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A Socio-Technical Approach in South India

With a Foreword by

Prof. Dr. R.C. Agrawal

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Foreword

This work deals with the very timely theme of enhancing energy efficiency in irrigation, exemplified by a pilot project in the state of Andhra Pradesh in India.

Notwithstanding its declining contribution to the national gross domestic product, a natural corollary to the development process, the agricultural sector in India is still crucial to the all-round development of the nation. The sector currently employs nearly half of the population and has a critical role to play in the attainment of the national goals of increasing food security and reducing rural poverty. The temporal growth pattern of the Indian economy in the last decades bears out the direct and significant relationship to the state of agriculture today.

In the last fifty years, Indian agriculture has made tremendous progress, initiated by what is commonly known as the Green Revolution. Food production rose from 82 million tons in 1960–1961 to an estimated 263.2 million tons in 2013–2014. The Green Revolution was primarily characterized by employment of a package of practices—seeds, fertilizer, irrigation, and plant protection measures—to be supported by strong institutions. Irrigation occupied a pivotal role among these mainsprings of production growth, enabling the cultivation of two or more crops per year from the same piece of land. Due to huge investments in irrigation, the irrigated area in India now exceeds 63 million hectares, the largest of any country in the world.

However, the Indian irrigation system is highly inefficient. According to the Agricultural Outlook 2014–2023, jointly published by the United Nations Organization for Economic Co-operation and Development and the Food and Agriculture Organization (OECD-FAO), "India has one of the world's largest irrigation systems but it also faces high levels of inefficiency, particularly for those relying on surface water sources, the efficiency for which is estimated at 35–40 %, as opposed to ground sources, whose efficiency is estimated at 65–75 %. More serious is the problem of groundwater depletion, which is viewed to be in crisis as a result of excess extraction, due in part to the lack of regulated use and power subsidies which lower extraction costs".

The use of electrically powered irrigation pumpsets in India is increasing at a brisk pace of about half a million per year. More than 19.17 million pumpsets had been installed in India by the end of November 2014, with the figures for 1999 and 2009 being 12 million and 16 million, respectively. With increasing use of pumpsets, energy consumption for irrigation has also increased rapidly, growing at a compound rate of about 7 % between 2006 and 2012. India imports nearly a third of its total energy needs, with the government's Twelfth Plan estimating that it would need to import 29 % of its energy by 2016–2017, increasing to 31 % by 2021–2022, thereby putting heavy pressure on the national balance of payments. Oil subsidies put an additional burden—amounting to 0.8–1.1 % of the national gross domestic product in Fiscal Year 2013–2014—on the national exchequer.

Thanks to factors like abominable infrastructure, weak institutions, poor planning and implementation of projects, introduction of agricultural measures without adequately involving farmers, inappropriate equipment, and high subsidies, energy use in Indian agriculture is utterly suboptimal today. The average efficiency of pumpsets is estimated to be barely 30–35 %. However, through achievement of a stable electricity supply and more efficient pumping, the input of electricity for five-horsepower pumpsets could be reduced by up to 40 %.

The recent decline in global oil prices has somewhat eased the pressure on energy import costs for India, yet there is no room for complacency, and the necessity of enhancing efficiency in the use of energy and irrigation water is even greater, especially when climatic consequences are also taken into account.

This SpringerBrief seeks to make a valuable contribution in this direction through presenting the methods and results for a pilot project conducted in the Indian state of Andhra Pradesh. The design of the project is conspicuous by its incorporation and examination of the relationships between social, institutional, and technical variables. In observing that some social problems encountered during the project would not have occurred if certain technical problems had been absent and that these technical problems were able to be absorbed with proper social implementation, the necessity of intense and long-term relationships among various stakeholders for enhancing energy efficiency is highlighted. This reinforces the significance of one of the hitherto well-known but rather less-appreciated ingredients for the success of a development project: all stakeholders must be active participants throughout all of its phases and must also be made to feel involved in it.

Though the findings presented here relate to the state of Andhra Pradesh in India, the lessons have wider relevance. Farmers do not want cheap, subsidized, or free energy which is unreliable. They rather prefer to pay more for a timely, trustworthy, and stable energy supply. This would be a win–win situation for all stakeholders involved.

Berlin Prof. Ramesh C. Agrawal

Preface

In 2008, the German Ministry of Education and Research launched the Future Megacities program, the aim of which was to identify scope for improvement in energy efficiency and climate change mitigation and adaptation strategies for rapidly growing megacities expected to reach a population size of ten million inhabitants within the next five years. Hyderabad, the capital of India's fifth largest state Andhra Pradesh,[1] was selected as one of these cities, with Humboldt-Universität zu Berlin, together with German and Indian partners, leading the project there. One focus, which became the theme of this SpringerBrief, was dedicated to challenges facing the power sector in Andhra Pradesh. As the agricultural electricity sector in Andhra Pradesh consumes about 30 % of total end-use in the state, it ends up playing a critical role for the urban electrical energy supply there. Consequently, the project consortium initiated a research agenda exploring possibilities for increasing energy efficiency in agriculture. Based on the findings from extensive field research, a pilot project was developed, the aim of which was, first, to understand existing agricultural electrical energy supply problems directly, from practice, and, second, to provide low-cost solutions which can be implemented independently of external funding. The relationship between social, institutional, and technical factors played a key role in the design of the project. Within the pilot project, about 800 shunt capacitors were installed to agricultural pumpsets used for irrigation in areas of rural Andhra Pradesh. Thirty farmer committees were formed, consisting of all farmers who participated in the project. The results were positive overall. Technically, an improvement of the power factor, an indicator of power supply quality, by about 16 % was measured, and field observations revealed an increased interest of farmers in the technology as well as regarding other aspects of irrigation and electricity. However, it was also realized that a narrowly technical approach can easily lead to failure, and intensive work with farmers is, in the end, a strong prerequisite for successful implementation. In practical

[1] On 2 June 2014, Andhra Pradesh was divided into two states, Andhra Pradesh and Telangana. As the pilot project ended in 2013, we will only consider the former state Andhra Pradesh in the SpringerBrief.

terms, severe problems with the capacitors occurred just after installation due to various reasons, including faulty maintenance and high-voltage fluctuations within the power system. This turn of events tested the robustness of the project in terms of social trust in the face of technical failures. It turned out that in villages, where the hold of the project was not strong, the project failed. Yet, in other villages, where more trust-building work had taken place, replacement of the failed equipment led to increased confidence among the farmers. All things considered, significant improvements can be achieved from upscaling the project. Assuming that all major electrically operated agricultural pumpset motors in Andhra Pradesh were to be equipped with a capacitor, overall energy savings could amount to 1,337 GWh per year, which would be equivalent to 1,216,623 tons of carbon dioxide equivalents emissions.

This SpringerBrief provides a comprehensive overview of the above-outlined project, including detailed description and analysis of how it was carried out. Background information on the power sector in India and Andhra Pradesh is also given, focussing on the special case of agricultural electricity supply and discussing strategies to improve it.

Project Background

The pilot project described here—Implementing Cooperative and Technical Solutions to Increase Energy Efficiency in Irrigation—was part of a research project on sustainable development in future megacities called Climate and Energy in a Complex Transition Process towards Sustainable Hyderabad: Mitigation and Adaptation Strategies by Changing Institutions, Governance Structures, Lifestyles and Consumption Patterns (hereafter, Sustainable Hyderabad). The Sustainable Hyderabad project was financed by the German Federal Ministry of Education and Research and consisted of the following German and Indian research institutions as its main partners: Humboldt-Universität zu Berlin; the Potsdam Institute for Climate Impact Research; Georg-August-Universität Göttingen; the nexus Institute for Cooperation Management and Interdisciplinary Research; and PTV Traffic Mobility Logistics AG, from the German side, and The Energy and Resources Institute, Delhi; Centre for Economic and Social Studies, Hyderabad; Osmania University, Hyderabad; International Crops Research Institute for the Semi-Arid-Tropics; and the National Institute of Technology, Warangal, from the Indian side. Additionally, each partner worked together with local bodies in Hyderabad, including ministries, governmental organizations, NGOs, other research institutes, and private consultants.

The Sustainable Hyderabad project's time frame ran between November 2008 and June 2013, focussed on different aspects of sustainable city development, including energy, water, transportation, food, health, and pollution. These topics were subgrouped into work packages and handled by the respective partners, each conducting their research from 2009 to 2011, including surveys, case studies, expert interviews, and theoretical calculations. The results of this initial work were used to initiate eight pilot projects from 2011 onwards, three of them in the energy sector. The Sustainable Hyderabad project came to an end in June 2013, issuing a Perspective Action Plan giving policy recommendations towards a more sustainable Hyderabad. A detailed description of the Sustainable Hyderabad project and additional information are available at www.sustainable-hyderabad.de.

Structure and Intention

This SpringerBrief outlines relevant aspects of the pilot project Implementing Cooperative and Technical Solutions to Increase Energy Efficiency in Irrigation in order to provide a basis for further discussion and implementation of such interventions. The overall aim of the project was to identify solutions for partly solving agricultural energy and water problems in Andhra Pradesh. The Sustainable Hyderabad project's research is focused on climate change adaptation and mitigation strategies, which the initiatives undertaken in the pilot project used as a primary guideline for implementation.

Here, the structure of this SpringerBrief will be summarized so as to guide readers on how best to read and understand it according to their interests. The SpringerBrief is divided into two main parts. *Part I: Background* deals with topics that are necessary for understanding the rationale of the pilot project, while also providing relevant information for readers who are not interested in the pilot project itself but want to acquire an understanding of topical issues in agricultural power supply, including solution strategies. *Part II: Pilot Project* presumes familiarity with the contents of Part I and explains the pilot project in detail. Readers who are already familiar with agricultural electrical energy supply in India, however, can start there directly.

Looking in more detail at the contents of this SpringerBrief, the first chapter introduces some basic concepts of power supply in India and briefly explains the persisting dilemma of low electrical energy quality for agriculture there. Chapter 2 provides information on the development of the power sector in particular Andhra Pradesh and India more generally, summarizing its current status with an emphasis on agricultural power supply and discussing the implications for farmers and other stakeholders of its flat-rate electricity tariff. Chapter 3 discusses strategies that can help reduce the power supply problem in this context. Section 3.1 summarizes recently completed and ongoing projects that have sought to improve the power supply for agricultural use in India. The Bureau for Energy Efficiency has, for example, initiated several large-scale projects which involve replacement of agricultural motors and initiation of high-voltage distribution systems. Apart from this, there have been smaller projects initiated by NGOs or universities trying to focus on farmers' involvement in managing power distribution. One example is the Lok Satta project, which established transformer committees for farmers in Andhra Pradesh. Section 3.2 discusses available options for improving farmers' supply situation, distinguishing between low- and high-cost solutions as well examining the interrelations between technical solutions and institutional requirements. We thereby draw a line between projects that aim to *replace* inefficient equipment, for example agricultural pumpsets, and projects that aim to *improve* the system with minor, but affordable technologies, even for farmers. Smaller solutions are more interlinked with the current institutional set-up than larger solutions and related technological changes, and a holistic approach demands the incorporation of technical and institutional solutions. Chapter 4 introduces some technical background information, explaining the Indian system of generation, transmission and distribution as well as the pumpsets, motors and capacitors in agricultural power supply there. This is important for gaining an understanding of some of the technical specifics that were part of the whole project's rationale. It is not necessary to be an electrical engineer to understand this chapter, as it is aimed to provide simple explanations reduced to the necessary facts and results. Readers who are aware of these basics can, however, skip the chapter.

Chapter 5 introduces Part II. Chapter 6 is perhaps the most important chapter in the entire document, as it gives an overview of all relevant topics required to understand the pilot project. First, the partners comprising the project team and the region where the project took place are introduced. Then, the stakeholders' aims, rationale, and technical and social approaches employed are explained and discussed. The technical and social approaches are discussed separately, though the project worked under the assumption that only a combination of both approaches could lead to project success. Chapter 7 summarizes the different steps in the project in chronological order, split into three phases: preparation and planning, implementation, and evaluation. The preparation and planning phase was used for undertaking intensive research in the project region in order to develop the overall concept and to select the technology, specific electrical feeders, and farming villages for the intervention. After having set up a detailed project plan, the implementation phase was initiated. This phase included awareness-raising meetings for farmers, installation of capacitors, and the establishing of farmer committees; we report on the conducting of this phase and discuss problems that arose during it. The evaluation phase primarily consisted of the measurement of technical parameters and was already initiated during the implementation phase. Different evaluation methods are compared, and the main hurdles encountered during evaluation are discussed here. The results of the evaluation are then discussed in Chap. 8, where we present the key performance indicators of the capacitors and use the resulting data for a marginal abatement cost analysis to compare the cost-effectiveness of the chosen solution in terms of carbon dioxide emissions with other available technologies, such as efficient motors and solar water pumpsets. Apart from the technical results, we briefly discuss some observations from the field, including what did and did not work. Finally, based on the results, Chap. 9 discusses the upscaling potential of the project, distinguishing between regional and technical upscaling and providing some ideas for a business model.

Finally, the last chapter summarizes the project and provides an outlook for further projects and research.

Work for the pilot project was complemented by several masters' and doctoral degree research investigations, some of the results of which have already been published in international journals and books. Throughout the text, the reader will find boxes summarizing some results of this research.

Relevance of this SpringerBrief to Other Areas and Contexts

In many countries, dependence on groundwater irrigation for agriculture is growing, while water and energy resources are becoming scarcer. Reasons for these tendencies are manifold and, in the context of climate change, irrigation is often considered as an adaptation measure, enabling farmers to be more independent of extreme heat waves, periods of no rain, and unpredictable weather events. But irrigation comes at the cost of increased usage of ground or canal water and energy resources, which are often not abundantly available either. Conditional on the institutional setting, energy in the form of diesel or electricity are the main inputs to power irrigation pumpsets. In Andhra Pradesh, one of the largest Indian states and the subject of this pilot project, groundwater irrigation is highly supported by local institutions, most obviously through the decade-old "free power to farmers" policy. As explained later in this SpringerBrief, such policies have created several dilemma situations or low-level equilibrium traps, where farmers, distribution companies, and the state as the cost bearer suffer from poor-quality electrical energy supply, high maintenance costs, and subsidy payments, respectively (Kimmich 2013). However, despite the very unique institutional situation, the problems farmers face in Andhra Pradesh are not very different to other states in India and many other agrarian countries. In particular in countries of the Global South, lack of financial capabilities, such as credits for suitable irrigation infrastructure, and social conflicts arising through the common pool resource characteristics of irrigation, similar problems as those in Andhra Pradesh, are observable. Researchers from various disciplines—including economics, the social sciences, and engineering—have conducted extensive research, providing a large range of possible solutions, including less resource-intensive technologies, incentive-based mechanisms, and collective action initiatives.

The concepts applied in the pilot project focussed on here have been adapted to the special conditions in Andhra Pradesh, yet many of its implications are generally valid. One main feature of the project was the formation of farmer committees to solve problems collectively. As the actions of farmers are interdependent, the behaviour of one farmer has effects on the outcomes of neighbouring ones. In our case, the unit of dependency was the distribution transformer, providing electrical energy to many farmers. Consequently, through inappropriate usage or over-pumping of water, one farmer can adversely affect the outcomes of others who are connected to the same transformer. Hence, we sought to find out whether managing groundwater pumping as a group could help towards overcoming such problems. During the pilot project, it became evident that farmers were able to collectively manage their distribution transformers and subsequent distribution systems in ways that are likely applicable to a variety of other contexts, even beyond agriculture and irrigation, as many kinds of development projects can be supported by collective action approaches. The key lessons learned from this project are, thus, not context-specific but rather valid everywhere where resources have public good characteristics. The pilot project itself relied on general results regarding collective action derived from various studies and experiments (see for example Ostrom 1990, 2005; Ostrom et al. 1994), thus benefitting from and then contributing towards further development of this field of inquiry.

The pilot project was focused on increasing energy efficiency. A simple technology, so-called shunt capacitors, was selected and installed into agricultural motors. The reasons for choosing capacitors instead of a broad range of other, perhaps more effective, solutions can be found in the specific conditions of agricultural power supply in Andhra Pradesh. In other areas, different technologies may suit the existing conditions better. Still, some important insights from using this particular technology may be valid for more general contexts, in that the project demonstrates the difficulties that can arise when introducing a new technology. Initial reluctance of stakeholders, lack of trust, and problems that arose due to technology failure are issues of a general nature, and the lessons learned from this project can be regarded as a guide to other projects aimed at working at the grassroots level on implementation of technological solutions.

The research community may also benefit from the pilot project's results. Although observations from applied projects sometimes lack scientific rigour, insights relevant to the behavioural sciences and the disciplinary interface between the natural and social sciences can be drawn from them. During the different phases of the project, complementary research was also being conducted, the results of which have provided insights regarding common behavioural patterns. For example, a framed field experiment was conducted with farmers, the aim of which was to better understand why cooperation sometimes fails, even if it promises better outcomes for all farmers. The research results from these investigations are currently being prepared for publication or are already published. This SpringerBrief provides an overview of the research conducted within the project and its main results.

To conclude, one thing has become obvious to those involved in the project: Projects aimed at enhancing development through new technologies need to seriously take into consideration the social dimensions of technological change and adaptation. This SpringerBrief seeks to demonstrate the validity of this assumption with reference to the pilot project's environment but with the intention of offering insights that may be relevant for many other contexts. The authors hope that readers can learn from the successes and failures of this project and use its findings to better design their own future projects.