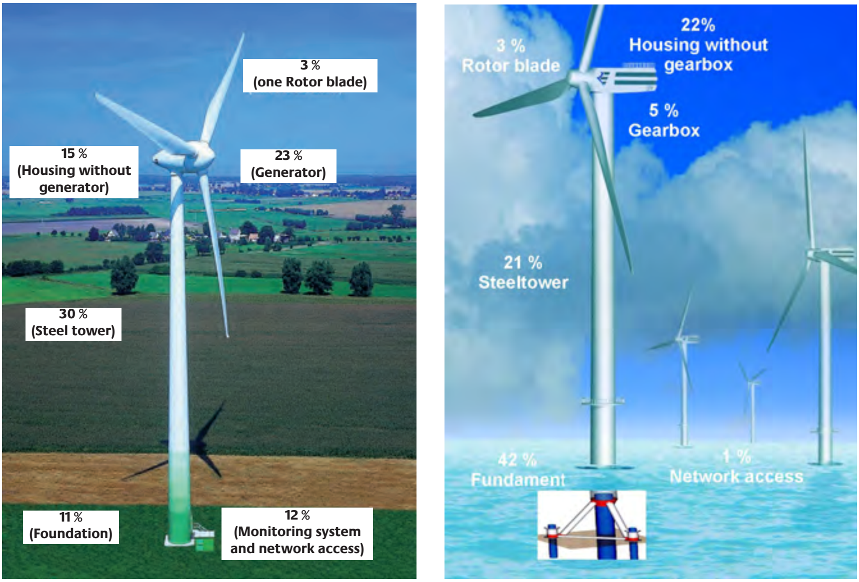
Besides water, biomass, photovoltaic and wind energy are the most favourable renewable energy technologies globally. There is an enforced market introduction from onshore and also offshore wind facilities worldwide. The construction of wind parks is material-intensive; it needs a big amount of conventional energy, such as fossils, to produce it.

To examine the energy efficiency under these aspects, the international methodical approach of Life Cycle Assessment (LCA) was used. LCA is an instrument to quantify all impacts of the entire energy supply chain. To obtain the Cumulative Energy Demand (CED) for production, for instance of a wind converter, the whole facility has to be split up into components, sub-components and their respective materials. Using this material balance with specific data for energy and emissions, it is possible to calculate the CED.

For the final evaluation of the energy systems, the Energy Payback Time as a relationship of produced energy (valued as primary energy) to total CED has been used to decide if market introduction of wind energy is sustainable enough or not.

Within a survey (Mathur, Wagner, Bansal, 2007) this has been examined and discussed for wind energy converters with different nominal power output. For calculating the annual energy output, two locations of wind



Comparison of on- and off-shore wind turbines: The percentages show, how the cumulated energy is splitted on production steps. The construction of the wind turbines is different. Not only the steel tower but also the electrical multipole generator are energy intensive components. Additionally, off-shore plants contain important amounts of energy under the sea.

converters have been selected: near coastal and offshore. A large Wind Energy Converter (WEC) of 1.5 MW with 67 m hub height and 66 m rotor-blade diameter has been chosen for consideration. In addition, a park of multimegawatt wind turbines in the ocean, 30 miles far away from the coast is considered. The reference unit for the offshore use is a prototype wind turbine of 5 MW with a 90 m hub high and 126 m rotor-blade diameter. For finding the material and energy balances, both wind turbines have been considered to be divided in four parts, which are: rotor blades, machinery, tower and foundation. In addition, energy consumption for service and maintenance and also for transportation, mounting and dismantling has been taken into account.

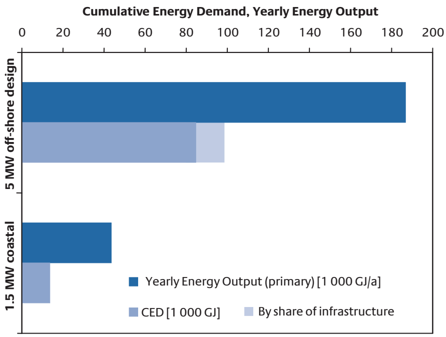
Cumulated Energy Demand

The CED of the regarded onshore wind turbine sums up to about 13,500 GJ. The most important component group, due to a high content of energy-intensive materials (e. g. copper for the generator), is the machinery with a share of about 46 %. The tower has also a big share of about 28 %. The foundation holds 11 % and rotor blades hold about 8 %. For service and maintenance only 1 % of the total CED is needed while transportation, mounting and dismantling contribute about 6 %.

The CED of the offshore wind turbine sums up to about 85,000 GJ whereas the tripod foundation made of steel has the biggest share of about 31 %. In contrast to the 1.5 MW wind turbine the machinery only has a share of about 20 %. The tower contributes about 15 % while rotor blades hold a share of 7 %. Service and Maintenance during the lifetime of the wind turbine contributes about 22 % to the total CED. The major share of maintenance goes in replacement of components (e. g. gearbox). For transportation, mounting and dismantling 5 % are needed.

Energy Payback Time

The net harvest of energy has to be appraised to calculate the Energy Payback Time (EPT). The net electrical power output can be found by the installed load of the wind turbines and the expected capacity factor. Using the German average primary energy conversion factor of electricity of 0.33 the net harvest has been converted to yearly energy output as equivalent primary energy (see Figure 1). The Energy Payback Time for the 1.5 MW coastal Wind Turbine is about four months while the Energy Payback Time for the 5 MW offshore design is approximately five months. The results show e. g. that – surveying the life cycle of a modern wind turbine, – much more primary energy can be harvested during the operational phase than is actually needed in the constructing phase.



Comparison of CED and yearly primary energy output

Wind Energy in India

The above-described studies have considered the situation in Germany. Another important country using wind energy is India. Therefore, also the energy analysis for Indian conditions is highly important. A very detailed and excellent analysis, also in respect to the possible maximum growth rates due to the needed CED, has been done by Mathur (Mathur et al., 2004). The results show that the offshore use of wind energy in different regions of India is also well-appropriated in respect of the yearly energy yield. To advise politics in term of market introduction of renewable energies, it is absolutely necessary to do such kind of investigations.

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Status of Planar SOFC Technology Development at CGCRI, Kolkata, India

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In India, Central Glass and Ceramic Research Institute (CGCRI), Kolkata has the strongest R&D group for technology development in the area of solid oxide fuel cells (SOFC). The related activities are being pursued for the last couple of decades. Initially, the main emphasis was on the materials/ component development. The R&D work has led to the successful development of fine powders of different SOFC components, namely Sr-substituted $LaMnO_3$ (LSM) cathode, NiO-8 mol % yttria stabilized zirconia (YSZ) anode and Ca-substituted $LaCrO_3$ (LCR) interconnect. The expertise in Lab scale powder preparation has been transformed to a large volume (in Kg level) continuous powder production facility using a modified spray pyrolyser designed by CGCRI. Since 2004, efforts have been primarily made to develop and demonstrate working SOFC stacks based on the planar anode-supported design under a National program.

Under this National project, large numbers of anode-supported single cells of dimension 10 cm x 10 cm x 1.5 mm have been fabricated using simple and up-scalable techniques such as tape casting and screen-printing (Basu et al. 2008: 5748). The processing parameters have been optimized to get a thin (≈ 10 μm) layer of fully dense electrolyte (YSZ) film that is well adhered to the 1.5 mm NiO-YSZ porous anode-support on one side and LSM-based cathode on the other side. The developed cells show reasonably good power output at an operating temperature of 800 °C (≈ 2.0 W/cm^2 at a cell voltage of 0.7 V).

Glass-based sealants, an essential component of planar SOFC stack, have also been developed in-house. Several glass compositions within Magnesium aluminosilicate (MAS), Barium aluminosilicate (BAS), Barium magnesium silicate (BMS) and Barium calcium aluminosilicate (BCAS) systems have been developed. The developed glasses exhibit very high electrical resistivity ($> 10^6$ Ω-cm) in both oxidizing and reducing environments. In order to seal dissimilar materials such as YSZ electrolyte with Crofer22APU, a distinctly new approach of applying a bi-layer glass, with a compositional gradation within the BAS and BCAS systems (so as to have a graded CTE within the bi-layered structure) have been successfully employed to make crack-free joints between the metal-glass-YSZ interfaces (Ghosh et al 2008: B473). The bi-layered glass seal has extremely low leak-rate (of the order of 10^{-7} Pa-m^2-sec^{-1}) as compared to others even after 5 thermal cycles (between 500 and 800 °C).

Using the developed 10 x 10 single cells, glass-based sealants, and ferritic steel-based metallic (Crofer22APU) interconnect and gas manifolds, several SOFC short stacks (up to 10-cell level) with counter flow design have been fabricated and demonstrated successfully for the first time in India. At 800 °C, the OCV per cell is found to be ≈ 1.1 V which is quite close to the theoretical value. Peak power obtained from short stacks is not satisfactory at this point of time. However, intense research work is in progress to get improved performances.

In parallel to the above technology development on planar anode-supported SOFC, CGCRI is also engaged in several frontier areas of research as mentioned below:

a) Electrode material for high performance SOFCs

Anode: CGCRI, Kolkata has developed a novel functional cermet anode by a novel electroless technique that contains much lower volume percentage of Ni (≈ 30 vol %) compared to the conventional Ni-YSZ cermet anode with ≈ 40 vol % of Ni (Mukhopadhyay et al 2008). Such functional anode has a thin coating of fine Ni-particles on the YSZ surface resulting in a core-shell microstructure.

Cathode: Nanocrystalline lanthanum ferrite-based (LSCF) cathode materials have been synthesized at a relatively low temperature by combustion synthesis using alanine as novel fuel (Dutta et al 2009). Recently, using spray pyrolysis technique, such nanostructured cathodes with tailor-made morphology have been developed for improved electrical and electrochemical properties.

Initial results of electrochemical experiments performed on planar anode-supported cells fabricated using such functional electrodes has shown a significant improvement in performance (current density > 3.0 A/cm^2 at 800 °C, 0.7 V)

b) Robust glass-based sealants

Recently, a novel glass-ceramic sealant has been developed at CGCRI that can be sealed at a much lower temperature (≈ 700 °C) than the SOFC operating temperature (>750 °C) leading to a much reduced chemical interaction with metallic interconnect like Crofer 22APU. Attempts are now being made to develop robust sealants (with repeated thermal cyclability between ambient to operating temperature) by adding suitable ceramic/metallic filler materials into such glasses.

c) Low temperature SOFC (LT-SOFC) materials: Using combustion synthesis technique, nanocrystalline and phase pure Gd-doped CeO_2 as well as pure $LaGaO_3$ has been prepared. Nanocrystalline and phase pure CeO_2 powders with co-doping of cobalt and gadolinium ($Ce0._{79}Gd_{0.20}Co_{0.01}O_{2-\delta}$) have also been synthesized. The developed powders have very high sinteractivity and at a temperature of only 1,100 °C, almost theoretical density is achieved in the resultant sample. High oxygen ionic conductivity of 0.021 S/cm^2 at 600 °C is obtained for such a dense electrolyte (Dutta et al 2009).

d) Modelling and simulation

Research activities regarding the modelling and simulation of the flow fields and stack designs have been initiated using computational fluid dynamics (CFD) and gPROMS-based softwares.

Apart from establishing linkages with various national laboratories and academic institutes, CGCRI has also established international linkages with reputed organizations like Forschungszentrum Jülich GmbH, Karlsruhe University and RWTH Aachen University, Germany. CGCRI has successfully (co-)organized two Indo-German Workshops on "Fuel Cells and Hydrogen Energy", one at CGCRI, Kolkata (January 2007) and the other at University of Karlsruhe (March 2009). We are looking forward for a future research collaboration of mutual interests.

The expertise developed in the area of SOFC has led the Ministry of New and Renewable Energy (MNRE), Government of India, to bestow upon CGCRI the responsibility to act as the Lead Institute for the development of SOFC technology for India under a Mission-mode Project.

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Energy Efficiency, New and Renewable Energy Resources

Solid Oxide Fuel Cells (SOFCs) – Highly Efficient Future Energy Converters

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"Energy is the very lifeblood of today's society and economy", has been stated by Loyola de Palacio, Vice President of the European Commission and Commissioner for Transport and Energy, and Philippe Busquin, Commissioner for Research, in the special report Hydrogen Energy and Fuel Cells – a Vision of Our Future of the European Commission. The worldwide demand for energy is steadily growing very rapidly, and an increase in power generation in the next decades will be based on a well-balanced distribution between fossil, nuclear and renewable resources.

The exploitation of fossil energy carriers will - without doubt - strike limits. Moreover, millions of tons of greenhouse gases and other pollutants are emitted and cause ecological problems, and the amount will even increase in the future. Therefore, power generation has to be more efficient.

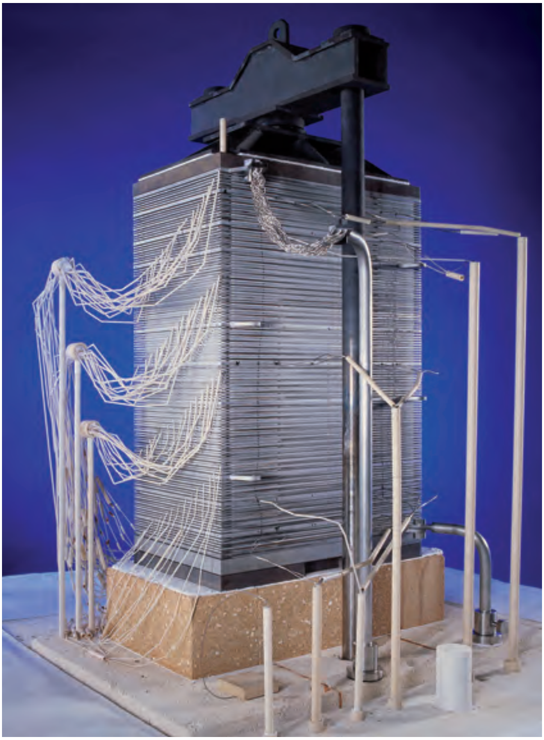
Fuel cells have a significantly higher efficiency and have lower emissions compared to conventional energy conversion devices based on combustion. Fuel cells are "direct" converters of chemical energy into electrical energy, without the intermediate steps of generating heat and mechanical energy as necessary in conventional heat engines. This means that their efficiency is not limited by the Carnot barrier.

There are many types of fuel cells, which mainly differ in their temperature of operation. Among them, polymer electrolyte membrane (PEM) fuel

Peterbilt truck equipped with Delphi Diesel SOFC APU Technology Demonstrator

cells operate at practically ambient temperature conditions, and there are already niche markets where the PEM fuel cell technology has been established. Nevertheless, the cost per Watt of power is the limiting factor, because the membrane and the electrode materials are expensive and the power density still needs to be increased. Ceramic high-temperature fuel cells or solid oxide fuel cells (SOFCs) operate at the highest temperatures, around 700 – 1,000 °C. These temperatures are high enough to convert oxygen and hydrogen into water and energy without any special catalyst for the electrochemical reaction. Moreover, carbon monoxide (CO) is converted to carbon dioxide (CO_2) and desorbed from the hot surface of the SOFC electrodes. Thus, carbon monoxide is not a poison for the SOFC. This is especially advantageous when using, for example, methane instead of hydrogen as a fuel: due to the catalytic activity of the SOFC anode methane is reformed to CO (or to CO_2 in the case of a water gas shift reaction or an electrochemical oxidation) and hydrogen.

The developments during the past years proved that – from the technical point of view – fuel cells are very promising candidates for future energy



60 cell SOFC stack manufactured and tested at Forschungszentrum Jülich, Germany. The stack delivers around 13 kW of electrical power

conversion. However, the system reliability is the most crucial parameter for any SOFC application. Reliability covers lifetime (i. e. low degradation), robustness against thermal cycling as well as emergency shut-downs, trouble and operator errors. The second key parameter is the cost (per kW) of the system in order to come to the market.

By building smaller or larger units, the power can be easily adapted to the demand. This aspect makes them highly feasible for larger stationary power plants, for decentralized power generation as well as for mobile applications. They can also play an important role in transition strategies from fossil feedstock to renewable energy carriers and to hydrogen, also encompassing future biomass-derived, carbon-based fuels.

Many achievements of today are based on the research and development of novel materials, which is also true for fuel cells. In the recent years, Indian and German researchers have made common research on materials for fuel cells at the same eye level (e.g. Al Daroukh 2003; Arul Raj 2004; Zahid 2006; Basu 2004).

A future common research and development can help to establish the same scientific and technical level of knowledge on fuel cells in Germany as well as in India. This enables Germany and India to decide independently which detailed technology concept might be suitable for which country, and how to cooperate best for gaining as many synergies as possible.

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Embedding Corporate Social Responsibility in Engineering Education through Project-Oriented Courses

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In a continual effort to promote the principles of innovative education through project oriented learning and international cooperation, the chair of Assembly Technology and Factory Management of the Technical University of Berlin offers, under the direction of Prof. G. Seliger, several project-oriented courses, such as Production Technology Project, Global Product Development, and Global Engineering Team, where students work on research-based projects in international teams with partners from Brazil, South Africa, South Korea and the United States.

The initiative Global Research for Industrial Development in Sustainability (GRIDS) has been introduced by the chair to integrate the idea of corporate social responsibility into their engineering education as well as to address the global need for increasing regional development in sustainable, customer-oriented products, processes and production systems by uniting the core values of educational institutions through the integration of world class engineering and local communities.

GRIDS is an aligned course which both moderates the meaning of sustainability in a theoretical way and creates a defined space in which groups of students can develop a solution to a specific problem statement. Giving the students a realistic problem statement motivates them to develop solutions-based approaches to solve the problem. Groups are composed of different cultural and social backgrounds to ensure that the work on questions of social matters includes different perspectives. To shorten the process of problem finding, it cooperates with organizations whose aims correspond to the goals of the course. Non-governmental organizations, as well as companies willing to broaden their field of expertise, contribute by providing technical support.

Global Product Development (GPD) is a joint project-oriented course of the Technical University of Berlin, Germany, the University of Michigan, Ann Arbor, USA, and Seoul National University, South Korea. The main objective of the course is to enable students to develop products through global collaboration. Engineering design and project-related knowledge is taught via video conference as well as in a one-week long presence workshop. The solution space is narrowed down through a project definition including product classes and/or market segments, such as "learning instruments for engineering education which demonstrate engineering principles to pupils", "internet-ready products for enabling sustainability," and "unique physical product which enables social business by satisfying real customer needs".

Exhibition of prototypes of products to enable social business, Seoul, Korea 2008

International partners working together

Global Engineering Teams (GET) is a joint master course of the Technical University of Berlin, Germany, the University of Stellenbosch, South Africa, the University of São Paulo, São Carlos, Brazil, the Educational Society of Santa Catarina, Joinville, Brazil, the University of Botswana, Gaborone, Botswana and the Pontifical Catholic University, Santiago de Chile, Chile. GET aims to develop technical competences as well as teamwork and digital cooperation skills of students with different technical and cultural backgrounds by engaging them in challenging projects provided and partially sponsored by industrial partners.

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Energy Generation: Needs a New Model of Development

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The existing model of development put more pressure on the resources and compelled the government to plan more developmental projects to meet out the growing need of the people. The need of any sort is to be fulfilled only by the exploitation of natural resources, which are less in number, and to be finished very soon at the present pace of their utilization. Every natural resource has been heavily targeted for exploitation.

During the course of study, it has been realized that the most important ideas of alternative approaches have been emerged from popular struggles of affected people. Developmental and planning era has been evidenced by many developmental struggles. The only reason responsible for these struggles is that the concerns of local people either displaced or people who are living in the vicinity of developmental projects have been ignored in the process of decision-making and implementation. The voices of the people coming from different movements advocate strengthening the efforts, visions, plans and approaches of development so that prevailing problems can be solved.

The need for energy and electricity has been increased with the development of civilization. In view of the present need, many countries including India are suffering from severe shortages and even crises. All of them face very real and very difficult questions of how to meet these needs. Energy generation through hydropower dam in the Himalayas has been found as a solution to meet a substantial part of these requirements.

Undoubtedly, these projects generate thousands of units of electricity, but at what cost? The economic cost has been calculated by the policy makers as well as by the executors, and these calculations have been made public. But at the same time, the cost of the projects in terms of social, environmental, livelihood, health, psychological and cultural impacts, impacts on the lives of local indigenous people living in the remote valleys of the Himalayas have always been ignored. The projects in the Himalayan region are threatening the identity and culture. Projects are being pushed forward under the pressure of lobbyists, unmindful of these social, environmental and cultural impacts, impacts that have not been fully and properly assessed.

Unfortunately, the people who have been/will be most severely affected have had little say in the planning, design and implementation and have no place in the decision-making structures. And social, environmental, psychological and cultural issues as compared to financial and economic are not important enough to be taken into consideration in the decision-making process.

Invitation to Disaster

Pushing ahead such a massive dam-building program in the fragile Himalayan region without proper social and environmental assessments and safeguards and ignoring the likely impacts of these projects including climate change may have catastrophic and unanticipated consequences. The recent devastation caused by the breach in the embankments of the Kosi River in Nepal and the subsequent change of course that wreaked havoc with the lives of millions of people is an indication of what lies in store if we undertake far-reaching interventions in sensitive regions of the Himalayas without fully evaluating the possible consequences.

The whole dam-building programme in each river basin in the Himalayas needs a comprehensive review. The existing data suggest that an alternative approach/model is required to fulfil the required energy need of any country in a sustainable manner. The choices are not easy, and the process will be difficult because the decision to adopt such type of approach/model is to be taken by the policy makers and by the leadership in the respective countries.

Involvement of local People in Decision-making

Local people must have a say in decision-making processes. They should be involved by visiting the local sites where the developmental project has been proposed. Every sacrifice made by them should be calculated and compensated before the commencement of any developmental project. To prevent traumatization, the concerns of oustees as well as native of the area should be considered and their rights respected. The interests of the local people must be given priority along with national interests, as they are the custodians of a treasure that is the common heritage of the entire world – the Himalayas.

Proposed Model of Development

The approach in my research is to find a strategy for long-term optimal benefit from natural resources promoting a sustainable growth path. Two questions appear: First, how to utilize the resources, e. g. at what pace the resources should be exploited? Secondly, how to get benefit from the exploitation of resources with the participation of local stakeholders, e. g. how should the earnings be used for the benefits of the local people as well as to sustain the local environment?

I propose to concentrate on Benefit Sharing Participatory Model of development (BSPM) as an answer to the existing lobbyist-pressurized model of development. Along with this, I propose to include SIA (Social Impact Assessment), LIA (Livelihood Impact Assessment), PIA (Psychological Impact Assessment) and HIA (Health Impact Assessment), CIA (Cultural Impact Assessment) in EIA (Environment Impact Assessment). Environment does not mean physical environment; the term environment should be used in a comprehensive manner. On the basis of these assessments, the stakeholders of a proposed developmental project should be involved in the process of decision-making. Monetary benefits drawn out from the developmental initiative should be shared with the affected as well as with the native people of the area concerned. A minimum percentage out of the profit earned should be agreed upon and be disbursed among stakeholders so that the real fruits of development can be reaped. I propose to develop a tool through which the above-mentioned aspects can be measured, and the participation of the affected community can be ensured. This would help the decision makers to make better decisions when, where, and how to deploy the development initiatives in Himalayas as well as in any part of the world.

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The Limits to the Application of Science and Technology for Sustainability

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"The Earth has enough for everyone's Need but not for everybody's Greed" – Mahatma Gandhi

Let me begin with a small anecdote, which I heard recently: The mother Earth has fever. It is lying in bed red in face with a scarf round her head and a thermometer in her mouth. The nearest neighbouring planet, Moon, came to visit and console her. She enquired: "What happened? You were alright until a few thousand years ago!" For that, the Earth replied: "I do not know what has happened, I have high fever for the past few years and the temperature is rising. I have requested Dr. Mars to help me and he made a house call and conducted some clinical tests. He concluded that I have a deadly viral infection called Homo sapiens." Moon consoled by saying: "Don't worry, you remember that you had another viral infection called Dinosaurs a million years back and it had suddenly disappeared on its own. Similarly, this infection will also run its course and will disappear on its own in a few decades!" This anecdote clearly highlights the limits to the growth of human civilization in its present form.

After the industrial revolution, science and technology was responsible for the spectacular growth in the standard of living of the human race. Only until a few years back, it was firmly believed both by the people and by the governments that industrialization is the only solution for the poverty and

backwardness in the developing or underdeveloped countries of Asia, Africa and Latin America. The model of development in Western Europe and North America was held as a role model for the rest of the world, and they were encouraged to copy it by the so-called development aid by international agencies like World Bank, United Nations and the like. Most populous countries like China and India have enthusiastically embraced this model in improving the standard of living of their people – with apparent success! The number of cars, telephones, refrigerators, etc. – the visible symbols of prosperity – have multiplied and even the status symbols like air travel have increased dramatically. But only of late, the realization has dawned on people that all these developments have a price to pay.

The environmental degradation has raised its ugly head with the air unbreathable, water undrinkable and the food contaminated with chemicals. Suddenly the quality of life has become a new paradigm in the human development. It is recognized that growth for growth sake is not only undesirable but can be dangerous to the survival of mankind. But the chain of events which were set in motion in the human development were not only difficult to stop but often impossible to reverse.

New messiahs of doom and destruction in the form of Senator Al Gore have appeared on the scene, armed with scientific measurements of global warming with dark forebodings of raising sea levels. This has been dramatized by the President of Maldives – a country consisting of several islands in the Indian Ocean where the highest point on land is hardly 1 meter above mean sea level – who has urged his countrymen to abandon their homes and migrate to other countries before it is too late. Refugees seeking asylum for environmental reasons has become a reality for the international community. Besides, we have been warned of increasing rapidity of floods, earthquakes and other natural disasters related to environmental degradation.

What are the solutions? People have been asked to look for alternative and renewable energy sources to the conventional coal and oil burning

technologies. Suddenly even hydro-electric power has become suspect and nuclear power downright dangerous.

Scientists and Technologists were asked to refocus their aims and efforts to find new forms of sustainable technologies. In this context, the German-Indian workshops on Sustainability assume special significance. Germany with its rich experience in green technologies and its public awareness for environmental degradation is an ideal partner for India, which is trying to improve the standard of living of its billion plus people with an eye on the environment. In addition, they have a long history of successful scientific cooperation and both being democratic countries where the results can be implemented in the society without much resistance. Hence, joint research projects with social relevance must be undertaken by scientists from both countries. It is important to associate institutions in both countries, which have their roots in the society, like non-governmental organizations, which will ensure speedy implementation of the scientific results at the grassroots level.

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Land Use

Sector Review

Research on Sustainable Land Use in Germany and India – Future Tasks

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Germany and India are strategic partners for cooperation and research. Thousands of researchers have been working in the respective partner country on a variety of topics and disciplines. Joint agendas in land use research in India and Germany are only a few but the topic is emerging. The present paper will provide an overview on the major trends and tendencies of agricultural land use research in both countries.

We hereby focus on agriculture and forestry and start our contribution explaining some general and common concepts of land use research. We conclude with a set of possible issues for a joint research agenda taking into account country-specific research interests and experiences, their strengths and weaknesses.

Investigating Land Use and Land Use Changes

Land use is characterized by the arrangements, activities and inputs people undertake in a certain land cover type to produce, change or maintain it (FAO 1997). It is a dynamic process that underlies a continuous development. Long-term land use change is induced by many factors including population growth and industrial development.

The related growing demand for infrastructural area and areas for the primary production of food, fibre and energy results in a growing scarcity of fertile land. Land use and land use changes directly affect the exchange of greenhouse gases between terrestrial ecosystems and the atmosphere (IPCC 2000) and, together with use of fossil fuels, are considered as the major anthropogenic sources of carbon dioxide.

Agricultural systems, their impacts and changes often include a very specific human dimension. We may speak of beneficiaries and victims of change. In the following, we would like to present some concepts from the field of land use research.

Concepts of agricultural Land Use Research

The idea of Ecosystem Services reflects the assumption that efforts and interventions to manipulate agro-ecosystems in order to meet specific production functions represent certain costs to the rest of the ecosystem. These costs can be expressed in terms of energy, matter and biological diversity, and often negatively affect goods and services that so far were considered to be free and abundant. Services such as nutrient cycles or the biological control of pests provide the biophysical necessities for human life or otherwise contribute to human welfare.

Another famous concept is the DPSIR framework that is applied e.g. by the European Environmental Agency (EEA) and the United Nations Environment Program (UNEP). This framework assumes cause-effect relationships between interacting components of social, economic, and environmental systems, which are[1]:

- **Driving forces of environmental change (e. g. industrial production)**
- **Pressures on the environment (e. g. discharges of wastewater)**
- **State of the environment (e. g. water quality in rivers and lakes)**
- **Impacts on population, economy, ecosystems (e. g. water unsuitable for drinking)**
- **Response of the society (e. g. watershed protection, cleaner production)**

Driving forces lead to a certain pressure on the environments leading to a certain state. The impacts of this state affect society, which responds to the case e. g. with a conservation effort.

As a variety of demands and land use options are available, the concept of Multifunctionality of land use is widespread. Indicators to link the socio-economic requirements with the landscape potential were developed (e. g. Wiggering et al. 2006).

As agricultural land use involves a variety of disciplinary knowledge, a transdisciplinary approach is required. Transdisciplinary studies on sustainable agricultural land use cannot be solved by one or even a few points-of-view. They gather a wide range of stakeholders including academic experts, field practitioners, community members, political leaders, and entrepreneurs among others to solve some of the pressing problems facing the world, from the local to the global.

[1]www.unep.org/dewa/assessments/ecosystems/water/vitalwater/12.htm#13, last access 11th of July

Environmental Impacts of agricultural Land Use

The negative impacts of agricultural land use on natural ecosystems, soil pollution and degradation, deforestation, erosion, consumption and pollution of water are well studied (e. g. McLaughlin and Mineau 1995; Lundekvam et al. 2003). The historical conversion of natural systems to agriculture has resulted in a net release of carbon dioxide to the atmosphere, determining alteration in the climate, and the biogeochemical cycling of carbon, nitrogen and other elements at a global scale (Schneider 1989; Houghton 1995; IGBP-FIDP 1995). On the other hand, these global changes may be probably inducing new shifts in land use by means of feedback mechanisms that are still poorly understood (Viglizzo et al. 1997). Climate change is expected to force farmers all over the world to develop adaptation and mitigation strategies for sustaining agricultural and silvicultural production.

Socio-economic drivers must be taken into account while analyzing future land use development as there are population growth, economic growth, changes in demographics, agricultural and forest prices, regional and local planning and politics including social and institutional frameworks. What is also to be recognized is the differential impacts of "key drivers" land use/ cover changes that impacts on a larger scale (policy dimensions and market pressures, both national and international) as distinct from lesser impacts at the local level, the "proximal drivers" arising at the local level from people living in the region (Indian National Science Academy 2001; Lambin et al., 2001). Indeed, these drivers differ in their intensity according to the natural and socio-cultural conditions and are highly site-specific.

Agricultural Land Use Research

Given the above-mentioned scenarios, sustainable land use and research has to provide problem-oriented and location-specific applicable solutions to society focusing on long-term resource availability. The well-known concept of "sustainability" is regarded a must in that context. It is of key interest to which landscapes the agricultural practices are leading.

Governance-oriented agricultural land use research can be divided in ex post "What happened in the past?" and ex ante "What may happen in the future?" approaches and a combination of both. To analyse land use systems in a way that adequately targets the multidimensionality of possible situations and the implications of certain changes a broad bundle of scientific disciplines come into action. Not only the "classical" agricultural and forestry disciplines related to production technology, soil and crop science, plant nutrition and pest management are required. Neighbouring disciplines such as geology, biology, ecology and meteorology but also social sciences such as economy, politics, law, sociology and land use/land use change research community.

The analysis takes place on different spatial levels and scaling up of static or dynamic situations is frequently done. Apart from the typical disciplinary approaches a large variety of methods and theories are therefore applied in land use research. Large multidisciplinary studies such as the Millennium Impact Assessment (MIA)[2] and the Global Biodiversity Assessment (UNEP

[2]www.millenniumassessment.org, last access 11th of July

1995) involving thousands of scientists help us to understand the current environmental situation on a global scale. The Global Land Project (GLP)[3] initiated by Geosphere-Biosphere Programme (IGBP) and the International Human Dimensions Programme (IHDP) targets the (1) Dynamics of Land Systems, the (2) Consequences of Land System Change and the (3) Integrating Analysis and Modelling for Land Sustainability. The urban and peri-urban context is also addressed in agricultural land use research as pressures in rural areas lead to migration and increased urbanization patterns. The "Emerging Megacities Project"[4] with a study in Hyderabad, India may serve here as an example.

Land Use and Sustainability Research in Germany

According to the European CORINE (Coordination of Information on the Environment) land cover project, roughly 54 % of the total area of Germany is agricultural land while forestry counts for another 30 %. Additional 4 % are covered by national parks or further categories of protected areas while only 12 % are classified as building area. BMELV (2003)[5] states that the share of the agricultural sector at the total GDP is less than 1.5 % while work force accounts for 3.2 % of all employees. German agriculture has a strong political lobby. Forestry and agriculture are increasingly engaged in energy production. FNR (2008)[6] figures that in 2008 energy crops were produced on 2 million ha representing roughly 17 % of the country's agricultural area.

The separation of Germany into two contrasting economic systems between 1949 and 1990 has led to two contrasting farm types that dominate the regions. Family farms around 25 ha size are typical for the western states dominated by small structured landscapes. Agricultural

[3] www.globallandproject.org, last access 11th of July

[4] www.emerging-megacities.org, www.sustainable-hyderabad.in, last access 11th of July

[5] www.bmelv-statistik.de, last access 11th of July

[6] www.fnr-server.de/cms35/index.php?id=140, last access 11th of July

enterprises with average farm sizes above 200 ha including single corporations that manage several thousands of hectares prevail in eastern Germany[7] . A decrease in both farm employment and the numbers of farms is documented while many of the remaining ones have increased in size, productivity and specialization. This trend has led to a reduction of the product variety and the establishment of the economic branch of agricultural contractors. These offer a variety of services from harvest to tillage and field management and have become important partners to farmers enabling them to benefit from scale effects.

Policy as the major Driver of German Agriculture

Agricultural markets in Germany are highly influenced by the policy framework within the Common Agricultural Policy (CAP) of the European Union. The CAP expenditure still covers more than 40 % of the whole EU budget (IEEP 2009)[8]. This legislative framework, which is implemented by the Member States, is based on two pillars that support and coordinate agricultural production, rural development and environmental protection related to agriculture. Pillar I is mostly known for direct payments related

[7] www.geographie.uni-marburg.de, last access 11th of July

[8] www.cap2020.ieep.eu/2009/6/26/cap-to-competitiveness, last access 11th of July

to the agricultural production activities that are tied to basic requirements concerning food safety, animal welfare and environmental protection also known as Cross Compliance. Pillar II known as rural development provides a bundle of incentive based measures such as agri-environmental programmes, compensation payments, trainings and other support to farmers. Changes in the policy framework are reflected in the production systems and the landscape appearance, a process that has been made quite clear through the "yellowing" of Germany's landscapes by Brassica napus, a subsidized oil seed crop for bio-energy production.

Impacts of German Agriculture on the Agro-Ecosystem

High-input agriculture along with the use of heavy machinery, larger parcels and narrowed crop rotation has led to negative impacts on the environmental services. Losses in biodiversity, increased erosion, pollution of ground and surface waters and a decrease of certain land use functions such as recreation are documented. The European Commission considered agricultural soil degradation as one of the principal environmental problems of Europe[9].

[9]www.ec.europa.eu/environment, last access 11th of July

Research on sustainable agricultural Land Use in Germany

The aims of planning and development of land resources in Germany are to improve the management of human settlement, conservation of natural goods and the support of the "Good Agricultural Practice". Some of the major fields of agricultural land use research in Germany are:

- **Basic research (e. g. nutrient cycles, organic matter fluxes, landscape dynamics)**
- **Climate change and agriculture (e. g. gas emissions from agricultural areas, fens)**
- **Impacts on public and private health (e. g. soil, groundwater and air quality)**
- **Sustainable production practices (e. g. conservation tillage, precision agriculture)**
- **Traceability systems in the food chain (e. g. systems, feasibility)**
- **Sustainable bio-energy production (e. g. impacts, conflicts, values)**
- **Structural change in rural areas (e. g. integrated rural development)**
- **Environmental standards and quality management (e. g. cross-compliance, certified food)**
- **Multifunctionality of land use (e. g. urban–rural interfaces, energy and agriculture)**
- **Policy related research (e. g. acceptance and adoption, planning tools, policy analysis)**
- **Rural sociology (e. g. migration, gender issues, employment)**

In Germany, today, 11 Universities and 13 Universities of Applied Sciences offer academic education in agriculture and related fields. Agricultural research in Germany is facing serious problems mainly due to budgetary issues. The German Board on bio-economic research (BioÖkonomieRat)[10] concluded in July 2009 that bio-economy has to provide solutions regarding

[10]www.biooekonomierat.de, last access 11th of July

the global challenges of climate change, food security and energy supply and that the sector therefore needs to be strengthened.

Land Use and Sustainability Research in India

India's main environmental problems are pollution, waste management and land degradation. India's food production heavily increased during the Green Revolution apart from the 1970s that broadly introduced high input agriculture. In parts, this led to homogenized landscapes and large ecological losses. Social conflicts related to agriculture are still reported and food security is remaining a major topic.

Driving Forces for Land Use Changes in India

In the following, we will provide an overview of some major ecological and socioeconomic drivers for agricultural land use changes and their impacts on the most common land use systems in India.

Climate Change

Not all possible consequences of climate change are yet fully understood, but the three main "categories" of impacts are those on agriculture, sea level rise leading to submergence of coastal areas, as well as increased frequency of extreme events. Each of these consequences poses serious threats to India (Parikh and Parikh 2002). Changed patterns in temperature and precipitation are expected. Considering a range of climate change scenarios which project a temperature rise of 2.5 °C to 4.9 °C for India, Kumar et al. (2001) concluded that without considering the carbon dioxide fertilization effects the yield losses for rice and wheat would vary between 32 and 40 %, and 41 and 52 %, respectively.

Population Dynamics

Among the socioeconomic drivers affecting land use demographic patterns are considered of key importance. Providing a sufficient supply of food and fibre for an increasing number of people poses an immense pressure on the remaining ecosystems. Across India, the estimated population for 2009 ranges

around 1.17 billion people of which 27.8 % (Census of India 2001)[11] are living in the cities. Population growth rate is estimated around 1.3 % (US Department of State 2009)[12] what stands for an increase of roughly 17 million people per year. The extensive use of fuel wood, mainly for cooking, has contributed to the high levels of airborne particulate matter and has contributed to depleting the forest cover around most Indian cities (Taylor 1996).

Economic Growth

The growing national economy in India embedded into global markets and economies shows a growing demand of suitable land for infrastructure and energy among other needs. Coal is still the major source of energy and CO_2 emissions (Parikh and Parikh 2002). The emergence of industrial centres was not reflected in adequate pollution control mechanisms.

[11]http://www.censusindia.gov.in/Census_Data_2001/India_at_glance/rural.aspx, last access 11th of July

[12]http://www.state.gov/r/pa/ei/bgn/3454.htm, last access 11th of July

Environmental Politics and Policy Implementation

Forest resources are mostly covered by the Forest Conservation Act from 1980, amended 1988, the National Forestry Action Programme (NFAP) founded in 1988 and the Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006. Restrictions of land use in some occasions have led to conflicts between villagers and the state or reserve authorities leading to such dramatic measures as resettlement of villagers from certain protected areas to areas outside a wildlife sanctuary (Karanth 2007). Many scientists concluded a better acceptance of protection schemes when participatory management approaches including the local population were pursued. Further studies (e. g. Das et al. 2006) provide an identification of zones most valuable for conservation for a more effective conservation planning. Case study approaches provide on the ground comparisons of different protection regimes and their impacts on varying sets of indicators (e. g. Nautiyal and Kaechele 2007). Conservation approaches in India are applied under the paradigms of sustainable use that favours the gentle use of natural resources under the principles of sustainability or the conservation paradigm that supports the restriction of certain forms of land use in "protected areas" (Madhusudan 2003).

Culture

The conservation of natural areas has a very old history in India. The concept of "sacred" biota and abiotic elements is known for several thousand years (Sinha 1995). Sacred groves are spread across the country and Malhotra (1998) estimated their number from 100,000 to 150,000. They form an integral part of the Indian landscape. Although some authors expressed critics that religious feelings do not longer detain rural dwellers from certain activities such as hunting (Madhusudan and Karanth 2002) sacred areas often remain as islands of biodiversity within highly degraded landscapes. But Chandrakanth et al. (2004) concluded that further governmental support is needed to strengthen the traditional village organizations in efforts to conserve the sacred groves in southern India.

Agricultural Land Use Systems and their Impacts in India

India is ranked among the mega diverse countries in the world (Shi et al. 2005). The country aims at maintaining and conserving its biodiversity while providing food security to its inhabitants. About 4.9 % of the total land surface is under protection. According to the Köppen system for climate zone classification, India covers six major climatic subtypes, ten bio-geographical regions, and as much as 29 different agro-ecological zones (Subramaniam 1983) are distinguished. Except the northern mountainous region, perennial agriculture is practiced throughout the country generating two to three harvests per year depending on the monsoon patterns. According to ADB (2005)[13] more than 30 % of Asia's irrigated land is in India, around 59 million hectares. Large amounts of the total area under cultivation in India are considered as substantially degraded. Timber extraction and the conversion of forests into agricultural lands including plantations (rubber, coffee, palm oil etc.) are having a strong impact on India's agro-ecosystems.

Land management systems vary from subsistence farming to intensive production systems. Low input farming systems are characteristic for e.g. the mountainous landscapes of the Himalaya and the Western Ghats. This rain fed agricultural systems are usually highly dependent on forest resources (e.g. fodder, straw, timber wood). Problems of land degradation due to overexploitation of land and forest resources are reported. Therefore, Nautiyal and Kaechele (2008) studied the impact of replacing firewood by liquid gas to lower the pressure on agro-ecosystems. The "Traditional Ecological Knowledge" (TEK) on forest management and community-based participatory forestry systems (Ramakrishnan 2007) is also receiving attention. The social and cultural dimension of land use, religious and gender topics related to land use and the use of medicinal plants are receiving increasing attention.

Intensive agricultural production systems basing on mineral fertilizer, application of pesticides with an increasing share in GMO varieties are

[13]http://www.adb.org/Water/actions/ind/irrigation-reforms.asp, last access 11th of July

prevailingly found in the Gangetic Plains. The plains that border the southern foothills of the Himalayas are the most productive agricultural area of the country. The intensive production systems are highly dependent on the water resources from the Himalayan region and are affected by changes in climate or land use patterns in the uplands. In the densely populated area population pressure is strong. Gopinathan and Sudhakaran (2009) document the competition between different forms of land use including bio-energy production, which is influenced by the international markets. Central India is dominated by semi arid conditions with low precipitation and poorer soils in comparison to the Gangetic Plains. It is highly dependent on irrigation.

Implications for Indo–German Land Use Research in India

Several future tasks for joint Indo-German approaches in the field of agricultural land use research in India can be identified. The climate change debate, the United Nations Millennium Development Goals on poverty reduction, the Convention on Biological Diversity and many other agreements remind us on our joint responsibilities for the earth ecosystem and its people. It is a particular achievement of climate change research to have spread the message that it does matter to other parts of the world what is done elsewhere.

Joint approaches of Indo-German teams in land use research in India should aim at cooperative ways of equal partnerships. In applied sciences, the institutional structure of the research process is crucial for generating solutions that can be accepted, implemented and sustained by local stakeholders. An exchange of knowledge on technology, methods and theoretical concepts is regarded as potentially fruitful in a variety of fields, which we may not prioritize.

We would like to encourage research related to the environmental impacts of agricultural land use systems. Methodologies should include participatory and community based approaches as well as economic, policy and institutional analysis, scenario development and modelling. Emission of greenhouse gases and adaptation and mitigation strategies to climate should be a major target of a holistic approach. The understanding of cultural landscapes and value systems should play a major role in the analysis of local situations to support socially and culturally acceptable solutions. Ecologically sound agricultural production technologies in line with improved production patterns are needed for the extensive agricultural systems. Traditional Ecological Knowledge (TEK) should be conserved and applied. Precise control and reduction of inputs while introducing a set of conservation measures (e. g. Precision Agriculture, Conservation Agriculture, and organic Agriculture) are promising approaches for the intensive systems. We may consider recycling strategies for organic matter and soil fertility management as key instruments towards non-polluting agriculture. A recent area of interest is the economic, ecologic and social dimension of bioenergy production. Hereby the identification of appropriate production systems including agroforestry systems and fast growing tree species within agricultural crop rotations and the integration of these systems within the local and regional context of energy and agricultural production is to be addressed. The conservation of agro-biodiversity, research in medical plants and afforestation are needed. Multifunctional land use approaches such as the recultivation and restoration of degraded areas, open-cast mining areas and transformation of these areas into recreational sites may be a further promising field of work.

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Land use R&D Policy and Funding by the Federal Ministry of Education and Research

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Global change and its interacting phenomena like globalization of trade and economy, demographic and societal changes and last but not least climate change are effecting the societies in industrialized nations as well as developing or transition countries. They all face enormous challenges in the coming years and investments in R&D-policies of countries and regions are considered to be a crucial factor to overcome negative effects of globalization and to shape the future. One of the future research fields that is not a brand new one, but even so has very high potential in this respect, is the field of land management.

On the one hand, land management is at the crossroads of climate change, energy- and food-demands and human needs and therefore particular capable to deal with the above mentioned problems in a holistic manner. On the other hand land use changes driven by global change phenomena are very directly affecting the life of millions of people around the world. Sustainable land management is of key importance in preserving our natural resources, because Global change will increase competition in the use of limited land resources in Germany and in many other parts of the world. It could be a prime example of research on sustainability.

Therefore, 2009, the Federal Ministry of Education and Research (BMBF) started, in the context of its framework programme "Research for sustainability, a new initiative called "Sustainable Land Management". The main aim of the research initiative is to elaborate and develop the necessary knowledge

base for sustainable land use management practices, including strategies, technologies and system solutions.

The program has a modular structure, allowing for the flexible integration of additional issue in the following years, but will focus in its initial phase on "Interaction between land management, climate change and ecosystem services" (module A) and "Innovative system solutions for sustainable land management" (module B). It will concentrate on regions that are classified in particular sensitive or are particular capable to serve as exemplary model regions (national/international).

Main topics of the call include e. g. regional consequences of global change on land management and socio-economy, land management strategies, interaction and feedback mechanisms between land use and ecosystem services (ESS), urban-rural relations and trade-offs and synergies between conflicting land management options. First projects are planned to start in 2010.

Key criteria across all aspects mentioned before will be the active involvement of stakeholders, the integration of different interests and the combination of economical, ecological and social approaches.

In this respect, the call could build the basis for level playing field to define "areas of overlapping interest" concerning new Indo-German initiatives.

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Land Use Change Implications on Forest and Agro-Ecosystems: Indian Perspective

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India has about 18 % of the world's population and 15 % of livestock population to be supported from only 2 % of geographical area and 1.5 % of forest and pasture lands. The increasing human and animal population has reduced the availability of land over the decades. The per capita availability of land has declined from 0.89 ha in 1951 to 0.37 ha in 1991 and is projected to slide down to 0.20 ha in 2035. As far as agricultural land is concerned, the per capita availability of land has declined from 0.48 ha in 1951 to 0.16 ha in 1991 and is likely to decline further to 0.08 ha in 2035. Forest and agro-ecosystems are very important in conserving the biodiversity, food security of the poor, climate balance and securing livelihood of rural poor and marginal farmers. The recent unprecedented price increase of food commodities and fall in agricultural productivity are threatening to undo the poverty reduction achievements and biodiversity conservation programmes in India.

Land Use Change in Forest Land

Although India is the seventh largest country in the world, only 1.8 % of the world's forests are found here. Based on recent Indian Remote Sensing Satellite data, forests in India cover approximately 21 % of the area. However, a more realistic estimate shows that forests cover only 11 % of the land base.

Agro-ecosystem of semi-arid region of Karnataka, south India, highlighting mixed cropping patterns of millets (Eleusine coracana) and plantation (banana) along with trees on interbund

Out of India's population of one billion, 360 million live in or around forest areas, exerting tremendous pressure on limited forest resources. This is in addition to the need to fulfil the requirements of urban population and wood-based industries (FAO, 2000).

India's Forest Policy in 1988 prescribed that 33 % of country land area should be brought under forest cover, but still it is around 21 % from last decade. Significant forest lands have been encroached upon by forest fringe communities, for growing crops, mining lease in forest area, leasing of forest lands to industries for meeting raw material needs, repeated forest fires, large scale monoculture energy plantations, pending land tenure rights, large scale conversion of forest for river valley projects, absence of integrated watershed policy etc., all of which have fragmented the forest landscapes and seriously threatened the biodiversity (Faizi and Ravichandran, 2008).

Efforts have been made in India to integrate social policies into the forest policies like social forestry and joint forest management programs in the last few decades, which raise questions like who is owning and conserving the forest. In view of this, Government of India enacted Recognition of Forest Rights Act – 2006 (RFRA – 2006) to provide property rights to scheduled tribes and forest dwellers (GOI, 2006). Social scientists opined that it is unworthy to exclude rural people to access the resources from their immediate parks and sanctuaries without providing them the alternative (Madhu, 2005). Contouring to this co-management initiative, many wildlife conservationists and environmentalists have strongly argued that if the rights on land and other forest resources were handed over to the community, no more wildlife conservation would be possible. Experts are also of the view that it will not only create fragmentation in protected areas, but also adversely affect the environmental services of forest of Himalayan and Western Ghats mountain ecosystems. These two biodiversity hotspots are already fragile and will further fragment if provided with property rights under RFRA. A progressive shift from traditional exclusive approach to community-driven, rightsbased approach is thus underway to protect social and human rights of local population in relation to biodiversity conservation in other developing countries also (Lockwood et al. 2006).

Land Use Change in Agriculture Land

Out of 328.7 million ha of geographical area of India, about 141 million ha is Net Cultivated area and of this, about 57 million ha (40 %) are irrigated and the remaining 85 million ha (60 %) are rainfed. This area is generally subject to wind and water erosion and is in different stages of degradation. Therefore, it needs improvement in terms of its productivity per unit of land and per unit of water for optimum production. According to the 2005 report of National Bureau of Soil Survey and Land Use Planning, an area of 146.82 million ha is suffering from various kinds of land degradation in India.

The recent Bio-fuel policy of Government of India aims at introducing a 5 % blend of bio-fuel by 2012, 10 % by 2017 and 20 % 2022. The natural question arising from the diversion of arable land from food production to bio-energy crops is likely impact on India's food production and food security. Bio-fuel proponents, and there is already a vocal "biological lobby", argue that bio-energy crops would only be grown on degraded or wasteland, not on

South Indian Western Ghats: Tropical rain forests of Kudremukh National Park. which is one of the global

fertile land. In this regard, the proposed bio-fuel policy will change the land use dynamics of agriculture lands in India, with grim prospects for the future.

The Special Export Zones Act (2005) allows industries to set up export economic zones in India. According to Ministry of Commerce and Industry, Government of India, totally about 41,700 ha of land is to be acquired for the formally approved and notified SEZ in India. The majority of these are going to come up in fertile agriculture lands. The diversion of agriculture land to industries will seriously affect not only agriculture productivity, but also leads to water scarcity around these SEZ. The agriculture areas around these SEZ are likely to be affected by pollutants discharged by these industries, and besides urbanization will change land use system of the region.

Conclusion

Natural resource decline, social unrest and poverty, exacerbated by climate change, among others will shape the land governance agenda in large parts of the developing world. India is experiencing rapid growth of population, consequent industrialization and urbanization, particularly in the post-independence era. However, not enough is known about the magnitude of these land use changes, state and non-state actors responsible for land use change and the relationship of these changes on forest and agriculture land

biodiversity hot spots of the world

use systems of India. The issues discussed above highlight the increasing importance of land use governance and reforms needed in the national and global agenda from the viewpoint of national food and energy security, economic growth, climate regulation, biodiversity conservation, and social perspectives. The complex and multidimensional nature of land requires a long term, well organized and coordinated research and action involving all the stakeholders.

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A Review of Water and Health in India: Towards Risk Governance in Complex Societies

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Water and health are intricately linked. Water is one of the life support systems that provides a fundamental need for the human species and for all other forms of life. Change in these conditions can significantly alter human well-being and health. The Millennium Ecosystem Assessment (Corvalan et al, 2005) warns of harmful consequences of this degradation for human health, which may grow significantly in the next fifty years.

The Earth System Science Partnerships (ESSP) reports that this form of degradation is likely to worsen with "periurbanization" in the 21st century (Confaloneri and McMichael, 2007) that will increase the emergence and spread of water-communicated diseases. While water plays a fundamental role, socio-economic factors, demography, technological advancement and the human body's metabolism equally influence human health as a system. Understanding the interaction between these two systems is vital for adaptation and prevention of diseases for human well-being and for alleviating poverty.

The interaction between water and health is only revealed when pathogens, virus, microbes and chemicals in water interact with the human body sufficiently to harm human health through water-communicated diseases. Though these diseases are well-known as (Ashbolt, 2004): water-transmitted diseases, those that are water-borne (e. g. diarrhea), water-related (e. g malaria), water-based (e. g. schistosomiasis), and water-washed diseases (e. g. scabies).

Underwater bridge for crossing a natural drainage channel after rais KC Canal irrigation system

There are two other groups of water-communicated diseases that are less known: (i) mineral contaminated diseases transmitted due to prolific contamination of geogenic minerals (e. g. arsenic); and (ii) chemical-contaminated diseases transmitted due to contamination of man-made pollutants in industrial and domestic wastewater.

The paper aims to review policies and programmes addressing water-communicated diseases in India. In specific, it will select diarrhea, malaria, arsenic, fluoride and industries related water diseases, as cases to review the policies and programmes. Policies to address these diseases come from government, international agencies, non-governmental organizations, private companies and civil societies. The paper reviews the working of these policies and programmes, the institutional structure for this implementation and its evaluation from government and independent agencies (such as NGOs, international agencies and research institutions) towards addressing water-communicated diseases. This will help to understand the unexplored inter-linkages between water and human health, and to identify gaps for policy makers to achieve sustainable water resources management for human wellbeing.

India is implementing one of the largest national water supply and sanitation programmes worldwide, with annual resource allocation of more than US $ 1.3 billion per year, since 1980's with the establishment of the International Drinking Water and Sanitation Decade (1981-90). Drinking water and sanitation has gained prominence in various national water policies (1987 and 2002), Rajiv Gandhi Drinking Water Mission (set up in 1991-92) and under various sectoral reforms. In addition, international agencies, NGOs and private companies have come out with various alternatives to address water-communicated diseases. Many research institutions have been set-up to address malaria, diarrhea, fluoride and arsenic. This has resulted in technological advancements to source water (from distant sources-large dams/ inter-basin transfer/bottled water, and in-situ rainwater harvesting/dug wells/tubewells) for meeting the drinking water need and in-situ disposal of sanitary waste.

Though these have significantly reduced water-transmitted diseases, such as diarrhea, sustaining these is questionable. Every year, the coverage of drinking water and sanitation is being revised, partly due to technological failures, a piecemeal approach, and poor governance. This has resulted in emergence and re-emergence of diseases, also partly due to disease-resistance and a changing environment. Many policies and programmes focus on diarrhea, malaria and geogenic chemicals, such as fluoride and arsenic, while ignoring the complex set of water-communicated diseases emerging and re-emerging as a result of rapid urbanization, globalization, population growth, and increased occurrence of floods and droughts, supposedly due to climate change.

The review reveals the following:

1. **The challenge in embedding a techno-centric approach in socio-cultural and institutional settings; The importance to understand human health influenced by the biological functioning of the human body, nutrition, and people's life history, as well as a collective property of the population (McMichael, 2001);**
2. **The challenge in understanding the interactive nature of different vectors, pathogens and pollutants once they are released to the environment;**
3. **The significant relationship between poverty and water-communicated diseases that has been ignored in the contemporary approach to fight human health;**
4. **The limited understanding of the uncertainty surrounding the impact of water communicated diseases on human health, especially when many of health impacts are revealed after many years of exposures;**
5. **The failure to understand the adaptive nature of the society to address water communicated diseases.**

The review concurs with McMichael (in conversation with Shetty, 2006) by emphasizing that most of the contemporary attempts are "attuned to simple high-school models of science, with clear-cut cause and effect relationship, most of us are yet to grasp the risks to human societies and health from these escalating changes to the world's complex non-linear systems, whether climate change or ecosystems". In this complex adaptive system, the paper calls for research that cuts across disciplines. Here powerful medicine to address water-communicated diseases emerges from a comprehensive understanding of risk from the way water is actually managed in contemporary policies and programmes - how risk is framed or created, what impacts it has on the society, what are strategies adopted by individuals and organizations to overcome risk, and changes brought by agents in the existing institutions and bio-physical resources to adapt to risk. This will help in governing risk to sustain livelihoods of the deprived section of the population to the growing challenges of environment. This if effectively combined with innovative integrated modelling tools (such as Bayesian network, agent-based modelling, Bayesian geo-statistical analysis) can uncover the complex relations between water and human health, and bring about necessary changes in the institutional and policy settings for human well-being.

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Cities Adaptation for Climate Change – Issues, Challenges and Opportunities

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Our world is increasingly becoming urban. The growth of cities is inevitable in the near future. Technological advances, comfortable lifestyle, new and better job opportunities and a popular notion that cities can always sustain one's life will continue to lure more and more people towards cities. Cities are energy-intensive and transform land use in and around them and play an important part in the overall phenomena of emissions of green house gases, in turn leading to global warming and subsequent climate change as they house great industries, automobiles and vehicles.

3/4th CO_2 released in the world is from the urban areas and cities are responsible for 26 % of direct greenhouse gas emissions. Research from all over the world has proved that urban development is a key contributor to climate change. Current urban development patterns encourage sprawling and auto-dependent development leading to increase in the GHG emissions and consequent climate change.

The risks from climate change are many, and vary from region to region. Sea level rise, glacial lake outburst; rainfall extremes involve risks of flooding. Some regions would face reduced rainfall whereas some would witness increase in incidences of extreme events. Urban areas would experience heat waves, particularly the enhanced heat island effect. Projected impact on coastal cities are even worse – loss of coral reefs, beaches, loss in tourist activities, floods and storms which would lead to complete devastation of

settlements and livelihoods. Tropical areas with warmer temperature are projected to face incidences of malaria, dengue and filariasis.

Indian cities are predicted to be at high risks due to climate change. This situation is accentuated due to expected 500 million people which are predicted to be added in 7,000 urban settlements by 2060 (McGranahan and Mercutollio, 2007). The predicted regional temperature rise along with the changes in the global climatic system would alter the monsoon system leading to increase of 7 to 20 % in the mean annual precipitation. A 10 to 15 % increase in monsoon precipitation, a decline of 5 to 25% in semiarid and drought prone central India and a decline in winter rainfall in northern India is also projected (Revi, 2008). The risks include decline in winter rainfall in northern India (Rupa Kumar et al., 2006), extreme precipitation events near the west coast (including Mumbai) and central India (Rupa Kumar et al., 2006) and a mean Sea Level Rise (SLR) up to 0.8 meters over the century (Aggarwal and Lal, 2001). In addition, hazards like expected cyclones and storm surges and glacial melt would result in high losses in infrastructure, livelihood and population. Expected increase in incidences of drought due to climate change leads to increased seasonal migration from rural to urban areas. These migrants in turn form the most marginalized and highly vulnerable groups in cities having limited skills, education, capital and limited social and economic mobility. Besides this, extreme precipitation-led floods have earlier caused large economic losses, particularly in State of Gujarat, and City of Mumbai. Earlier such events caused great losses of people, buildings, lifeline infrastructure and economic assets across ten coastal and six inland districts including number of towns and cities (TARU/BMTPC, 2000). Cyclones and storm surges could have devastating impact on coastal metropolitan cities of Mumbai and Chennai, million-plus cities of Vishakhapatnam, Surat, Bharuch, Bhavnagar, and Jamnagar. Vulnerable stretches to sea level rise lie along the western coast, Mumbai, parts of Konkan coast and South Kerala. Significant settlements would be lost in the deltas of Ganga, Krishna, Godavari, Cauvery and Mahanadi on the east coast.

These risks pose challenge to resource management and infrastructure planning and display urgency of the need to adapt city level operations to both current climate variability and future climate change. As against mitigation, which is primarily greenhouse gas reduction, adaptation is a fast emerging issue towards responses to climate change. This is because the cities that are greatly impacted by climate change are not the ones, which are high emitters of greenhouse gases.

Intergovernmental Panel on Climate Change 2007 describes adaptation as adjustment in natural or human systems in response to actual and expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Primarily three types of adaptation interventions exist. Anticipatory adaptation, also known as proactive adaptation, is the approach where adaptation is anticipatory to the impacts of climate change. Autonomous adaptation is spontaneous adaptation, which does not involve a conscious response to climate stimuli but is triggered by either ecological or human system changes. Planned adaptation involves deliberate policy decision based on the understanding that conditions have changed or are about to change and an action is required to either return to the original state or maintain the present state to avoid any further harm. At an operational level though, as Hannah et al. (2007) describe, the interventions involve technological changes, behavioural changes and policy decisions to support them. In the context of cities, the intervention involves targeting land use, infrastructure, transport, and social and economic security.

The following interventions are particularly important in cities' adaptation:

- **Relocation of residential population and economic activities to less vulnerable parts of the urban area**
- **Channelization of investments and new land uses towards less vulnerable areas**
- **Assisting poor and informal settlements to vacate vulnerable areas**
- **Sea surge protective barriers and dams**
- **Reconstruction of harbour facilities**
- **Building flood barriers and tsunami-prevention facilities**
- **Land use planning and building codes that internalize climate change constraints**
- **Use of vegetation and light colored surfaces reduce heat island effect**
- **Use of suitable design techniques to reduce energy consumption**
- **Climate proofing of infrastructure systems**
- **Protection/relocation of waste management facilities**
- **Hydro-geological consolidation work –flood defense system**
- **Emergency preparedness mechanisms**
- **Health facilities**

The issue of institutional setup to support adaptation is one of the foremost to confront while planning adaptation interventions. This holds particularly true in the Indian context as there are many challenges and development priorities that need to be addressed and climate change adaptation is not amongst them presently. However, the awareness and willingness towards this has increased and is reflected in India's National Action Plan for Climate Change (NAPCC), which clearly articulates adaptation as an important area of intervention for Indian cities and towns. However, institutionalizing adaptation in Indian cities is necessary as well as is a challenge due to the following:

- **Lack of understanding of the impacts of climate change and the fact that adaptation interventions are best employed and covered at the local level**
- **Creating awareness amongst the local government that adaptation is synonym to their functions and their development goals**
- **Translation of global impacts of climate change to local level has been missing**
- **Already pressing development pressures might overlook adaptation issues**
- **Lack of capacity within the local government**
- **Development plans of cities do not factor climate change related factors**
- **Integrating adaptation at municipal level would be difficult because of the perception of contest for budget**
- **Lack of data and modelling framework at the city level**

There is therefore a strong need to understanding impacts of climate change on Indian cities and assessing interventions to counter these impacts. The cities should be made resilient to climate extremes. This brings forth the need to mainstream adaptation in local governance. There is also the need to understand what adaptation planning entails, and how its components are in line with the development priorities of an urban area. This is also to understand that adaptation planning at city level is not a hindrance; rather it is an essential component of sustainable development and growth. Substantial research and development effort is required to better understand city specific impacts of climate change and to be able to design precise adaptation plans for them. The need is to recognize urban areas as important areas for research and identify the components for adaptation.

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Land Use Change in Meghalaya

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Human interventions in natural systems have resulted in large changes in vegetation composition and distribution patterns. Changes in land use and hence in vegetation cover, due to climatic change and human activity, affect surface water and energy budgets directly through plant transpiration, surface albedo, emissivity and roughness. Thus, there is a need for spatial and temporal characterization of vegetation cover at different scales. Satellite remote sensing provides detailed information regarding the spatial distribution and extent of land use changes in the landscape.

Meghalaya, in North-East India, is one of the most important, biologically rich landscapes. Degradation due to shifting cultivation, clear felling of forests for timber, and mining, have altered the natural landscape to a great extent. Because of these increased anthropogenic activities, the natural landscape has been modified which has resulted in a fragmented landscape with poor species composition. These changes in the landscape were analyzed using IRS 1A, 1B and Landsat Multi-Spectral Scanner (MSS) data during the period 1980-1995 by Roy and Tomar (2001) in their study “Landscape cover Dynamics Pattern in Meghalaya”.

Land use/land cover (LU/LC) change affects ecological energy flows and biogeochemical cycles at local to global scales. Anthropogenic disturbances in both natural and managed ecosystems can cause changes in ecosystem structure and function and potentially alter biogeochemical cycling and overall sustainability of ecosystems. For example, human-induced changes in forest

Forest cleared and burnt for cultivation

cover through deforestation have been shown to result in multiple ecological impacts, such as decreased biodiversity, degradation of soil conditions and changes in the balance of greenhouse gases. Similarly, land use change in agricultural ecosystems can result in changes in carbon fluxes, including soil organic carbon and carbon dioxide emissions. Traditional methods for examining land use change and impacts on various ecosystems have typically treated the socioeconomic and ecological effects independently. However, there is a need to define appropriate and measurable variables to understand and quantify social, cultural and biophysical phenomena in an integrated approach for understanding LU/LC change and their ecological impacts.

The total population of Meghalaya is 2,306,070 in 2001 census. Agriculture is the mainstay of the people of Meghalaya. About 85 percent of the population of the State lives in rural areas and depends on agriculture for its livelihood. Of the total geographical area, about 13 percent is under cultivation. Agriculture is in the primitive stage of shifting cultivation in major parts of the State.

Shifting Cultivation, known locally as "Jhum", is practiced extensively on the hillslopes in the Garo Hills and part of the Khasi and Jaintia Hills Districts. The soil and climatic condition of the State is suitable for growing different types of agricultural crops from cereals to fruits in both tropical and temperate climatic environment occurring on different altitudes. The State is rich in species of flora and varies from open scrub to dense forests. The rest is covered by mostly deciduous to evergreen forests and transitional tropical moist deciduous pine forests. The Jhum cycle in Meghalaya has been reduced to 3-5 years and in parts 1-3 years. The rationale behind the persistency of the system greatly lies in its compatibility with the physical environment. This has made the land highly unproductive and is alarmingly leading to extensive land degradation and imbalance in the socio–economic setup of the village community.

Jhum products of Garo Hills

Typical Khasi house in Khasi Hills

The rationale behind the continuation of Jhum cultivation also lies in these advantages of this system over settled cultivation. The village and community ownership of land and forest helps in reinforcing the system even if it is no longer viable and sustainable. With the growth of population and reduction on area available for jhumming, the rotation cycle has gone down to around 5 years. As a result, the fertility of soil and production from Jhum is constantly declining so much that the system of today has become hazardous that leads to progressive degradation of the production base. Due to intensive Jhum cultivation, soil erosion has increased.

Shifting cultivation is practiced in remote and scattered areas, and is becoming unsustainable due to increasing pressure on land resources. It is difficult to provide any meaningful development infrastructure to these areas due to the remoteness and scattered nature of the settlements.

Shifting cultivation is estimated to support currently between 300-500 million people worldwide.

An essential feature of Jhum is mixed cropping as though to imitate nature in terms of species diversity (i.e. as though to replicate the very forest- with all its species- that is been slashed and burned). The crops generally grown include rice, maize, tapioca, colocasia, cucurbits, chilies, ginger, sweet potato, turmeric, millet, cotton, tobacco, taro, etc. The large crops species over both space and time are effectively managed by sequential harvesting throughout the year.

A complete change or switch over from shifting cultivation is neither possible nor advisable in view of the terrain, fear of changes in tribal dietary habits and other viable alteration with immediate effect. Instead of changing shifting cultivation to another type, the effort should be to improve and control the process. Though the Government spent considerable effort to settle shifting cultivators and stabilize their farming techniques, large shares of forest land in the highlands are still cultivated.

Shifting cultivation is a dynamic process, which needs to be monitored every year. Using satellite data is the only source of getting authentic and current seasonal data to carry out such study. Therefore, to monitor the land use changes in the shifting cultivation areas, study-based remote sensing data and analysis through GIS-based input like mapping and analysis is a must. The research on land use change in Meghalaya is of great significance to prioritize land use planning programmed for sustainable development.

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Multifunctional Land Use in Semiarid Ecosystems in India – Development of Integrated Sustainability Evaluation Tools

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Indian agriculture is passing through a critical phase when gains accrued from the Green Revolution has slowly stabilized with little scope of increasing agricultural production further from the region. To meet the increasing demand of food and fiber in the country, increasing agricultural production in the rainfed regions namely, the semiarid and subhumid regions is critical; hence efforts to develop the region which is strapped for biotic resources and faces numerous abiotic stresses like rainfall variability, drought, pests, high temperature, water scarcity, poor fertile soils, etc., need to be continued. However, it is becoming increasingly difficult with competing demands for land.

The situation is further compounded with small fragmented holdings of 1 to 2 ha, which are cultivated in traditional way by millions of farmers who practice agriculture as a way of life even today. These farmers and their livestock require the traditional land use arrangement and any change would require the new arrangement of land use to take care of the interests of these two major players. This warrants the evaluation of multiple functions of Land Use and the advantage of newer uses over traditional ones and the tradeoffs if necessary for achieving sustainable development. For this purpose, it would be useful to develop an Integrated

Evaluation Tool (IET) that would help in evaluating sustainability of multifunctional land use for developing rural – urban linkages, and agriculture and allied sector linkages.

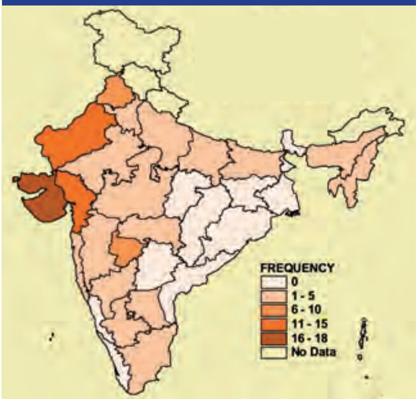
Challenges of semiarid tropical (SAT) Regions in India

Development of SAT region is understandably a priority for India as it covers 95.05 m ha spread across 283 districts in 11 states in the country. Equally fragile ecosystems like the arid and dry subhumid extend to 37.12 m ha which along with the SAT are vulnerable to climatic change that could impact lives of an estimated population of 130 million persons as in 2008 (NFHS, 2007). Climatic aberration, fall in dominance of agriculture sector, increased urbanisation, mining, infrastructure development, Govt. initiated projects, etc., have lead to change in the multiple functions of land in the region (Katyal et al., 1996). Obvious signs of this change are the spread of built-up area, fragmentation and loss of contiguous agricultural land, development of transport network, loss of small water bodies and encroachment at the fringes of large water bodies, shifting of rural population across the SAT region, and drift of rural people to urban center (Ramachandran and Padmaja, 2008).

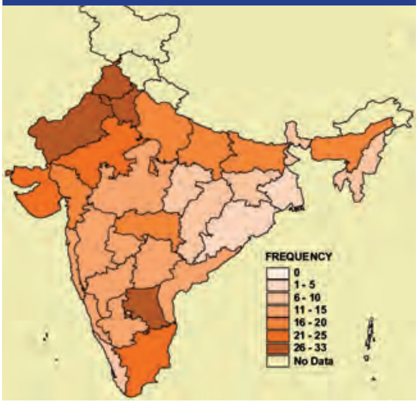
Research Approach

The changing nature of this relationship between agriculture and other sectors and the rural and urban land uses, has deep consequences both for quality of life for human beings in the region and for the fragile ecosystem, in particular. To understand the process that drive those changes we need to improve our knowledge and create better tools to assess the future environmental, social, and economic impacts of these changes. Only then can we identify effective strategies for planning of sustainable land use systems and functions in the SAT regions in India. The proposed Integrated Evaluation Tools (IET) would help in improving the understanding of multi-functionality of land use in the SAT and help in drawing informed policy decisions for sustainable land use in the

India: Severe Drought (1871-2004)

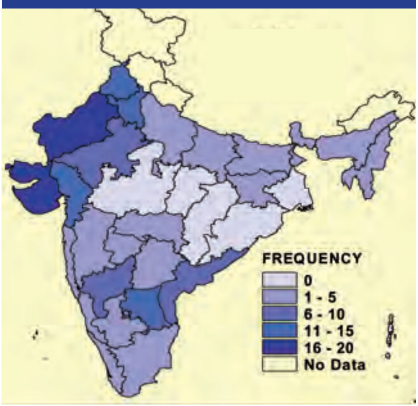


India: Moderate Drought (1871-2004)

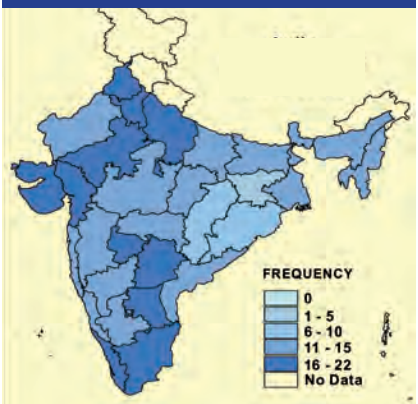


Incidence of drought during SW monsoon in met. subdivisions: Although rainfall variability is high, drought events are neither frequent nor always severe in rainfed areas

India: Severe Flood (1871-2004)



India: Moderate Flood (1871-2004)



Floods during SW monsoon in met. subdivisions: Rainfall variability more often leads to flood events region as in a ground – breaking study undertaken by ZALF for EU (Helming, 2009) and another study in Saarland, Germany (Kubiniok and Löffler, 2008).

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Integrated Land and Water Management under Changing Climatic Conditions in the Ecologically Fragile Mountain Region of North India

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India is home to almost 1.2 billion people and population growth is still high (1.6 % in 2008, estimated in CIA World Factbook, Version May 16, 2008). The population density of 349 inhabitants per km² (2008) is among the highest in the world, although the distribution is very uneven. Even though the ecologically fragile mountain region of North India is less populated, population and economic growth of the country will put a high pressure on land and water resources also in this region. Particularly the demand for energy and high-value food products will significantly increase. Above all, effects of climate change will have a strong impact on the environment and land use.

The Himalayan region of North India with the states of Jammu and Kashmir, Himachal Pradesh, and Uttarakhand are highly diverse in natural landscapes and culture. The states cover a wide range of altitudinal and climatic zones from the subtropical foothills and valleys to the Himalayan peaks and glaciers. The unique region includes various vegetation types, such as alpine meadows, alpine to subtropical forests, and subtropical grassland. These ecosystems are habitats of many rare and endangered species. Some of them, such as the snow leopard and the Bengal tiger, are icons of wildlife conservation. For this reason, large areas are protected as national parks and other conservation units. This applies particularly for the state of Himachal Pradesh, where forests cover about two thirds of the territory, of which 90 % are under protection. Altogether 11 national parks with a total area of about 14,300 km² are located in the three states. The Nanda Devi and Flowers National Park in Uttarakhand is listed as a UNESCO world heritage site.

While the alpine regions are sparsely inhabited, settlements and agricultural activities are concentrated along the fertile valleys and on the plateaus. The main Kashmir valley for instance is about 100 km wide and covers about 15,500 km² . Due to its favourable climatic conditions and fertile soils it is an important agricultural area and it is densely populated. The economies of all states highly depend on agriculture and tourism. Furthermore, hydropower became increasingly important, particularly in Uttarakhand.

The glaciers of the region are water sources for many important Indian rivers, such as the Ganges. Considering that these rivers supply water for domestic, industrial and agricultural use in densely populated economic areas of India, changes of the natural environment should be properly observed and analyzed.

Glacier retreat and permafrost thaw in the Himalaya have presently reached an alarming extent and speed and it is common understanding that the diminishing of these water resources must be attributed to climate change (ICIMOD, 2007). Studies reveal that it is likely that many glaciers will disappear completely with dramatic consequences for the natural and human environment. Some of the main effects discussed in literature are

- **Snow melt dynamics will shift with earlier peaks aggravating spring floods at the cost of the dry season base (Kääb et al., 2005), which in turn will affect rainfed and irrigation agriculture.**
- **Glacier melt will increase melt water volumes in headwater rivers, however, when glaciers further retreat or even disappear this amount will significantly be reduced in the future.**

- **Reduction in water supply from the glaciered headwater catchments will have negative impacts on the economy of the region by limiting the production of hydropower and thereby affecting the industrial productivity (World Bank, 2003).**
- **The role of ground ice in the hydrological cycle is largely unknown. Permafrost melt could for a limited time release additional water resources. On the long-term, however, adverse effects from permafrost thaw such as slope instability processes and changes in the sediment balance will likely predominate (Kääb et al., 2005).**
- **Melt water trapped in glacial lakes generates destructive Glacier Lake Outburst Floods (GLOFs) (ICIMOD, 2007), which endanger livelihood and property, particularly of the highly vulnerable poor.**
- **Rivers dammed by landslides are affected by flash floods (Subba, 2001).**
- **Surface water deficit during the dry season will pose considerable stress to present water management in downstream forelands and floodplains in both, water quantity and quality (Hilhorst et al., 2004).**
- **Increasing water stress will likely lead to enhancing of present water-related conflicts between different water users.**
- **Higher temperatures and reduced precipitation in the dry season will put environmental systems such as wetlands and indigenous forest under further stress, thereby contributing to the reduction of biodiversity.**
- **The low quality of rural livelihood and human health will be reduced by water stress impacting especially women and children of more vulnerable families, which might force them to leave rural settlements and migrate towards the cities causing consequent numerous social, economic and cultural implications for both the rural and urban areas.**

Considering the complex interactions between climate, the other geo- and biosystems and human activities, the author suggests integrated research approaches on the landscape level, including particularly the fields of hydrology, geomorphology, agricultural and soil sciences, biodiversity, and social sciences. The impacts of climate change can be assessed by downscaling of the global macro-scale resolution to a regional basin scale by Regional Climate Models (RCM). The results of the various areas should be integrated in a vulnerability model, which is an adequate instrument to develop adaptation and mitigation strategies.

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Land Use Changes due to Coal Mining Activities: A Case Study of Singrauli Coalfield, Central India

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Singrauli coalfield lies in central India and is managed by Northern Coalfields Ltd. (NCL), a subsidiary of Coal India Ltd. The coalfield covers an area of over 300 sq km and is one of the most important coalfields in India in terms of both reserves and productions. The coalfield produces high-quality coal used primarily for thermal power generation by many Super Thermal Power Stations (STPS) in the adjoining areas. Singrauli coalfield has coal reserves to the tune of 1789.41 million tonnes. There has been a steep rise in the coal production from 35.2 million tonnes in 1995-96 to 49.95 million tonnes in 2004-05.

The geology of the area is represented by Pre-Cambrian gneiss, schists, quartzites and phyllites, which are overlain by Gondwana rocks, defined by Talchir, Barakar, Barren Measures and Raniganj formations (Singh et al, 1997). The drainage in the area is defined by main Rihand river and its tributaries Kanchan and Mayar, besides many other smaller streams are also present. Drainage pattern is dendritic to sub-dendritic but at places structural control drainage has locally developed. Majumdar and Sarkar (1994) carried out a study on the impact of mining and related activities on the environment around Singrauli coalfield. They compared land use data of pre-mining and industrialization period with post mining and industrialization period in order to assess the impact on cultural and physical environment of Singrauli coalfield. Singh et al. (1997) also carried out land use change analysis in and around Singrauli coalfield using multi-temporal satellite data. They concluded that there have been larger scale

Singrauli region: Dry stream

changes in land uses between 1975 and 1991. These changes were mainly reduction in forest cover, and increase in the area under degraded forest. However, efforts by NCL under its 'Green Gold' programme have yielded good results in protecting the environment and reclamation of degraded lands during 1986-1991 period.

The present study makes an attempt to analyse the land use and land cover changes, which have taken place in the recent past (1993-2003). The study uses multi-spectral and multi-temporal data of Indian Remote Sensing Satellites pertaining to 1993 and 2003. Survey of India toposheet 63 L/12 on 1:50,000 scale was used for preparation of base map and familiarizing with the general topography of the study area. Besides, secondary data obtained from other published and unpublished sources such as Journal of Indian Society of Remote Sensing (JISRS), internet (www.ncl.nic.in, www.ntpc.com, www.sighi.nic.in), etc. were also helpful. Base map of the area having details such as settlements, road and railway line network, rivers and water bodies, etc. was prepared from Survey of India toposheets. Base map was superimposed on geocoded False Colour Composite (FCC) data for visual interpretation, which led to the identification of various land cover categories in the study area. Land cover categories such as agricultural land, wasteland, open scrub, open forest, dense forest, degraded forest, mine pits, over burden, etc. were delineated on the satellite data on the basis of photographic recognition elements.

Two time series data of 1993 and 2003 were used for monitoring the land cover changes, which have taken place due to the coal mining activities. Limited ground truth verification was conducted before finalization of the land cover maps. The maps were then digitized using ArcInfo GIS software and polygon topology was built assigning unique id for each polygon showing the land use category demarcated on the map. The area under each category of land cover was determined and a matrix was prepared to assess the changes, which have taken place during the 1993-2003 period, due to mining activities. It is interesting to note that the area under dense forest has been adversely affected and has reduced from 77 sq km in 1993 to only 2.0 sq km in 2003, primarily due to the new coal mining blocks where mining has expended into the deep inside the forest. However, open forest has almost remained the same during this period, but there is substantial increase in the open scrub from 6 sq km in 1993 to 61 sq km in 2003, mainly due to the plantation activities undertaken by NCL. The positive side of the coal mining activities and its related development in terms of industrial development (e. g. availability of water in the reservoir) has resulted in expansion of agriculture, which has shown an increase in area from 68 sq km in 1993 to 100 sq km in 2003. This increase is due to the declamation of the wasteland and bringing the land under agriculture due to the initiative of the NCL with local community. The wasteland has reduced from 21 sq km in 1993 to 3.0 sq km in 2003.

Change in Singrauli area under land cover from 1993 to 2003				
Land use category	**Area (km²) 1993**	**Area (km²) 2003**	**net change (km²)**	**% Change**
Agriculture	68.13	100.83	32.70	47.99
Dense forest	77.70	2.26	-75.45	-97.09
Open scrub	5.91	61.92	56.01	947.67
Open forest	54.15	50.75	-3.40	-6.28
Thermal power plant	6.59	7.08	0.49	7.47
Barren land	7.26	9.34	2.08	28.69
Water body	40.98	45.98	5.00	12.20
Mine pit	12.13	6.97	-5.15	-42.49
Over burden	11.79	12.17	0.39	3.28
Wasteland	21.60	3.34	-18.26	-84.55
Ash pond	5.18	0.77	-4.41	-85.09
River sand	0.84	0.41	-0.43	-50.94
Fallow land	0.00	10.43	10.43	10.43
Total	**312.25**	**312.25**		

The land use changes in Singrauli area represent a mix of positive and negative environmental changes from 1993 to 2003 period as has been assessed by the satellite data.

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Land Use and Watershed Management for Sustainable Development Using Geoinformatics

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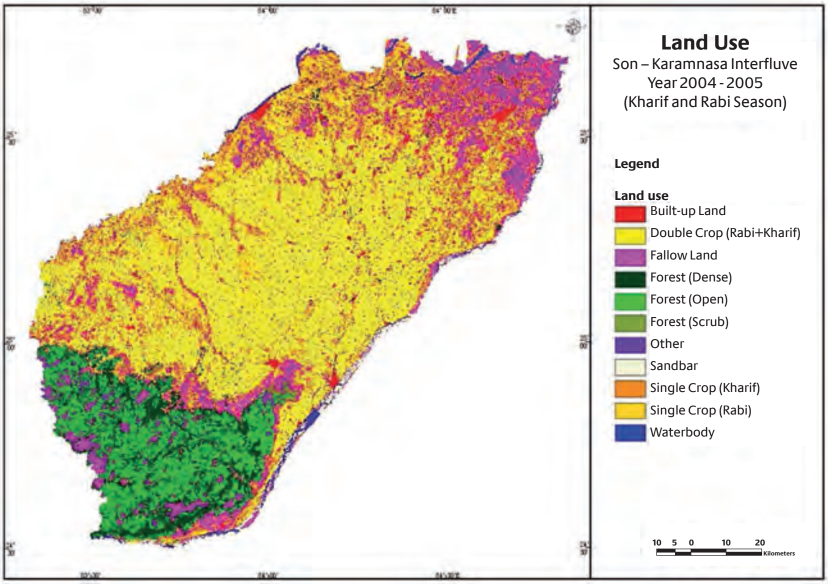
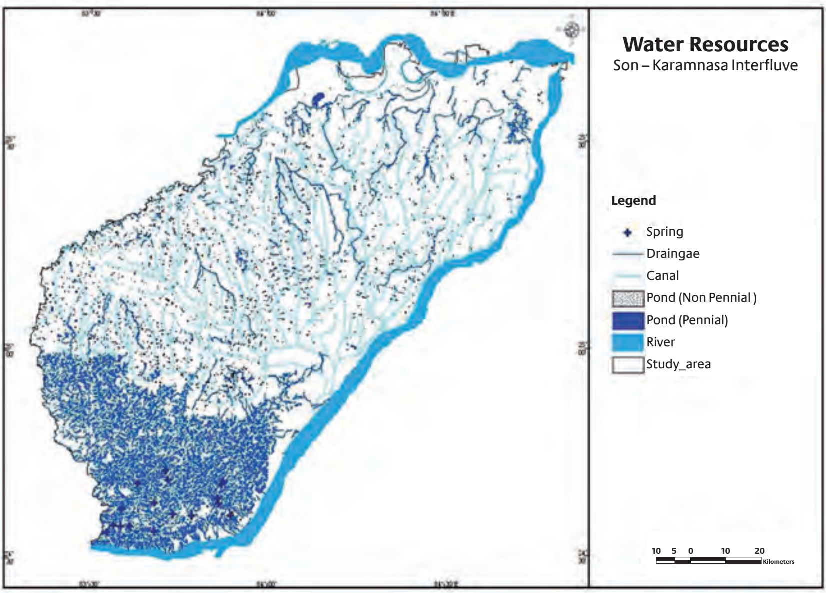
Natural resources, particularly land, water and energy, which form the basis for sustainable development, have reached a critical point by the anthropogenic pressure posed by the rapidly growing human population in India. Land use is one of the significant drivers of sustainability. More than 90 % of rural and nearly 30 % of urban population (Kumar and Singh, 2003) in India is dependent on ground water sources for meeting their drinking and domestic water requirements. It also forms the major source of irrigation. Frequent flood and drought are the regular phenomena (Singh, 2005). 60 % of Indian population depends on land-based biomass energy. In order to regenerate forests and vegetation cover for about 33 % from present about 20 % in India, land-based Joint Forest Management (JFM) is being implemented (Singh, 2009).

Such multiple requirements call for the optimum utilization of land in order to achieve sustainable development. After 73rd Constitutional Amendment, watershed development has been included in the schedule of subjects to be handled by panchayats (village government). This provides opportunities for combining development of grass roots democracy and land and water resources in an integrating way. This calls for an integrated watershed management for better utilizing land and water resources after taking into account the landscape synthesis and prevailing environmental conditions.



Geoinformatics-based spatial information technology has been applied to generate sustainable development plan for an area, which is optimally suitable to the terrain and to the productive potential of the local resources so that the level of production is sustained without decline over time. Geoinformatics include integration of data coming from remote sensing, GPS and conventional sources like Census and Survey of India maps etc. together with analyzing under Geographical Information System (GIS) framework (Jha and Singh, 2008). The objectives of the paper include (i) to monitor the existing land use pattern and changes, (ii) to promote the water harvesting structures for water resource development and (iii) to suggest integrated land and water management plan for sustainable development. Agriculture is the backbone of Indian economy. Agriculture and allied sectors like forestry, logging and fishing accounted for about 16 % of GDP and employ about 60 % of India's population. About 43 % of total



geographical area of the country is used for the land based agricultural practices. Despite a steady decline of its share in the GDP, agriculture remains largest economic sector and plays a significant role in the overall socio-economic development of India. Indian agriculture is dependent on monsoon. Rice and wheat are the principal food crops grown over the large tract (about 70 % of agricultural land) of the country.

The present study area – the Ganga sub-basin – is one of the highly densely populated and underdeveloped regions of India. Indian remote sensing data has been used for land use analysis. The region is predominantly alluvial plain with about one-fourth area under single crop, which should be taken into consideration for the optimum use. About 15 % of the area is under the fallow land and these lands can be used for other purposes. The analysis reveals that there is little area under forest category and more than

50 % are degraded in form of open and scrub forest. The analysis reveals that the double crop area can be increased from one-third to two-third area. In this way, geoinformatics have been very useful for land capability classification, predicting land degradation hazards like soil erosion taking into consideration of slope, vegetation, soil quality and rainfall intensity (Singh, 2006) using multi-criteria analysis.

Integrated land management plan should be based on participatory design, diagnosis and development incorporating responses of the people. The alternative land use systems like horticulture, agro-horticulture, agroforestry, fish culture and integration of livestock enterprises with the agriculture system have been suggested for integrated land management. For water resource development various water-harvesting structures like farm ponds, percolated tank, check dams, etc., have been suggested. These land and water resource development plans can increase the productivity and reduce wasteland to negligible level. The analysis reveals that about two-third of the total land should be used for double cropping. About 8 % and 3 % of the study area should be put under agro-horticulture and horticulture respectively. The watershed wise alternate land use model is prepared in such a way that every piece of land should have optimum use. Multiple land use options are well received by the people. Thus, geoinformatics technology is emerging as a tool for decision support system in land and water management in India.

The present study contributes required input for policy makers and other agencies for planning the best use of the available resources in order to improve the socio-economic and environmental conditions. The approach is gaining currency based on various interventions related to land and water resources at the micro-watershed level. There is a need to improve environmental governance in the country towards promoting sustainable development. Civil society, particularly business houses (companies), has to take a pro-active role. Recently the Citizen's Front for Water Democracy came into existence. However, there exist regional differences in the implementation. Thus, improving governance would ensure the supply of water to every field, remove poverty from poor areas, provide green cover

over deforested areas and improve the environmental quality. Integrated land and water management is also described as the programme that holds the key to solving problems of sustainability through improvement of employment, economy, exports, equity and environment.

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Steering Mechanisms for Sustainable Land Use and Protection of Groundwater Resources

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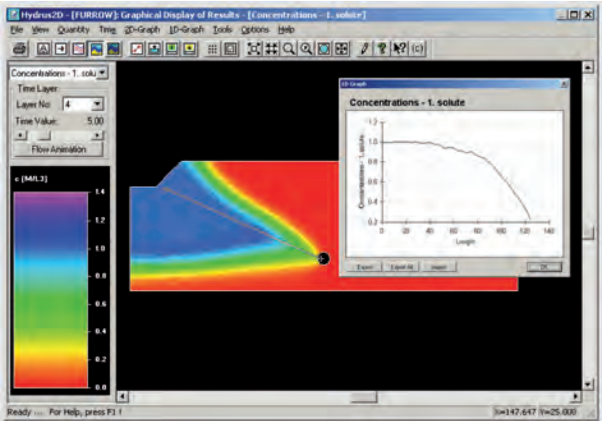
Water resources are easy to affect, because they are vulnerable to land use, as there is an interaction between both. Any form of excessive withdrawal or infiltration of pollutants can disturb their sensitive balance. To develop conceptions for sustainable water management, it is important to know all influencing parameters, which lead to direct consequences or interact in a secondary way. Arid and semiarid regions are increasingly faced by water shortages and degradation of water quality. Depletion of surface and groundwater resources is the result of growing water demand and sometimes ineffective water use of domestic, industrial and agricultural sectors.

Risk management is done considering all processes from the release of contaminants at the surface along the pathway within the unsaturated zone to the groundwater resource. The main focus is generally on groundwater vulnerability to contamination, which is the evaluation of the unsaturated zone with respect to their protective function to groundwater, and the potential threat (hazard). The evaluation of the potential risks of land use for groundwater resources is usually implemented using geographic information systems producing maps with the relevant information.

Especially the conversion of native grasslands and forests to agriculture and urbanization are anthropogenic effects in changing land use, which have a great impact on groundwater resources. With regard to land use, agricultural practices are often the most significant sources of



Modelling of contaminant transport to groundwater

health-related groundwater pollution. Nitrate contamination can be found in many parts of the world mainly due to the large land area used for agriculture and the use of different forms of fertilizers to increase production yield. A wide range of pesticides can also be transported with the percolation water and contaminate the groundwater. In order to avert the resulting danger to human and the environment the impact of land use on groundwater resources is one focus to identify potential contamination risks and to ensure a sustainable and integrated groundwater management.

One of the important modules of an information system is the evaluation of the impact of land use on groundwater vulnerability to contamination. Vulnerability assessment and the quantification of the pollutant impact into the water resources using newly developed methods can be implemented together to produce quantified vulnerability maps as basis for water management concept with a decision support.

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Lower than Expected Risks of Wastewater Irrigated Agriculture along the Musi River, India

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One result of the growing water scarcity in many parts of the world is that wastewater is increasingly used for irrigation purposes. According to the WHO, more than 10 % of the world's population consumes food produced by irrigation with wastewater (WHO, 2006). In India, an example of wastewater-irrigated agriculture can be found along the Musi River.

The Musi River flows through the city of Hyderabad, collecting more than one million litres of wastewater per day (Amerasinghe et al., 2008). Only some of this wastewater receives treatment before being discharged into the Musi. A variety of food and non-food crops is irrigated with this water supporting the livelihoods of the households of thousands of farmers along the river. In a research project funded by the German Federal Ministry of Economic Cooperation and Development (BMZ) and coordinated by the International Water Management Institute (IWMI), risks and benefits of wastewater irrigation in six villages along the Musi River were analysed from 2006-2008. The international research team consisted of scientists from the fields of public health, soil and agricultural sciences, social and economic sciences and geography.

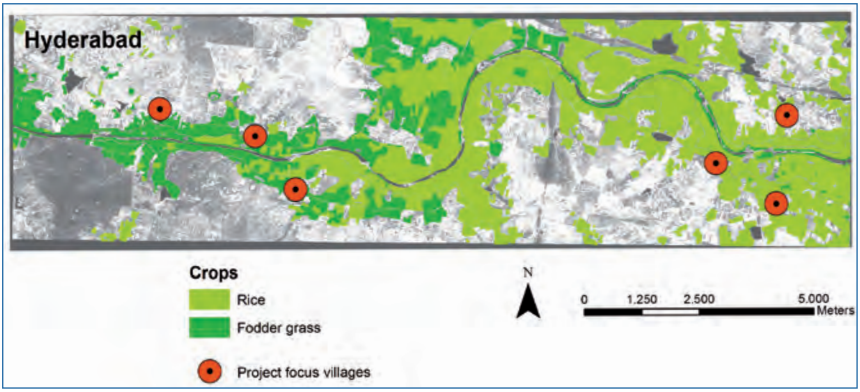
The Musi River near Hyderabad

Rice farming with river water

The vast majority of the households in the research area (88 %) were involved in agriculture. On most of the agricultural area (86 %), river water was used for irrigation.

Among the risks of wastewater irrigation that have been mentioned most in the literature are health problems, in particular hookworm infections and environmental pollution, especially soil pollution (WHO, 2006). However, contrary to expectations, the levels of parasite infections in the research villages along the Musi River were low. In four out of six of the research villages, no hookworm infections were found. Also the levels of other parasite infections were low (Amerasinghe et al., 2008).

Also with regard to levels of heavy metals in soils and crops, the situation was not as serious as generally expected: levels of Lead in all soil samples and levels of Zinc in almost all soil samples analysed were significantly below the EU Maximum Permissible Level (MPL). With regard to Cadmium, even though some of the soil samples exceeded the MPL, there was hardly any uptake of Cadmium by plants due to a high soil pH (ibid.). Another unexpected finding was that, contrary to previous suggestions (compare for example Clemett and Ensink, 2006), biodiversity under wastewater



Fodder grass and rice production along the Musi River

irrigation did not decline. A great variety of vegetables was produced with Musi water (Jacobi et al., 2009). One strategy of farmers to cope with the high nutrient load of the river water was to change the crops they cultivated: in locations close to the city, the predominant crop rice was replaced by fodder grass and in the case of vegetable farmers irrigating with river water, green leafy vegetables were produced instead of fruit-bearing vegetables.

This research shows that, contrary to common perception, wastewater can be regarded as a valuable resource. Properly managed, wastewater irrigation can make an important contribution to providing fresh, affordable food to rapidly growing populations of cities in water scarce regions.

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Land Use Changes and Conservation of Water Resources in Himalayan Headwaters

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In Himalaya, nature of terrain and climate impose severe limitations on the scale of productive activities as well as on efficiency of infrastructural facilities. As a result, biomass based subsistence agriculture constitutes the main source of rural livelihood, and more than 75 % of population depend on traditional agriculture even though the availability of arable land is severely limited and productivity is poor. During recent years, a variety of changes have emerged in the traditional resource-use structure in Himalaya, mainly in response to population growth, and the resultant increased demand of natural resources. Moreover, global climate changes have already stressed natural ecosystem through higher mean annual temperatures, altered precipitation patterns, more frequent and extreme weather events, and forest fires in Himalaya.

These are intensifying land use and exerting sharply accentuated pressure on natural resource base of headwaters, which constitute crucial areas for the conservation of water resources. As a result, critical natural resources, such as land, water, forests, biodiversity, etc., have depleted steadily and significantly, leading to their conversion into degraded and non-productive wastelands, reducing groundwater recharge, and disrupting the hydrological regime of Himalayan headwaters. Hence, the regime of water resources in Himalaya is changing rapidly, with respect to water discharge, volume and availability.

Women carrying compost manure to farmland

The main objective of the paper is to interpret the trends and magnitude of land use changes in ecological and socio-economic backdrops and to assess their impact on water resources, and to evolve an integrated land and water management framework with a case illustration of Kosi Headwater in Kumaon Lesser Himalaya, Uttarakhand, India. The paper attempts to bring out: (i) a detailed analysis and appraisal of land and water resources, using satellite data and Geographic Information System (GIS); (ii) interpretation of community resource utilization patterns in varying ecological and socio-economic situations through conducting comprehensive socio-economic surveys using exclusively designed schedules and questionnaires; (iii) monitoring land use dynamics using multi-date satellite data; (iv) analysis of land use and water interactions using field survey and mapping techniques, hydrological monitoring and integrating data in Geographic Information System (GIS); and (v) evolving an inclusive, adaptive and participatory land and water resource management framework.

A hamlet of the village surrounded by mixed agricultural land use

The study revealed that out of total area (107.94 km²) of the headwater 7.81 % has changed from one land use to other between 1978 and 2008. Cultivated land has increased by 14.33 %, forests have declined by 4.36 %, and barren and degraded land has increased by 2.14 % during last 30 years. It was investigated that the amount of surface run-off from cultivated (80 %) and barren lands (85 %) is much higher compared to that of forests (25 %).

Consequently, ground water recharge has reduced drastically mainly due to a decrease in forest area. These hydrological disruptions are now clearly discernible in (i) long-term decreasing trend of stream discharge, (ii) diminishing discharge and drying of springs, and (iii) biotic impact on surface run-off flow system and channel network capacity. Nearly 33 % of natural springs have dried out, 11 % of springs have become seasonal, and a

streamlength of 736 km has dried. More than 61 % villages of the watershed are facing great scarcity of water for all purposes. All this undermines livelihood and food securities of both highland and lowland population dependent primarily on subsistence agriculture. Consequently, supply of biomass to agriculture has declined (41 %), irrigation potential has reduced (18 %) and food productivity has decreased (25 %), increasing deficit levels in food, fodder and fuel-wood respectively by 32 %, 20 % and 27 %. Integrated land and water management framework, which evolved for the region is based on terrain and hydrological characteristics, and developmental needs and priorities of local people. It makes provisions for water-conserving forestry and horticultural practices, rainwater harvesting schemes, livelihood improvement through cultivation of less water requiring and drought resistant food as well as cash crops, and enhancing resilience of both natural and human systems to long-term impacts of climate change based on local knowledge and in agreement with local communities and government agencies.

Further Readings

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Agricultural Sustainability – Securing Food Supply and Income in Rural Areas

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Even under the optimized conditions of modern agriculture, about one third of the potential annual crop harvest is lost to pathogens, pest, and competing weeds. Large-scale losses in cereal production in the 1950s due to devastating fungal epidemics triggered the Green Revolution, culminating in the development of disease resistant, high yielding crop varieties. These, however, typically require extensive irrigation, fertilization, and chemical plant protection.

While the Green Revolution has helped combat hunger worldwide - and nowhere more efficiently than in India - we are currently entering a situation in which the growing world population once again faces decreasing crop productivity. This is in part due to a combination of decreased availability of irrigation water, increased irrigation-caused soil salinity and soil nutrient exhaustion - all of which appear to be more pronounced in tropical and subtropical compared to temperate regions. The situation is further aggravated by the increasing occurrence of novel fungicide-resistant or highly virulent pathogen strains, global trafficking of crop diseases, global climate change, loss of arable land by urbanization, increasing meat consumption in countries such as China and India, and the increasingly large scale production of energy plants. Clearly, a new and more sustainable Green Revolution will be required to meet this challenge. We strongly believe that this time, the concept must and can come from the emerging tropical and subtropical countries themselves, rather than from the developed temperate countries.

Chitosan-based seed coatings; groundnut: + ≥ 25 %

A joint effort of German and Indian researchers will certainly have the potential to develop sustainable solutions far beyond the immediate needs of our two countries. To be successful, this approach will need to integrate the best – i. e. the most efficient, the most environment friendly, the most consumer safe, the most sustainable – solutions offered by biology, biotechnology, and agrochemistry. Agrochemistry may supply functional plant protectants, plant strengtheners, plant safeners, and fertilisers. Biotechnology may supply disease resistant plants, plants with enhanced salt or draught tolerance, and enhanced nutrient or water use efficiency. And biology may supply plant growth promoting rhizobacteria, biocontrol agents, and bio-fertilisers. It will be of paramount importance to integrate these approaches in an interdisciplinary way, at the same time making use of the large potential of international collaboration, e. g. mobilizing the advanced agrochemistry resources in Germany, the advanced research avenues into biologicals in India, and the rapidly evolving biotechnology potential of both countries.

As an example, we propose to develop a sustainable approach to plant protection based on bio-control agents synergistically combined with advanced techniques of protein and polysaccharide engineering and biotechnology. This project would rely on ample prior research of partners from Academia and Industry in Germany and India, partly individual and partly joint Indo-German projects, financially supported in the past by both national and international agencies, aiming at realising the largely untapped nanobiotechnological potential of chitosan – an added-value product that can be generated from e. g. shrimp shells, i. e. from a problematic waste by-product of the fishery industries. The enzymes needed for the upgrading of raw chitosan into bio-engineered speciality chitosans with known and reliable physico-chemical properties and biological functionalities can be found in a number of recently identified novel sources of biodiversity found in India.

To be successful, such a research project will need to have a strong local, bottom-up approach that takes into account regional diversity in both biology and sociology. There will also be the need for a transdisciplinary approach including the people directly involved in the planned use of the research results, both from industry and from agriculture. Therefore, relevant stakeholders from biotech companies and local farmers should participate in the project from its planning stage to ensure smooth technology transfer into practical use.

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Cluster 4: Securing Food Supply and Income in Rural Areas

1. Agricultural Sustainability – Securing Food Supply and Income in Rural Areas

Acronyms and Abbreviations

ABETS	Advanced Bioresidue Energy Technology Society
ADB	Asian Development Bank
AI	Andaman Island
AOGCM	Atmosphere-Ocean General Circulation Model
AR4	Assessment Report 4
BARC	Bhabha Atomic Research Centre
BAS	Barium Aluminosilicate
BCAS	Barium Calcium Aluminosilicate
BMBF	German Federal Ministry for Education and Research
BMELV	German Federal Ministry of Food, Agriculture and Consumer Protection
BMS	Barium Magnesium Silicate
BMTPC	Building Materials and Technology Promotion Council, Ministry of Housing and Urban Poverty Alleviation, Government of India
BMU	German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

BMWI	German Federal Ministry of Economics and Technology
BMZ	German Federal Ministry for Economic Cooperation and Development
BOD	Bacterial Oxygen Demand
BRICS	Brazil, Russia, India, China and South Africa
CAP	Common Agricultural Policy
CCM	Climate Change Mitigation
CDM	Clean Development Mechanism
CED	Cumulative Energy Demand
CETP	Common Effluent Treatment Plant
CFD	Computational Fluid Dynamics
CGCRI	Central Glass and Ceramic Research Institute
CGPL	Combustion, Gasification and Propulsion Laboratory
CIA	Cultural Impact Assessment
CNGI	Cluster Network Germany-India
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COD	Chemical Oxygen Demand

CORINE	Coordination of Information on the Environment
CSIR	Council of Scientific and Industrial Research
CTE	Coefficient of Thermal Expansion
D4S	Dialogue "Sustainable Solutions – Science for Sustainability"
DAE	Department of Atomic Energy
DBT	Department of Biotechnology
DPSIR	Driving Forces-Pressures-State-Impacts-Responses
DST	Department of Science and Technology
EE	Energy Efficiency
EEA	European Environmental Agency
EEC	Excellence Enhancement Centre
EIA	Environment Impact Assessment
EPT	Energy Payback Time
ESCO	Energy Service Companies
ESS	Ecosystem Services
ESSP	Earth System Science Partnerships
EU	European Union

FAO	Food and Agriculture Organization of the United Nations
FCC	False Colour Composite
FNR	German Agency for Renewable Resources
G8	Group of Eight
GBA	Global Biodiversity Assessment
GDP	Gross Domestic Product
GET	Global Engineering Teams
GH	Gas Hydrates
GHG	Greenhouse Gas Emissions
GHGs	Greenhouse Gases
GHSZ	Gas Hydrate Stability Zone
GIS	Geographic Information System
GLP	Global Land Project
GMO	Genetically Modified Organism
GPD	Global Product Development
GRIDS	Global Research for Industrial Development in Sustainability
hh	Households

HIA	Health Impact Assessment
ICMR	Indian Council of Medical Research
IEEP	Institute for European Environmental Policy
IGBP	International Geosphere-Biosphere Programme
IGCAR	Indira Gandhi Centre for Atomic Research
IGEF	Indo-German Energy Forum
IGSTC	Indo-German Science and Technology Centre
IHDP	International Human Dimensions Programme on Global Environmental Change
IIT	Indian Institute of Technology
IPCC	Intergovernmental Panel on Climate Change
ITER	International Thermonuclear Experimental Reactor
IWMI	International Water Management Institute
JFM	Joint Forest Management
JISRS	Journal of the Indian Society of Remote Sensing
JNU	Jawaharlal Nehru University
KGB	Krishna Godavari Basin
LCA	Life Cycle Assessment

LIA	Livelihood Impact Assessment
LPG	Liquefied Petroleum Gas
MAS	Magnesium Aluminosilicate
MIA	Millennium Impact Assessment
mmt	Million metric tonnes
MNRE	Ministry of New and Renewable Energy
MoP	Ministry of Power
MPL	Maximum Permissible Level
NAPCC	India's National Action Plan on Climate Change
NBRAP	National Biomass Resource Atlas Project
NCL	Northern Coalfields Ltd.
NFAP	National Forestry Action Programme
NGO	Non-governmental Organization
NRSA	National Remote Sensing Agency
OECD	Organization for Economic Co-operation and Development
PEM	Polymer Electrolyte Membrane
PIA	Psychological Impact Assessment

PIK	Potsdam Institute for Climate Impact Research
PPP	Public-Private Partnership
R&D	Research and Development
R+M	Rehabilitation and Modernisation
RE	Renewable Energy
RFC	Regional Forest Change
RWTH Aachen	RWTH Aachen University (Rheinisch-Westfaelische Technische Hochschule Aachen)
S&T	Science and Technology
SG	Sub-groups
SIA	Social Impact Assessment
SLR	Sea Level Rise
SOFC	Solid Oxide Fuel Cell
STPS	Super Thermal Power Station
TBS	Technical Building Services
TEK	Traditional Ecological Knowledge
TERI	The Energy and Resources Institute
UASB	Upflow Anaerobic Sludge Blanket

UNEP	United Nations Environment Program
UNU	United Nations University
WCED	World Commission on Environment and Development
WEC	Wind Energy Converter
WHO	World Health Organization
YSZ	Yttria-stabilized Zirconia

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and Research

Sustainable Solutions
Science for Sustainability