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Alexander Zahnd

The Role of Renewable Energy Technology in Holistic Community Development

Doctoral Thesis accepted by
Murdoch University, Perth, Western Australia

Springer

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ISSN 2190-5053 (electronic)
ISBN 978-3-319-03988-6 (eBook)
DOI 10.1007/978-3-319-03989-3
Springer Cham Heidelberg New York Dordrecht London

Library of Congress Control Number: 2013956336

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Parts of this thesis have been published as journal articles and as peer reviewed conference papers as following:

Zahnd Alex, Jan Kleissl, Angel Clark, Wendy Cheung, Linda Zou, "Minimizing the Lead-Acid Battery Bank Capacity through a Solar PV—Wind Turbine Hybrid System for a high-altitude village in the Nepal Himalayas", ISES Solar World Congress, Cancun, Mexico, 3.–7.11.2013

Zahnd Alex, Philip Jennings, "The Role of Renewable Energy Technology in Holistic Community Development", Green Energy, chapter 5, pages 75–142, November 2012, Book editors: Dr. M. D. Tiwari, Dr. Anurika Vaish, River Publishers, PO box 1657, Algade 42, 9000 Aarborg Denmark

Zahnd Alex, The Role of Renewable Energy Technology in Holistic Community Development, ISES Solar World Congress 2011, Kassel, Germany, 28.8.–2.9.2011

Karaliunas M., P. Vitta, A. Žukauskas, Alex Zahnd, D. Bista, B. B. Chhetri and M. R. Updhyaya, "Characterization of Nepali Solid-state Lamps", Electronics and Electrical Engineering, 2009 No. 1(89) ISSN 1292–1215

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Zahnd Alex, “Appropriate Technology for the Poorest Mountain Communities in the Nepal Himalayas”, Sustainable Resources Conference 2003 (SR03) Boulder Colorado, USA, 1.10.–4.10. 2003

Supervisor's Foreword

This thesis describes the main results of 20 years of theoretical and practical work in the remote, impoverished mountain communities of Nepal. The author, Alex Zahnd, did not set out to write an academic thesis when he began his community development work in Nepal in 1996, after he had been in Nepal since the mid-1980s. His goal was to bring some benefits from modern technology to the isolated and disadvantaged villagers who have a very low life expectancy and suffer from numerous illnesses that are rare now in industrialized countries. From the outset, Alex Zahnd sought to utilize local resources and appropriate technologies, developed for the local context, which the villagers would be able to understand and maintain. Rather than tell them what they needed, he sought to find out what their most pressing needs were and to design systems to assist them. Thus, he developed the concept of holistic community development (HCD), in which he attempted to address the core needs of the community in an integrated manner. This was a difficult task as he had to address social, cultural, economic, and technical issues with his system designs. Ultimately he succeeded in developing, deploying, and testing technologies to address the key needs of water supply, food for the long cold winter months, energy for cooking and lighting, sanitation, and community education.

This thesis has a strong theoretical basis, which Alex Zahnd has developed into a method or strategy for addressing community needs in developing countries. It includes details of the consultation processes, the system designs, the installation and education programs, the evaluation procedures, and the follow-up technologies to address further needs. This work has now been under way for 20 years and it has been continually evaluated and refined. The author now has a technique for sustainable community development in the third world and he wanted to share his knowledge with the international development community. Thus, he was persuaded in 2005 to start to write up the key aspects of his theory and its applications so that many others could benefit from his experience.

His work in Nepal is ongoing and he is continuing to apply his approach to holistic community development and new designs and insights continue to appear. However, it is now abundantly clear that Alex Zahnd has developed a versatile and robust approach to community development which should be applicable in many developing countries.

The thesis is a comprehensive account of the theory and application of HCD in the context of the impoverished districts of Humla and Jumla, located in the remote and hard to access northwest of Nepal. The Appendices contain details of many of the designs and educational programs that he has developed. They also highlight the importance of knowing the local culture and traditions, in order to have newly developed technologies and HCD concepts based on the local context, thus making them more likely to be acculturated, or sustainable, over the generations to come. My role as his main thesis supervisor was primarily to help him to tell his story in the form of an academic thesis, and it was a privilege to be associated with such important and beneficial work. I hope that this thesis will be widely read by community development practitioners and that it will lead to improved outcomes from international development programs.

Perth, Australia

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Emeritus Professor of Physics
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Preface

This Ph.D. thesis has not come together through the more traditional route; a predefined Ph.D. research project which emerged in the quest to find answers and solutions to problems/issues that have not been previously addressed and thus pose new challenges to be tackled. Rather, the present Ph.D. thesis is an amalgamation of a work in progress, initially started in 1996/1997 through realizing the urgent need for changes in the field of utilized and applied renewable energy resources and technologies, respectively, and community development, but without defined, satisfactory, or available solutions and tools to put into practice.

The author recognized this need by observing that the impoverished alpine communities of Nepal need solutions that are more holistic, applicable within their defined context, and with a much more practical angle compared to the current "standard" approach to community development projects.

Thus, from 1997 onwards, the author started to develop and apply new ideas and concepts of holistic community development. The concepts gradually included more and more projects that meet identified basic energy service demands through converting the locally available renewable energy resources.

The author was initially inexperienced in this field, and often had to make ad hoc decisions to do justice to the local circumstances and needs. The first few years were very much a phase of learning-by-doing. Many mistakes were made due to the limited understanding and knowledge at the time of how inclusive and holistic solutions need to be in order to bring forth long-term changes that are suitable for varying contexts and communities.

In particular, the decade from 2001 onwards was devoted to developing and implementing holistic community development projects in close partnership with the local communities through the NGO, RIDS-Nepal. The experience of working at a grass-roots level, and the initial results that the concept of applied renewable energy technologies, paired with long-term holistic community development brought forth, were most encouraging. Gradually, these projects brought substantial life improving changes to the small communities that RIDS-Nepal works with in the high-altitude Himalayan mountain valleys in Nepal.

Recognizing that there are many other impoverished communities in similar circumstances, in other areas in Nepal and indeed in other, similar needy countries, encouraged the author first to start writing papers and publications about the individual project parameters of the new holistic community development

concepts of the "Family of 4" and the "Family of 4 PLUS", and the reasons why the author has developed these new concepts, their outworking, and their impact among those with whom they have been applied.

Work experience, results, and impacts seen and experienced on the ground through the last 16 years of practical community development encouraged the author to put together all the papers and publications written since 2005, and to synthesize the results in the form of a Ph.D. thesis. It is his hope that other agencies, communities, and scholars may benefit from these experiences and apply them in contextualized ways within their own defined surroundings and communities.

Acknowledgments

It may not come as a surprise that there are many people I would like to thank and acknowledge for having been an active part in the long journey, since 1996, when I set out to learn and develop new concepts and understanding of how the needs and demands of impoverished communities can be addressed. With limited space available I can only mention some of the numerous people who supported and guided me with their experience, mind provoking ideas, cautions and advice through this passage of my life, which will continue after the submission of the Ph.D. thesis, with more understanding, wisdom, and even more vigor and determination.

In particular I want to acknowledge and thank Prof. Philip Jennings, my principal supervisor, for his invaluable guidance and advice throughout the process of the Ph.D. research program. I would like to extend my utmost gratitude to him for all his kind and continuous support, encouragement, and mentorship. He is one of the "real" Professors in the sense of the word, able to guide and lead younger professionals through his outstanding academic knowledge, expertise in industry, and international recognition, paired and enforced through his life-long experience as educationalist and expert of renewable energy and the needs of society. Special thanks I would like to extend as well to Dr. Peter Freere, my associate supervisor, for all his encouragement and valuable comments, particularly in the final stages of this thesis. His knowledge of Nepal and his practical experience of applied renewable energy technologies in the context of developing countries and the need for community development made him an ideal supervisor. He provided positive, critical advice to make the thesis applicable for a wider, professional interest community.

There would have been no opportunities for me to even start thinking about new ways of how to conduct projects without the village communities, motivated and interested to develop and implement with us in RIDS-Nepal, the new Holistic Community Development (HCD) concepts. Thus, I would like to acknowledge and thank all of the people of the 13 villages, one school and one health post with whom we have worked intensively since 2002 in the Humla district. They have allowed us to participate in their lives and become in many cases much more than mere project partners, but friends. They are: Chauganphaya Village and Chaughanphaya High School, Syada Health Post staff, Dhadhaphaya Village, Tulin Village, Kholsi Village, Pamlatum Village, Tangin Village, Hepka Village,

Darapori Village, Jharkholsi Village, Chala Village, Sata Village, Yangu Village, Lekha Village.

Likewise, there would have been no projects with these impoverished and needy communities without all the various donors from around the world, who supported our community-based implementation projects and research projects throughout the years. Thus, I would like to extend my gratitude and thanks to all of them, in particular to the ISIS Foundation (in particular Associate Prof. Kimber Haddix McKay, Leo Excel and Audette Excel, founder of the ISIS Foundation, who all became much more than project partners or donors, but close, life-long friends), Kadoorie Charitable Foundation (KCF), Light in Nepal (LiN), American Himalayan Foundation (AHF), Nepal Himalayan Mission (NHAM) and multiple individual people and enthusiasts who with their financial and moral support enabled me and RIDS-Nepal as a team, to carry out all the HCD projects in partnership with the local village communities. Their understanding and encouragement, particularly during times when things were very difficult, are greatly appreciated.

I would like to express my appreciation to the leadership of the Kathmandu University, Prof. Suresh Raj Sharma, our Vice Chancellor, Prof. Dr. Bhola Thapa, Dean of our School of Engineering and Prof. Dr. Bim Shrestha, my Head of Department of the Mechanical Engineering Campus, on whose staff team I have been a member since 2001. Kathmandu University (KU) provided the best environment within Nepal where I was able to start new student research projects each year that were relevant to the remote mountain communities. The results benefited not just the students, but also the end users in the remotest parts of Nepal. Over the years, seven of KU's graduated students have been my research assistants and worked with me for 3 years each at KU and through RIDS-Nepal, continuing to highlight the importance of applied practical student R&D projects and field-based research. They all have been as well to the remote villages, participating in the implementation of the projects with the mountain communities. Most of them have already finished their Master's Degrees in a University abroad and they are the ones that I hope will lead Nepal on the path of sustainable development in the years to come. Thus, I want to thank Kanchan Rai, Biraj Shrestha, Avishek Malla, Sujit Thakuri, Rojan Pandey, Nawaraj Sanjel, and Malesh Shah, for all their hard work and involvement in our projects during their time as my research assistants. I see them as future professional leaders of Nepal as they have embraced the vision for Nepal's needs and how they can be addressed.

Without the dedication and tireless effort of all our staff at RIDS-Nepal I would have not been able to bring ideas to fruition with our project partner villages. They have been faithfully working for years in this remote, harsh, and difficult working environment, with minimal equipment and facilities. Thus, I would like to extend my thanks and gratitude to the following staff who have been with me on this long journey of learning by doing and getting up after having fallen and continuing to focus on the vision and mission. Govinda Nepali, Haripal Nepali, Bam Bahadur Rokhaya, Sunita Budha, Sarita Shahi, Sher Bahadur Rokhaya, Gogan Rokhaya, Pradeep Shahi, Barka Shahi, Nayan Singh, Ram Raja Singh, Manish Pradhan,

Jhabendra Bhatterai, Bodh Raj Pandt, Palden Sunar, Sanjay Nidhi, Bishal Thapa, Prabin Pant, Bir Jung Shahi, Govinda Lama, Resham Katri, Uttam Khatri, Pradhuman Dhakal, and all the expatriate volunteers from around the globe who came for a defined time period to share their professional skills. With them I have been able to enjoy the smiles of the local end users which made up for all the hardship. I extend my thanks to Muni Raj Upadhaya, the owner of Pico Power Nepal (PPN), who is one of my earliest close Nepali friends and co-founder of RIDS-Nepal and with whom I have been working closely since 1997. He often worked with me relentlessly on new technical ideas, which initially have not found many supporters, to put them into practice, and to learn and improve them through experience.

Most of all I would like to thank my dear wife Sheila, who has always been my strong moral support with never ending patience and love during times when things just got "too" much. Also, I wish to thank my dear son Joel and my dear daughter Jessica, who showed kind understanding in times of extreme stress and time constraints. I cannot express enough thanks for their understanding and having enabled me to work in such remote and difficult areas, with extended absences from them. I am indebted to Murdoch University, from where I have previously graduated with my Renewable Energy Master's Degree as an external, online student in 2004. Through its relevant and motivating higher education programs I have benefited greatly for my professional career and services in Nepal. They provided a firm basis, paired with many years of practical experience, to undertake a Ph.D. research project. An Australian Government Endeavour Ph.D. scholarship, which was awarded to me, made it financially possible for me to undertake this Ph.D. research project.

Contents

Abbreviations and Acronyms

AD	Anno Domini; the number of years counted based on the traditionally reckoned year of the conception or birth of Jesus Christ of Nazareth
a-Si	Amorphous Silicon solar photovoltaic module material/technology
AC/DC	Alternating current/Direct Current
ACF	Action Contre La Faim, (a French INGO), or in English: Action against Hunger
ADB	Asian Development Bank
AEPC	Alternative Energy Promotion Centre (under the Nepali Government)
AGM	Absorbed Glass Mat–Battery (sealed and valve regulated lead-acid batteries which demand low maintenance and no topping up of distilled water)
Ah	Ampere-hour; value of a battery's energy storage capacity
ALRI	Acute Lower Respiratory Infection
AM	Air Mass
AMP	Amperes
Albedo	Fraction of shortwave solar radiation energy reflected from the earth's or a body's surface back into space/intercepted object
A.P.C.S.	Analog Process Control Services ltd in NSW Australia
ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers
AURI	Acute Upper Respiratory Infection
BC	Before Christ; the number of years counted before the traditionally reckoned year of the conception or birth of Jesus Christ of Nazareth
BOS	Balance of System
BS	Bikram Sambat
BTU	British Thermal Unit (1 BTU = 1.06 kJ, or 0.293 Wh)
°C	Degrees Celsius
CIBSE	Chartered Institute of Building Services Engineers
CC	Charge-/Discharge-Controller

CDM	Clean Development Mechanism
CDO	Chief District Officer (the government position with the highest political rank on a district level in Nepal)
CEM	Channel Extension Module
CFL	Compact Fluorescent Lamp
CIA	Central Intelligence Agency: The World Fact Book
CIE	Commission Internationale de l'Eclairage (French: International Commission on Illumination—standardization body)
CLO	Clothing Level. ASHRAE provides a CLO calculator to measure people's clothing level (by weight) to determine their living "comfort" level
COHb	Carboxyhemoglobin level (in %) of CO in the blood stream
C_{20}	Capacity (in Ah measured) of a battery discharged over 20 h
DANIDA	Danish International Development Agency
DDC	District Development Committee (a Nepal government appointed committee working in each district of Nepal)
DIY	Do It Yourself
DoD	Depth of Discharge, indicating the level of discharge of a battery/battery-bank. A DoD of 10 % means that the battery/battery-bank has been discharged by 10 % of its full capacity and thus remains 90 % full, or has a SOC of 90 %
DT605	Data logger from the company dataTaker, type 605
DT80	Data logger from the company dataTaker, type 80
EPA	Environmental Protection Agency (a USA Government Agency)
ESAP	Energy Sector Assistance Project (run by DANIDA and AEPC)
FFW	Food For Work
FY	Fiscal Year
GDP	Gross Domestic Product
GOBI	Growth monitoring; Oral rehydration therapy; Breastfeeding; Immunisation. Acronym for UNICEF's primary health care program
HASWH	High-Altitude Solar Water Heater
HASWHBC	High-Altitude Solar Water Heater Bathing Centre
HARS	High-Altitude Research Station (RIDS-Nepal's Simikot office and high-altitude research station, located, at 3,000 m above sea level)
HDI	Human Development Index
HMG	His Majesty Government of Nepal
IEA	International Energy Agency
IFA	International Fund for Agricultural Development (A UN financial institution)
INGO	International Non-Governmental Organisation
IPP	Independent Power Producer
ISIS	*The ISIS Foundation*
ISO	International Standard Organisation
ISPS	Institutional Solar PV Systems

K	Degree Kelvin
KLDP	Karnali Local Development Program, Jumla, Nepal
KU	Kathmandu University
km	Kilometre
kW	Kilowatt (power unit)
kWh	Kilowatt-hour (energy unit)
LED	Light Emitting Diode
LoL	Loss of Load, indicating the amount of time (in % of 24 hours a day) the load could not be provided because the system was designed too small, thus not able to provide the needed energy
l/s	Litres per second
LUTW	Light Up The World, Calgary, Canada
m	Metre
MOA	Ministry of Agriculture (a Nepali government Ministry)
m.a.s.l.	Metres above sea level
MDGs	Millennium Development Goals (to be reached in 2015)
MHP	Micro-Hydro Power Plant/Project
MJ	Megajoule (1 MJ = 0.278 kWh)
MOLD	Ministry of Local Development (a Nepali government Ministry)
Mongoloids	The Mongol people from East Asia, who conquered much of Eurasia in the thirteenth century, establishing the Mongol Empire
MOST	Ministry of Science and Technology (a Nepali government Ministry)
MPP	Maximum Power Point, indicating the point of highest power output
MW	Megawatt (1 MW = 1,000 kW, or 10^6 W)
MWh	Megawatt hour (1 MWh = 3.6 GJ)
NEA	Nepal Electricity Authority (Government owned), Kathmandu
NFE	Non-Formal Education classes mainly for women and out of school children, mostly girls
NGO	Non-Governmental Organisation (such as, e.g. RIDS-Nepal)
NHE	Nepal Hydro Electricity (a Nepali company)
NOTC	Nominal Operation Collector Temperature
NM	Nanometre (1 nm = 10^{-9} m)
NPV	Net Present Value
NREL	National Renewable Energy Laboratories, in Golden CO, USA
NRs	Nepali Rupees. The unit of currency in Nepal. One Rupee has 100 Paise
OECD	Organisations for Economic Cooperation and Development
O&M	Operation and Maintenance
PMV	Predicted Mean Vote
POA	Plain of the Array (means at the same angle as the equipment)
PPD	Predicted Percentage of Dissatisfaction
PPA	Power Purchase Agreement
PPN	Pico Power Nepal (a Nepali company)

PPP	Purchase Power Parity
PSH	Peak Sun Hours (number of sun hours per day with 1,000 W/m^2 global solar radiation intensity)
PV	Photovoltaic
PVSOL	Solar Photovoltaic System design software (Germany)
PVSyst 5.571	Solar Photovoltaic System design software version 5.57 (29th May 2012) develoepd by the University of Geneve in Switzerland
RAPS	Remote Area Power Supply
RET	Renewable Energy Technology
RETScreen	Renewable Energy Technology Screening software (Canada)
RIDS-Nepal	Rural Integrated Development Services-Nepal
RTD	Resistance Temperature Detector
Sanskritic	Much of the roots of Hinduism are in the Vedic civilisation which have been written in the Sanskrit language, relating Hinduism and Sanskrit inseparably
SHS	Solar Home System (small solar PV system for one home/family)
Si mono	Si mono-crystalline solar photovoltaic module material/technology
Si poly	Si poly-crystalline solar photovoltaic module material/technology
SINTEF	Selskapet for INdustriell og TEknisk Forskning ved norges tekniske hoegskole (The Foundation for Scientific and Industrial Research at the Norwegian Institute of Technology), http://www.sintef.no/Home/ (accessed July 30, 2012)
SOC	State of Charge, is the level of a battery or battery-bank's charging level. 100 % SOC means the battery/battery-bank is fully charged
STC	Standard Testing Conditions (1,000 W/m^2, 25 °C Ambient Temperature, 1.5 AM (1.5 Air Mass is the amount of air mass the sun's radiation passes through when reaching and penetrating earth's atmosphere at an approximate angle from the horizon of 48.2°))
SWOT	Strength—Weakness—Opportunities—Threats Analysis
TRNSYS	Transient Systems Simulation Program
TWh	Terawatt hour (1 TWh = 1,000 GWh, or 10^{12} Wh)
UA	UA (W/m^2 K) is the overall conductance value and is defined as the product of the overall heat transfer coefficient and the heat transfer area. It defines the heat transmission through a material or assembly of materials per unit surface area. The U-value of a material indicates how well heat passes through the material. The lower the U-value, the greater the resistance to heat and therefore the better this material insulates against heat losses. Thus, if a wall material has a UA value of 1 W/m^2 K, it means that for every degree of temperature difference between the inside and outside surface there would be 1 W of heat energy flowing through each m^2 of its surface
UN	United Nations

UNFCCC	United Nations Framework Convention on Climate Change
US	United States of America
UV	Ultra Violet (electromagnetic waves in the range of 100–400 nm)
V	Volts
VDC	Village Development Committee
W	Watt (power unit)
WB	World Bank
WECS	Water and Energy Commission Secretariat (in Nepal)
WHO	World Health Organization
Wh	Watt-hour (energy unit)
WLED	White Light Emitting Diode (a solid-state lighting technology using multi-layered semiconductor material, emitting light when connected to/powered by DC electricity)
Wp	Watt peak power output
W_R	Watt rated power output