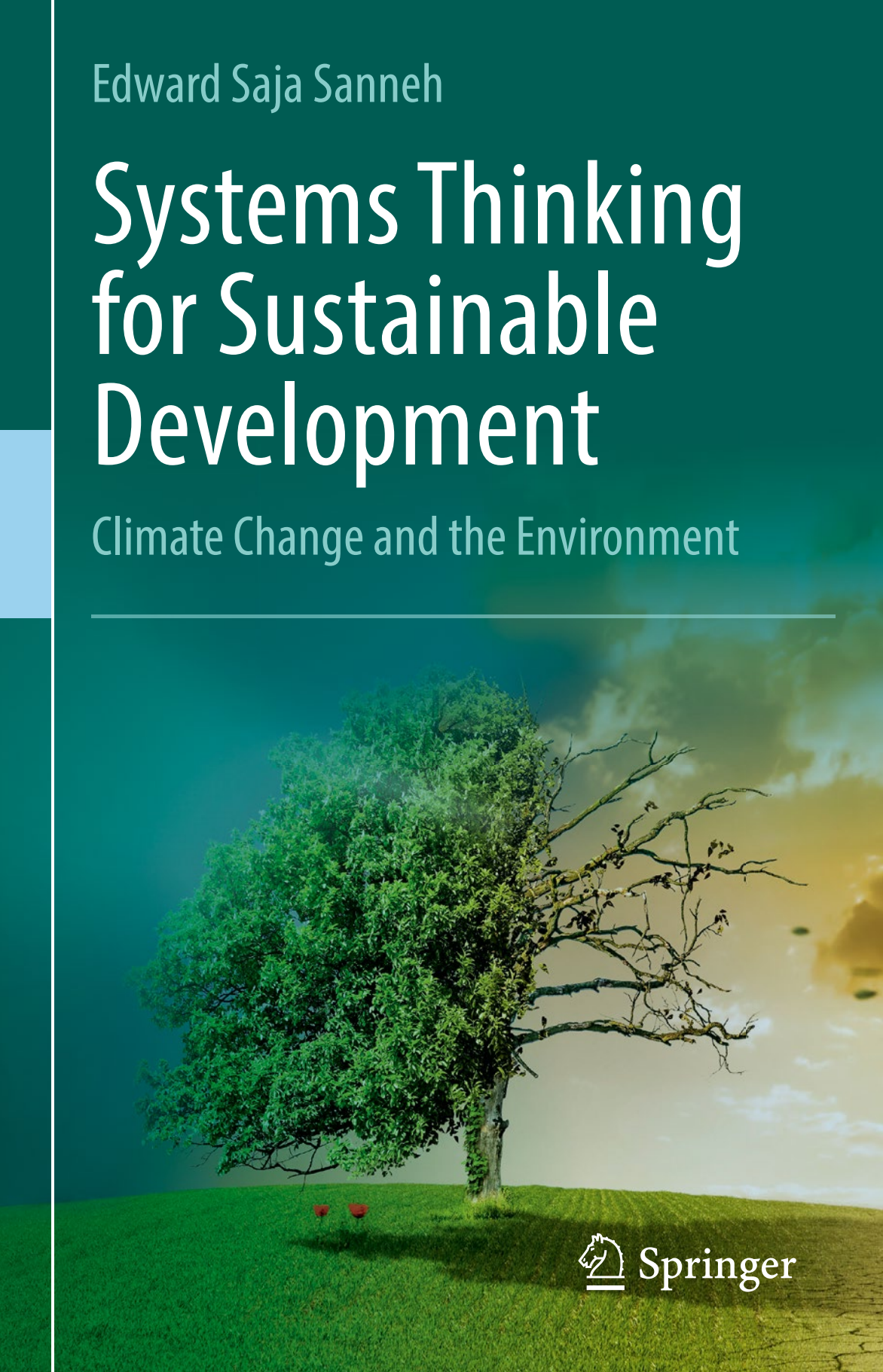
Edward Saja Sanneh

Systems Thinking for Sustainable Development

Climate Change and the Environment



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Edward Saja Sanneh
Madison, WI, USA

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I dedicate this work to the evergreen memory of my late father, Mr. Patrick J.K Sanneh, and my heritage, "Gilleh Kunda," and humanity.

Foreword

I had the privilege and pleasure of collaborating with Dr. Edward Saja Sanneh from 2005 to 2013 when he was a graduate student of the Institute of Environmental Engineering and Management, National Taipei University of Technology (Taipei Tech). The Gambia Petroleum Company supported his graduate study in Taiwan; thus, his MS thesis focused on pollution control of petroleum and underground storage tanks under the instruction of Professor Tien-Chin Chang and with assistance from China Petroleum Company. After obtaining his MSc in 2007, Edward wanted to continue his stay in Taiwan and immerse in further study of environmental management and sustainability to achieve his objective of eventually serving the Gambia, his home country. Accordingly, he eventually decided to pursue a PhD under my supervision. Given that Edward's intention after graduation was to return to his country and serve his people, I endeavored to discuss with him a broad and challenging but fulfilling research scope – that is, to establish "sustainability." The topics highlighted include adaptation to climate change, sustainable energy, safe drinking water, basic health care, sustainable solid waste management, sustainable used ICT (information and communication technology) products, and pollution control from petroleum industry. Accordingly, this book is mainly the product of Edward's PhD dissertation.

I am extremely happy to know that after obtaining a PhD from Taipei Tech, Edward returned to the Gambia and pursued government service as Minister of Energy, thereby enabling him to implement several ideas he discussed in this book. Under his excellent leadership, the technical arm of the African Union New Partnership for Africa's Development (NEPAD) recognized and extolled the Gambia as "taking the lead in achieving sustainable energy for all in Africa." This book focuses on ideas and concepts that should be able to inspire developing countries to focus on sustainability. Well done, Edward. I am proud of you.

Preface

The Brundtland Commission highlights the importance of balancing the economy, the environment, and the society for sustainable development, as well as the sustainable development goals (SDGs). Key environmental issues were investigated showing their relationship to socioeconomic aspects of development. With increased climate threats and environmental disasters, this book presents a systems thinking approach about the SDGs for sustainable national development. Systems thinking is a process for understanding the interrelationships among the key components of a system; this book illustrates the sustainable development as a system.

The Johannesburg Plan of Implementation highlights the role of energy service to promoting sustainable development and facilitating the achievement of the MDGs. Persistent energy poverty is a growing concern that is seriously impeding socioeconomic development, particularly in sub-Saharan Africa. Renewable energy is the solution to the growing energy challenges of developing countries. This book attempts to initiate, from a broad-based socioeconomic and environmental point of view, the feasibility of a decentralized solar photovoltaic (SPV) system as a source of power for rural and peri-urban communities in developing countries.

Predicted climate change is likely to add measurable stress to water resources in many regions of the world. The research investigated access to safe drinking water in the Western Region of the Gambia, in relation to the efforts to achieve the SDGs. Addressing the underlying determinants of health is a key factor in achieving SDGs and ensuring sustainable development. This book illustrates a multi-stakeholder model which includes the government, the World Health Organization (WHO), the United Nations International Children's Emergency Fund (UNICEF), and the Medical Research Council (MRC). It highlights the collaborative approach in making health care accessible in rural communities.

In proposing various adaptation approaches, the United Nations Intergovernmental Panel on Climate Change (IPCC) requires nations to prepare adaptation plans of action. However, the areas of priority in climate change adaptation have not been considered. This book highlights a new prioritization methodology for climate change adaptation in developing countries. The results indicate that the five most important adaptation categories are health, forestry, water, food, and energy, with

health as the number one priority in climate change adaptation. There is a lack of complementary action from different stakeholders in municipal solid waste management, which is why waste management is left to the municipal council to handle. This book proposes the introduction of a recycling system to enhance municipal solid waste management (MSWM). Environmental legislation has been developed globally that prohibits the shipment of toxic waste to developing countries. Other regulations require manufacturers of ICT products to adopt an environmental approach to design and end of life management. The systems thinking framework developed in this book is not exhaustive, and further interconnectedness can be highlighted in relation to other development issues.

Madison, WI, USA Edward Saja Sanneh

Acknowledgments

First and foremost, I would like to give thanks and praises to the Almighty Allah (God), the Provider, Cherisher, and Sustainer of everything on earth living and non-living. I thank the Almighty Allah for giving me the strength, wisdom, and will-power to seek knowledge.

I would like to express sincerest gratitude and thanks to my adviser and mentor Professor Allen H. Hu for his guidance, insight, patience, and help during my PhD dissertation research. I am grateful and humbled to have had Professor Hu as a mentor, appreciative of the knowledge and insight he shared with me, and in debt of his care. My respect goes to his wife Mrs. Hu, a mother figure. I would also like to acknowledge the institutional support received from the National Taipei University of Technology president, Prof. Yao, and Dr. Ding for initially motivating me to pursue a graduate degree at NTUT. The education and support I received throughout the time provided me has resulted in the publication of this book. Special thanks to Dean Prof. Tien-Chin Chang, my adviser during my master's degree studies. I also acknowledge and thank the entire staff for their invaluable assistance.

A huge thank you to my parents who taught me to be hardworking. Thank you for showing me the value of learning. A special posthumous thank you to my father Patrick J.K Sanneh, who instilled in me the love of reading and learning. To my mom, Emily Fatou Marong (a retired teacher), thank you too. They deserve special thanks; it is not only their constantly supportive love but also the way I was brought up to never give up that made it possible.

Lastly, I offer my great regards to the individuals who agreed to conduct research with me. Their cooperation and candor made this document to exist. I humbly thank Prof. Chang Yu Ming, Dr. Chia Wei Hsu, Dr. Buba Manjang, Modou Njai, Dr. Edrisa Sanyang, Omar Malleh Ceesay, and Yankuba B Manga for designing all the figures and formatting.

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About the Author

Dr. Edward Saja Sanneh obtained a Higher National Diploma in public health at the Gambia College in 2001. Six years later, on a Gambia Government scholarship, he received a master's degree in environmental engineering from the prestigious National Taipei University of Technology (NTUT) in Taiwan. He continued to a doctorate program, which he completed in August 2013, and then returned to the Gambia to serve as Minister of Energy between 2014 and 2016.

Having worked as a public health officer at the Kiang Karantaba Health Centre, the Serrekunda Health Centre, and the Jammeh Foundation for Peace Hospital, Sanneh has a solid background in preventive health promotion and environmental sanitation coupled with a special interest on issues contributing to sustainable development of communities at the bottom of the pyramid. It is this background that has shaped the thoughts contained in this book. He speaks Chinese fluently.

List of Abbreviations

AHP	Analytical hierarchy process
BAN	Basel Action Network
BOP	Bottom of the pyramid
CFC	Chlorofluorocarbon
CILSS	Comité Inter-Etate pour la Lutte contre la Sécheresse au Sahel
CRR	Central River Region
CW	Covered well
DALY	Disability adjusted life years
EDF	European Development Fund
EEE	Electronics and electrical equipment
EPR	Extended producer responsibility
ESCO	Energy service company
ETC	European Topic Centre
FAHP	Fuzzy analytic hierarchy process
GHG	Greenhouse gas
GNP	Gross national product
GOTG	Government of the Gambia
HDI	Human Development Index
ICT	Information and communication technology
IPCC	Intergovernmental Panel on Climate Change
IWSSD	International Water Supply and Sanitation Decade
KMC	Kanifing Municipal Council
LCA	Life cycle assessment
LCM	Life cycle management
LRR	Lower River Region
MDG	Millennium Development Goals
MICS	Multiple Indicator Cluster Survey
MSW	Municipal solid waste
MSWM	Municipal solid waste management
NAPA	National Adaptation Programmes of Action
NAWEC	National Water and Electricity Company

NBR	North Bank Region
OECD	Organisation for Economic Co-operation and Development
OLW	Open lined well
OUL	Open unlined well
PV	Photovoltaic
PVMTI	Photovoltaic Market Transformation Initiative
PXDD	Polyhalogenierte Dibenzo-p-dioxine und Dibenzofurane
RET	Reticulation system
RIV	River
RNG	Random number generator
RoHS	Restriction of the use of certain hazardous substances
RSP	Regional solar program
SHS	Solar home systems
SI	Standard interview
SPACO	Strategy for Poverty Alleviation Coordinating Office
SPV	Solar photovoltaic
TFN	Triangular fuzzy number
TOE	Tonne of oil equivalent
U5MR	Under-five mortality rate
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNICEF	United Nations International Children's Emergency Fund
UNIDO	United Nations Industrial Development Organization
UNODC	United Nations Office on Drugs and Crime
URR	Upper River Region
USAID	United States Agency for International Development
WEEE	Waste Electrical and Electronic Equipment
WR	Western Region

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Chapter 1
Introduction

Abstract The United Nations Sustainable Development Goals targets key development issues that are a challenge to poor communities around the globe. It highlights key environmental issues relating to socio-economic aspects of development through systems thinking. Using a system thinking approach, the interconnectedness of development issues is illustrated. With increased climate threats and environmental disasters, this chapter presents a system thinking approach in relation to the SDG's for sustainable development. Energy security is a challenge to developing countries. Thus renewable energy is proposed as a sustainable source of electricity for developing countries. Adaptation to climate change should help communities to cope with water scarcity to achieve the targets of the SDG. Climate change will also increase the occurrence of diseases, and poor rural communities are suffering from lack of access to basic healthcare. Strategies are being adopted to make healthcare accessible to poor rural communities for sustainable development. Prioritization of climate change adaption approaches has been identified to be effective in helping communities to cope. Environmental sanitation and municipal solid waste management are essential for a healthy population to mitigate the occurrence of communicable diseases. This will enhance sustainable socio-economic development especially when reduce, reuse and recycling initiatives are implemented. The shipment of toxic waste to developing countries has been an issue; recently, the shipment of used ICT products is contaminating the environment in developing countries. Environmental legislation should be adapted to reduce the flow of these waste products.

Keywords Sustainable development · Water scarcity · Access · Climate change · E-waste extended producer · Used ICT

1.1 Background

The Human Development Index (HDI) ranks many developing nations especially those in Sub-Saharan Africa with a low grade. Despite recent progress, low HDI nations still suffer from inadequate incomes, limited schooling opportunities, and

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life expectancies far below world averages due to deaths from preventable and treatable diseases. The multidimensional poverty index calculus shows that 1.7 billion people in 109 countries lived in 'multidimensional' poverty (Alkire et al. 2011). That compares to the 1.3 billion people estimated to live on US$1.25 a day or less. The growing population and commercial needs of nations and communities lead to increased demand for high-quality environmental conditions, e.g. water, energy, healthcare, waste management, climate change adaptation and clean air. Innovations at the Base of the Pyramid (BOP) would help in poverty reduction, and meeting targeted SDG's. Integration of development-oriented research in decision-making and management will catalyze interactions among relevant disciplines. Developing countries are making great strides in addressing development needs; this book suggests a harmonization of those efforts through the identification of the interrelatedness of development issues.

1.2 Compartmentalization Approach

The compartmentalization approach to development might not be effective for sustainability; a holistic formula will be ideal. Though poverty is predominantly a rural phenomenon, urban poverty is rising fast. Women are particularly disadvantaged, while regional disparities are also evident. Income inequality, as measured by the Gini coefficient, is high, indicating that the benefits of increased economic growth have not been distributed evenly and have gone disproportionately to a small segment of the population. The availability of clean drinking water, electricity supply, basic health care and proper waste management system, as well as excellent communication and transportation facilities including access roads, is quite imperative in mitigating poverty to a large scale. Reductionism generates knowledge and understanding of phenomena by breaking them down into constituent parts and then studying these simple elements in terms of cause and effect.

1.3 Climate Change Adaptation

Continued climate change threatens to reverse human progress. Based on reports of the Intergovernmental Panel on Climate Change (IPCC), the ongoing rise in the atmosphere's CO2 concentration has come to be viewed as a monumental danger not only to human society but to the world of nature as well (Levene 2013). The picture is not pretty, heat waves killing the poor and elderly while drying up precious farmlands. Melting polar ice caps, raising sea levels and flooding coastal lowland is frequent and diseases spreading to regions previously considered immune. Disappearing coral reefs dissolving into oblivion as oceans warm and turn acidic, and migrating plants and animals unable to move to cooler locations fast enough to avoid extinction. Access to land, dwindling water supplies to grow food to

feed burgeoning populations might lead to instability. Prevention of climate change impacts must address social, economic, and environmental effects on communities.

Climate change forces communities in the developing countries to adapt to the extreme and unpredictable weather. Sustainable development requires that all responses to climate change are successful in reducing poverty. For the foreseeable future, prevention of climate change effects must address social, economic, and environmental effects on communities. This book has developed a new prioritization methodology for climate change adaptation in developing countries. The results indicate that the five most important adaptation categories are health, forestry, water, food, and energy, with health as the number one priority in climate change adaptation. Further findings show that the prioritization order of the adaptation approaches to climate change is as follows: "Health education," "public sensitization," "water supply infrastructure development," "microfinance," and "infrastructure and technology enhancement."

The African continent has been focused as particularly vulnerable in the coming decades, primarily because of its low adaptive capacity (Hope Sr 2009). Adaptation to climate change has been recognized as very important in developing countries that face the greatest threats from global warming. In proposing various adaptation approaches, the United Nations Intergovernmental Panel on Climate Change required nations to prepare adaptation plans of action. Greenhouse gas reduction is the primary goal of climate change mitigation; adaptation aims to cope with, anticipate effects of climate change. Adaptation to climate change can be implemented at local and regional levels.

1.4 Environmental Sanitation

Solid waste management should be shifted towards a more sustainable approach. An unreliable and irregular collection of municipal solid waste still exists. The waste collection system has not delivered the optimum economic and environmental result for now and has not provided enough room to adapt to future pressures. Environmental sanitation is a key target; thus, the introduction of a recycling system is being proposed for sustainable municipal solid waste management. Recycling of municipal solid waste that reduces dumping has been proposed in this book. Sustainable waste management calls for resource conservation measures, which in turn requires that attention be given to more than just existing waste.

The potential adverse health and environmental consequences of the incorrect end of life management of Waste Electronic and Electrical Equipment (WEEE) (e.g. in China, India, USA, etc.), has further heightened concerns in relation to the management of WEEE. WEEE can be regarded as a resource of valuable metals such as copper, aluminum, and gold (Govender 2016). When such resources are recovered, raw materials can be extracted and processed to make new products. This can result in a significant reduction in the loss of resources and environmental damage.

The current disposal methods mostly depend on the obsolete dumping with the associated environmental and social risks. The environmental policy would enhance the sustainable flow of used ICT products. This will further assist the adoption of "Cradle to Cradle" product life cycle management than the "Cradle to Grave" system wherein the waste is disposed of. Resource recovery, not waste disposal, must be the ultimate goal with clearly defined end user markets so that the recovery loop is complete.

Environmental contamination by heavy metal is becoming a major concern as a result of the importation of used ICT products such as computers. Agenda 21 asks each country to develop a domestic policy framework that will encourage a shift to more sustainable patterns of production and consumption (Barber 2003). Legislative documents have been drafted and implemented globally that require manufacturers and stakeholders to adopt an environmental approach to design and assess the impact of their products throughout their lifecycles. Extended Producer Responsibility policy should be initiated for a sustainable flow of used ICT products to developing countries.

1.5 Lack of Electricity Supply

The provision of electricity to communities would encourage economic activities thereby improving their living standards. Four out of five people without access to electricity live in rural areas of the developing world, mainly in Sub-Saharan Africa. Moreover, under today's policies and investment trends in energy infrastructure, 1.5 billion people will still lack access to electricity in 2030 (Hawila et al. 2014). Hence a major expansion of power supply is needed in both the urban and rural areas. The high cost of inefficient energy-using devices and the lack of access to modern energy sources become part of the "poverty penalty." Moreover, the provision of renewable energy can influence socio-economic growth and help in the preservation of the environment.

Electricity is one of the elements of a country's development and is one of the main infrastructural requirements for agricultural, industrial and socio-economic development. This book illustrates renewable energy use for the Bottom of the Pyramid to achieve sustainable socio-economic development. The role of energy in development is crucial. Energy fuels economic growth and is therefore of paramount concern for all countries. This was one of the main themes at the world summit on sustainable development (WSSD) held in South Africa in 2002. The Johannesburg plan of implementation highlighted the role of energy service to promote sustainable development and to facilitate the achievement of the MDG's (Pisano et al. 2015). One of the growing concerns is the persistent energy poverty that is seriously impeding socio-economic development, particularly in sub-Saharan African and in countries of South Asia, but also in many other developing countries. Renewable energy is the solution to the growing energy challenges of developing countries. The heavy reliance on imported fossil fuel coupled with the growing demand for electricity and declining wood fuel supplies call for alternative sources of energy. Finding ways to

expand energy services, while addressing the environmental impacts associated with energy use, represents a critical challenge for humanity. Recent developments in countries like China and India, where energy production has increased significantly, demonstrate how difficult it is (Ahuja and Tatsutani 2009). The decentralized approach based on power produced with locally available renewable energy resources is, for various reasons, gradually being recognized as a viable alternative. This book attempts to initiate, from a broad-based socio-economic and environmental point of view, the feasibility of a decentralized system as a source of electricity.

1.6 Inadequate Drinking Water Supply and Poor Water Quality

Water is increasingly seen as one of the most critically scarce resources, requiring the attention of policy makers, resource managers, and governments. Inadequate drinking water supply and poor water quality are among the world's leading causes of disease and death. Water scarcity is likely to lead to greater human and political insecurity. At the world summit on sustainable development in Johannesburg 2002, the world community committed itself to halve by 2015 the proportion of people without access to safe water (Hughes and Hillebrand 2015). Ensuring safe access to water through continuous funding will mitigate the effects of water scarcity as a result of climate change.

There is growing recognition for urgent water stewardship worldwide, particularly in countries of the developing world. Ensuring safe access to water through continuous funding will mitigate the effects of water scarcity as a result of climate change. Access to water and sanitation are among the top priorities for poverty reduction and sustainable development. There is a need for a new convergence in thinking and practice to develop the synergies required to achieve the common goal of sustainability. Providing safe drinking water becomes a greater challenge as economic development and population growth place increasing demands. Water is an indispensable resource for life and human development. More sustainable water use will depend upon efficiency standards. Strategies must aim for ecological integrity, efficiency, equity, and participatory decision-making by shareholders. Conferences in 1992, in Dublin and Rio de Janeiro, generated a statement of principles on sustainable water (Pahl-Wostl et al. 2011). The World Bank, in 1993, developed a framework for water management that treats water as an economic good.

1.7 Poor Access to Health Care

The availability of health goods and services are critical to national development and poverty alleviation. Poor access to health care, which results in delayed attendance at a health facility or none at all, is a key determinant of mortality in children less than five (5) years of age in developing countries. Protecting and improving the

health of a community, application of sanitary measures and monitoring of environmental hazards can enhance sustainable human development. Despite remarkable reductions in the incidence of disease and mortality rates over the last decades, ill health in developing nations remains an enormous impediment to development (Bishwajit et al. 2014).

The desire to propose an innovative theory for sustainable development is consistent with the equilibrium of ecosystems and promotion of human health. Inequalities do exist in health status and that, in general, the residents of rural communities are in poorer health. Spending, especially on health care, also depends on access to services. Although infant mortality rates have fallen, average life expectancy is still low. Poor access to health care, which results in delayed attendance at a health facility or none at all, is a key determinant of mortality in children less than five (5) years of age in developing countries (Halwindi et al. 2013).

There is evidence to believe that the development of health is essential for economic development. Development in health is a precondition for the economic prosperity of a nation. Access to life-saving and health-promoting interventions should not be denied, especially for those with economic or social deprivations. Although there are substantial 'health promotion' or health education activities, it can be enhanced with ICT to introduce e-health. This would help in addressing the social determinants of health, tackling inequalities and empowerment.

1.8 Systems Thinking Approach

The central argument of this book is that "everything is connected to everything" in relation to systems thinking. Systems' thinking is the ability to think about a system as a whole, rather than only considering the parts individually. Systems' thinking involves the use of various techniques to study systems of many kinds. In nature, systems thinking examples include ecosystems in which various elements such as air, water, movement, plants, and animals work together to survive or else they perish (Wilson 2012). In organizations, systems consist of people, structures, and processes that work together to make an organization "healthy" or "unhealthy". As governments and individuals, sustainability concepts should be incorporated into planning, policy, and implementation (Arena et al. 2015). Through the use of "systems thinking approach" an understanding of the qualitative, as well as quantitative aspects of development trends for sustainability, can be explored (Moldavska and Welo 2015).

There are many definitions of systems thinking. Peter Senge's book "The Fifth Discipline", defines systems thinking as a discipline for seeing wholes. He further defines systems thinking as a "framework for seeing interrelationship rather than things, for seeing patterns of change rather than static snapshots" (Senge 1990). (Davidz and Nightingale 2008) builds further upon the notion of interrelationships, and interdependencies. She defines systems thinking as the "analysis, synthesis and understanding of interconnections, interactions, and interdependencies that are

technical, social, temporal and multi-level" (Davidz and Nightingale 2008). (Moore et al. 2010), identify some of the same concepts as Senge and Davidz in their definition of systems thinking is "the ability to recognize, understand, and synthesize the interactions, and interdependencies in a set of components designed for a specific purpose. This includes the ability to recognize patterns and repetitions in interactions". The ability to understand interrelationships is a recurring theme in all of these definitions. Systems' thinking perceives the world as a complex system and supports the understanding of its interconnectedness and interrelationships (Kasser et al. 2013).

Systems' thinking is a way of seeing the connections, links, or relationships among different disciplines or sectors. Instead of seeing parts and pieces of how things happen, it allows the interdependent whole to be appreciated (Karimi 2016). Systems thinking focus on how the thing being studied interacts with the other constituents of the system instead of isolating smaller parts. It is about interdependence and interrelationships with connections. In systems of greater complexity, the system as a whole may have properties and organization that cannot be understood by studying its parts in isolation (Goldstone and Wilensky 2008). Most fundamental concepts of systems thinking were developed in the early twentieth century in disciplines such as organismic biology, ecology, psychology and cybernetics (Mingers and White 2010). Currently, systems thinking has closed ties with the basic concepts of systems ideas, such as parts and wholes, system and sub-systems, boundary and environment, emergent properties, hierarchy of systems, communication and control, synergism and effect, etc. (Mingers and White 2010), and it is usually considered as holism thinking to look things as a whole. There is recognition that new approaches are needed that would allow knowledge and understanding to emerge from processes involving stakeholders.

There is a shift away from single disciplinary projects toward multidisciplinary and interdisciplinary research, and approaches that allow for the recognized complexity of and uncertainty within systems (King et al. 2000). Through the use of systems thinking approach, this book presents the issues and challenges of providing health care in rural communities and examines the role, both existing and potential, of governments in this area. Prioritization of climate change approaches will enhance sustainable adaptation as discovered in this book. Health is a priority in adaptation to climate change. System thinking in this book explores interconnected aspirational goals within various UN declarations, to support economic, social and environmental objectives. Systems thinking entail stakeholder involvement and knowledge sharing to understand cause and effect relationships for actions and goals. Systems thinking can be used to explore problems and subsequently make decisions about management issues with a range of stakeholders (Turner et al. 2016). Incorporating research from different disciplines and SDG's provides understanding on pieces and parts for change in environmental, economic and social conditions.

1.9 Systems Thinking for Sustainable Future

The book proposes a better understanding of the interrelationships within the development system. The reassessment of international development over the past decade, the acknowledged failure of results-based management methods and the shift toward capacity development at a national rather than at project levels poses many challenges. The first World Summit on Sustainable Development in Rio de Janeiro in 1992 established Agenda 21 and suggested that all countries should formulate economic policies with a minimum impact on the environment, encourage the social promotion of individuals and communities. The desire to propose systems thinking approach on SDG's will influence socio-economic development and maintain ecosystems. The issues discussed in this book are multi-dimensional and interconnected. It is a scientific environmental perspective that is development-oriented and relates to the SDGs.

Agenda 21 asks each country to develop a domestic policy framework that will encourage a shift to more sustainable patterns of production and consumption (Barber 2005). The different topics discussed in this book are directed to different targets of the SDGs. Valid knowledge and meaningful understanding come from building up whole pictures. Figure 1.1 is a schematic diagram depicting the interconnection among the issues studied and their relationship to sustainable development. The overall objective of this book is to work towards global efforts such as the UN's Sustainable Development Goals with an innovative interdisciplinary approach to sustainable development. The main objective is to propose solutions by using systems thinking that will help achieve sustainable development.

Sustainable development should be an opportunity and not a challenge or burden for developing nations and communities. It sets out goals to enable people throughout the world to satisfy their basic needs and enjoy a better quality of life, without compromising those of future generations. The strategy outlined in Fig. 1.1 indicates some aspects of the UN SDGs: Energy, Water, Health, Climate Change Adaptation and Environmental Sanitation (MSWM, Used ICT products). Policy approaches globally are aimed at improving environmental quality in relation to human health and socio-economic development (Everett and Kell 2010). This book highlights the relationship between the economic, social and environmental aspects of sustainable development for developing communities. One of the main themes of the Rio+20 Conference is green economy that contains inspiring agreements for future generations in the context of sustainable development and poverty eradication. A holistic approach to environmental issues relating to the SDGs, specifically relating to climate change adaptation, should be a major focus for sustainability.

This book initiates to connect or link the fragmented approach to development and work into more of a sustainable view. Environmental and socio-economic issues are interdependent and nested within a system. With this perspective, it would create the opportunity for better solutions to development challenges. It would enhance a

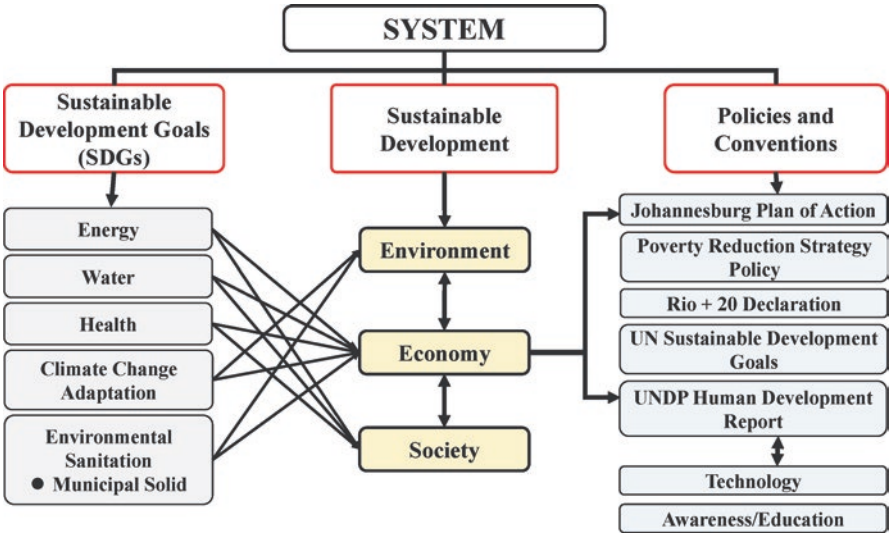

Fig. 1.1 Developmental targets and their interalation to sustainable development

shared vision among different disciplines to align and harness efforts of people towards a target e.g. the SDGs. It would also leverage productive usage of capital, technology, and human resources, coordinated towards the same ends. Figure 1.1 aims to be a useful and accessible reference to help illustrate the linkages of sustainable development goals to less developed nations as a system.

This requires improved understanding of the issues highlighted, that is, the social, economic and environmental benefits that can be achieved. The departmentalized structure within nations has led to distinct approaches, each seeing their area of expertise and knowledge rather than a holistic view. Eradicating poverty is a global challenge and requirement for sustainable development particularly for developing countries. Measures are required at all levels to enable developing countries to achieve poverty reduction related targets and goals. Good governance within a country is essential for sustainable development. Sound environmental, social and economic policies, democratic institutions and an enabling environment for investment are the basis for sustainable development (Barr 2012). Using an interdisciplinary approach, Fig. 1.1 highlights the interconnectedness of development issues. The approach that is evolving emphasizes the integrated functions of the respective aspects of development in nations and communities. It is not only the explicit relationships between issues as highlighted and the ability to influence development. It illustrates international conventions and ratifications that have benchmarks with measurable developmental indicators as highlighted in the UNDP HDI.

References

Ahuja, D., & Tatsutani, M. (2009). *Sustainable energy for developing countries*. SAPI EN. S. Surveys and Perspectives Integrating Environment and Society, (2.1).

Alkire, S., Foster, J., & Santos, M. E. (2011). Where did identification go? *Journal of Economic Inequality, 9*, 501–505.

Arena, R., Guazzi, M., Lianov, L., Whitsel, L., Berra, K., Lavie, C. J., Kaminsky, L., Williams, M., Hivert, M.-F., & Franklin, N. C. (2015). Healthy lifestyle interventions to combat non-communicable disease – A novel nonhierarchical connectivity model for key stakeholders: A policy statement from the American Heart Association, European Society of Cardiology, European Association for Cardiovascular Prevention and Rehabilitation, and American College of Preventive Medicine. *European Heart Journal*, ehv207.

Barber, J. (2003). Production, consumption and the world summit on sustainable development. *Environment, Development and Sustainability, 5*, 63–93.

Barber, J. (2005). Production, consumption and the world summit on sustainable development. In *The world summit on sustainable development*. Dordrecht: Springer.

Barr, S. (2012). *Environment and society: Sustainability, policy and the citizen*. Farnham: Ashgate Publishing, Ltd.

Bishwajit, G., Ide, S., Hossain, M. A., & Safa, M. N. (2014). Trade liberalization, urbanization and nutrition transition in Asian countries. *Journal of Nutrition Health & Food Science, 2*, 5.

Davidz, H. L., & Nightingale, D. J. (2008). Enabling systems thinking to accelerate the development of senior systems engineers. *Systems Engineering, 11*, 1–14.

Everett, T., & Kell, C. (2010). *Human movement: An introductory text*. London: Elsevier health sciences.

Goldstone, R. L., & Wilensky, U. (2008). Promoting transfer by grounding complex systems principles. *The Journal of the Learning Sciences, 17*, 465–516.

Govender, K. (2016). *The management of electronic waste: A case study of the Umbogintwini Industrial Complex and Southgate Business Park in KwaZulu-Natal, South Africa.*

Halwindi, H., Siziya, S., Magnussen, P., & Olsen, A. (2013). Factors perceived by caretakers as barriers to health care for under-five children in Mazabuka District, Zambia. *ISRN Tropical Medicine, 2013*, 1–10.

Hawila, D., Mondal, M. A. H., Kennedy, S., & Mezher, T. (2014). Renewable energy readiness assessment for North African countries. *Renewable and Sustainable Energy Reviews, 33*, 128–140.

Hope Sr, K. R. (2009). Climate change and poverty in Africa. *International Journal of Sustainable Development & World Ecology, 16*, 451–461.

Hughes, B. B., & Hillebrand, E. E. (2015). *Exploring and shaping international futures*. London: Routledge.

Karimi, B. (2016). Applying the economic, homeland and National Security Analysis Framework. *Homeland Security Affairs, 12*.

Kasser, J., Hitchins, D., Frank, M., & Zhao, Y. Y. (2013). A framework for benchmarking competency assessment models. *Systems Engineering, 16*, 29–44.

King, G., Tomz, M., & Wittenberg, J. (2000). Making the most of statistical analyses: Improving interpretation and presentation. *American Journal of Political Science*, 347–361.

Levene, M. (2013). Climate blues: Or how awareness of the human end might re-instil ethical purpose to the writing of history. *Environmental Humanities, 2*, 147–167.

Mingers, J., & White, L. (2010). A review of the recent contribution of systems thinking to operational research and management science. *European Journal of Operational Research, 207*, 1147–1161.

Moldavska, A., & Welo, T. (2015). On the applicability of sustainability assessment tools in manufacturing. *Procedia CIRP, 29*, 621–626.

Moore, S. M., Dolansky, M. A., Singh, M., Palmieri, P., & Alemi, P. (2010). *The systems thinking scale* (Unpublished manuscript).

Pahl-Wostl, C., Jeffrey, P., & Sendzimir, J. (2011). Adaptive and integrated management of water resources. In *Water resources planning and management* (pp. 292–310). Cambridge: Cambridge University Press.

Pisano, U., Lange, L., Berger, G., & Hametner, M. (2015). *The Sustainable Development Goals (SDGs) and their impact on the European SD governance framework*. Preparing for the post-2015 agenda. ESDN Quarterly Report.

Senge, P. (1990). *The fifth discipline: The art and science of the learning organization*. New York: Currency Doubleday.

Turner, B. L., Menendez, H. M., Gates, R., Tedeschi, L. O., & Atzori, A. S. (2016). System dynamics modeling for agricultural and natural resource management issues: Review of some past cases and forecasting future roles. *Resources, 5*, 40.

Wilson, G. (2012). *Module 2: The lived experience of climate change. T869 climate change: From science to lived experience. Workbook*. Milton: Open University.

Chapter 2
Renewable and Sustainable Energy

Abstract The role of energy in development is crucial. Energy fuels economic growth and is therefore of paramount concern for all countries. This was one of the main themes at the world summit on sustainable development (WSSD) held in South Africa in 2002. The Johannesburg plan of implementation highlighted the role of energy service to promote sustainable development. Renewable energy is the solution to the growing energy challenges of developing countries. The heavy reliance on imported fossil fuel coupled with the growing demand for electricity and declining wood fuel supplies call for alternative sources of energy. Finding ways to expand energy services, while addressing the environmental impacts associated with energy use, represents a critical challenge for humanity. Recent developments in countries like China and India, where energy production has increased significantly, demonstrate how difficult it is. The decentralized approach based on power produced with locally available renewable energy resources is, for various reasons, gradually being recognized as a viable alternative in remote places. This chapter attempts to initiate, from a broad-based socio-economic and environmental point of view, the feasibility of a decentralized solar photovoltaic (SPV) or wind turbine system as a source of power for rural and urban communities in developing countries.

Keywords Paramount · Sustainability · Alternative · Decentralized · Energy · Rural

2.1 General Background

Energy is a key factor for sustainable development and poverty eradication. The UN's Sustainable Development Goals call for progress in economic growth, poverty reduction, health, and education. Energy is crucial for achieving the Sustainable Development Goals, through eradication of poverty, health, education, water and adapting to climate change. This is the target of the SDG 7 and is consistent with UNSE4ALL's objectives on energy. Expanding infrastructure and upgrading

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technology with clean energy sources such as solar, wind, and hydroelectricity increases access. Transition to a clean energy economy according to the Marrakech Action Proclamation is needed to limit temperature rise and avert impacts of climate change (Scanferla 2016). It demonstrated multilateral cooperation on the implementation of the UNFCCC Paris 2016 agreement. The decisions would accelerate response to the challenges posed by climate change and sustainable development. This will facilitate government's ability to operationalize the Paris climate agreement as a global community with a common direction. Investment for large-scale renewable energy and waste management projects should be mobilized to curb greenhouse gas emissions. Stepping up corporate investments in clean energy and lowering the carbon footprint of operations and supply chains should be supported. Advancing clean energy policies and investments will support the Paris accord and the Marrakech climate negotiations.

Ensuring universal access to modern energy services, improvement in energy efficiency and doubling the share of renewable energy in the global energy mix are the UNSE4ALL objectives. Achieving each of the three objectives would realize multiple, substantial benefits to countries, companies, and society. The transition to sustainable energy systems provides opportunities to adopt cleaner, efficient technology and leapfrogging infrastructure (Ahuja and Tatsutani 2009). Under the United Nations Sustainable Energy for All Initiative (UNSE4All) umbrella, initiatives such as the US Government to Power Africa, The European Investment Bank, the Economic and Social Commission for Western Asia, Rio + 20 initiatives such as Kazakhstan's Green Bridge have laid important institutional and cooperative foundations for effective international governance. The investment for clean energy is available under existing policies and market trends. Accelerating and expanding global clean energy investment is essential to realizing its goals. New policies and approaches will be needed to bridge the gap.

Electricity is one of the most required elements of a country's development and one of the main infrastructural requirements for agricultural, industrial and socio-economic development (Ahuja and Tatsutani 2009). In most parts of the world, areas without electricity are far less developed than those with electricity. Renewable energy uses and applications have been justified and strongly recommended. The decentralized approach based on power produced with locally available renewable energy resources is, for various reasons, gradually being recognized as a viable alternative. A closer look would, however, demonstrate that the nature of the energy sector in Africa offers enormous opportunities for formulating and implementing ambitious renewable energy programs that will bring about an environmentally sound and secure energy (Bakker 2003).

The current effort to provide energy services to the rural and peri-urban populace has been slow. The main energy resource comprises fuel wood, petroleum products, Liquefied Petroleum Gas (LPG) and renewable energy. The provision of efficient, reliable and affordable energy that is sustainable and environmentally sound should be the main objective. The solar radiation is strong in most African nations especially those closer to the equator e.g. Angola. Electricity generation from renewable

energy technologies, such as solar PV systems, can be a cost-effective alternative for off-grid rural households.

Around 30% of the world population has no access to affordable energy sources. However, less than 4% of the African population has access to electricity, the majority in rural and peri-urban areas (Davidson 2001). Access to sustainable and green energy is fundamental to health, development and economic growth. Conventional energy sources are harmful to the environment and human health. Unlike widely used fossil fuels that emit enormous amounts of greenhouse gasses, solar/wind energy is green, clean and limitless. The primary goal of the use of sustainable energy is to improve the living conditions of communities in areas off the electric grid through the supply of reliable and sustainable electricity. This will enhance setting up local production enterprises, help villagers to cope with living conditions and counteract migration into the cities.

Commercial electricity production is marked by a number of challenges. These include under-capitalization, a rigid tariff system, escalating fuel prices, transmission and distribution losses and non-settlement of electricity bills. Consequently, utility companies have great difficulties in meeting operational costs, replacing obsolete equipment, investing in generation capacity and expansion. Conventional electricity is produced mainly by thermal generation through a central power station and smaller generation units.

In some areas access to electricity is actually declining, as existing systems flounder for lack of maintenance and extensions of the service fail to keep pace with population growth. The transmission and distribution network has technical and non-technical losses. The world is bracing for a looming energy crisis, fueled by skyrocketing oil prices because of increasing demand for energy and fewer resources (Sanneh and Hu 2009). Solar panels/ wind turbines are becoming a more lucrative and attractive solution for powering our energy-hungry world. As the price of fossil fuels increases and as the cost to the environment becomes a major concern, solar panels are becoming more affordable and cost effective.

The core objective is to increase generating capacity and capital investment to improve the poor state of the transmission and distribution system. Improved efficiency would reduce the high cost of electricity tariff. Measures should be undertaken to overcome these challenges through institutional strengthening and restructuring. In that regard, governments should encourage local and foreign investors so as to reduce the cost of electricity and increase accessibility as well as the reliability of electricity. The use of alternative and renewable energy is gaining recognition, especially the use of solar PV from both individuals and groups. However, the deterring factor in the widespread utilization of renewables is the initial cost of investment, which is beyond the reach of many. Most solar PV and wind installations are donor funded. Renewable energy provides better alternatives to imported fuels. The production and utilization of clean fuels have the following positive impacts:

1. Creates employment
2. Increases cash incomes and hence reduce poverty

3. Enhances the environment
4. Reduces balance of payment
5. Ensure a sustainable supply of energy

There are many factors that contribute to achieving sustainable development. Electricity services are complementary factors for social and economic development. In countries where the availability of energy is limited for households or society in general, development is impaired (Bain et al. 2013). Energy is thus an essential ingredient for socio-economic development. Rightfully then, issues of energy supply, access and security should be at the core of development. According to the United Nations Industrial Development Organization (UNIDO), high levels of income per capita tend to be associated with higher levels of industrialization. Though not specifically referred to in the Millennium Development Goals (MDGs), energy supply is an underlying requirement to development that is highlighted in the SDGs. Without access to adequate energy services, the development of communities will continue to be a challenge. According to the World Bank indicators database, there is a strong correlation between modern energy consumption and GNP per capita (Lambert et al. 2014). The GNP tends to rapidly increase as commercial energy use per capita increases. This applies mainly to low-income countries.

Nearly two billion people in the world are living without electricity and another billion people are relying on kerosene, candles or batteries (Van Acker et al. 2014). Energy links with other sectors are decisive for economic growth that reverses poverty. Energy deficiency makes education, health, and livelihood extremely difficult in developing countries. Solar energy can be used to empower three billion people in rural communities and urban settlements. In addition, the solar panel-based outfits can be used to pump water for household needs, agriculture, and small and medium enterprises. Moreover, computers, printers, and telephones in rural areas can be operated by solar power. Solar panels can be used very effectively and appropriately in rural communities because the cost of expanding the conventional power grid might be expensive. Developing countries are heavily dependent on fuel imports to meet their energy needs. Petroleum is an important source of energy in developing countries and it is mostly imported.

Better access to sustainable energy services is needed to foster economic growth with a view to stimulating income-generating activities. Extending the conventional grid to most rural households has been generally deemed financially costly (Government of The Gambia – GOTG 2005). The micro-grid alternative using diesel generators is also largely unviable due to difficulties in accessing technical support and high costs of fuel transportation. Against this background, the World Bank and many governments started considering renewable energy systems as an alternative for electrification (United Nations Economic Commission for Africa – UNECA 2006). Solar-based technologies are in a good position to meet the growing need for energy in developing countries.

Energy emissions contribute to global warming, making the trend towards natural disasters in many parts of the world worse. Following the Stern Review and the February 2007 report of the IPCC, there is no longer any real doubt that climate

change is occurring. World energy demand is expected to rise. The pressure to find alternative and efficient energy sources will only become greater. Renewable energy and solar PV, in particular, is a viable option for electrification and has considerable potential to meet the needs of rural populations. The decentralized nature of solar PV means that it requires local installation, operation and maintenance capabilities. Solar Home Systems (SHS) can meet some of the electricity needs of the rural population, generating electricity for a household to provide home lighting whilst displacing kerosene lighting and dry cell battery powered devices.

There are many barriers to the widespread diffusion of renewable energy technologies. However, the market for direct purchases is often small. Studies by Enersol have shown that very few rural households can afford to purchase a system directly (Sanneh and Hu 2009), Financing schemes for solar home systems become an important step in facilitating solar system purchases. However, lending to rural families with little "collateral" is viewed as a risky venture. Credit schemes should be initiated, in which a retailer provides a credit plan. Multilateral lenders can provide wholesale loans to intermediate, in-country institutions for retail lending at the village level. The multinational lender faces lower risk by lending to a secure institution such as a local bank, an NGO or a large retailer. This model may result in large infusions of capital such as Photovoltaic Market Transformation Initiative (PVMTI).

Revolving loan funds can be set up by communities to provide low-interest loans to individuals. The terms of the loans are often less strict than they would be from a financial institution. A third party can buy the systems at bulk rates and sell them through long-term contracts to consumers. When grid extension is not a viable option for a particular population, the government may grant a concession to a private institution to serve the community with electricity. This system is particularly useful when the service area is deemed to be too dispersed or sparsely populated.

An Energy Service Company (ESCO) can also sell energy services but retains ownership. Cooperatives, NGOs, electric utilities and private companies can serve as ESCOs. System costs are reduced because of the bulk buying, and the ESCO is seen as a less risky investment to financiers, leading to better interest rates. Energy service costs are akin to grid energy services because the end-user pays for the systems in smaller increments over a longer time frame (10 years or more). It is important to make sure that there is enough demand for electricity. Financing schemes should include installation and maintenance. Financing schemes can also incorporate money for training of technicians for proper care for the systems at all levels (Sanneh and Hu 2009).

Options for energy production and consumption have a direct impact on the ecosystem, climate change, and human health. The severe economic and environmental implication of the way energy is produced and consumed has propelled energy initiatives such as the United Nations Sustainable Energy for All Initiative (UNSE4ALL). For most stakeholders, sustainable energy implies either renewable energy sources or/and the use of technologies that ensure a minimum or no damage to the environment. People at the base of the pyramid are the key to commercializing tomorrow's clean technology for there is an opportunity for innovation. People in developing countries are paying more in 1 year for

Table 2.1 Price of SHS in developing countries

Country	Estimated SHS cost (50 Wp; US$)	GNI/Capita (US$ per year)	Cost/Income ratio
Eritrea	650	160	4.06
Ethiopia	750	100	7.5
Kenya	550	350	1.57
Lesotho	1000	530	1.87
Somalia	> 800	296	>2.7
Sudan	650	340	1.91
Tanzania	850	270	3.15
Uganda	500–700	260	2.8
Zambia	1200	320	3.75
Zimbabwe	800	387	2.07

Energypedia: Basic Energy Services (https://energypedia.info/wiki/Basic_Energy_Services_Solar_PV_(SHS,_Solar_Lanterns)#Costs_of_SHS)

kerosene or candles than the one-time cost of a solar PV system (Lins 2013). The basic DC SHS with a 50 Wp panel, battery control unit and battery, capable of powering a small rural household, might not be too costly. The price of PV modules dropped and is expected to decrease further due to economies of scale. Operations costs which cover maintenance, repair, and replacement of battery, lamps and electrical system over the lifetime of the SHS can be developed. Concurrently monthly payments can be borne by the end-users to cover only the service. Table 2.1 shows the price of SHS in developing countries.

Most households in the rural communities do not have access to modern energy services. Therefore, solar PVs are seen as an excellent alternative to grid extension. Some households in urban communities purchase solar PV either because they are not connected or because they want to be sure to have reliable electricity supply. With cash purchase out of the question, most rural families will have to resort to some form of financing. If one is a member of a credit union, or a rural-based civil servant, such as a teacher, one can enter an agreement to have a monthly deduction from one's salary. If they are a member of a cooperative organization, they can take out a loan at a lower interest rate. Grid-based electricity is more expensive in rural than in urban communities due to lower load densities, lower capacity utilization rates (Mahapatra and Dasappa 2012). Alternative approaches are necessary in order to meet rural electricity needs in the least expensive ways.

The use of solar PV by rural households and services will lead to reduced CO2 emissions by means of the avoided use of kerosene for lighting in households and the avoided use of diesel in generators. The higher cost of inefficient energy-using devices and the lack of access to modern energy sources such as electricity becomes an added cost of being poor. Unlike other power generating systems such as diesel generator, SHSs do not require any fuel, maintenance and spare parts. Widespread use of solar PV systems should go hand-in-hand

with a recovery system for batteries to prevent chemicals being dumped into the environment. We live in a world dominated by a "center-periphery" consciousness. Access to energy is concentrated in urban areas that are connected to centralized power grids. Remote communities are deprived of basic energy services. Four out of five people without access to electricity live in rural areas of the developing world, mainly in South Asia and Sub-Saharan Africa (Kaygusuz 2012). Policies and investment trends in energy infrastructure should enhance access to electricity. Innovating financial schemes would further help communities access them.

2.2 Optimizing the Use of Renewable Energy

2.2.1 Aurore, India. Solar Power for Communities, Farmers and Market Traders Across India

Aurore is a non-profit organization which was established by the trustees of the Auroville Centre for Scientific Research in Auroville, Tamil Nadu, India. Established over 30 years ago, Auroville is a unique hybrid of spiritual retreat, experimental multinational community, and environmental research center. Over a period of 6 years, it has facilitated the installation of nearly 2 MWp of photovoltaic (PV) systems across India, including 845 PV-powered water pumps, 8700 domestic PV systems, and over 6000 PV-powered lanterns.

2.2.2 Barefoot College, India

2.2.2.1 Solar Energy to Meet Basic Needs in the Himalayas

This project has introduced solar technology to remote and inaccessible villages in the Himalayas. Run by the Barefoot College in Rajasthan, India, the project has shown that with appropriate training, poor and rural communities can install solar equipment in their villages and then maintain it without any further external help. The project has trained illiterate and semi-literate villagers as 'Barefoot Solar Engineers', (BSEs) at its Barefoot College in Rajasthan. After the training, they return to their home villages to install solar units and provide their communities with a skilled and competent repair and maintenance service. The project has been working in six states along the Himalayas since 1990. A total of 110 Barefoot Solar Engineers, including women, have been trained during this time. They are maintaining and repairing more than five thousand solar lighting systems.

2.2.3 *Zara Solar Ltd, Tanzania Mohamed Rafik Parpia*

Zara Solar, based in Mwanza, is providing affordable solar PV systems in north Tanzania and has recently opened a second branch in the capital Dar-es-Salaam. The company was launched in 2005 from Mona-Mwanza Electrical & Electronics, an established family business. Tanzania has a low rate of electrification, rural communities dependent on kerosene for lighting. A network of 25 self-employed technicians spread around the region in rural communities. Solar PV systems are able to provide electricity to light homes and watch television. These services also bring great benefits in health care, education and social welfare. It can also facilitate the operations of small and medium size enterprises. Zara Solar and its sister company Mona-Mwanza Electrical & Electronics, both based in Mwanza; provide high-quality, affordable PV systems in Northern Tanzania. Recognizing that the customer base is poor and difficult to reach for servicing, Zara Solar insists on high-quality equipment that is less likely to break. The next step is offering micro-credit facilities to make solar PV available to people who can afford monthly payments and do not have the money to pay upfront.

2.2.4 *Rural Solar Photovoltaic Electrification Project (Morocco)*

The Moroccan Office National de l'Electricité (ONE) entered into a fee-for-service partnership with a renewable energy services company (RESCO) to electrify rural households by using solar PV systems. The RESCO is responsible for the installation and maintenance of solar equipment in 24 provinces. In the fee-for-service model, customers pay an initial connection fee and a monthly service fee.

The various studies and pilot programs operated provided technical, social and economic data validation on the need and design of such a program. This information assisted the Moroccan government in opting for the fee-for-service model, instead of the sale of equipment model that has been adopted in other countries implementing rural solar electrification projects. The fee-for-service business model helped to make the project viable and sustainable.

Having local offices and local representation at the weekly markets has helped the company develop a reputation for accessibility and trustworthiness throughout the communities. This attention to customer support has resulted in the low payment default rate. In the electrification scheme in Morocco, the RESCO is obliged to advance money for the equipment before being reimbursed through a subsidy.

2.3 Enabling Environment

Policy interventions removed barriers to rural solar electrification in Morocco by developing the capacity for conventional and renewable rural electrification. It established electricity markets, updating and maintaining the grid. This program led to the installation of photovoltaic systems, funded in part by the users, as well as several group systems. It demonstrated that rural customers could become accustomed to making payments with the help of an appropriate organizational structure.

With village connection rate low, the program goal aimed to increase rural connections. It provided electricity to a lot of villages by connecting them to the national power system and decentralized system based on mini-networks. The decentralized electrification program is based on a sale of service model to ensure long-term success. When a rural household decides to install a solar home system, they sign a contract with the service provider. The provider installs the equipment and collects monthly fees. The monthly fees are based on the income level of a household, mostly adapted to the cost of Kerosene or candles being used.

This can influence individuals to venture into socio-economic activities using electricity. This increased the availability of solar PV in rural villages with high installation rates. Prior to implementation, defined specifications and standards were advocated to solar systems' operator. The subsidy was also provided, which enables the operator to cost installation service at a rate that is affordable. The lanterns are no more expensive than their kerosene equivalents, but are much more reliable; provide a more constant light and cleaner. Solar chargers supply electricity to devices or charge batteries. They are generally portable and are mostly used to charge cell phones.

2.4 Water Pumps

Access to water and sanitation are among the top priorities for poverty reduction and sustainable development. Availability of adequate supplies of water and ready access to them are essential prerequisites for good health, food sufficiency, and socio-economic development. In semi-arid to arid countries, water supply challenges will increase in the future with demographic and climate change putting pressure on available resources. Thus, proposing the use of PV modules for powering water pumps. The pump lifts water from a well or boreholes to supply clean drinking water for communities and may also be used to run irrigation systems.

Reliable access to water is critical for developing countries, solar-powered water supply systems have been used in Cabo Verde, Cambodia, Mali, Niger, and Sudan. In Cape Verde, such systems irrigated land for farming, accessible drinking water improving health and hygiene. In Cambodia, solar pumps have improved access to water, improved the economy and created food security. In Mali, solar pumps provided water to women engaged in vegetable gardening.

2.5 Hybrid Systems

Technology advances over the past decade have made renewable energy sources more viable to meet isolated grid power needs. The hybrid energy system is an excellent solution for electrification of remote rural areas where the grid extension is not economical. As the wind blows and the sun shines, solar and wind hybrid system together with storage batteries can be a sustainable source of energy for developing countries. Developing countries burdened by the high costs of imported fuel can benefit from small, sustainable hybrid systems that use a combination of solar, wind, and micro-hydro technologies to electrify rural, off-grid towns and villages. Village hybrid energy systems employing renewable energy offer an attractive and practical approach to meet electrical power needs in rural communities around the globe.

Of the nearly 260 million unserved rural households, many reside in isolated communities far from the national electricity network. These "off-grid" communities are generally small and dispersed, consisting of low-income households. Hybrid system incorporates a combination of several renewable energy sources such as solar photovoltaic, wind energy and sometimes generators for backup (Budischak et al. 2013). Hybrid systems can provide electricity at a comparatively economic price in many remote areas. Reliable electricity can be obtained from a hybrid system at an economical price, with optimal design in terms of operation, and management.

A combination of solar, wind and generator systems, have an advantage of both, i.e. can be connected to the utility grid or standalone. The most common generation sources for a hybrid power system are photovoltaic and wind turbines with a diesel generator as a backup (Sawle et al. 2016). The major advantage of wind energy is that when used together with solar photovoltaic, the reliability of the system is enhanced, also can have batteries to store electricity. A hybrid power system becomes an attractive option where there are opportunities to provide power generation with optimum efficiency through the combination of traditional and renewable energy sources. A hybrid system using a combination of solar PV, wind turbine, and power generators generally increases the average power capacity by 10–30% when compared to a traditional single unit using either solar or wind energy (Budischak et al. 2013). A hybrid solar/wind system is more efficient since the solar system provides power for the unit during the day to charge the storage batteries, while the wind system is used to supply power or store energy during the night when solar energy is not available. In rural communities, where utilities have little incentive to connect customers located beyond their limit, renewable energy can be a good alternative. Privatizing electricity generation and distribution in developing countries can help improve access especially for off-grid communities. Policy decisions for electrification investments should be based on targets including creating an energy mix, leakage reduction within the grid and expansion.

References

Ahuja, D., & Tatsutani, M. (2009). *Sustainable energy for developing countries*. SAPI EN. S. Surveys and Perspectives Integrating Environment and Society, (2.1).

Bain, L. E., Awah, P. K., Geraldine, N., Kindong, N. P., Siga, Y., Bernard, N., & Tanjeko, A. T. (2013). Malnutrition in Sub–Saharan Africa: Burden, causes and prospects. *Pan African Medical Journal, 15*, 120.

Bakker, K. (2003). Archipelagos and networks: Urbanization and water privatization in the south. *The Geographical Journal, 169*, 328–341.

Budischak, C., Sewell, D., Thomson, H., Mach, L., Veron, D. E., & Kempton, W. (2013). Cost-minimized combinations of wind power, solar power and electrochemical storage, powering the grid up to 99.9% of the time. *Journal of Power Sources, 225*, 60–74.

Davidson, D. (2001). *Inquiries into truth and interpretation: Philosophical essays*. Oxford: Oxford University Press.

Government of The Gambia – GOTG. (2005). *National energy data*. The Gambia: Office of The President.

Kaygusuz, K. (2012). Energy for sustainable development: A case of developing countries. *Renewable and Sustainable Energy Reviews, 16*, 1116–1126.

Lambert, J. G., Hall, C. A., Balogh, S., Gupta, A., & Arnold, M. (2014). Energy, eroi and quality of life. *Energy Policy, 64*, 153–167.

Lins, C. (2013). Renewables 2013 Global Status Report. *Renable energy for 21st century*.

Mahapatra, S., & Dasappa, S. (2012). Rural electrification: optimising the choice between decentralised renewable energy sources and grid extension. *Energy for Sustainable Development, 16*, 146–154.

Sanneh, E. S., & Hu, A. H. (2009). Lighting rural and peri-urban homes of the gambia using solar photo-voltaics (Pv). *The Open Renewable Energy Journal, 2*, 00–00.

Sawle, Y., Gupta, S., & Kumar Bohre, A. (2016). Pv-wind hybrid system: A review with case study. *Cogent Engineering, 3*, 1189305.

Scanferla, G. (2016). *Why is it so difficult to see climate change as a problem? Objectives and results of the new energy revolution*. Università Ca'foscari Venezira.

United Nations Economic Commission For Africa – UNECA. (2006). *The economic report on Africa: Capital flows and development financing in Africa*.

Van Acker, V., Szablya, S. J., Louie, H., Sloughter, J. M., & Pirbhai, A. S. (2014). *Survey of energy use and costs in Rural Kenya for community microgrid business model development*. Global Humanitarian Technology Conference (Ghtc), 2014 IEEE, pp. 166–173.

Chapter 3
Access to Safe Drinking Water

Abstract Unclean water and a lack of basic sanitation are undermining efforts to end extreme poverty and disease in the world's poorest countries. Availability of adequate supplies of water and ready access to them are essential prerequisites for health, food sufficiency and socio economic development. Predicted climate change is likely to add measurable stress to water resources in many regions of the world. In working towards improvements in the quality of life and the achievements of the Sustainable Development Goals (SDG's), water is a key issue around which much revolves. The objective of this research is to look at the access to safe drinking water, in relation to the efforts to achieve the SDGs. Using a structured questionnaire and observational checklist, information was collected from female household heads in villages. Key indicators used in this survey are distance to sources of water, and the type of water supply system. In order to assess performance, four scenarios are created and their impacts are analyzed. Most of the scenarios indicate that continued and adequate funding is absolutely necessary for increasing access and achievement of the SDGs. The worst scenario is high population growth with no funding, which will result to a decrease in water coverage. This study also found that safe water supplies are available within 160 meters. Although queuing times may be quite long, unprotected sources are not used for drinking purposes.

Keywords Water availability · Water resources · Access · Adequacy · Funding · SDGs

3.1 General Background

Water is at the core of sustainable development and has strong linkages to all of the other SDGs. Meeting SDG 6 would go a long way towards achieving much of the 2030 Agenda. Water and climate are linked. It is crucial for human development, education, health, stability and food security. Water resources are impacted by climate change requiring an action agenda. United Nations climate change conferences devote action on water. Integrated and sustainable water management can help meet the challenges related to water availability. Water shortage is costly and will be expensive in the future, thus water is critical to sustainable development.

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Technical solutions exist; political leadership in collaboration with organizations and communities is required on dedicated goal on water (Cohen 2010).

Water scarcity affects as a result of dwindling supplies is alarming and will increase with the rise in global temperatures. It is important to mainstream water and sanitation in policies and plans to support social, economic and environmental dimensions of the 2030 Agenda for Sustainable Development. The SDG target is access to improved water quality, sanitation, and hygiene, water-use efficiency, integrated water resources management, protect and restore water-related ecosystems (Weitz et al. 2014). Clean, accessible water is a goal and there is sufficient fresh water on the planet. Cooperation, capacity-building, and sanitation related support to developing countries should focus on water harvesting, desalination, wastewater treatment, recycling and reuses technologies. The comprehensive and coordinated approach, action and advocate on financing and implementation to increase access for sustainable management of water and sanitation (SDG 6). It expands the MDG focus on poverty reduction to cover all aspects of sustainable development towards a dedicated water goal. The water-related linkages are interdependent and need an integrated approach for implementation.

Global development is moving from aid to market-based solutions and products. Businesses have an active role to play in the achievement of SDG 6 through community involvement in addressing issues related to water and sanitation. They face financial risks connected to water, through their operations, products, and services. The partnership is required to effectively address issues in the supply chain. Coca-Cola's partnership with World Wildlife Fund extends across nearly 50 countries, improving water efficiency, operational advancements and maintaining healthy, resilient water systems (Muller 2015).

Urbanization is occurring, food requirements are rapidly expanding, floods and droughts are growing in frequency, numerous aquifers are under threat, and climate change will exacerbate these problems. Water and sanitation are necessary for human dignity and economic growth through public health, food security and environmental wellbeing. Well-designed multi-purpose resilient infrastructure is critical for access to quality water, sanitation, irrigation services, flood protection and water storage. Mitigating climate change requires fundamental shifts in politics, economics and technological innovation. As the SDGs represent an opportunity to drive scale through innovation, businesses can add real value with their expertise. P&G's initiative is combatting diarrheal diseases through the distribution of its purifying product, PUR. Unilever's Lifebuoy program improves hand washing behaviors. The Toilet Board Coalition includes governments, sanitation experts, and non-profit organizations aiming to develop commercially sustainable and scalable solutions to sanitation. Businesses are able to address the needs of the poor through flagship community programs.

Safe drinking water is a precondition for health and development and a basic human right, yet it is still denied to hundreds of millions of people throughout the developing world. According to the (United Nations 2009), 35% of the developing countries (with available data) have achieved or are on track to achieving the improved water target, while 24% have achieved or are on track for improved

sanitation target. Fifty-seven percent of countries (with available data) in the Middle East, North Africa, and Central Asia are seriously off track in improving access to safe drinking water. Progress is slow for improved sanitation in sub-Saharan African and Central Asia.

Despite continuing efforts by governments, civil society, and the international community, people still do not have access to improved clean drinking water. Unclean water and a lack of basic sanitation are undermining efforts to end extreme poverty.[1] This inequality in access to water is largely due to inefficient allocation of water resources. Access to a safe and adequate water supply and environmental protection is a universally recognized human right. The challenge of water-quality management associated with the principle of sustainable development has been of concern. It requires not only the reinforcement of established principles and technologies but also their extension to much wider scope. It is indicated that during the past two decades much progress has been made on different aspects of water resources development and management. In spite of such progress, however, much remains to be done.

Water supplies are limited and are without substitutes. Water scarcity is likely to lead to greater human and political insecurity. Freshwater resources have faced a crisis worldwide. These challenges include increasing scarcity of fresh water, lack of accessibility to adequate clean drinking water and sanitation, deterioration of water quality, fragmentation of water management, nationally and globally (Water-UN 2006). In working towards improvements in the quality of life and the achievements of the SDGs, water is a key issue around which much revolves. The objective of this book is to look at the access to safe drinking water in relation to the efforts to achieve the SDGs. Using a structured questionnaire and observational checklist, information was collected from female household heads in ten villages in the Western Region of The Gambia. Key indicators used in this survey are the distance to sources of water, and the type of water supply system. Most of the scenarios indicate that continued and adequate funding is absolutely necessary for increasing access and achievement of the SDGs.

Water is increasingly seen as one of the most critically stressed resources, requiring attention. Billions of people are living in water stressed or scarce communities. In semi-arid to arid countries, water supply challenges will increase with climate change. Despite continuing efforts by governments, civil society, and the international community, people still lack access to improved water sources (Budds and McGranahan 2003). In sub-Saharan Africa, millions of people lack access to clean drinking water. Lack of universal access to water and sanitation results in millions of preventable deaths. Sustainability in water and sanitation would enhance development by meeting the needs of the poor.

Providing safe drinking water becomes a greater challenge as economic development and population growth place increasing demands. Water is an indispensable resource for life and human development. Inequality in access to water is due to inefficient allocation of resources. It is estimated that one in three people in developing

[1] http://www.un.org/en/sections/issues-depth/water/

countries lacks access to clean drinking water (Moe and Rheingans 2006). This has a macroeconomic impact as well. Nearly 10% of the total burden of disease worldwide is attributable to unsafe water, sanitation and hygiene. WHO data on the burden of the disease shows that a significant percent of deaths worldwide is attributable to unsafe water, sanitation and hygiene. These factors entrench social inequalities.

The high cost of water and lack of water quality for the poor are responsible for low levels of personal hygiene and diseases (Wenhold and Faber 2009). The challenge of water-quality management associated with the principle of sustainable development has been an issue. This book suggests that it does not only require the implementation of the plans of actions in the SDG targets, but also the establishment of principles and technologies. Water management should be based on sustainability due to far-reaching social, economic and environmental implications. This book focuses on adequacy, access (socio-economic) and reliability of water supplies. Increasing populations and uncertain climatic changes will pose heavy demands on water. Water scarcity can be expected to worsen with climate change.

Continued and adequate funding is necessary for safe water supply. Successes of water and sanitation have been documented in Mauritania, Mali, Niger, Uganda and Tanzania (Haysom 2006). Persistent droughts and water shortages as a result of climate change have drawn attention to the need to provide adequate supplies of safe drinking water. Access to improved water supply has increased rapidly over the past two decades. There are, however, wide disparities between urban and rural areas in terms of coverage. Promoting greater awareness of the linkages between safe drinking water and human health would ensure safe handling of water from source to point of consumption.

A list of all the villages obtained from the population census was sorted according to population size. The sorted list was then divided into villages/settlements using a type of water supply system provided in relation to population criteria. A percentage of each type of water supply system per number of villages was used to determine the number of questionnaires that were administered. The unit of the survey is the household, with females as subjects for they are traditionally associated with the collection, utilization, and management of water at household level. A total of 100 respondents were recruited for the survey. The questionnaire was completed by village-based community workers. It had four dimensions that characterized access to safe water supply, adequacy, reliability, and safety, see in Appendix I. Standard interview (SI) was conducted in Mandingo, the respondent's first or second language.

Initial focus on improved water has been emphasized in promoting interventions to increased access to microbiologically improved drinking water. The increase in coverage is not keeping pace with population growth; urban-rural disparities are particularly striking in Sub-Saharan Africa. Perceived satisfaction of requirements and the availability of water for all uses were used as a criterion of adequacy. A significant number of respondents said the water was sufficient. Some of the respondents were not satisfied with the volume of water collected due to the low discharge rate (low pressure) and a number of people depending on a single source.

During the past two decades, progress has been made on different aspects of water resources development and management in different parts of the world. In spite of such, however much remains to be done, especially in developing countries. The challenges include deterioration of water quality, a decline of financial resources allocation for water infrastructure development and continuing lack of awareness of the magnitude of the problem. The SDG target refers to sustainable access to safe drinking-water and basic sanitation. In order to achieve this vision, decisions must be made about allocation mechanisms and conservation of water that are compatible with economic efficiency and sustainability.

An indicator of adequacy in the survey is service level, associated with queue length, and total time spent on queues. Most of the respondents affirm joining queues to get water. Two variables were used as a measure of total time spent in getting water: (1) time spent on queues, and (2) time spent on filling receptacles. Thirty-two percent of interviewees spent more than 30 min in queues, while about 5% do spend less than 10 min on queues. Queue length is a function of discharge rate and the number of people in queues at a moment (i.e. peak and slack hours). The number of people served by a water point also has an impact on queue length. It is expected that bringing water closer to homes will improve services. Firstly, it will increase the number of supply points, thereby reducing queue lengths. Secondly, it will reduce the amount of time and drudgery of carrying water from its collection point to the house.

Water is an indispensable resource for life existence and human development. Inequality in access to water is largely due to inefficient allocation of water resources. Water requirements of individuals differ in different stages in life, e.g. childhood, pregnancy, lactation and the elderly. Sources of water supply are assumed to be safe when potential contaminants (e.g. human and animal waste) are not within sanitary distances. Many of the women interviewed got water from covered wells with hand pumps or reticulation systems. The remaining affirmed source of drinking water is from open unlined wells. Adequate amounts of water collected and used by households have an influence on the health of individuals and families.

Improvements in developing countries are not providing water of adequate quality for domestic purposes. According to the survey, most respondents claimed to get water from a safe source located at a convenient distance. Some highlighted that the water was enough for all the desired needs and a majority joined queues to get water. Water quality is a growing concern in developing countries and water sources are under increasing threat from contamination. These have consequences to health, economic and social development. Sub-Saharan Africa accounts for over a third of that number and is lagging behind in progress towards meeting targets (Kumasi et al. 2010). Water-related diseases, poor sanitation, and hygiene cause deaths, mostly children.

In rural communities, high rates of infant and under–five mortality are due to infectious diseases, diarrhea, and malnutrition. Factors that influence child mortality are malnutrition and poverty, all of which have shown substantial increases in recent years. Some children live in extremely poor households, which have serious implications for their nutritional status and health. Access to improved drinking water is widely advocated as an effective way to reduce morbidity and mortality. In

the survey villages, water supply coverage and under-five mortality rate (U-5MR) associated with diseases are related. It showed that a great percent treat drinking water, using filtration, boiling or herbal products.

Perceived satisfaction with availability of water for all uses was used as a criterion for adequacy. Discharge rate and a number of people depending on a source are major obstacles. Inequality in access to water is largely due to inefficient allocation of resources. Sources of water supply are assumed to be safe when contaminants are not within a sanitary distance. The nature and structure of water facilities should prevent contamination pathways. To combat the menace of diarrhea among children, much effort is needed to design effective interventions that either gets the water close to people or transported in a protected manner.

Providing technology and hardware in meeting standards and reducing contaminants are issues that water and sanitation interventions should aim at. With the inherent need to combat diarrheal diseases, drinking water should be taken to be a matter of people. Access to improved drinking water is widely advocated as a way to reduce morbidity and mortality, particularly in poor communities (Huicho et al. 2008). Globally, millions of children under 5 years of age live in households without access to improved water. Improvements in sanitation will result in better health, increased child growth, and lower morbidity and mortality (Checkley et al. 2004).

Water is increasingly seen as one of the most critically stressed resources, requiring the attention of policy makers, NGO's and governments. Potable water is a scarce commodity in some developing countries. Access to water and sanitation are among the top priorities for poverty reduction and sustainable development. There is a need for a new convergence in thinking and practice to develop the synergies required to achieve sustainability (Montgomery et al. 2009). Poor communities are often unable to afford the costs or lack the skills to maintain pumps and boreholes. This makes a case for the importance of stakeholder involvement for water as a vital component in poverty reduction.

Maintenance of water supply and sanitation facilities are commonly given minimal attention, construction of new facilities is more likely to gain political support and funding. Access to water and sanitation are among the top priorities of the poor and directly contributes to sustainable development. Reforms will seek to create a policy within a sustainable development framework through integrated water resources management. Public information and participation in decision-making related to water resources management are paramount. Promoting priority action by governments, with the support of all stakeholders in water management and capacity building at both national and regional level should also be initiated.

There is urgent need to address the causes of ill health and their impact on development. The goals of sustainable development can be achieved in the absence of high disease prevalence. Obtaining health gains for a population requires poverty eradication. Affordable sanitation, industrial and domestic wastewater treatment can prevent pollution, reduce health hazards and protect ecosystems. It will mitigate the effects on groundwater. Water resources developed for municipal water supply can be upgraded to meet escalating demands. Developing strategies, plans and programs such as integrated river basin, watershed and groundwater management will help to adapt to climate change.

Improving efficiency in water infrastructure reduces losses and increase reuse of water. Implementation of water conservation includes leakage detection, repair and maintenance materials, retrofit equipment, utility and specialized transport. The diffusion of technology and capacity building for water resources and conservation technologies is vital for regions facing water scarcity. Prevention and protection measures to promote sustainable water use to address water shortages should be promoted. Monitoring and assessing the quantity and quality of water resources with databases is essential.

References

Budds, J., & Mcgranahan, G. (2003). Are the debates on water privatization missing the point? Experiences from Africa, Asia and Latin America. *Environment and Urbanization, 15*, 87–114.

Checkley, W., Gilman, R. H., Black, R. E., Epstein, L. D., Cabrera, L., Sterling, C. R., & Moulton, L. H. (2004). Effect of water and sanitation on childhood health in a poor Peruvian peri-urban community. *The Lancet, 363*, 112–118.

Cohen, J. H. (2010). *Cooperation and community: Economy and society in Oaxaca*. Oaxaca: University of Texas Press.

Haysom, A. (2006). *A study of the factors affecting sustainability of rural water supplies in Tanzania* (p. 54). Bedfordshire: Cranfield University.

Huicho, L., Scherpbier, R. W., Nkowane, A. M., Victora, C. G., & Group, M.-C. E. O. I. S. (2008). How much does quality of child care vary between health workers with differing durations of training? An observational multicountry study. *The Lancet, 372*, 910–916.

Kumasi, T. C., Obiri-Danso, K., & Ephraim, J. H. (2010). Community engagement in the sustainable management of rivers: Barekese catchment, Kumasi, Ghana. *Environment, Development and Sustainability, 12*, 927–943.

Moe, C. L., & Rheingans, R. D. (2006). Global challenges in water, sanitation and health. *Journal of Water and Health, 4*, 41–57.

Montgomery, M. A., Bartram, J., & Elimelech, M. (2009). Increasing functional sustainability of water and sanitation supplies in rural sub-Saharan Africa. *Environmental Engineering Science, 26*, 1017–1023.

Muller, M. (2015). The “nexus” as a step back towards a more coherent water resource management paradigm. *Water Altern, 8*, 675–694.

United nations: Department of economic & department of public information. (2009). *The millennium development goals report 2009*. New York: United Nations Publications.

Water-UN. (2006). *Water, A Shared Responsibility* (The United Nations World Water Development Report 2). Paris: UNESCO. www.unesco.org/water/wwap

Weitz, N., Nilsson, M., & Davis, M. (2014). A nexus approach to the post-2015 agenda: Formulating integrated water, energy, and food SDGs. *SAIS Review of International Affairs, 34*, 37–50.

Wenhold, F., & Faber, M. (2009). Water in nutritional health of individuals and households: An overview. *Water SA, 35*, 61–71.

Chapter 4
Access to Basic Health Care in Communities

Abstract This chapter focuses on lack of access to basic health care, which is one of the hindrances to the development of the poor, and subjects them to the poverty penalty. It is also contributing to the Bottom of the Pyramid in a general sense, in addition to meeting the health needs of communities where people live on less than $1 a day. Strengthened multi-stakeholder responses and better-targeted, low-cost prevention, and care strategies within health systems are suggested to address the health burdens of poverty-stricken communities. A multi-stakeholder model includes the government, World Health Organization, United Nations Children Emergency Fund, and the Medical Research Council was created to highlight the collaborative approach. The result shows infant immunization and antenatal care coverage were greatly improved which contributes to the reduction in mortality. This case study also finds that strategies addressing health problems in rural communities are required to achieve Sustainable Development Goals. In particular, actual community visits to satellite villages within a district (area of study) are extremely vital to making health care accessible.

Keywords Access · Bottom of the pyramid · Multi-stakeholder · Partnership · Poverty penalwty

4.1 General Background

Increasing economic integration, mobility, and political instability pose health challenges and risks. Improvement of health outcomes through action across all SDGs is necessary to address challenges. The SDG 3 provides an opportunity for the private sector to support the delivery of health needs. This could expand access to healthcare and improve health outcomes. The expansion of health globally should address domestic health priorities and intervention. Easing health burden calls for preventive interventions with medical services and affordable access to medicine.

Poor health threatens education, limits economic opportunities and increases poverty. In addition, it is connected to other aspects of sustainable development. The Sustainable Development Goals (SDGs) for a healthier and more sustainable society would require additional focus on public health (Piot et al. 2015). A Global Coalition

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on Health, Environment and Climate Change proposal should be implemented. Ensuring healthy lives and promoting well-being is essential to sustainable development. Institutions should be supported to ensure sustained progress in health and addressing climate change impacts with appropriate adaptation measures.

Improving access to health in developing countries is not only by reducing travel time and distance to a health facility; it also requires improvements in rural communities' socio-economic systems and access to financial resources. A rural community with low economic activities is mostly associated with an increased risk of infant mortality. Factors such as social support for primary caregivers, the degree of financial autonomy and source of revenue for healthcare expenses are significantly associated with child death (Quansah et al. 2016). Financial autonomy is likely to increase rural community's ability to access health care and pay for it. Research in Ghana has highlighted the importance of female financial autonomy for household expenditure in health care. In Tanzanian, children of women who are the decision-makers regarding health care were significantly less likely to die (Quansah et al. 2016). Entrepreneurship and market-driven development are efficient and effective only when social, political and physical conditions are adapted to support development. Government regulations, education, and infrastructure are necessary factors for the genesis of a new generation for sustainable development. Poverty in developing countries is perpetuated by a plethora of factors. The causal factors of underdevelopment, such as political structures and economic systems, will require time and internal change. However, the third sector, here defined as non-profits, universities, and academia, have a crucial role to play. The failure of development efforts and interventions lies, in part, with the lack of collaboration between the many different stakeholders. This is a tragedy that can be easily averted through cooperation.

Protecting and improving the health of a community, sanitation, and monitoring of environmental hazards can enhance sustainable human development. During the past decade, resources have been invested in health as a key driver of socioeconomic progress (Tulchinsky and Varavikova 2014). Yet poverty continues to contribute to poor health, and poor health traps large populations in poverty. Access to life-saving and health-promoting interventions should not be denied, especially for those with economic or social deprivations. These would help in the attainment of the health-related SDGs.

There is a vast discrepancy in access to health care and public health initiatives between developed and developing nations. Available data on health indicate that extremely high levels of preventable illness prevail in these countries. Millions of parents living in developing countries face a tough dilemma: How can they protect the lives of their children if they don't have access to basic health care? Most often they just live too far away from health facilities. Sometimes they don't realize the importance of preventative measures like vaccines and mosquito nets. Average health spending by BOP households varies widely across developing countries. A social gradient in health through society is that those that are poorest generally suffer the worst health. Despite enormous progress in the prevention, diagnosis, and treatment of diseases, developing countries remain largely excluded from the benefits of modern science (Gureje et al. 2015). Caught in a cycle of poverty and

disease, people are facing shorter life expectancies and economic decline. The delivery and availability of health goods and services are critical to the successful national development and poverty alleviation (Marter-Kenyon 2007).

Both an adequate amount of water and quality are essential for public health and hygiene. The BOP issue can create new knowledge area, and there is need to broaden the scope. The aim is to contribute to the BOP so that the needs of the poor can be achieved through products, services, and innovations. The availability of health goods and services are critical to national development and poverty alleviation. Many complications in maternal and child health are believed to be due to availability and access to health services (Navaneetham and Dharmalingam 2002). Poor people in developing countries tend to suffer from a phenomenon known as poverty penalty, the additional cost paid for goods and services. Factors contributing to the mortality of children under 5 years old have been attributed to inadequate access to health services (Rutherford et al. 2009). According to the United Nations Population Fund, maternal deaths are preventable, yet women die from pregnancy-related causes (WHO 2004).

In 1978, the historic declaration of Alma-Ata was adopted to promote primary health care. It endorses health as a basic human right, offering values, principles, and approaches aimed at the promotion of global health (Walley et al. 2008). These included controls of endemic diseases, immunization, water and sanitation improvement, reproductive and child health care. Access to health care is a key determinant of the survival of infants and mothers during pregnancy and birth particularly when complications arise.

Health Policy Frameworks highlight "Health as Wealth," to address common health desires through initiatives in both preventive and curative services. A PHC-modelled health system is organized into village health services, major and minor health centers and hospitals. Major health centers are staffed by doctors, state registered nurses (SRNs), assistant public health officers (APHOs), state enrolled nurses (SEN), and other technical staff. Minor health centers have similar staff profiles and are without medical doctor and laboratory services. Nurses can provide the majority of clinical care at all levels of health service. SRNs and SENs are primarily employed in health facilities, whereas community health nurses (CHNs) in community work. APHOs are responsible for health promotion and protection, including environmental hygiene and sanitation, immunization, and preventive measures at various levels of the delivery system.

The Village Health Service (VHS) can be established to provide primary health care services. Communities are involved in VHS through Village Development Committees (VDC) and Catchment Area Committees (CAC). The key targets of the PHC should be rural settlements. For each PHC village, a VHW and a TBA can be trained to provide primary health care in their communities. VHWs are assigned the role of maintaining the supply of essential drugs, conducting home visits, and health education. TBAs assist in deliveries and referral of at-risk antenatal to health facilities.

Several interventions can be initiated by stakeholders to make health care accessible and affordable. The appropriate interventions would include improved staffing, traditional birth attendants, and village health workers through Primary Health

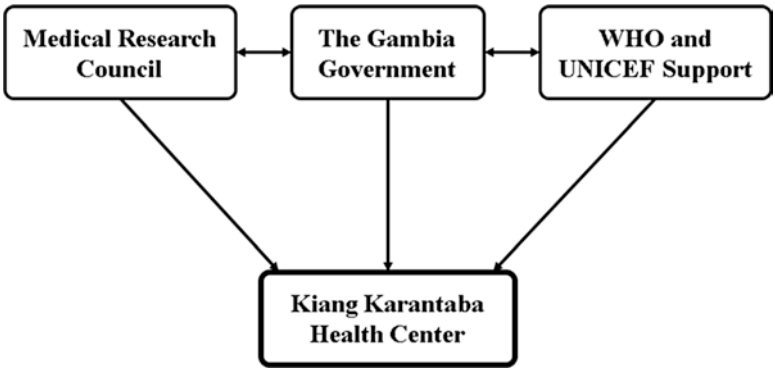

Fig. 4.1 Multistakeholder model

Care (PHC). The Expanded Programme on Immunization (EPI), funded by the World Health Organization, Global Alliance for Vaccines and Immunization, and United Nations International Children Emergency Fund, aims to prevent infant mortality by providing vaccines for childhood diseases. Providing young children with two high doses of Vitamin A annually is cost-effective and efficient for eliminating vitamin deficiency and improving child survival.

The multi-stakeholder model is an operational description of personal access to health care in a rural community. It is illustrating the collaborative interventions by government, the Medical Research Council (MRC), the WHO and the United Nations International Children's Emergency Fund (UNICEF) (Fig. 4.1).

The WHO and other stakeholders support various government programs. The government as a recipient, plans, organizes and coordinates the implementation of programs to solve health issues. Research institutions like the MRC generate the much-needed information for planning. Non-government organizations can operate clinics and provide healthcare services especially in areas where the government cannot afford to do so. Stakeholder's collaboration in making basic health care accessible will help in achieving the sustainable development goals.

For example, Kiang West is located in the Lower River Region (LRR) of The Gambia. It is bordered to the west and north by the River Gambia and on the south by a large tributary. The study area is located in a region that has almost 50% poverty rate. Existing distributions of health personnel and access to primary health care services are inadequate. This district is comprised of approximately 30 villages in sparse settlements. It's inadequate infrastructure and unpaved roads make it inaccessible, especially during rainy seasons.

Access to healthcare services is closely related to poverty and population. The LRR is the lowest percentage of the population with access to PHC coverage. In 1995, the Baby Friendly Community Initiative was piloted in communities in the LRR (which includes Kiang West). This led to the expansion of the initiative to 293 communities across the country (National Nutrition Agency – NaNA 2009). The WHO has acknowledged the involvement of these systems by challenging global

communities to improve standards of living through better access to health care (World Health Organization – WHO 2011).

Every month, the staff of the Health Centre conducts community visits to satellite villages. Infant immunization is conducted with antenatal and maternal health care. During community visits, sick people living in villages far from health centers are attended to, thus mitigating the villagers' need to travel long distances to receive medication. The MRC also conducts similar community visits to other villages. Although their interventions are research-based, they operate an outpatient department, offer nutrition supplementation, and support the health center.

Increased access to, and appropriate utilization of, health services can reduce costs incurred by the overuse of expensive health services, as often happens in emergency departments and minimize delay. The theoretical concept analysis is a multi-stakeholder model created to analyze the collaborative interventions by the government, MRC, WHO, and UNICEF, which has been feasible and can be replicated in other communities in a similar situation.

Strengthened multi-stakeholder response, implemented within health systems with better-targeted, low-cost prevention and care strategies are suggested as the best interventions initiated for health care accessibility. The Reproductive and Child Health Services have been expanded, in addition to case management of common childhood illnesses/conditions.

Health issues challenge development in many developing countries. Improving the health of developing countries with low income per capita would enhance sustainable development. Policy frameworks should focus on the promotion and provision of health through equitable access and affordable services. These should prioritize poor communities in rural areas. International organizations such as the WHO and UNICEF, act as decisive bodies of oversight and governance for broad goals, 'Sustainable Development Goals', and Global Fund against Tuberculosis and Malaria programs. All of these efforts aim to ease the health burden in developing countries. The multi-stakeholder approach would provide a sustainable approach that will involve communities. Reproductive and Child health care strategy is decentralized to be accessible. Strategies for active surveillance of infectious diseases should also be boosted.

The primary health care strategy has paved the way for decentralization and near-target population management to improve the efficiency of national programs. Active disease surveillance should be developed and strengthened at both national and community levels. Thus, target diseases such as poliomyelitis, measles, and neonatal tetanus can be eliminated. These can be facilitated through a collaborative approach of governments and NGOs.

Improved childhood vaccination coverage is a key indicator for health policy objectives. As availability increases, addressing issues of demand and timely schedule completion will be solved. Vaccinations conducted by public health officers at outreach stations protect infants from disease and curtail infant mortality. Services provided by midwives help reduce maternal mortality. Coverage of antenatal care by skilled personnel is increasing, majority receiving care during pregnancy.

Services provided by midwives help reduce maternal mortality. A survey of antenatal care delivery, coverage, and access revealed that a high percentage of pregnant women used formal antenatal services at a health center, an outreach post four or more times, with satisfied services received. This validates the effectiveness of the multi-stakeholder collaboration and community involvement through the training of VHWs and TBAs, in making health care accessible.

It has been documented that good nutrition including appropriate infant and young child feeding practices is central to healthy growth and development. The associated effects of poverty, inadequate household access to food, infectious disease, and inadequate breastfeeding lead to illness. Feeding practices often cause growth faltering, nutrient deficiencies, delayed development, and death, a major obstacle to sustainable socio-economic development. Vitamin A is critical for a child health and immune function. Giving Vitamin A to breastfeeding mothers helps protect babies during their first months. In the final analysis of this book, no single organization, sector, or approach can provide answers for underdevelopment, poverty, and ill health. The economic activity in rural communities, where households live below the poverty line cannot change their situations by themselves. Lack of communication services and public transport make the situations of impoverished communities even more difficult. Women struggle to take sick family members to health facilities. This situation, however, is not unique to a particular region or community, as many places in the developing world face difficulties. We believe that the multi-stakeholder model is feasible and appropriate, and can be replicated in other communities.

The identified barriers such as poverty, access to basic health services due to inadequate transportation and communication impacts heavily on the health and wellbeing of communities. The inadequate number of health personnel deprives communities' access to timely health care. The effort to address these barriers by stakeholders should include the application of the PHC strategy where health providers travel to communities. The importance of visiting villages far removed from health centers is recognized. The model eases the health care burden for isolated communities located far away from health centers.

Expansion of water coverage, preventive measures against malaria, research and policy evaluation would enable greater success. Although there are substantial health promotions or health education activities, it can be enhanced with ICTs to introduce e-health. This would help in addressing the social determinants of health, tackling inequalities and empowerment. It is hoped that developing countries can provoke debate within the international community about ways forward in technology transfer within the health sector.

Addressing the underlying determinants of health is a key factor in achieving sustainable development. Each strategy and actor have its drawbacks and unique advantages. The importance of cooperation, both within a specific sector and across sectors, cannot be stressed enough. Progress should be made in forging closer ties between the health sector and other sectors, particularly through local, national, and multi-stakeholder development. Further research on medical access, specifically in terms of healthcare delivery system, availability of resources, perceived morbidity, and mortality of communities at risk, should be a priority. Despite remarkable

reductions in the incidence of disease and mortality rates over the last decades, ill health in developing nations remains an enormous impediment to development. High levels of preventable illness still prevail in these countries. There is evidence to believe that the development of health is essential for economic advancement. Developing countries may remain stagnant unless the burden of illness is reduced. Development in health is a precondition for the economic prosperity of a nation.

References

Gureje, O., Nortje, G., Makanjuola, V., Oladeji, B. D., Seedat, S., & Jenkins, R. (2015). The role of global traditional and complementary systems of medicine in the treatment of mental health disorders. *The Lancet Psychiatry, 2*, 168–177.

Marter-Kenyon, J. (2007). Bridging the divide: A third-sector approach to health and development. *Greener Management International, 51*, 53–65.

National Nutrition Agency – NANA. (2009). *NaNa Working with the communities for better health and nutrition: Annual Report December 2009*. The Gambia: Banjul. Retrieved from http://www.nana.gm/reports/NaNAAnnualReportfor2009.pdf.

Navaneetham, K., & Dharmalingam, A. (2002). Utilization of maternal health care services in Southern India. *Social Science & Medicine, 55*, 1849–1869.

Piot, P., Karim, S. S. A., Hecht, R., Legido-Quigley, H., Buse, K., Stover, J., Resch, S., Ryckman, T., Møgedal, S., & Dybul, M. (2015). Defeating AIDS – Advancing global health. *The Lancet, 386*, 171–218.

Quansah, E., Ohene, L. A., Norman, L., Mireku, M. O., & Karikari, T. K. (2016). Social factors influencing child health in Ghana. *PLoS One, 11*, e0145401.

Rutherford, M. E., Dockerty, J. D., Jasseh, M., Howie, S. R., Herbison, P., Jeffries, D. J., Leach, M., Stevens, W., Mulholland, K., & Adegbola, R. A. (2009). Access to health care and mortality of children under 5 years of age in the Gambia: A case-control study. *Bulletin of the World Health Organization, 87*, 216–224.

Tulchinsky, T. H., & Varavikova, E. A. (2014). *The new public health*. London: Academic Press.

Walley, J., Lawn, J. E., Tinker, A., De Francisco, A., Chopra, M., Rudan, I., Bhutta, Z. A., Black, R. E., & Group, L. A.-A. W. (2008). Primary health care: Making Alma-Ata a reality. *The Lancet, 372*, 1001–1007.

WHO, U. (2004). *UNPF: Maternal mortality in 2000*. Geneva: Estimates developed by WHO UNICEF and UNFPA WHO.

World Health Organization – WHO. Closing the Gap. (2011, October 19–21). Policy into practice on social determinants of health. *Proceedings at the World Conference on Social Determinants of Health*, Rio de Janeiro.

Chapter 5
Climate Change Adaption

Abstract Adaptation to climate change has been recognized as very important in developing countries that face the greatest threats from global warming. In proposing various adaptation approaches, the United Nations Intergovernmental Panel on Climate Change required nations to prepare adaptation plans of action. However, the areas of priority in climate change adaptation have not been considered. This study has developed a new prioritization methodology for climate change adaptation in developing countries. Five categories and 25 approaches in climate change adaptation were adopted through a thorough and detailed analysis of pertinent literature related to the National Adaptation Program of Action (NAPA). A fuzzy analytic hierarchy process-based questionnaire survey was designed and presented to 12 experts. The survey was made to determine the relative importance of the strategies for climate change adaptation. The results indicate that the five most important adaptation categories are health (0.223), forestry (0.213), water (0.210), food (0.181), and energy (0.174), with health as the number one priority in climate change adaptation. Further findings show that the prioritization order of the adaptation approaches to climate change is as follows: "Health education," "public sensitization," "water supply infrastructure development," "microfinance," and "infrastructure and technology enhancement."

Keywords Climate change adaptation · Fuzzy analytic hierarchy process · Global warming · Prioritization

5.1 General Background

The economic and social costs of climate change are increasing, renewing urgency to adapt. Strides have been made on international agreements, declarations, and laws towards sustainability, equity, and prosperity. The magnitude of the task requires a change in behavior, economies, protecting our environment towards a sustainable future. Resilience building should align climate change ambition and Sustainable Development Goals implementation. These include the 2030 Sustainable Development Agenda, the Paris Agreement, numerous Action Agendas committed to reducing the impacts of climate change.

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There is focus on the implementation of actions to achieve the Paris Agreement to limit temperature increase. The adverse impacts of climate change to health and livelihood is a challenge in meeting the Sustainable Development Goals (SDGs) (Oldekop et al. 2016). The nations involved in Conference of Parties aim to keep warming below 2 degrees Celsius and pursue efforts to limit temperature increases. Continued innovation in technology, energy, finance, and conservation sectors should be promoted. Reducing CO2 emissions is essential to limit warming and can be achieved by emission reduction such as black carbon (BC), methane and hydrofluorocarbons (HFCs). The Kigali Amendment to the Montreal Protocol, recommends the phasing out of HFC's to avoid warming. At the Marrakech Climate Change Conference, nations of the world committed to enhance ambitions, promote implementation and provide support (UNFCCC-COP22 2016). The Central focus is placed on continuing to strengthen the global response to the threat of climate change.

Climate change threatens to undermine development gains as a result of increasing and intense extreme weather events such as droughts, floods, and storms (SDG 13.) Climate change and development goals cannot be pursued separately. Their interrelatedness has been recognized by including climate change as an SDG. Taking action to combat climate change highlights an important milestone as the issue was not addressed through the Millennium Development Goals (MDGs). A warming climate will affect the availability of freshwater, food security, and energy. SDG No. 13 has set out a number of global targets which countries need to take ownership, define specific responsibilities and targets. The proposed SDGs are aimed at successful achievement by 2030. The development of innovative technology and processes will be a solution to mitigate climate change effects. Biomimicry is one such example including solar cells inspired by leaves or whale fin design to improve the efficiency of wind turbines (Perez 2015).

According to the United Nations Framework Convention on Climate Change (UNFCCC), climate change adaptation is an international environmental law. Greenhouse gas reduction is the primary goal of the Intergovernmental Panel on Climate Change (IPCC), according to the Kyoto Protocol, climate change mitigation; adaptation should be mainstreamed into development objectives (UNFCC COP 21 2015). The African continent has been singled out as particularly vulnerable because of its low adaptive capacity. Sub-Saharan Africa will be hit disproportionately (KR Hope Sr. 2009). The Sahel region in West and Central Africa is likely to face a serious food crisis if early and effective action is not implemented. The overall adaptive capacity of Africa is low because of poverty, weakening of social safety nets and high morbidity rate(Niang et al. 2014).

The connection between the divided worlds of science and practice must be improved to be effective in the adaptation processes. Most of the literature on climate change and climate change policy shows that climate change effects abound. In general, scientists assume that climate change includes changing rainfall patterns, increasing weather unpredictability, rising temperature and drought spells (Martens et al. 2009). Weather forecasts in Africa are inadequate, and local communities do not have access to information (Reid et al. 2009). Many governments have developed national adaptation strategies; however, because of limited resources in developing countries, they face challenges in prioritizing key adaptation. In southern Kenya,

Maasai herders engage in farming as a supplement to livestock. In Kano, Nigeria, peri-urban vegetable gardening has expanded (Adams and Mortimore 1997). Fulbe herders have increased the number of herd displacements among pasture areas (Pamo 1998). Focus at the community level is not always enough because of the interdependence of communities on some issues, for example, water. Climate changes are taking place in the context of development stresses, notably poverty. Climate change and global warming can bring harmful effects on human life, which pose considerable threats to food and water security (Roshan et al. 2010).

Climate change adaptation is increasingly associated with poverty alleviation. Science, policy and implementation should have an integrated approach to the formulation of climate change and sustainable development policies. The determinants of adaptive capacity (i.e. people's ability to adapt) are related to the economic, social, institutional, and technological conditions that facilitate or constrain the development and deployment of adaptive measures. The effects of future climate change should be linked to the vulnerability of multiple stresses.

The present national-level planning process for adaptation requires a lot of resources. With the increase in extreme weather events, development should assess household and community-level adaptations to help sustain resilience of socio-economic and environmental systems. Climate change could hinder attainment of SDGs. The time spent finding and fetching water is already a major concern in some developing countries. The poverty that keeps children away from classrooms will be aggravated by global warming, increasing the number of environmental refugees and displaced people. Thus adaptation plays a key role in sustainable development (Conisbee and Simms 2003).

As detailed in the first National Communication of the UNFCCC, the potential effects of climate change on socio-economic sectors are mostly negative. This stimulates a critical re-examination of the effects of climate change on societal and natural systems, including agriculture, livestock, fisheries, energy, health, water resources, sensitive coastal environment, and forests. It has uncovered compelling areas of research that could add value to adaptation strategies. Emphasis is made on effective partnerships for successful implementation of priority adaptation activities.

Adaptation strategies should go beyond climate change adaptation and consider sustainable development to reduce vulnerability. Through a thorough and detailed analysis of pertinent literature and in-depth interviews with experts, a tentative list of five categories and 25 approaches in climate change adaptation was developed as the basis for the fuzzy analytical hierarchy processes (FAHP) based survey questionnaire, shown in Fig. 5.1. The categories and approaches identified are considered important for climate change adaptations and are related to the SDGs. It would help address food security, water supply, and management, health, energy and forestry.

The prioritization of climate change adaptation approaches is a multi-criteria decision problem. The analytical hierarchy process (AHP) method used, identifies the prioritization of a set of alternatives and determines the relative importance of attributes in a multi-criterion decision-making problem (Saaty 1978). The preferences in AHP are essentially human judgments based on human perceptions and allows for a more accurate description of the decision-making process. Fuzzy sets provide a representation of the knowledge of experts to deal with vagueness and

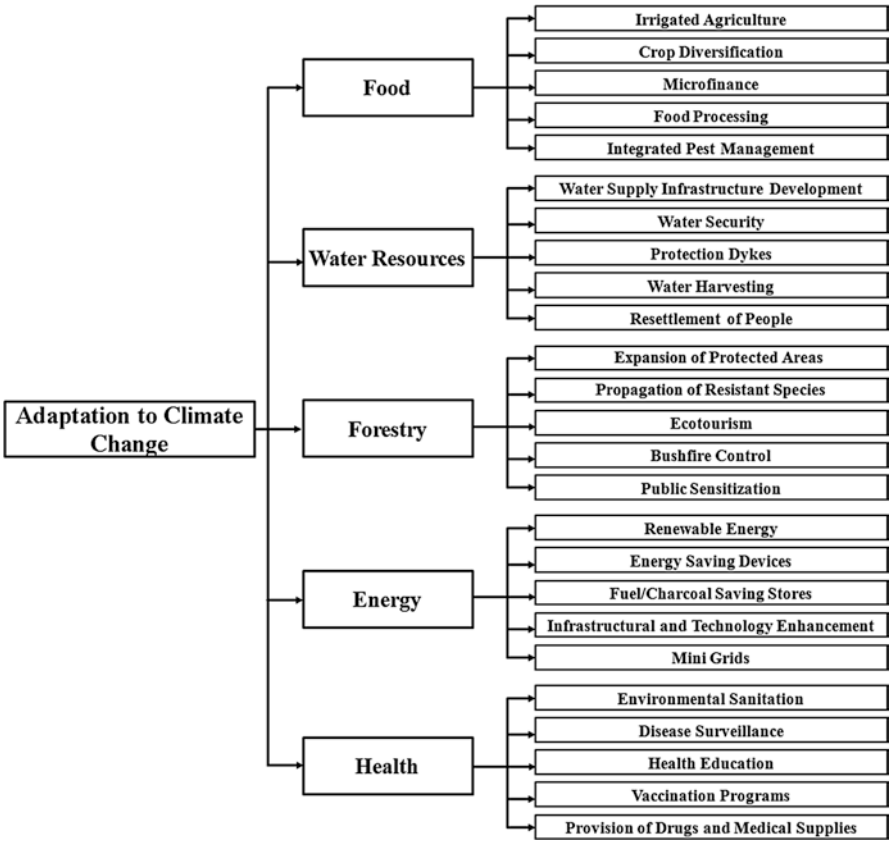

Fig. 5.1 Proposed categories and approaches for climate change adaptation

uncertainty of adaptation approaches. It also allows them to focus on the comparison of just two objects.

The population of Sub-Saharan Africa and other developing countries will increase gradually. Most of their economies can be categorized into the following: agriculture and natural resources, services and industry. Their GDP is low compared to other nations. Agriculture and natural resource-based economic activities have accounted a significant percentage of the GDP, whereas services and industry have gained momentum. Principal exports are agricultural products including fisheries and imports consisting primarily of food, machinery, and transport equipment. A great percentage of the total land area along the coastal communities in Sub Saharan are less than 30 m above mean sea level, one-third is at or less than 20 m above sea level while others are seasonally or diurnally flooded.

Figure 5.2 clearly shows the African regions that are most at risk from climate change. Based on this map, the arid and semi-arid regions in Sub-Saharan Africa face the highest risks. The main observed changes include higher temperatures,

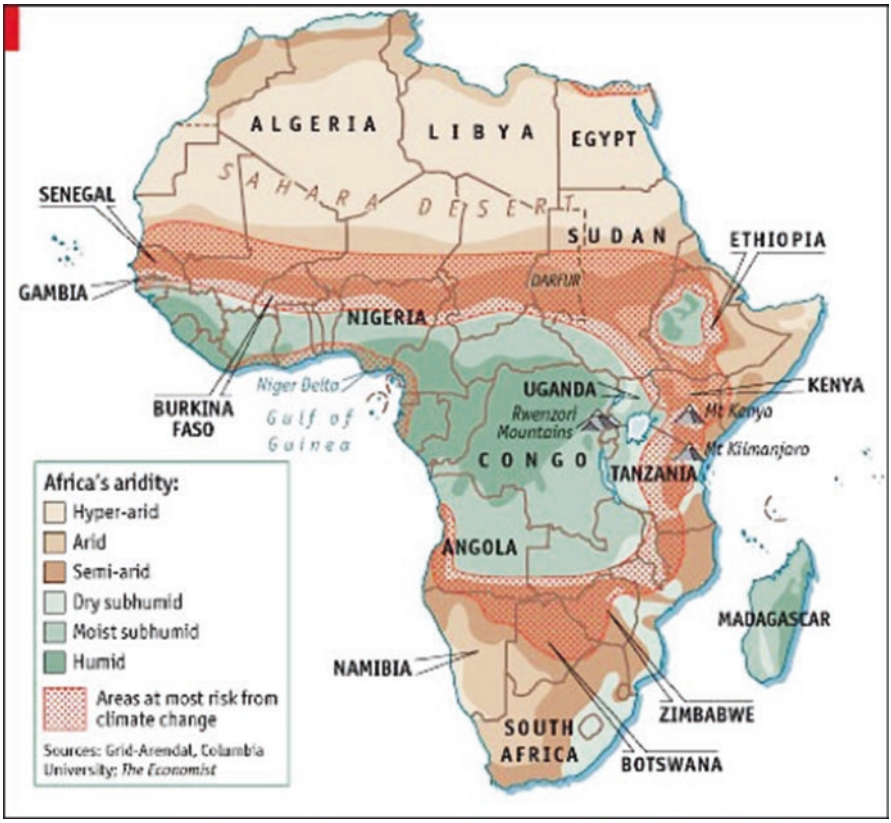

Fig. 5.2 Map of the African regions that are at risk from climate change (https://kenvironews.files.wordpress.com/2007/08/africa-climate-change.jpg)

temporal variability, extremes in and decreased rainfall, more droughts, increasing aridity, floods, and rising sea level (Twomlow et al. 2008).

The Food and Agricultural Organization (FAO) pled for a sustainable adaptation to climate change in Africa. According to the contribution of Working Group II, Fourth IPCC Assessment Report, Africa is one of the continents that is most vulnerable to climate change. Food production will be severely affected by a decrease in suitable farmlands and shortening of the length of growing seasons. In some countries, yields from rain-fed agriculture can be reduced. Towards the end of the twenty-first century, projected sea-level rise will affect highly populated low-lying coastal areas. Mangroves and coral reefs will be degraded, causing problems in fisheries and tourism (Huq and Ayers 2007).

After consolidating the categories and approaches obtained from expert's views, FAHP was applied. The numerical results obtained were used to detect high-priority intervention for adaptation to climate change. The results are shown in Table 5.1, highlighting scores of the 5 categories and 25 approaches of climate change adaptation. Among the five categories, health is the highest priority area for adaptation,

Table 5.1 Weights of adaptation approaches and dimensions from the expert's opinion

Category and approach	Local weights	Overall weights	BNP	STDBNP	Rank
Food	**(0.1602, 0.1810, 0.2038)**		**0.1816**	**0.1807**	**4**
Irrigated agriculture	(0.1869, 0.2116, 0.2381)	(0.0300, 0.0383, 0.0485)	0.0389	0.0381	12
Crop diversification	(0.1869, 0.2132, 0.2421)	(0.0300, 0.0386, 0.0493)	0.0393	0.0385	11
Microfinance	(0.1901, 0.2176, 0.2488)	(0.0305, 0.0394, 0.0507)	0.0402	0.0393	9
Food processing	(0.1362, 0.1554, 0.1800)	(0.0218, 0.0281, 0.0367)	0.0289	0.0282	25
Integrated pest management	(0.1799, 0.2022, 0.2273)	(0.0288, 0.0366, 0.0463)	0.0372	0.0365	14
Water	**(0.1849, 0.2104, 0.2376)**		**0.2110**	**0.2098**	**3**
Water supply infrastructure development	(0.2164, 0.2445, 0.2743)	(0.0400, 0.0514, 0.0652)	0.0522	0.0512	4
Water security	(0.2157, 0.2418, 0.2706)	(0.0399, 0.0509, 0.0643)	0.0517	0.0507	5
Protection dikes	(0.1599, 0.1799, 0.2034)	(0.0296, 0.0379, 0.0483)	0.0386	0.0378	13
Water harvesting	(0.1468, 0.1639, 0.1839)	(0.0271, 0.0345, 0.0437)	0.0351	0.0344	18
Resettlement of people	(0.1493, 0.1698, 0.1939)	(0.0276, 0.0357, 0.0461)	0.0365	0.0357	16
Forestry	**(0.1851, 0.2121, 0.2442)**		**0.2138**	**0.2127**	**2**
Expansion of protected areas	(0.1371, 0.1503, 0.1658)	(0.0254, 0.0319, 0.0405)	0.0326	0.0320	23
Propagation of resistant species	(0.1324, 0.1458, 0.1606)	(0.0245, 0.0309, 0.0392)	0.0315	0.0310	24
Ecotourism	(0.1404, 0.1543, 0.1707)	(0.0260, 0.0327, 0.0417)	0.0335	0.0329	19
Bushfire control	(0.2490, 0.2708, 0.2938)	(0.0461, 0.0574, 0.0717)	0.0584	0.0575	2
Public sensitization	(0.2555, 0.2788, 0.3028)	(0.0473, 0.0591, 0.0739)	0.0601	0.0592	1
Energy	**(0.1546, 0.1737, 0.1962)**		**0.1749**	**0.1739**	**5**
Renewable energy	(0.1656, 0.1893, 0.2163)	(0.0256, 0.0329, 0.0424)	0.0336	0.0329	19
Energy-saving devices	(0.1792, 0.2040, 0.2328)	(0.0277, 0.0354, 0.0457)	0.0363	0.0355	17
Fuel/charcoal-saving stoves	(0.1646, 0.1876, 0.2137)	(0.0255, 0.0326, 0.0419)	0.0333	0.0326	22
Infrastructural and technology enhancement	(0.2062, 0.2313, 0.2593)	(0.0319, 0.0402, 0.0509)	0.0410	0.0402	8

(continued)

Table 5.1 (continued)

Category and approach	Local weights	Overall weights	BNP	STDBNP	Rank
Mini grids	(0.1629, 0.1878, 0.2161)	(0.0252, 0.0326, 0.0424)	0.0334	0.0329	19
Health	**(0.1969, 0.2228, 0.2524)**		**0.2240**	**0.2229**	**1**
Environmental sanitation	(0.1713, 0.1897, 0.2175)	(0.0337, 0.0423, 0.0549)	0.0436	0.0428	7
Disease surveillance	(0.1457, 0.1622, 0.1823)	(0.0287, 0.0361, 0.0460)	0.0369	0.0363	15
Health education	(0.2212, 0.2481, 0.2784)	(0.0436, 0.0553, 0.0703)	0.0564	0.0553	3
Vaccination programs	(0.1570, 0.1743, 0.1928)	(0.0309, 0.0388, 0.0487)	0.0395	0.0388	10
Provision of drugs and medical supplies	(0.1995, 0.2256, 0.2466)	(0.0393, 0.0503, 0.0622)	0.0506	0.0497	6

BNP (Best non-fuzzy performance) = [(U − L) + (M − L)]/3 + L
STD_BNP: Standardized BNP

followed by forestry, water, food, and energy. As mentioned earlier, adaptation is likely to play a key role in meeting the SDGs, achieving poverty reduction and fostering sustainable development. Considering the weights presented in Table 5.1, the order of priority of approaches for adaptation to climate change is as follows: "health education," "public sensitization," "water supply infrastructure development," "microfinance," and "infrastructure and technology enhancement". Detailed explanations of categories and approaches are presented as follows:

"Health education" is recognized as the most important approach to ensure adaptation to climate change. Warmer and wetter conditions can trigger unprecedented levels of disease outbreaks (Opschoor 2008). "Vaccination programs" serve as the second most important approach. The incidence of water-borne diseases can increase because of the unavailability of water supply infrastructure to meet water demand. "The provision of drugs and medical supplies" is the third priority approach for adaptation in the health category. "Environmental sanitation" and "disease surveillance" are the fourth and fifth priority adaptation approaches, respectively. There will be a projected increase in the spread and incidence of diseases.

Modification of the land cover, deforestation, and fragmentation of habitats caused by drought and human activities are evident. "Bushfire control" is identified as the priority adaptation approach in the forestry category. The results identified "public sensitization" as an approach that can enhance the development of innovative conservation methods and promote the use of alternatives to forest resources. Affected communities should be involved in protecting ecosystems through "ecotourism". "Expansion of protected areas" has been identified as the fourth priority approach for adaptation under the forestry category. "Propagation of resistant species" that are more drought-resistant and fire-tolerant would help in forest regeneration.

Climate change will lead to decrease in water availability. "Water supply infrastructure development" is identified as number one priority adaptation measure to provide reliable and affordable water supply and minimize the spread of water-related diseases. "Water security" is being identified as an adaptation approach due to the combined effects of climate change and escalating human demand. "Water harvesting" is an important adaptation approach too, as water scarcity can intensify conflict between human and environmental demands. Communities in low-lying coasts of West Africa will be severely affected by the rise in sea levels. "Protection dikes" as an adaptation approach would help. Flooding will contaminate surface water and wells with human waste, thus increasing the incidence of water-borne diseases, such as diarrhea, typhoid, and cholera. "Resettlement of people" is being identified as an adaptation option to cope with predicted storms and floods that might displace communities.

"Infrastructure and technology enhancement" of energy delivery systems that reduce pressure on natural forests are recommended as effective priority approach. "Energy saving devices" as an adaptation approach would ensure sustainable and efficient use of fuel. "Renewable energy" as an alternative is an essential investment for a more energy-secure future. "Mini-grids" would help in the expansion of energy services as an approach in coping with limited finance and technological capacity of power utilities. Public awareness on "fuel/charcoal-saving stoves" will support changes in fuel use and consumption patterns.

Changes in rainfall and temperature are expected to constrain the productivity of some crops. Higher temperatures and humidity have measurable adverse effects on small ruminants (i.e., goats and sheep). The decline in yields will affect food consumption and nutrition of populations. In addition, reduction in income levels will limit the ability of people to buy food. "Microfinance" has been identified as the highest priority adaptation approach to enable communities cope. Crop yields in sub-Saharan Africa are projected to fall. "Crop diversification" is identified as the second priority in this category. Changes in rainfall timing are typical characteristics of regional climate. "Irrigated agriculture" as an adaptation approach would minimize the effects of rainfall variability, provide an opportunity to extend the natural growing season, and expand total cultivated area (Conceição et al. 2011). In the face of expected changes in parasite ecology, "integrated pest management" is identified as an appropriate adaptation approach. Food security and human development are intricately linked, thus "food processing" is a suitable adaptation approach.

This survey provides insights into the recognition and prioritization of adaptation approaches. Modifying the exposure of a system to the effects of climate change can be achieved. Climate change forces communities in developing countries to adapt to the extreme and unpredictable weather. Sustainable development requires that all responses to climate change are successful in reducing poverty. For the foreseeable future, prevention of climate change effects must address social, economic, and environmental effects. A better understanding of how communities are affected by climate change has been highlighted. The prioritized categories and approaches can be applied at both local and national scales.

Development and application of holistic frameworks that look across disciplines for sustainability should be initiated. The National Adaptation Program of Action

(NAPA) served as the basis for formulating FAHP methodology. Health, forestry, and water are the most important categories in climate change adaptation. Meanwhile, public sensitization, bushfire control, health education, water supply infrastructure development and water security are priority approaches. Relatively few scientists have addressed cultural factors such as people's perceptions of climate change, which is quite important in decision-making processes. Cultural perceptions to the weather fluctuations to be something from God and not human made as a result of the emission of $C0_2$ should be investigated. Traditional beliefs and norms should be investigated in order to influence proper adaptation approaches.

The IPCC defines adaptation as adjustments in ecological, social or economic systems in response to actual or expected climatic stimuli and their effects. Ghana's economy is primarily composed of climate sensitive sectors of agriculture, forestry, and energy (Dinar et al. 2012). Evidence abounds in Ghana that temperatures in all the ecological zones are raising; whereas rainfall levels and patterns have been generally reducing and increasingly becoming erratic. The national economy will suffer from the impacts of climate change because it is dependent on climate-sensitive sectors such as agriculture, energy, forestry, etc. Based on a 20-year baseline climate observation, it is forecast that maize and other cereal crop yields will reduce by 7% by 2050. Available data also shows a sea-level rise of 2.1 mm per year over the last 30 years, indicating a rise of 5.8 cm, 16.5 cm and 34.5 cm by 2020, 2050 and 2080 (Agyemang-Bonsu et al. 2008). To effectively deal with the projected impacts, the government's strategy is to build climate resilience and sustainably manage natural resources of the country.

Adopting a proactive approach is obviously more effective and less costly than responding reactively to climate change impacts as they happen. Accordingly, the National Climate Change Adaptation Strategy of Ghana intends to ensure a consistent, comprehensive and a targeted approach to increasing climate resilience and decreasing vulnerability. Awareness raising and sensitization of the populace, particularly policy makers facilitates the mainstreaming of climate change for disaster risk reduction into national development. The criteria for the selection and prioritization of adaptation interventions were developed during stakeholder consultation. The five criteria used covered (a) resilience of the adaptation intervention; (b) how sustainable the intervention will be; (c) the potential to have multiplier effects (co-benefits) as a result of the implementation of the adaptation intervention; (d) extent of replicability of the intervention; and (e) how feasible the whole intervention is (Dinar et al. 2012).

As part of Ghana's effort in developing a national climate change adaptation strategy, a series of sectoral studies was carried out. These studies led to the proposal of 75 sectoral adaptation options. Accordingly, a team of sectoral experts was assembled to apply a cross-sectoral planning and analytical decision-making tool (Akropong Approach). It selected suitable adaptation options across the various climate-vulnerable sectors that were assessed. The experts further subjected the proposed adaptation options to qualitative and quantitative analysis to bring the diverse options manageable and harmonized with other cross-sectoral strategies. The teams of sectoral experts worked to provide a preliminary list of adaptation options which

clearly highlighted the synergies and conflicts. These options were further subjected to general national stakeholders Multiple Correspondence Analysis review and endorsement. The revised adaptation programs which were endorsed by the general stakeholders were subjected to log frame analysis to develop the program implementation plans. To be most effective in adaptation interventions, it was decided that ecosystem and programmatic-based harmonized adaptation interventions be developed. The programmatically based approach led to the identification of ten top national priority adaptation programs which are provided in Table 5.2. To reduce mal-adaptation, the working group used the cross-sectoral impact planning and analysis methodological tool "the Akropong Approach".

Senegal is predicted to face a decreased amount of rainfall with increased temperatures and sea-level rise. Drought and saline intrusion threaten water sources, while coastal erosion threatens infrastructure (Pullzin and White 2011). The National Climate Change Committee, through the creation of ten Regional Committees, coordinates climate change activities across the country. Senegal's NAPA contains a good overview of major impacts and vulnerabilities in three areas or sectors of particular relevance to the country (agriculture, coastal zones, and water resources). The NAPA is anchored within overall country priorities, including the National Poverty Reduction Paper and other development frameworks, such as the decentralization policies. The government is committed to decentralization, recognizing that local capacity is critical. This includes greater job security and training. Specific capacities to access, use, and distribute climate

Table 5.2 Identified climate change adaptation approaches in Ghana

Item	Titles of adaptation programmes
1	Increasing resilience to climate change impacts: Identifying and enhancing early warning systems
2	Alternative livelihoods: Minimizing impacts of climate change for the poor and vulnerable
3	Enhancing national capacity to adapt to climate change through improved land use management
4	Adapting to climate change through enhanced research and awareness creation
5	Development and implementation of environmental sanitation strategies to adapt to climate change
6	Managing water resources as climate change adaptation to enhance productivity and livelihoods
7	Minimizing climate change impacts on socioeconomic development through agricultural diversification
8	Minimizing climate change impacts human health through improved access to healthcare
9	Demand- and supply-side measures for adapting the national energy system to impacts of climate change
10	Adaptation to climate change: Sustaining livelihoods through enhanced fisheries resource management

information; the capacities to use planning tools appropriately and learn from previous adaptation efforts.

Located 80 kilometers south of Dakar, the Senegalese capital city is Salty, a seaside resort. In the past years, sea waves eroded sand from the beach and damaged hotels infrastructure (Pullzin and White 2011). The Government created an Integrated Coastal Management Plan as a policy to facilitate engineering works required to protect the coast. A project was initiated to build a protective rock wall. Engineers from the Senegalese military built a sea defense wall and trained local staff. The results were immediately noticeable once the work was complete, and in the time following the beach has begun to regenerate. Had the construction work not been done, the hotels would have begun to disappear. By bringing together sectors and raising funds from all entities concerned about the erosion, this project demonstrated the efficiency of partnerships between public and local authorities in adaptation.[1]

The government of Senegal and its development partners implement a large number of policies and projects supporting rain-fed crop agriculture and livestock husbandry in the country (Pullzin and White 2011). This is to boost production, improve market and insurance. Livestock infrastructures are rehabilitated such as improved wells, boreholes, vaccination centers, and micro-dairy facilities. The integration of livestock into farming constitutes system transformation. Management plans also have been developed for rangelands. Projects such as Second Sustainable and Participatory Energy Management (PROGEDE) have promoted demonstrations of agroforestry practices that contribute both to farm soil fertility and livestock fodder. Attempts have been made to delimit fixed corridors, to limit conflict between farmers and herders. Efforts also have been made to identify trees for reforestation. Research on cowpeas has focused on both adaptation to drier climate and resistance to parasites, and a number of new varieties have been developed and widely adopted.

Since the droughts of the late 1960s, investments in greater use of Senegal's river water have increased significantly (Salami et al. 2014). In particular, the dams of Manatali and Diama have enabled both controlled recession and irrigated farming. The Manantali Dam is on the Bafing River, a tributary of the Senegal River. It has a power station and network of 1300 km of transmission lines to the capitals of Mali (Bamako), Mauritania (Nouakchott) and Senegal (Dakar). The dam is 1460 m long and 65 m high. It created a reservoir with a storage capacity of 11.3 billion m^3 and a surface area of 477 km^2. The Diama Dam is a gravity dam also on the Senegal River, spanning the border of Senegal and Mauritania (Hirji and Davis 2009). The purpose of the dam is to prevent saltwater intrusion upstream, supply water for the irrigation of about 45,000 ha (110,000 acres) of crops and create a road crossing between St. Louis and Nouakchott in Mauritania. The approach has constructed water retention ponds in Matam. A number of practices to decrease erosion and increase water availability to crops have been studied and extended. Methods for which technical guidance has been developed and extended to include embankments, stone barriers, and live fences.

[1] https://www.undp-aap.org/countries/senegal

Conserving and restoring forests promotes sustainable management of land. Avoiding deforestation in agriculture, grasslands, and wetlands through stakeholder involvement would restore ecosystems. Forests are critical to reduce climate change by affirming the role of ecosystems, biodiversity and land use can reduce greenhouse gas emissions. This will help communities and countries reduce risks and adapt to climate change impacts. Civil society and community groups play a crucial role in climate action and adaptation at national and local levels. This will safeguard poor and vulnerable communities that lack political voice. Adaptation processes will be more legitimate when civil society is involved in policymaking decisions. It will strengthen initiatives through mobilization, awareness-raising, training and legislation. Conservation can make ecosystems healthy and protect people from the effects of climate change (Mul et al. 2015). This will maximize the absorption and storage of carbon, increasing the resilience of communities. It will also create developments on social, environmental and economic aspects.

References

Adams, W. M., & Mortimore, M. (1997). Agricultural intensification and flexibility in the Nigerian Sahel. *Geographical Journal, 163*, 150–160.

Agyemang-Bonsu, W., Minia, Z., Dontwi, J., Dontwi, I., Buabeng, S., Baffoe-Bonnie, B., & Frimpong, E. (2008). *Ghana climate change impacts, vulnerability and adaptation assessments*. Accra: Environmental Protection Agency.

Conceição, P., Mukherjee, S., & Nayyar, S. (2011). Impacts of the economic crisis on human development and the MDGs in Africa. *African Development Review, 23*, 439–460.

Conisbee, M., & Simms, A. (2003). *Environmental refugees: The case for recognition*. London: New Economics Foundation.

Dinar, A., Hassan, R., Mendelsohn, R., & Benhin, J. (2012). *Climate change and agriculture in Africa: Impact assessment and adaptation strategies*. London: Routledge.

Hirji, R., & Davis, R. (2009). *Environmental flows in water resources policies, plans, and projects: Findings and recommendations*. Washington, DC: World Bank Publications.

Hope, K. R., Sr. (2009). Climate change and poverty in Africa. *International Journal of Sustainable Development & World Ecology, 16*(6), 451–461.

Huq, S., & Ayers, J. (2007). *Critical list: The 100 nations most vulnerable to climate change* (Sustainable Development Opinion). London: International Institute for Environment and Development.

Martens, P., Mcevoy, D., & Chang, C. (2009). The climate change challenge: Linking vulnerability, adaptation, and mitigation. *Current Opinion in Environmental Sustainability, 1*, 14–18.

Mul, M., Obuobie, E., Appoh, R., Kankam-Yeboah, K., Bekoe-Obeng, E., Amisigo, B., Logah, F. Y., Ghansah, B., & Mccartney, M. (2015). *Water resources assessment of the Volta River Basin*. Accra: IWMI.

Niang, I., Ruppel, O. C., Abdrabo, M. A., Essel, A., Lennard, C., Padgham, J., & Urquhart, P. (2014). Africa. In: *Climate change 2014: Impacts, adaptation, and vulnerability. Part B: Regional aspects*. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, pp. 1199–1265.

Oldekop, J., Holmes, G., Harris, W., & Evans, K. (2016). A global assessment of the social and conservation outcomes of protected areas. *Conservation Biology, 30*, 133–141.

Opschoor, J. H. B. (2008). Fighting climate change—Human solidarity in a divided world. *Development and Change, 39*, 1193–1202.

Pamo, E. T. (1998). Herders and wildgame behaviour as a strategy against desertification in northern Cameroon. *Journal of Arid Environments, 39*, 179–190.

Perez, L. (2015). *Sustainable Development Goal 13: Urgent action to combat climate change* [Online]. GreenBiz. Available: https://www.greenbiz.com/article/sustainable-development-goal-13-urgency-combat-climate-change 2017

Pullzin, R., & White, P. (2011). Climate change and aquatic genetic resources for food and agriculture: State of knowledge, risks and opportunities. *Background Study Paper*.

Reid, P. C., Fischer, A. C., Lewis-Brown, E., Meredith, M. P., Sparrow, M., Andersson, A. J., Antia, A., Bates, N. R., Bathmann, U., & Beaugrand, G. (2009). Impacts of the oceans on climate change. *Advances in Marine Biology, 56*, 1–150.

Roshan, G. R., Ranjbar, F., & Orosa, J. (2010). Simulation of global warming effect on outdoor thermal comfort conditions. *International Journal of Environmental Science & Technology, 7*, 571–580.

Saaty, T. L. (1978). Exploring the interface between hierarchies, multiple objectives and fuzzy sets. *Fuzzy Sets and Systems, 1*, 57–68.

Salami, A. O., Stampini, M., Kamara, A. B., Sullivan, C. A., & Namara, R. (2014). Development aid and access to water and sanitation in Sub-Saharan Africa. *Water International, 39*, 294–314.

Twomlow, S., Mugabe, F. T., Mwale, M., Delve, R., Nanja, D., Carberry, P., & Howden, M. (2008). Building adaptive capacity to cope with increasing vulnerability due to climatic change in Africa – A new approach. *Physics and Chemistry of the Earth, Parts A/B/C, 33*, 780–787.

UNFCC COP 21. (2015). *Paris climate change conference*. http://www.cop21paris.org/about/cop21

UNFCCC-COP22. (2016). *Report of the GEF to the 22nd Session of the COP to the UNFCCC* [Online]. World Bank Group: UNFCCC COP22 | Global Environment Facility. Available: https://www.thegef.org/documents/report-gef-22nd-session-cop-unfccc

Chapter 6
Sustainable Development

Abstract Strides have been made on international agreements, declarations and laws towards sustainability, equity, and prosperity. Entrepreneurship and market-driven development is efficient and effective only when Social, political and physical conditions are adapted to support development. Protecting and improving the health of a community, application of sanitary measures, and monitoring of environmental hazards can enhance sustainable human development. Climatic changes are taking place in the context of other developmental stresses. Adaptation is being considered as an integral component of poverty reduction. Safe water is a precondition for health and development and a basic human right, yet it is still denied to hundreds of millions of people throughout the developing world. Utilization of natural resources should be in a sustainable manner in order to ensure conservation. A major objective is to build and maintain a healthy and clean environment which is devoid of any source of pollution. We are living in a global village now as everything is inter-connected. With the formation of the UN SDGs, different agencies and organizations will be able to change their challenges into opportunities. It sets out goals to enable people throughout the world to satisfy their basic needs and enjoy a better quality of life, without compromising that of future generations. Policy approaches globally are aimed at improving environmental quality in relation to human health and socioeconomic development.

Keywords Climate change · Adaptation · Development · Healthy · Policy

6.1 General Background

The 2030 Agenda for Sustainable Development promotes a transition to a green economy through collective efforts. Comprehensive climate action will facilitate the Sustainable transition of economies, and economic diversification to meet SDG's (Baudot and Moomaw 2016). Capacity building with new technology will support developing countries and the most vulnerable. Developing countries have the opportunity to leapfrog to a green economy, mitigating the economic and social impacts of climate change. Policies and developmental plans should support cooperation, knowledge sharing and partnerships. Greening will transform our perception about

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the planet with challenges and opportunities. The UNFCCC's adoption of an economic diversification program for the low-greenhouse gas economy and carbon neutrality will create sustainability. Education and training will be critical for opportunities to emerge and harnessed. Support in finance, science, technology and capacity building will spur innovation on sustainable production, consumption and waste management. The transition to a green economy is holistic in nature and will require countries to make adjustments (Dechezleprêtre and Glachant 2014).

Population growth and natural resource use in an unsustainable manner will impose limits to socio-economic growth. Population growth and economy activities should be within the planet's carrying capacity. Compelling evidence is already showing that humanity is moving deeper into an unsustainable situation. We are drawing on the world's resources faster than they can be restored, and releasing waste and pollutants faster than the Earth can absorb (Hardman 2013). This might lead us towards global environmental and economic problems. The threats to water resources are pathogens, persistent bioaccumulative toxins; contaminant mixtures, groundwater overdraft, and wastewater reuse issues. The same importance and urgency is apparent for the other environmental media, i.e. air and land resources. Integration of research and education with environmental analysis and management will catalyze interactions among relevant disciplines. Science should be devised with engineering and policy options for decision making to prevent and mitigate adverse environmental impacts (Garnett and Godfray 2012).

The past decades have shown progress, including new technologies and awareness of environmental issues. The world is experiencing deforestation, global climate change, dwindling oil supplies, and species extinction. If the present growth trends in world population, industrialization, pollution and resource depletion continue unchanged, the limits to growth on this planet will be reached sometime. The new trends of sustainable resources, a "Zero Waste Programme" to minimize waste, and promote green manufacturing, resource recycling, reuse, and reprocessing should be initiated. Implementing these programs will help to decrease the use of raw materials and effectively recycle resources. Government subsidies should support education, promotion of resources recovery and recycling. The waste disposal policy and regulations of most developing countries should be revised, instituting a legal framework for sustainable disposal methods, reduce, reuse and recycle.

Policy initiatives should strengthen storage, transportation, and ultimate disposal. This will strengthen on-site pollution monitoring and enhance the economic effects of recycling. The waste management system should be shifted from end control to source management. That is proper storage, collection, and disposal or end of life management through sorting of waste into different categories such as recyclable, reuse, composting, landfilling or incineration. Reusing resources would add value to manufacturer's corporate social responsibility. Recycling and treatment or end-of-life management have evolved with disassembling of parts for reuse. To effectively strengthen pollution management and control, end-of-life activities should be monitored. Industries should take the lead in greening their products for recycling and recovery. Enterprises already engaged in recycling, disassembly, shredding or sorting of end-of-life products can be encouraged through appropriate

regulations. Restriction on the importation of products containing mercury, Lead, Cadmium, Hexavalent Chromium, Polybrominated Biphenyls (PBB) and Polybrominated Diphenyl Ethers (PBDE) concentration exceeding standard limits should be implemented.

Toxic chemicals should be classified and requirements made for registration, approval and reporting mechanisms. Dry cell batteries are being used in toys, flashlights, clocks and other electronic devices. Some batteries contain elements that are harmful to the environment, such as mercury, cadmium, and lead (Tchounwou et al. 2012). Waste materials contain both reusable parts such as light tubes, holders, and heavy metals. Without proper handling and disposal, it will pollute the environment thereby jeopardize human health. The aim should be to reduce environmental impacts and hazards, improve environmental protection and public health, and maintain sustainable use of resources.

Air pollution is an environmental health risk causing disease and death globally. It also contributes to global warming. Indoor and outdoor air pollution kills people worldwide and contributes to global warming. The deaths of children less than 5 years old due to pneumonia are attributed to indoor air pollution (Selvaraj et al. 2014). Efforts to reduce air pollution are rising; a response is needed to meet the Sustainable Development Goals. Taking action on waste management, transport and industry by changing practices and technologies to reduce emissions can limit global warming. It will also provide benefits to human health and ecosystems. Cleaner transport, access to clean cooking technologies, efficient energy use, and waste management are scaling up. Mitigating greenhouse gas emissions in cooking and adapting to global warming will inspire innovations in climate friendly, clean and sustainable sources (Jackson et al. 2015). Governments are aware of the health and climate impacts from air pollution, and achieving WHO Air Quality Guidelines by 2030. It provides solutions at city and national levels to reduce emissions and protect human health.

The UN's World Commission on Environment and Development (WCED) put the idea of sustainable development on the political agenda with their report Our Common Future. The WCED emphasized solidarity both within and between generations by defining sustainable development as the ability "to meet the needs of the present without compromising the ability of future generations to meet their own needs" (Lohani et al. 1997). This is to strike a balance between environment and development, and between the future and the present. The concept emphasized in particular "the essential needs of the world's poor, to which overriding priority should be given," and also "the environment's ability to meet present and future needs". A vital issue has been the aim of economic growth, which it encourages in both developed and developing countries. Developed economies can also become sustainable by reducing resource and energy intensive activities (Sorrell 2015).

By transferring technology, the use of energy and CO_2 emissions could be reduced while permitting economic and social development. To achieve sustainable development and a higher quality of life for all people, appropriate policies can be introduced to reduce unsustainable patterns of production and consumption. The instrument of Clean Development Mechanism (CDM) under the Kyoto Protocol

aims to contribute to the objective of a cleaner environment and assist in sustainable development (Pechak et al. 2011). Development projects should consider economically, ecologically sustainable aspects, their impacts on biodiversity, air and water quality. This could help enhance both environmental aspects and broader sustainability impact. Environmental conservation related development projects can accrue added value through the CDM (Howard et al. 2015).

The generation of biomass energy can create an energy mix through grid connection or use for isolated rural communities and homes. The grid connected initiatives can contribute to socio-economic development through generation of additional income to farmers by selling crop residues and biomass, employment in collection and transportation. Sugar mills can also be integrated for bagasse cogeneration to diversify and improve the viability of electricity supply (Eggleston et al. 2015). Such projects increase local personnel employment for operation and maintenance of equipment or management. The profiles of rural communities in developing countries are mostly farmers with poor asset base and skills. This limits their participation in economic activities. Their poor purchasing power would not improve their access to grid-connected electric power. Therefore, renewable energy may reduce the poverty gap. Renewable energy technologies are characterized as low hanging fruits. Governments of developing countries should recognize the contribution of renewable energy to sustainable development. The sustainable development potential of the diversification of energy sources is a win-win.

The benefits of initiatives that focus on improving energy efficiency in industries and fossil fuel switching have positively impacted growth in corporations (Oyedepo 2013). The welfare impact of energy is beyond households, communities, and nations. The effect of improved electrification on poverty arises from its stimulus to growth and employment opportunities. Infrastructural development, poverty alleviation, and rural electrification are important criteria for sustainable development. However, expenditure on grid extension is low in government expenditure on rural electrification in most developing countries (Ahlborg and Sjöstedt 2015). Most initiatives relating to poverty alleviation are road construction, agricultural research, and education. Generating power from landfill is largely confined to the urban population. Biogas projects contribute to environmental sustainability and socio-economic development. Small-scale biogas plants can provide electricity to rural households and contribute to socio-economic development. Solar energy for rural communities might have huge economic benefits to the rural poor. Reforestation has more synergy with poverty alleviation as the poor depend on resources from forests. Socioeconomic development objectives should include initiatives that are similar to the BOP concept in order to spur growth in poor communities.

The globe has for centuries faced natural climate variabilities such as fluctuating rainfall and extreme weather events (Stott et al. 2016). The poorest communities remain extremely vulnerable to natural climate variability because they lack the resources needed to adapt. In Vietnam, the Red Cross worked with its local branches and communities to plant hectares of mangroves and constructed river dikes. The project benefited millions of people, protecting communities from the impact of Hurricanes.

Climate change is already impacting in communities like Kenya's Turkana nomadic pastoralists through deforestation and land conflicts (Scheffran et al. 2014). In line with the predictions of climate change, the crisis is exacerbated by less frequent and less reliable rain. They now face more frequent droughts. These impacts are predicted to get worse if global warming is not kept to less than 2 °C. Communities dependent on glacial water will face more floods and avalanches, followed by water shortages (Nehren et al. 2013). Climate change could alter health outcomes, increasing the occurrence of disease, water, and vector-borne pathogens. Climate change could increase demand for medical and pharmaceutical products. It is expected to increase the prevalence of pathogens such as malaria, cholera, diphtheria, West Nile virus and trypanosomiasis (sleeping sickness) (Neiderud 2015).

In India, Oxfam's local partners piloted a scheme to raise the foundations of flood-prone mud houses. In Bangladesh, CARE (funded by CIDA) supported communities to adopt flood-resilient livelihood strategies, flood-proof storage of food, harvesting rainwater, and creating floating vegetable gardens (Alauddin and Rahman 2013). In Peru, farmers were faced with increasingly heavy rain and dry winters causing water shortage. Practical Action's local partners supported rural communities to understand the risks faced, diversify their livelihoods, and cultivate native crops. In Zambia, where farmers face reduced and more erratic rainfall, Tear fund has supported local NGOs in spreading the practice of minimum tillage farming, retaining soil moisture, aiming to benefit households. In Nicaragua, farmers are faced with both droughts and flood risks. Oxfam's local partners have supported communities with conservation agriculture, tree planting and water conservation (Intergovernmental Panel on Climate Change 2014).

Developed nations are investing in adaptation, recognizing the importance and cost effectiveness of acting early. In the Netherlands, projects were undertaken to re-zone flood areas and reposition dykes (Halbe 2016). After France's heat-wave, extra funding was committed for hospital emergency services. Climate change would lead to an increase in heat waves, exacerbated by humidity and pollution in urban areas (Webster et al. 2002). This would cause illnesses. In the UK, the government invested in cooling systems for the London Underground, partly in preparation for climate change. Increase in flooding would increase the number of people exposed to vector-borne, water-borne and diarrheal diseases. In Germany, a new sea wall was constructed for the city of Hamburg. In Wangerland, a coastal town on the North Sea, the existing dyke is being raised and a new one is also being built (Adger et al. 2003).

The Canadian government allocated funds for research in Agriculture and food, to help farmers adapt to the changing climate. The Australian government, as part of its National Climate Change Adaptation Programme, invested in coping with water scarcity and in raising building-design standards to protect against storms and cyclones (Wilhite et al. 2014). Compensatory finance to developing countries is in line with international development objectives. Additional finance for adaptation is essential to enable poor communities to adapt. In line with the 'polluter pays' principle, it is owed to developing countries as compensatory finance from high emitting countries. That is, high emitting nations should assist developing countries that are low emitters financially and technically to develop clean energy sources. This

would give developing countries an opportunity for integrating adaptation into development plans.

The WHO has estimated that climate change is already causing more deaths per year. Global warming may cause dryer weather conditions to arid environments. Access to clean water and security will drive investment and demand into water plants, equipment and technology development (Kochhar 2015). Clean water is already an issue for one third of the world's population and is set to increase. To reduce the impacts of water scarcity, significant investment is required for storage and transport. Water desalination technologies are likely to attract investment in the years ahead (Mehta et al. 2014).

Higher temperatures, excessive heat and drought in many regions of the world are the adverse effects of climate change. Risks from global warming would lead to deterioration in water quality resulting from rapid melting Polar icecaps, flooding and drought. Crop yields in many regions may decrease, exacerbating risks of hunger and malnutrition. This could make the cultivation of crops more difficult and impact on poor communities. It is likely that global warming will have a major impact on agriculture. Crops which have traditionally been grown in warmer climates may become more suitable for cultivation in what have been more temperate climates. Also, the traditional crops of the temperate climates, such as cereals and vegetables, may become more suitable in other regions (Lobell and Gourdji 2012). There would be similar issues for livestock, with the cost of maintaining domestic animals in warmer climates rising. This could lead to the farming of livestock challenging, increasing cost of meat products.

Businesses will be affected by global climate change; the degree to which they will be affected is dependent on a number of factors (Mozell and Thach 2014). They will be exposed to reputational and competitive issues relating to climate change that could have financial commitments. Both quantity and quality of capital and labor will be affected by the impacts of climate changes. Extreme weather events might damage land, infrastructure and installations, while labor, too, can be negatively affected by adverse weather conditions through an increase in ill health. Companies that stand to benefit from climate change include those that recognize its importance, anticipate to the implications for their respective industries, and work proactively to adapt (Averchenkova et al. 2015). The challenge for business to tackle the issue is significant, and will necessitate solutions driven through human ingenuity and technological advancement.

The UNFCCC formed in 1992 by 196 parties, set the objective to stabilize greenhouse gas concentrations in the atmosphere. The Kyoto Protocol took an approach, establishing negotiated binding emissions targets for developed countries. With the Copenhagen Accord and the Cancun Agreements, parties established a parallel "bottom-up" framework, with countries undertaking national pledges for 2020 (Bodansky 2010). This approach attracted much wider participation, including mitigation pledges by developing countries. In Copenhagen, countries agreed to establish the multilateral Green Climate Fund (GCF) to help mobilize funding to reduce

emissions and adapt to climate change. This Accord was expanded and formally adopted in the Cancun Agreements. The climate negotiations in Durban, South Africa, set the Paris summit as a new international agreement.

The Paris Agreement reflects a "hybrid" approach blending bottom-up with top-down initiatives, to promote sustainability (Andresen 2015). It represents a fundamental shift from the Kyoto Protocol towards different provisions. The agreement commits parties to pursue domestic measures to achieve objectives of its Nationally Determined Contributions (NDCs) and achievement of non-binding obligations. It also encourages countries to develop and communicate long-term low emission strategies. It reaffirms the binding obligations of developed countries to support the efforts of the developing. It also encourages voluntary contributions from developing countries. It calls for a new mechanism, similar to the Clean Development Mechanism under the Kyoto Protocol, enabling emission reductions in one country to be counted towards another (Andresen 2015).

Developing countries are promised capacity-building support to help them meet new requirements. A committee of experts is to be "facilitative" in nature and operate in a "non-adversarial and non-punitive" manner. The agreement establishes a "double trigger" for entry-into-force: it requires approval by countries accounting for most of the global greenhouse gas emissions. A priority for many developing countries is strengthening adaptation strategies under the UNFCCC. This is to establish a global goal of enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change. Scaling up public finance to support adaptation and mitigation action should be aligned with other public finance for development. The agreements on climate change and the SDGs should be seen as complementary, with opportunities for mutual benefit. It places emphasis on adaptation and establishes a goal of enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change. It requires all parties to plan and implement adaptation efforts. Parties reporting on adaptation are encouraged to include the provision of details of their priorities (Andresen 2015).

The Paris Agreement requires countries to make significant commitments to address climate change. Countries responsible for 97% of global emissions have already pledged their NDCs. Developed countries will continue to provide climate finance to help the most vulnerable adapt to climate change and build low-carbon economies (Andresen 2015). The agreement contains provisions to hold countries accountable to their commitments and mobilize greater investments to assist developing countries. With more ambitious national mitigation pledges, better delivery of existing financial commitments and more action in key sectors, such as energy efficiency, renewable energy deployment and forest protection are required (Andresen 2015). New and strengthened initiatives also came from "non-state actors," including cities, states and regions, companies and investors.

References

Adger, W. N., Huq, S., Brown, K., Conway, D., & Hulme, M. (2003). Adaptation to climate change in the developing world. *Progress in Development Studies, 3*, 179–195.

Ahlborg, H., & Sjöstedt, M. (2015). Small-scale hydropower in Africa: Socio-technical designs for renewable energy in Tanzanian villages. *Energy Research & Social Science, 5*, 20–33.

Alauddin, S., & Rahman, K. F. (2013). Vulnerability to climate change and adaptation practices in Bangladesh. *Journal of SUB, 4*, 25–42.

Andresen, S. (2015). International climate negotiations: Top-down, bottom-up or a combination of both? *The International Spectator, 50*, 15–30.

Averchenkova, A., Crick, F., Kocornik-Mina, A., Leck, H. & Surminski, S. (2015). *Multinational corporations and climate adaptation – Are we asking the right questions? A review of current knowledge and a new research perspective*. Grantham Research Institute on Climate Change and the Environment.

Baudot, B. S., & Moomaw, W. R. (2016). *People and their planet: Searching for balance*. Springer.

Bodansky, D. (2010). The Copenhagen climate change conference: A postmortem. *American Journal of International Law, 104*, 230–240.

Dechezleprêtre, A., & Glachant, M. (2014). Does foreign environmental policy influence domestic innovation? Evidence from the wind industry. *Environmental and Resource Economics, 58*, 391–413.

Eggleston, G., Delucca, A., Sklanka, S., Dalley, C., Cyr, E. S., & Powell, R. (2015). Investigation of the stabilization and preservation of sweet sorghum juices. *Industrial Crops and Products, 64*, 258–270.

Garnett, T., & Godfray, C. (2012). Sustainable intensification in agriculture. Navigating a course through competing food system priorities. *Food climate research network and the Oxford Martin Programme on the future of food*, University of Oxford, Oxford, p. 51.

Halbe, J. (2016). *Governance of transformations towards sustainable water, food and energy supply systems*. Osnabrück: University of Osnabrück.

Hardman, J. (2013). *Leading for regeneration: Going beyond sustainability in business education, and community*. Hoboken: Routledge.

Howard, R. J., Tallontire, A., Stringer, L., & Marchant, R. (2015). Unraveling the notion of "fair carbon": Key challenges for standards development. *World Development, 70*, 343–356.

Intergovernmental Panel on Climate Change. (2014). *Climate change 2014 – Impacts, adaptation and vulnerability: Regional aspects*. Cambridge: Cambridge University Press.

Jackson, R. B., Canadell, J. G., Le Quéré, C., Andrew, R. M., Korsbakken, J. I., Peters, G. P., & Nakicenovic, N. (2015). Reaching peak emissions. *Nature Climate Change*, *6*, 7–10

Kochhar, K. (2015, June). *Is the glass half empty or half full? Issues in managing water challenges and policy instruments* (IMF Staff discussion note, p. 7). Washington, DC: International Monetary Fund.

Lobell, D. B., & Gourdji, S. M. (2012). The influence of climate change on global crop productivity. *Plant Physiology, 160*, 1686–1697.

Lohani, B. N., Evans, J. W., Everitt, R. R., Ludwig, H., Carpenter, R. A., & Tu, S.-L. (1997). *Environmental impact assessment for developing countries in Asia: Volume 1-overview*. Manila: Asian Development Bank.

Mehta, D., Gupta, L., & Dhingra, R. (2014). Forward osmosis in India: Status and comparison with other desalination technologies. *International Scholarly Research Notices, 2014*, 1–9.

Mozell, M. R., & Thach, L. (2014). The impact of climate change on the global wine industry: Challenges & solutions. *Wine Economics and Policy, 3*, 81–89.

Nehren, U., Kirchner, A., Sattler, D., Turetta, A. P., & Heinrich, J. (2013). Impact of natural climate change and historical land use on landscape development in the Atlantic Forest of Rio de Janeiro, Brazil. *Anais da Academia Brasileira de Ciências, 85*, 497–518.

Neiderud, C.-J. (2015). How urbanization affects the epidemiology of emerging infectious diseases. *Infection Ecology & Epidemiology, 5*, 27060.

Oyedepo, S. O. (2013). Energy in perspective of sustainable development in Nigeria. *Sustainable Energy, 1*, 14–25.

Pechak, O., Mavrotas, G., & Diakoulaki, D. (2011). Role and contribution of the clean development mechanism to the development of wind energy. *Renewable and Sustainable Energy Reviews, 15*, 3380–3387.

Scheffran, J., Ide, T., & Schilling, J. (2014). Violent climate or climate of violence? Concepts and relations with focus on Kenya and Sudan. *The International Journal of Human Rights, 18*, 369–390.

Selvaraj, K., Chinnakali, P., Majumdar, A., & Krishnan, I. S. (2014). Acute respiratory infections among under-5 children in India: A situational analysis. *Journal of Natural Science, Biology and Medicine, 5*, 15.

Sorrell, S. (2015). Reducing energy demand: A review of issues, challenges and approaches. *Renewable and Sustainable Energy Reviews, 47*, 74–82.

Stott, P. A., Christidis, N., Otto, F. E., Sun, Y., Vanderlinden, J. P., Van Oldenborgh, G. J., Vautard, R., Von Storch, H., Walton, P., & Yiou, P. (2016). Attribution of extreme weather and climate-related events. *Wiley Interdisciplinary Reviews: Climate Change, 7*, 23–41.

Tchounwou, P. B., Yedjou, C. G., Patlolla, A. K., & Sutton, D. J. (2012). Heavy metal toxicity and the environment. In*Molecular, clinical and environmental toxicology*. Basel: Springer.

Webster, M. D., Babiker, M., Mayer, M., Reilly, J. M., Harnisch, J., Hyman, R., Sarofim, M. C., & Wang, C. (2002). Uncertainty in emissions projections for climate models. *Atmospheric Environment, 36*, 3659–3670.

Wilhite, D. A., Sivakumar, M. V., & Pulwarty, R. (2014). Managing drought risk in a changing climate: The role of national drought policy. *Weather and Climate Extremes, 3*, 4–13.

Chapter 7
Introduction of a Recycling System for Sustainable Municipal Solid Waste Management

Abstract This chapter proposes for the introduction of a recycling system in developing countries to enhance sustainable municipal solid waste (MSW) management. Poor infrastructures, coupled with inadequate resources and lack of funding, work against the optimization of a MSW disposal service. Authorities in charge of waste management need to change not only behaviors, but modernize their processes. Recycling technology is a key part of the solution. A model has been developed which suggest the involvement of stakeholders to achieve meaningful sustainable MSWM. This can be achieved by recognizing the role of the informal sector through community-based organizations, Non-Governmental Organizations (NGOs), and the private sector. The open dump approach is leading to severe environmental consequences as groundwater and soil is been contaminated. In this chapter, an integrated municipal solid waste management approach was developed with a model to help achieve sustainable municipal solid waste management. Resource recovery, not waste disposal, must be the ultimate goal with clearly defined end user markets so that the recovery loop is complete. Mandatory sorting of waste at household level would help greatly in making recycling activity successful.

Keywords Impacts · Municipal · Stakeholders · Resource recovery · Model

7.1 General Background

The Global Waste Management Outlook (GWMO) indicates that waste generation will continue to increase in African and Asian cities by 2030. Waste management is not only an environmental and public health necessity; it is a sound economic investment (Wilson et al. 2012). Reduce; reuse, recycle and life-cycle management could make economic benefits toward realizing the Sustainable Development Goals (SDGs). The emission of methane and CO_2 from poorly managed waste dumpsites is increasing the impact of climate change. Waste management is a priority in meeting the Sustainable Development Goals (SDGs). Sustainable waste management provides opportunities to collaborate and work in partnership.

The SDGs are linked to waste management to ensure sustainable consumption and production. The proposed SDG 12 on sustainable consumption and production,

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promoting sustainable lifestyles supports Article 6 of the UNFCCC (SDG 13). Unsustainable consumption and production patterns are caused by poor design and material choices leading to resource depletion, waste generation, and pollution. Goal 12 aims to achieve environmentally sound management of chemicals and wastes throughout their life cycle. This will reduce release to air, water, soil and exposure to hazardous chemicals. It advocates for chemicals management integration into national environmental and poverty reduction planning frameworks.

According to the UN revision of world urbanization prospects, half or more of the African population is expected to live in cities by 2030 (Cohen 2006). An estimated two-thirds of the world's people will be living in cities by 2025. Urbanization is not necessarily a problem, however haphazard and unplanned settlements can result in environmental problems such as public space and riverbank encroachment, air and water pollution (Troschinetz and Mihelcic 2009). Economic development contributes to improvements in living standards. However, it also induces environmental degradation with long-term economic, social and environmental consequences. Knowledge of municipal solid waste (MSW) composition is essential for the determination of waste management options such as recycling (Miezah et al. 2015). Some major categories of waste in these communities are Organic matter, PET bottles, plastic, paper, cardboard, wood, rubber, glass, metals, textiles, and WEEE.

The waste management system being used is not regular, doesn't separate wastes and there are not enough vehicles for collection. As a result, there is the indiscriminate disposal of waste within neighborhoods and commercial areas. The burning of waste contributes to air pollution. Indiscriminate dumping of solid waste pollutes the environment. Uncollected garbage also has a potential effect on public health as it promotes the reproduction of vectors of diseases such as cockroaches, rats, flies and mosquitoes. The involvement of civil society in the management of municipal solid waste should be promoted. Currently, there are no waste treatment technologies being used creating an unhygienic condition.

Many households either bury or burn their garbage in their compounds or dump it at an adjacent unauthorized dump site or even on the street. The Municipal Councils does not operate any meaningful garbage collection services. A site investigation on a dump Site found that it does not fulfill the standards required for locating a landfill. That is, to be located far from human settlements, does not pose a hazard to health, environment, and society. Appropriate technology should be applied and equipment for control tipping and lining provided. Despite the failure of the dumpsite to meet these criteria's, it is not feasible to close the site for a suitable alternative is yet to be developed.

The dump site is located in a densely-populated area and is visible to residents, passers-by, and motorists. This has a negative visible impact, as a result of smoke from burning debris. Such fires start due to the immense release of methane which results from poor sorting of waste. The waste is neither covered nor compacted. Due to its proximity to residential areas, people are affected by the smoke from burning debris and the stench of decomposing waste. Under the existing conditions, open burning of unsorted waste is common. The stench and other nuisances are worst during the rainy season as the area becomes infested with flies and insects.

Open dumpsites are a major source of leachate, which contaminates soil and groundwater (Kanmani and Gandhimathi 2013). Leachate typically contains concentration of organic carbons, ammonia, chloride, potassium and hydrogen carbonate. Once released into the soil, it can get to the ground water. The groundwater table at the refuse dump site investigated is less than 2 m. There is a high level of fecal and total Coliform contamination in some wells located near the site. The high level of bacteriological contamination means that the water should not be used for even washing utensils or bathing. Water samples collected from wells at approximately 100 m from the dump site shows a high level of fecal and total Coliform. A high percentage of the samples had fecal Coliform counts >100, 93% and total Coliform counts >100 per 100 ml. The high Coliform count in the wells is attributed to their proximity to the dump site.

Municipal Solid Waste Management (MSWM) encompasses the functions of collection, transfer, resource recovery, recycling, and treatment. The primary target of MSWM is to protect the health of the population, promote environmental quality and sustainability. To meet these goals, sustainable solid waste management systems must be embraced fully by local authorities in collaboration with the public and private sectors. Although the quantity of solid waste generated in urban areas of developing countries is low compared to industrialized countries, MSWM still remains inadequate. The collection, transportation, and disposal of MSW are unscientific and chaotic, left entirely on municipalities. Uncontrolled dumping of waste on outskirts of towns and cities has serious environmental implications in terms of groundwater and soil contamination. Open burning of waste leads to air pollution in terms of increased total suspended particles (TSP) and particulate matter (PM).

The aim of solid waste disposal is to remove waste from the community, reduce its volume, making it stable and hygienic. In choosing the process of proper treatment and disposal, the economic cost and the level of technology should be considered. The investigated dump site is on the site of an old quarry and occupies an area of about 17.8 ha. Garbage is dumped along the edge of the site, with a pungent smell engulfing its environs. Burning and smoldering garbage is a regular feature in most dump sites. There is no compaction of waste or application of cover material. There is no equipment on site and the dumping of waste is uncontrolled.

The prevailing method of open dumping is a major source of environmental pollution. Moreover, it has become increasingly difficult to identify new sites for disposal due to the cost of land and lack of appropriate location. The operational efficiency of solid waste management depends on the active participation of the citizens. Since the social status of solid waste management is low, there is apathy towards it. This leads to uncollected waste and deterioration of aesthetics. According to estimates from the World Resources Institute and the USAID, many local authorities in developing countries spend over 30% of their budgets on refuse collection and disposal but can only collect at most 50–70%. Most do not meet environmentally safe MSW disposal levels because of a lack of sanitary landfills.

Waste management and disposal is a pressing issue facing developing countries since most of it is disposed by open dumping (Anaman and Nyadzi 2015). Some commonly used methods of waste management are: incineration, landfilling and

composting. However, these methods are inefficient and harm the environment. This book illustrates that the solution to waste management is not merely technical, but also organizational. There is a great need to move away from the disposal-centric approach toward the recovery-centric. This paradigm shift requires some level of public participation by regulating and monitoring waste collection and disposal. In a world of limited resources, recovery is fundamental to sustainable development. A recovery-centric approach to municipal solid waste management can be functional with active citizen participation. Proper implementation of regulations for storage, collection and sorting would be required. Globally, there is a drive for sustainability and efforts to reduce material consumption. Accordingly, 3R initiatives have been introduced to reduce, reuse and recycle waste materials (Shekdar 2009). Affluent countries provide substantial financial and regulatory resources for recycling waste fractions such as glass, metals, paper and plastics. By contrast, in developing economies, recyclable fractions can often be sold for profit, and recycling is an economic activity for certain sectors of society.

It has been argued that the effectiveness of solid waste management is an indication of good governance (Wilson and Ing 2013). The focuses of the SDGs are on poverty reduction, improvement of the quality of life and environmental sustainability. This book suggests that the recycling of MSW possesses acknowledged development potential. Although there are no recycling plants, people are aware of the potential. Official recognition and support of alternative waste management, resource recovery and recycling for socioeconomic development is proposed. Cooperation with and support of the informal recycling could lead to resource recovery; create employment and reduction in the amount of waste requiring ultimate disposal in landfills.

This book brings into focus waste management through recycling in order to achieve economic viability. Sustainable options can be explored that conserve both natural and man-made resources to avert ecological risk. Attempts have been made to clear waste by door-to-door collection using dumper trucks. However, this is proving unsustainable, for the trucks are expensive for most municipalities in developing countries to buy. The integrated waste management system is proposed as an option, which includes collection, transport, and processing of waste in an environmentally sound way. The challenge of solid waste management is the absence of adequate policies, enabling legislation, and an environmentally stimulated and enlightened public. Government policies on the environment are piecemeal where they exist and are poorly implemented. Public enlightenment programs need to be restructured for more coverage and intensity. There should be continuous efforts to correct the apathetic public attitude towards the environment. Successful solid waste management will require a holistic program that will integrate technical, economic, social, cultural, and psychological factors.

In recent years, a significant increase in municipal solid waste has been noted, yet there is no fully efficient system for its treatment in developing countries. Attempts should be made to educate and mobilize society to segregate recyclables to produce satisfactory results. Society's awareness in this field needs to be raised. There should be adequate information on quantification and characterization of waste; health, the

social, economic and environmental impact of municipal solid waste management. The waste management system currently has not properly integrated solutions like collection, treatment, and supply for reuse, reprocessing and final disposal. The system has also not provided enough room to adapt to future pressures. The rapid increase in volumes of unattended solid waste with the associated risk to human health is a source of concern. There is also a steady increase in the cost and logistics for municipal solid waste management. This has put increasing pressures on the infrastructure and authorities responsible for the management of solid waste. It is, therefore, prudent to look for and implement long-term integrated waste management strategies like recycling system that ensure sustainability.

Many developing country cities aspire to modern waste management systems that are associated with relatively high recycling rates of clean, source-separated materials. Most already have informal recycling systems sector, which is driven solely by the revenues derived from selling recovered materials. There is clear potential for 'win-win' cooperation between the formal and informal sectors. Providing support to the informal sector to build recycling rates to address social issues could reduce the overall costs of waste management. The presence of waste materials with positive value represents a potential source of livelihood for the urban poor (Sanneh et al. 2011). This was true for medieval cities and for rapidly industrializing cities of Europe and North America in the nineteenth century.

Developed countries typically utilize curbside recycling programs to collect and sort waste for recycling and processing. Conversely, developing countries can utilize the social sector known as scavengers to handle such activities. Scavengers are citizens with low- to no-income that collect materials either dispersed throughout the city or concentrated at dumpsites. These materials are then sold to recycling shops, middlemen, or exporters. Supporting scavenging would end exploitation and discrimination. Jobs will be created, poverty reduced, resources are conserved, pollution is reduced, and the environment is protected. Such a systems-wide perception has the potential to make significant improvements in the MSWM of developing countries.

While identifying each of the stakeholders that influence recycling in developing countries, their involvement and collaboration improve the various aspects of MSWM (Troschinetz and Mihelcic 2009). Collaboration is identified as a catalyst for awareness of recycling. This can enhance waste handling and disposal operations through characterization and segregation. The utilization of scavengers as agents of MSWM through policy initiatives will create sustainability. Costs can be reduced through sharing of facilities and equipment. Thus, this book recognizes stakeholder involvement as an overarching theme essential to sustainable management of municipal solid waste.

The collaboration web shown in Fig. 7.1 was designed as a result of the stakeholder theme highlighted. The functionality of the relationships or institutional collaboration greatly influences the success of sustainable MSWM (Troschinetz and Mihelcic 2009). A solid line represents a relationship between institutions necessary for a given factor to sustainable recycling, whereas a dashed line implies heightened influence on sustainable recycling through institutional interaction. In other words,

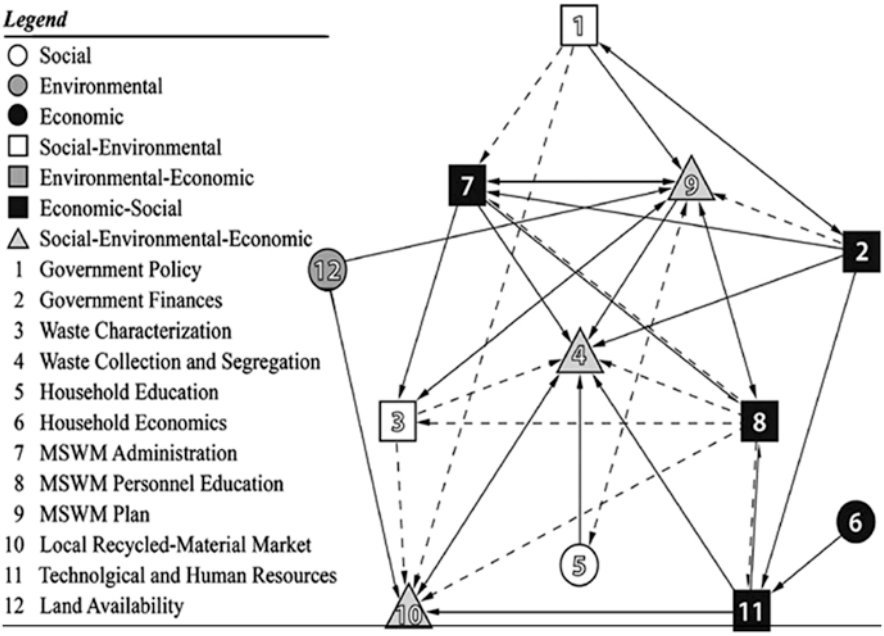

Fig. 7.1 Collaboration web for sustainable MSWM (Sustainable recycling of municipal solid waste in developing countries Alexis M. Troschinetz *, James R. Mihelcic)

institutional collaborations shown by solid lines are critical for more sustainable MSWM through recycling. Relationships shown by dashed lines further highlight sustainable MSWM through recycling and are not critical to its presence. Collaboration, in general, demands active participation by all parties working towards a common goal. The common goal would be striving for more sustainable MSWM through material recovery.

In order to fulfill the goals of waste collection and segregation, residents need to be educated on the separation of waste. Labor and equipment are needed for collection and processing. The system needs to manage the finances associated with operations, and MSWM administrators need to have a plan. Educating MSWM workers to understand the characteristics of the waste stream will enhance efficiency. Policy creation provides the regulations needed to formulate the MSWM plan. Sustainability requires de-compartmentalization to better understand the impacts of a given action in pursuit of one goal (Ni et al. 2009). This figure illustrates how certain MSWM activities typically thought of as pertaining to recycled material market have been thrust into being multidimensional due to the necessary and beneficial interactions.

For broader applicability to most developing countries, it includes action items pertaining to social factors and education, household waste characterization, collection, and resource recovery. This book raises attention to key topics within MSWM in developing countries especially those in Sub-Saharan Africa. The disease burden, public health and sanitary conditions of cities require consideration in the

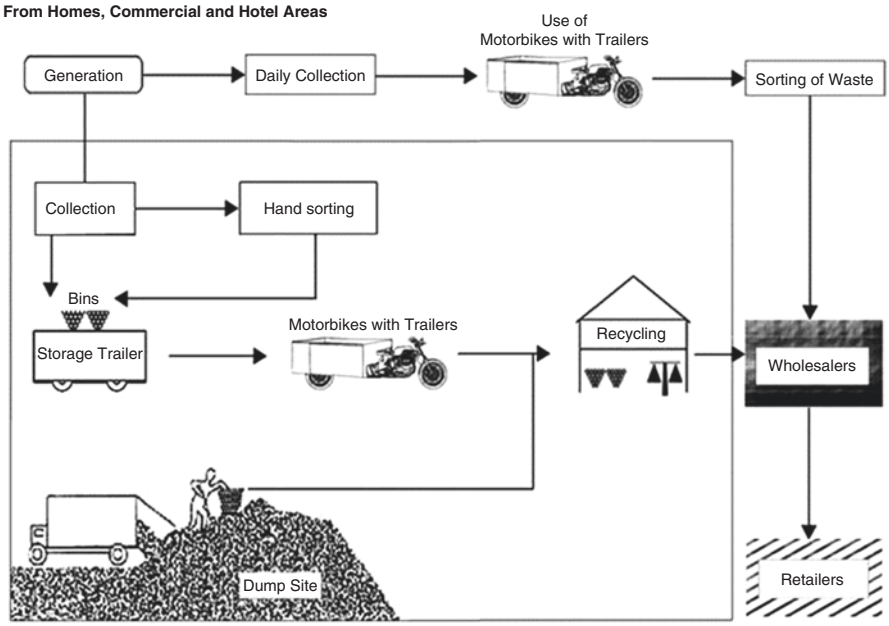

Fig. 7.2 Scheme developed to enhance the collection and transportation of MSWM

drive to achieve the sustainable development goals. Thus, this book recognizes stakeholder involvement as an overarching theme.

To meet the goals of a sustainable society and respond to growing concerns over environmental impacts of MSWM, an integrated solid waste management approach should be adopted. Recycling of materials can lessen environmental burdens, lower the costs of waste disposal, and reduce dependence on resources (Yolin 2015). It can also create job opportunities and increase GDP. The recycling system should integrate to the effect that community, garbage collection teams, recycled materials dealers will all work together. Much effort should be devoted to formulating regulations and programs for waste reduction and resource recycling.

An unreliable and irregular collection service still exists. There are shortcomings in the existing MSWM system that needs correction. To effectively manage MSW, proper and feasible collection mechanisms should be available to have a lasting solution. Dumper trucks are expensive for municipal councils in developing nations to buy and maintain, thus we propose the use of motorbikes with trailers. Motorbikes are cheaper and easier to maintain, while the trailers can be made locally. The introduction of motorbikes with trailers, along with separation of waste and the establishment of a recycling and recovery system would facilitate a solution to the waste management problem. With improper urban planning, some of the streets are narrow and inaccessible; motorbikes with trailers can access entire municipalities. Figure 7.2 is a scheme developed to enhance the collection and transportation of MSW. Changes in the working environment for the workers will be instrumental in

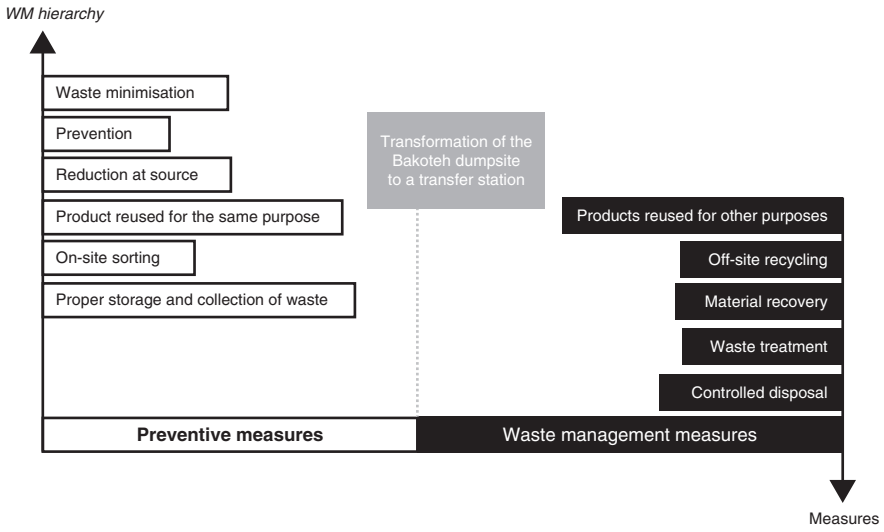

Fig. 7.3 Proposed waste management concepts

providing a livable wage. Therefore, the scavengers at dump sites should be incorporated in the approach to managing waste through recycling. This book is an attempt to find alternatives to improve the existing system.

The construction of transfer stations and the positioning of garbage trailers within the communities are suggested as a solution to reduce distances between households and collection point. Transfer stations and garbage trailers would enable the waste collection system to expand and improve services. Developing sound resource management strategies will create a better policy to encourage recycling. This will further bolster the growth of the solid waste recycling market. It is a model that can help Sub-Saharan African countries to properly manage MSW and enhance a healthy populace. Source reduction, reuse, and recycling are the most preferred methods, followed by composting and landfills. Municipalities should encourage public and private participation. Awareness campaigns should also be conducted to improve proper segregation of waste. The waste management system will be shifted from end-of-pipe and open dumping to source management. This approach will help decrease the use of raw materials and effectively recycle resources. Figure 7.3 shows procedures that can be adapted for sustainable MSWM.

Collection of un-separated solid waste in an urban area is difficult and complex. The generation of residential and commercial solid waste takes place in every home, commercial and industrial facilities, streets, parks and vacant areas. As the patterns of waste generation become more diffuse and the total quantity of waste increasing, the logistics becomes more expensive. Although these problems have always existed they have now become more critical because of the high costs of resources. Waste collection should include not only the gathering or picking up of waste from the various sources but also hauling. Proper management can be achieved with a waste management plan. Waste management planning should avoid waste generation, using cleaner technology, promoting recycling and recovery.

The lack of collection of waste is attributed to the lack of collection vehicles which are expensive to buy and maintain. This book recommends the use of motorbikes with trailer (locally made). The unplanned nature of some urban settlements makes it difficult for dumper trucks to access homes/households to collect waste. As a developing country, it might also be difficult for the municipal authorities to purchase dumper trucks to serve the whole area. It is believed that with this collection system, environmental and sanitary conditions would be improved. The health of the inhabitants will be improved in relation to common sanitary related diseases such as malaria, dysentery, diarrhea, skin diseases etc.

As landfill sites fill up, the real alternative to incineration is recycling. In both developing and developed countries, recycling generates jobs, produces less pollution and is sustainable (Akkucuk 2014). The production and disposal of a large amount of waste are seen by many to represent squandering the Earth's resources. Relating this to the "Limits to Growth" concept, raw materials are being used at a faster rate than they are being replaced or alternatives being found. Whilst all methods for treating and disposing of waste are known to have environmental impacts, waste must still be dealt with. Therefore, recovering materials from MSW would help in conserving both environment and resources.

The manual sorting of solid waste components can be done at the source where solid waste is generated, at a transfer station, at a centralized processing station and disposal site. The sorting of waste creates raw materials which can be used in the manufacture of new products, and thus the exploitation of virgin raw materials is reduced (Padam et al. 2014). This also results in the lowering of the amount of waste which ends up in landfills. The sorting of hazardous waste prevents toxic and explosively fragile substances from descending into landfills. Sorting waste is also economically viable.

The author opines that MSWM is not just a technological system facilitating the handling and disposal of MSW. It also deals with many other factors such as socio-economic conditions, operating environment and actions of the municipal government. Authorities should consider environmental impact in disposal sites to reduce pollution of surface and groundwater. Illegal dumping of MSW poses both environmental and economic threats.

MSWM is meant for the public, and, without the public's cooperation, the system cannot be operated and maintained appropriately (Sanneh et al. 2011). Hence, it is necessary to make the public involve through active participation. In practice, system efficiency is directly proportional to the number of participating citizens. Without public participation, it may be difficult to maintain cleanliness in a city. Resource recovery systems may become less effective if the waste is poorly separated at the source. With the proper education and awareness raising programs, recycling could be initiated. The approach's main strategic objectives should include the following:

1. Provide technical assistance and training for recycling
2. Create feasible policies for a recycling system
3. Encourage economic growth related to recycling

4. Create a marketing program for recyclable materials.

Current waste management practices are unable to keep pace with generation rate. The suggestion has been made to clear waste using motorbikes with trailers while separating recyclable from non-recyclable. There should also be complementary action from different stakeholders; and not only left to the municipal council (Troschinetz and Mihelcic 2009). Political support is important to provide adequate infrastructure, funds and encourage stakeholder's participation. It is important that resources for the waste management program are properly harnessed. Financial resources, legal institutional framework and human resources are the fundamental components. The success of a recycling program depends on the active and sustained participation of citizens in the correct separation and collection of recyclables. As GDP per capita increases, MSWM per capita generation also increases and it becomes saturated at high GDP. Resource flows link the economy with the ecosystem and forms the bridge between human activities and environmental impacts. The use of resources leads to wealth and economic growth.

References

Akkucuk, U. (2014). *Handbook of research on developing sustainable value in economics, finance*. Hershey: IGI Global.

Anaman, K. A., & Nyadzi, W. B. (2015). Analysis of improper disposal of solid wastes in a low-income area of Accra, Ghana. *Applied Economics and Finance, 2*, 66–75.

Cohen, B. (2006). Urbanization in developing countries: Current trends, future projections, and key challenges for sustainability. *Technology in Society, 28*, 63–80.

Kanmani, S., & Gandhimathi, R. (2013). Assessment of heavy metal contamination in soil due to leachate migration from an open dumping site. *Applied Water Science, 3*, 193–205.

Miezah, K., Obiri-Danso, K., Kádár, Z., Fei-Baffoe, B., & Mensah, M. Y. (2015). Municipal solid waste characterization and quantification as a measure towards effective waste management in Ghana. *Waste Management, 46*, 15–27.

Ni, Y., Zhang, H., Fan, S., Zhang, X., Zhang, Q., & Chen, J. (2009). Emissions of PCDD/Fs from municipal solid waste incinerators in China. *Chemosphere, 75*, 1153–1158.

Padam, B. S., Tin, H. S., Chye, F. Y., & Abdullah, M. I. (2014). Banana by-products: An under-utilized renewable food biomass with great potential. *Journal of Food Science and Technology, 51*, 3527–3545.

Sanneh, E., Hu, A. H., Chang, Y., & Sanyang, E. (2011). Introduction of a recycling system for sustainable municipal solid waste management: A case study on the greater Banjul area of the Gambia. *Environment, Development and Sustainability, 13*, 1065–1080.

Shekdar, A. V. (2009). Sustainable solid waste management: An integrated approach for Asian countries. *Waste Management, 29*, 1438–1448.

Troschinetz, A. M., & Mihelcic, J. R. (2009). Sustainable recycling of municipal solid waste in developing countries. *Waste Management, 29*, 915–923.

Wilson, D. C., & Ing, L. R. D. (2013). Integrated sustainable waste management in developing countries. *Proceedings of the Institution of Civil Engineers, 166*, 52.

Wilson, D. C., Rodic, L., Scheinberg, A., Velis, C. A., & Alabaster, G. (2012). Comparative analysis of solid waste management in 20 cities. *Waste Management & Research, 30*, 237–254.

Yolin, C. (2015). *Waste management and recycling in Japan opportunities for European companies (SMEs focus)*. Tokyo: EU-Japan Centre for Industrial Cooperation.

Chapter 8
Shipment of Used ICT Products to Developing Countries

Abstract As a measure to avert environmental hazards, conventions and regulations have been formulated, which are complex and getting stricter. The purpose of this chapter is to propose environmental policy to influence sustainable flow of used Information and Communication Technology (ICT) products to West African Countries. The research investigated the role of Life Cycle Management (LCM) and Extended Producer Responsibility (EPR) environmental policy to improve end of life management of used ICT products. The study was conducted using theoretical descriptive (explanatory) analysis based on past literatures and related research. The first model identifies the current end of life management impacts. The second model presents an environmental policy (EPR) that encourages waste minimization through reuse and recovery initiatives. The aim is to establish feedback loops from downstream (end-of-life management) to upstream (producer of the product) through a take back system for used ICT products. Further investigation highlights the influence of environmental regulation with a SWOT analysis. It was found that environmental regulation mediates social, health and environmental concerns. However, for sustainability, ICT product manufacturers should be responsive to their customers' environmental concerns and needs.

Keywords Extended producer responsibility · Used ICT · West African countries · Environmental impact

8.1 General Background

Environmental pollution has been a challenging phenomenon for decades, although its impact was not felt as much as it is present. The ever-growing human populace necessitates increasing the production of goods and services. The more technology is applied in production; the environment is affected more through pollution. As a result, many conventions were organized and ratified, policies formulated and communiqués adopted for environmental protection. The restriction on Chlorofluorocarbon (CFC) of the "Montreal Protocol", reduction in the emission of CO_2 of the "Kyoto Protocol", the Rio summit, and Sustainable Development Announcements of Johannesburg World Summit. The European Union adopted

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restriction of the Use of Certain Hazardous Substances (RoHS) in Electronic and Electrical Equipment (EEE). The Millennium Development Goal and Sustainable Development Goals of the United Nations recently adopted. The rise of concepts and regulations of environmental protection have brought significant impacts on society. These were all principally initiated for sustainable human development.

The increasing demand for consumer electronics and electrical products, with the accelerated pace at which technology is evolving, resulted in an increased amount of obsolete, discarded, broken and abandoned products. As the cost of managing and disposing of waste safely became a challenge, exporting the problem to developing countries began. Environmental and workplace legislation is either inadequate or unenforced in recipient nations. Moreover, it is cheaper to "recycle" waste in developing countries. The United Nations Office on Drug and Crime (UNODC), 2009 published the report "Transnational trafficking in West Africa". It identifies trafficking in persons, drugs, oil, cigarettes, counterfeit medicines, toxic waste and electronic waste ("e-waste"). This is posing a serious threat to security and development. In West Africa, most electronic and electrical waste products are not treated; instead, they are usually burned or buried. The studies executed by the Basel Convention E-waste Africa project assessments have shown that Africa's consumption of EEE is growing (Magashi and Schluep 2011). According to the Greenpeace study in Accra and Korforidua, e-waste dismantling and recycling site in Ghana is contaminating the environment with toxic and hazardous metals.

The Basel Action Network (BAN) coordinated the study in Nigeria, entitled Exporting Reuse and Abuse to Africa, revealed the level of trans-boundary movement of second-hand scrap electronics and electrical equipment. The BAN study observed that most of the imported secondhand computer wares are unusable junk that is non-functional or irreparable. A similar studies/review on Ghana also revealed the same (Prakash and Manhart 2010). The studies conducted by the Basel convention Africa Programme in five West African countries suggest that up to 70% of all imports are used EEE, with 30% of the used EEE imported being determined to be non-functioning (e-waste). It is estimated that during the past few years, at least 250,000 tons of e-waste per annum, illegally entered the ports of five selected West African countries, namely Benin, Côte d'Ivoire, Ghana, Liberia and Nigeria, shown in Table 8.1.

Table 8.1 Penetration rate of selected EEE (in installed units per capita)[a]

		Imports of EEE		EEE in use		E-waste generated	
Country	Year	tonnes/ year	tonnes/ year	tonnes	kg/ inhabitant	tonnes/ year	Collected
Benin	2009	16,000	16,000	55,000	6.32	9700	N/A
Côte d'Ivoire	2009	25,000	25,000	100,000	4.8	15,000	N/A
Ghana	2009	215,000	215,000	984,000	41.0	179,000	172,000
Liberia	2009	3500	3500	17,000	4.6	N/A	N/A
Nigeria	2010	1,200,000	1,200,000	6,800,000	44.0	1,100,000	N/A

[a]Basel Convention e-waste Africa program

An analysis conducted on behalf of the Danish Environmental Protection Agency indicated that Danish shipments to a large extent consisted of used products or e-waste (Hossain et al. 2015). Based on Danish figures, the European Topic Centre on Resource and Waste Management (ETC/RWM) suggested that tons of used TVs, computers, monitors, screens, refrigerators, and deep freezers may be exported from the European Union each year. Examples include stationery computer shipments to The Gambia and Senegal (Nordbrand 2009). These countries have started to experience huge imports of second-hand computers accumulating in landfills. There is a desperate need for ICT products and other information technology tools in West Africa. Trade in second-hand ICT products generates both positive and negative effects. On the one hand, it may increase public access to ICT products and extend the lifespan, which is environmentally sound. Several reviews stated the benefits that can arise from integrating environmental sustainability issues into product development and business operations.

The backyard recycling of electronic waste carried out in many developing countries poses risks that could be avoided. There is a paucity of empirical data on environmental and human health risks caused by certain treatment options. Literature reviews show that there is two main ends of life management models used for electronics recycling. In the first model, manufacturers are financially responsible for collection and recycling costs. This is an expression of the idea of Extended Producer Responsibility (EPR). The second is a financial incentive e.g. deposit, where the consumer pays an extra sum when the device is purchased which is returned when turned in for recycling. Understanding the influence of policy as a result of mainstreaming current situation and sustainability has become a strategic priority.

Life Cycle Management (LCM) is an integrated framework for managing the total life cycle performance of goods and services (Ageron et al. 2012). It is for integration of economic, social and environmental considerations. The earliest life cycle assessment (LCA) study on the disposal of EEE was conducted in the European Union (EU). Some of the environmental impacts were an accumulation of photochemical smog, hazardous and radioactive waste generation. Maine was the first US state to mandate producer responsibility for recycling household WEEE. Its program instituted a shared cost responsibility among producers, municipalities, and consumers (Wagner 2009).

There WEEE recycling operators in Australia has a facility that is capable of recycling tons of WEEE per year. A National Waste Policy was introduced for resource recovery and recycling of TVs and computers. Most of the Organization for Economic Co-operation and Development (OECD) member countries, along with other nations, has developed policies for e-waste based on the EPR principle. These policy initiatives shift the financial burden for collection and recycling from the public to the producers. They have been effective in establishing an adequate infrastructure for collection and treatment. In China, there are two alternative approaches to e-waste policy. The first aims to create a formal collection and recycling system with an economic incentive to consumers. The second objective is to design a financial model for an e-waste collection/recycling system (Yepsen 2007).

Import of e-waste is causing environmental and health problems in a number of West African countries. The policies practiced so far center on banning inappropriate practices, such as open burning and regulating imports. However, such policies have so far been relatively weak. Waste management practices in West African countries should consider impacts on the local economy. Impacts arise because waste-derived materials are an important input to production. These countries should have resource recovery and recycling industries. The material collected by scavengers can be recycled or bought by manufacturers as raw materials (Unit 2007). Enterprises specialized in waste management are eager to participate in this resources recovery market.

Sustainable WEEE management in West African countries can be through an alternative form which relies on contracting with small, local entities. The opportunities can be unlocked if stakeholders work together with a shared agenda. As a measure to avert environmental hazards, this book suggests that regulations should be formulated. Using life cycle management perspective, this book analyzed the end of life management impacts of used ICT products shipped to West Africa. The environmental policy and sustainable initiatives proposed in this study are multi-faceted, thus integrating stakeholders for sustainability. The proposed method harnesses the drive to expand markets to provide waste management services in ways that can benefit communities.

In a US electronics recycling facility, assessment of air quality in the vicinity of waste shredders has shown cadmium and lead levels (Peters-Michaud et al. 2003). Mercury, found within light sources (e.g. fluorescent tubes in scanners, photocopiers) and switches, may be released into the air. Formation of Polychlorinated dibenzo-p-dioxins/polychlorinated dibenzofurans (PCDDs/Fs) was observed in experimental studies on simulating open burning of wires (Gullett et al. 2007). Combustion generates suspended particles and fine particulate matter. Computers contain lead, blood lead levels (BLLs) found in children of Guoyu, exceed the Chinese mean (9.29 μg dL^{-1}) (Hou et al. 2013). This poses a potentially serious threat to health and the environment.

The total lifecycle management of ICT products is not sustainable if effects on developing nations such as the end of life management techniques are taken into account. Employing Life Cycle Management (LCM) thinking, highlighted in Fig. 8.1, disposal stage, depicted as impact area, illustrates serious effects. It consists of collection, dismantling processes for recycling, and incineration or open dumping. Of these processes, open dumping may be the most substantial factor leading to human toxicity. For example, metals leak from dump sites to the natural environment. The electronics waste burning is not done separately but a mixture of computer motherboards, keyboards, cases with municipal waste. The presence of brominated flame retardants in the waste would result in the emission of bromine. Incineration and landfill treatments of end-of-life products are harmful to the environment. The likely rebound effects of non-initiation of policies to control and monitor such practices would result in air quality deterioration through particulate matter loading, low water quality through biological oxygen demand (BOD) and total suspended solids. Radioactivity is a potential human health hazard, which

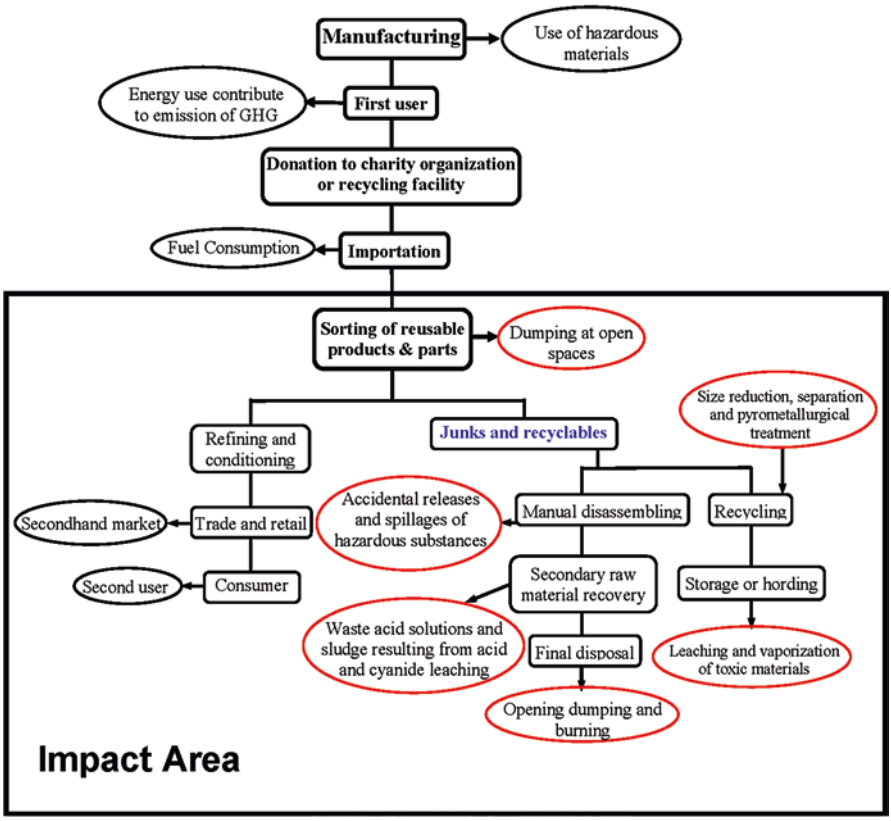

Fig. 8.1 Current end of life management of used ICT products in West Africa

causes Ecotoxicity. Chronic impacts on human health will arise as a result of occupational and public exposure. This will lead to aesthetic impacts as a result of odor nuisances. Dumping into water bodies will lead to aquatic ecotoxicity and as open dumping continues, there will be terrestrial ecotoxicity.

Toxic chemicals are polluting ecosystems, affecting biodiversity, agricultural production, and water sources. The Stockholm convention requires implementations to reduce levels of persistent organic pollutants (POPs) in the environment. It aims to eliminate the use of certain toxic chemicals, referred to as POPS. The post-2015 Development Agenda provides an opportunity for sound management of chemicals and waste. Stakeholders should strengthen legislative and regulatory frameworks for chemicals and waste, mainstreaming into sustainable development. Industry participation across the life cycle should incorporate policies and practices for recovery and management.

Integrating life cycle management perspective will enhance current end of life management techniques and make the process of bridging the digital divide sustainable. The book suggests this would help in improving the current end of life

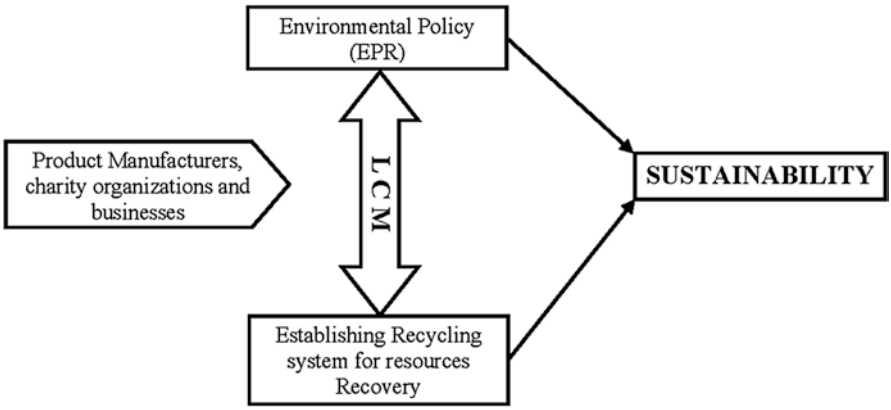

Fig. 8.2 Proposed policy and recovery framework to improve flow of used ICT products

management techniques through take-back initiatives. At present, there is no legislation that monitors e-waste handling, recycling, and disposal. International regulations developed under the Basel Convention on a global ban for transboundary movements of e-waste are yet to be effectively implemented (Perkins et al. 2014). Thus, the proposed introduction of EPR, LCM policies, while adapting environmental ratifications, recycling processes and SDGs, shown in Fig. 8.2.

The above framework shows proposed environmental policy and recovery initiatives for used ICT products shipped to developing countries. It suggests that a recycling system is developed to enhance waste management and assist the adoption of "Cradle to Cradle" product manufacture than the current systems "Cradle to Grave". Establishment of feedback loops from downstream (end-of-life management) to upstream (producer of the product) is the core of Fig. 8.3, thereby closing the loop. Charity Organizations or philanthropists donating used ICT products should understand the transformational role that they can play in enabling sustainable development and bridging the digital divide. This book recommends testing of products for functionality, through certification programs that ensure the protection of social, economic and environmental concerns. The proposed EPR approach will reduce consequences on society through cost and environmental savings as a result of decreased pollution.

The transfer of ICT technology through EPR should be promoted by governments of developing countries. The roles of different stakeholders, their information requirements and processes are identified. The aim is to make resource recovery become a central consideration for used ICT products shipped to West Africa. Stakeholders identified should be knowledgeable in product take back concepts and EPR procedures. The EPR policy should be communicated to all stakeholders and society to make it effective. Designing products for easy disassembling and dismantling will provide ease in managing greater volume when recycling or repairing parts. Here, manufacturers are required to make recycling products and parts possible, to reduce landfill materials.

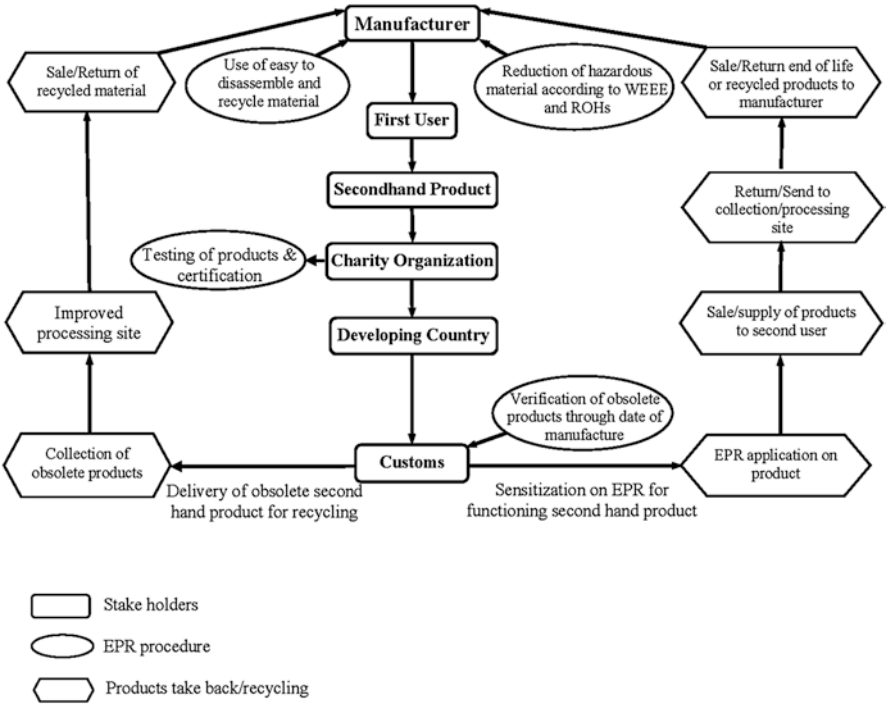

Fig. 8.3 Proposed EPR model to enhance flow of used ICT products

The importation and distribution points of used computers should be monitored to verify obsolete products. The main activities that contribute to sustainability are stakeholder involvement and impact area management. Developing a good understanding of EPR concepts can be marketed to customers and should be supported by a series of best practice case studies. Environmental policy regulation can be understood by integrating social and economic concerns into their values, decision making and operations to establish better practices. Waste management costs can be shifted by changing designs for recyclability, longevity and reduced toxicity (Brogaard et al. 2015). This can be achieved through raw material selection based on life cycle assessment, ease of reuse and recyclability. A SWOT analysis shown on Table 8.2 highlights the challenges and opportunities of enhancing end of life management through EPR and LCM.

The above table gives a scenario of strengths, weaknesses, opportunities and threats (SWOT) analysis of adopting EPR, LCM and resources recovery. Stated therein are the strengths, weaknesses, opportunities and threats to improve end of life management techniques for used ICT products. Although policies are viewed as threats, manufacturers can embrace opportunities presented with compliance. According to reviewed literature, manufacturers and businesses that are proactive to initiate investments in environmentally friendly activities would reap the 'first-mover' benefits and gain competitive advantage. This is due to the fact that

Table 8.2 SWOT Analysis of EPR and LCM to enhance end of life management of used ICT products

Strengths	**Weaknesses**
Influence the integration of environmental issues in design and product manufacture	Lack of financial resources for implementation
Create environmental awareness among customers and society	Lack of environmental and sustainability intellectual capital and technology
Ability to recover resources and protect the environment	Lack of a recycling facility
Opportunities	**Threats**
Gaining social, economic and environmental benefits	Continual reinforcement of environmental regulations
Secure incentives for sustainable production and consumption	Price competition with conventional products
Attracting partners especially environmental nongovernmental organization (NGO)	Lack of consumer environmentalism

customers are inclining towards environmental consciousness. This will ensure environmental sustainability through balancing nature and development so that social welfare does not decline. Without appropriate institutions in West Africa, external costs will be imposed on communities in the form of pollutants.

8.2 E-waste Dilemma

The global market for electrical and electronic equipment continues to expand (Hatcher et al. 2013). There is evidence that e-waste is transported internationally from many countries to destinations where informal recycling and disposal take place. These are often in small workshops with little or no regulation. As a result, impacts have already been reported in many countries. There has been a growth in these types of activities in some African countries, including Ghana. The operation in Ghana is in Korforidua, a small city to the north of Accra. At these workshops, e-waste

is recycled in a crude way, primarily involving manual disassembly and open burning to isolate copper from plastics. Much of the work is carried out by children, commonly using only rudimentary tools with no protective equipment. Severe chemical contamination was found in ash-contaminated soil samples from open burning sites, as well as sediments in a lagoon. Most samples contained numerous toxic and persistent organic chemical pollutants (Akinloye et al. 2009). The nature and extent of chemical contamination found at these sites are similar to those found in e-waste open burning sites in China, India, and Russia.

At the open burning sites, heavy and toxic metals concentrations are beyond acceptable levels. Numerous classes of organic chemicals were also present including halogenated (chlorinated or brominated) chemicals. Also, there are phthalates, such as PVC used as plasticizers, polybrominated diphenyl ethers (PBDEs) and triphenyl phosphate (TPP). Flame retardants and polychlorinated biphenyls (PCBs) have been banned for use in manufacturing and it's still persistent in these sites. Other compounds found are known to be formed when hazardous materials in e-waste, such as PVC, are burned. Overall, a wide range of the chemical contaminants present in the samples are toxic and able to bioaccumulate (build up in the body). The Soil in the open burning site is contaminated with sediment from the lagoon, containing high levels of toxic, persistent and bioaccumulative chemicals. In countries where e-waste recycling takes place, increased exposure to toxic chemicals has been reported for workers and residents (Borthakur and Sinha 2013) The chemicals identified are chlorinated dioxins and furans (PCDD/Fs), Polybrominated diphenyl ethers (PBDEs), and lead. This study demonstrates the urgent need for action to address the problems posed by the crude recycling and disposal of e-waste in Ghana, as well as in other places with similar activities. This requires controls on the trans-boundary movement of e-waste, especially obsolete equipment and the manner in which they are disposed of.

The recovery of materials at these sites is carried out with little regard for the health, the safety of the workers and the environment. These practices have resulted in severe contamination of the workplaces with a range of toxic metals. Many of the chemicals identified may be associated with the presence of polyvinyl chloride (PVC) formulations within e-waste. The extent of workplace contamination found in Ghana was similar to that reported for locations in other countries where manual dismantling and open burning of e-waste is carried out (Julander et al. 2014).

Pollution is a representation of the inefficient use of resources. Informal dismantling and recycling of e-waste, the so-called "backyard activities," is emerging. In this process, e-scrap is treated by open incineration, cyanide leaching, and simple smelters to recover copper, gold, and silver. These techniques include burning, component separation, toner sweeping, plastic chipping and melting, burning wires to recover copper, heating and gold recovery (Leung et al. 2006). Studies have indicated that the environment and human health is at risk as a result. Workers engaged in sorting, dismantling, refining, and conditioning operations are exposed to toxic substances. Alluding to the above, lifecycle management concept can

influence sustainability. It affects all facets of product life; from manufacturing, consumption, to disposal.

When scrap, harmful substances, or pollutants are discharged into the environment, it is an indication that resources have not been used completely, efficiently and effectively. Sustainability requires additional performance activities that add value for society. Decreasing the use of virgin materials by replacing them with post-consumer materials through reuse are key elements in a sustainable system. Adopting these models, this book anticipates sustainable waste minimization to lower the environmental impact associated with inadequate disposal. By making recycling product parts possible, manufacturers can decrease production costs, reduce refuse and landfill materials.[1] Adopting requirements for disassembling and dismantling a product, the process can be completed in less time, with minimal efforts and tools.

Worth noting is that resources in this area are currently expensive, and the lack of consumer environmentalism could be a setback. Hence, the education system should integrate environmental and sustainable development courses. Proper storage and transportation equipment for dismantled EEE can prevent leaching and vaporization of toxic metal into the environment. This will prevent ecotoxicity and exposure of communities to health risks. Recyclability, resource-efficiency, and low pollution intensity should be part of the regulatory approaches. Proper enforcement of these regulations would require exports of electronic equipment are tested for functionality and reuse.

There are no separate collection points or processing facilities available in countries like Nigeria and Ghana, and the entire end of life management activity is unregulated (Oteng-Ababio 2012). These sites should be upgraded with modern recycling techniques and monitored to prevent open burning, dumping on open spaces and surface water. Workers engaged in the processing and handling of waste EEE should be provided with occupational health and safety gears as well as periodic medical consultation. There are little incentives for this sector to voluntarily regulate itself without government policy. Innovative approaches to environmental regulations can be useful for the development of valuable models and operations. There has been extant literature on regulations compliance performances and competitive advantage since the ratification of various environmental policies.

This book presents a model that encourages waste minimization through the implementation and maximization of reuse and recycling initiatives. Through the use of EPR and LCM, there is a clear win-win situation for business, society, and the environment. By improving access to information and enabling communication, ICT can play a critical role in reaching SDGs such as the elimination of extreme poverty, combating serious diseases, and achieving universal primary education. A long-term solution for the application of EPR involves the development of processing infrastructure. This can be achieved through the creation of relevant domestic policies. At the port of destination, customs officials can identify obsolete

[1] https://www3.epa.gov/region9/waste/solid/reduce.html

products through the date of manufacture, allowing them to implement policies. The path taken by Thailand can be followed: worried that the Thai market may be flooded with e-waste, the government placed restrictions on the importation of used electronic goods. Thus, used copiers imported for reuse are required to be 5 years old or less (Kojima 2005).

Although awareness and readiness for implementing improvements are increasing rapidly, there are many obstacles to manage end-of-life of ICT products safely. Integrated to economic activities, policy and regulatory activity by governments can influence the adoption of proactive strategies. This is able to develop new markets. Regional and national initiatives should accelerate the shift towards sustainable consumption patterns. This will promote social and economic development within the carrying capacity of ecosystems. Customers and vendors could also initiate voluntary self-regulation activities.

The aim is to promote sustainable practices in the shipment of used ICT products by addressing the current situation and proposing a way forward. With sustainability dominating the global agenda, developing countries should embrace the opportunities. Research into this area to mainstream it into development strategies requires technology for initiatives to be sustainable. To protect the environment and human health, environmental regulations should be adapted, since many of these countries are recipients of e-waste and not manufacturers. Considering the requirements for the introduction of such initiatives, stakeholders should be identified. The current situation of e-waste management in West African countries has serious environmental and ecological impacts that might hinder sustainable development. Governments and regional organizations should be able to identify and formulate necessary environmental regulations to prevent pollution. The EU and other developed nations did it through regulations.

An ecological footprint is the amount of land and water area a person or a population would need to provide resources required to sustain it and absorb waste. Footprinting is widely used around the globe as an indicator of environmental sustainability (Hoekstra 2016). It is commonly used to explore the sustainability of individual lifestyles, goods, and services, organizations, industry sectors, regions, and nations.

The concept of ecologically benign materials was initiated to encourage the development of materials that are non-damaging to the environment. These places less impact on the environment during production, for example, by being highly recyclable, or by making more efficient use of raw materials. The concept of Eco materials was born through discussions about the resources in the service of humankind and its relation to the environment. Considering the finiteness of the Earth and the biosphere, being conscious of the environmental load that our products and materials place on them is important (Santoyo 2013) Humans produce materials from raw materials taken from the environment to expand their frontiers and make their lives more comfortable. Eco materials development takes a holistic view of the ecosphere. Eco Balance offers the services needed to take advantage of the many opportunities facing businesses and communities striving for ecological sustainability (Deale 2010).

The term eco-efficiency is based on the concept of creating more goods and services while using fewer resources and creating less waste and pollution. The 1992 Earth Summit endorsed eco-efficiency as a means for companies to implement Agenda 21. The term is synonymous with the philosophy geared towards sustainability. According to the World Business Council on Sustainable development (WBCSD) definition, eco-efficiency is achieved through the delivery of competitively priced goods and services that satisfy human needs and bring the quality of life while reducing environmental impacts. This will reduce resource intensity throughout the life-cycle of goods and services to a level with the Earth's carrying capacity. This concept describes a vision for the production of economically valuable goods and services while reducing the ecological impacts. In other words, eco-efficiency means producing more with less.

Dematerialization is a process that over time offers an obvious path to achieve environmental and economic efficiency (Bleischwitz 2002). Reduction of pesticide use per unit crop, for example, dematerialize food production. It is also worth recognizing that the similar concept of producing equal units of energy while releasing less carbon as a result of fossil fuel combustion commonly referred to as "De-carbonization" is an important sub-class of dematerialization.

Zero Waste is a design principle for the twenty-first century that seeks to redesign the way resources and materials flow through society. Zero Waste requires reducing raw material extraction and waste disposal, making producers responsible for their products' from cradle to cradle. The goal is to promote clean production, prevent pollution, and create communities in which all products are designed to be cycled safely back into the economy or environment.

8.3 Sustainable Production and Consumption

This concept is promoted by the United Nations Agenda 21 that deterioration of the global environment is unsustainable due to consumption and production patterns, particularly in industrialized countries. The issue of sustainable production and consumption has been the subject of considerable interest. The agreement was reached at an international gathering held in Marrakech, Morocco on mapping out a 10-year plan for revising patterns of production and consumption. The Johannesburg Plan of Implementation, adopted at the World Summit on Sustainable Development contains commitments on changing unsustainable patterns of consumption and production (Mediterranean Action Plan 2009).

References

Ageron, B., Gunasekaran, A., & Spalanzani, A. (2012). Sustainable supply management: An empirical study. *International Journal of Production Economics, 140*, 168–182.

Akinloye, O., Adaramoye, O., & Kareem, O. (2009). Changes in antioxidant status and lipid peroxidation in Nigerian patients with prostate carcinoma. *Polskie Archiwum Medycyny Wewnętrznej, 119*, 526–532.

Bleischwitz, R. (2002). *Governance of eco-efficiency in Japan: An institutional approach*. Econstor.edu

Borthakur, A., & Sinha, K. (2013). Generation of electronic waste in India: Current scenario, dilemmas and stakeholders. *African Journal of Environmental Science and Technology, 7*, 899–910.

Brogaard, L. K., Petersen, P. H., Nielsen, P. D., & Christensen, T. H. (2015). Quantifying capital goods for biological treatment of organic waste. *Waste Management & Research, 33*, 96–106.

Deale, C. S. (2010). Sustainability education: Focusing on hospitality, tourism, and travel. *Education, 2010*.

Gullett, B. K., Linak, W. P., Touati, A., Wasson, S. J., Gatica, S., & King, C. J. (2007). Characterization of air emissions and residual ash from open burning of electronic wastes during simulated rudimentary recycling operations. *Journal of Material Cycles and Waste Management, 9*, 69–79.

Hatcher, G. D., Ijomah, W. L., & Windmill, J. F. (2013). Design for remanufacturing in China: A case study of electrical and electronic equipment. *Journal of Remanufacturing, 3*, 3.

Hoekstra, A. Y. (2016). A critique on the water-scarcity weighted water footprint in LCA. *Ecological Indicators, 66*, 564–573.

Hossain, M. S., Al-Hamadani, S. M., & Rahman, M. T. (2015). E-waste: A challenge for sustainable development. *Journal of Health and Pollution, 5*, 3–11.

Hou, H., Zhao, L., Zhang, J., Xu, Y., Yan, Z., Bai, L., & Li, F. (2013). Organochlorine pesticides and polychlorinated biphenyls in soils surrounding the Tanggu Chemical Industrial District of Tianjin, China. *Environmental Science and Pollution Research, 20*, 3366–3380.

Julander, A., Lundgren, L., Skare, L., Grandér, M., Palm, B., Vahter, M., & Lidén, C. (2014). Formal recycling of e-waste leads to increased exposure to toxic metals: An occupational exposure study from Sweden. *Environment International, 73*, 243–251.

Kojima, M. (2005). Current trade flows in recyclable resources within Asia & related issues. *International Trade of Recyclable Resources in Asia, 3*.

Leung, A., Cai, Z. W., & Wong, M. H. (2006). Environmental contamination from electronic waste recycling at Guiyu, southeast China. *Journal of Material Cycles and Waste Management, 8*, 21–33.

Magashi, A., & Schluep, M. (2011). *E-Waste assessment Tanzania*. UNIDO e-waste initiative for Tanzania. Cleaner production centre of Tanzania https://www.unido.org/sites/default/files/2011-03/110120_Assessment-Tanzania_FINAL_01_0.PDF

Mediterranean Action Plan. (2009). UNEP(DEPI)/MED IG.19 16th Ordinary meeting of the contracting parties to the convention for the protection of the marine environment and the coastal region of the Mediterranean and its Protocols Marrakesh (Morocco), 3–5 November.

Nordbrand, S. (2009). *Out of control: E-waste trade flows from the EU to developing countries*. Stockholm: SwedWatch.

Oteng-Ababio, M. (2012). When necessity begets ingenuity: E-waste scavenging as a livelihood strategy in Accra, Ghana. *African Studies Quarterly, 13*, 1.

Perkins, D. N., Drisse, M.-N. B., Nxele, T., & Sly, P. D. (2014). E-waste: A global hazard. *Annals of Global Health, 80*, 286–295.

Peters-Michaud, N., Katers, J., & Barry, J. (2003). Occupational risks associated with electronics demanufacturing and CRT glass processing operations and the impact of mitigation activities on employee safety and health. In *Electronics and the Environment, IEEE International Symposium on*, 2003 (pp. 323–328). IEEE.

Prakash, S, & Manhart, A. (2010). *Socio-economic assessment and feasibility study on sustainable e-waste management in Ghana*. Report, 2010. Freiburg: Freiburg Head Office. Google Scholar.

Santoyo, M. C. (2013). *The cultural influence on environmental behavior in middle class households.* scholarworks.calstate.edu. http://hdl.handle.net/10211.3/115597

Unit, E. I. (2007). *The 2007 e-readiness rankings: Raising the bar*. New York: The Economist.

Wagner, T. P. (2009). Shared responsibility for managing electronic waste: A case study of Maine, USA. *Waste Management, 29*, 3014–3021.

Yepsen, R. (2007). Building program participation-encouraging sustainable recycling behavior through financial incentives-recyclebank's rewards-based participation program began this year in Wilmington, Delaware, the company's first large-scale client. Wilmington's landfill diversion rate rose to 35 percent, with 90 percent biweekly participation. *Biocycle, 48*, 34.

Chapter 9
Underground Storage Tank System (USTs) Environmental Management and Petroleum Pollution Control

Abstract Underground storage of liquid petroleum products, such as motor fuel and gasoline presents a potential threat to public health and the environment. Preventing tank spills and leaks is especially important because gasoline, diesel and fuel oil can move rapidly through surface layers and into ground water. Also, vapors from underground leaks that are collected in basements, sumps or other underground structures have the potential to explode. Petroleum fuels contain a number of toxic compounds, including solvents such as benzene, toluene and xylene, as well as additives such as ethylene dibromide (EDB) and organic lead compounds.

With the operational nature of gas stations, it was identified as a potential source of both soil and groundwater contamination. Monitoring of storage tanks by taking soil gas measurements from monitoring wells is seen as a good method of detecting leakages. This chapter shows that most of the soil and groundwater pollution occur as a result of leakages from storage tanks (underground and aboveground), pipelines and delivery vehicles. Spills can occur as a result of accidentsor faulty machines.

Keywords Public health · Sumps · Additives · Monitoring wells · Solvents

9.1 General Background

Pollution Prevention and Control protects the environment from emissions that pollute the air, water, and land. Installations will transition for minimizing environmental impacts and contamination. Underscoring that climate action makes good economic sense, businesses and investors express support for the Paris accord (Jackson et al. 2015). It promotes reduction in the use of fossil fuels. The goal is to decrease temperature and reduce greenhouse gas emissions in the second half of this century. The Oil and Gas Climate Initiative (OGCI) commits to develop and accelerate the deployment of innovative low emissions technologies.[1] The aim is to deploy new technologies among member companies and beyond. It will also identify ways to cut the energy intensity in partnership with initiatives across all stakeholders. The Oil Pollution policy and regulation addresses oil and hazardous

[1] www.oilandgasclimateinitiative.com/news/announcing-ogci-climate-investments

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substance spill response. The Oil Pollution Prevention Regulation indicates a facility's preparedness and responds to petroleum pollution.[2] Facilities that store and use oil should have a Facility Response Plan (FRP). The goal is to prevent oil from reaching water sources and contaminating them. It requires facilities to implement Spill Prevention, Control, and Countermeasure (SPCC). It ensures safe drinking water, protects ecosystems, human health, support economic activities and preserving habitat for fish, plants, and wildlife.

Preventing petroleum contamination of soil and groundwater approaches should provide protection of the environment, society, and economy. Suitable technologies are highlighted to be used to remediate contaminated sites. Emphasis is laid on the proper handling, transportation, and storage of petroleum to avoid pollution.

Petroleum contains products that can adversely affect the environment and human health. There are recommended measures that when applied will minimize the possibility of contamination. Studies have shown that most of the soil and groundwater pollution is as a result of leakages from storage tanks (underground and aboveground), pipelines and delivery vehicles.[3] Spills do occur as a result of accidents or faulty machines. Proper construction and location of storage tanks, lying of pipelines in a manner that will prevent leakages are recommended. Best management practices should be followed in dealing with petroleum to make sure that it is being properly handled. Monitoring of storage facilities and transportation channels to detect possible contamination is cited as an important facet in preventing pollution. On the event that a spill occurs and contaminates the environment, the most suitable treatment technology is recommended to be used in order to prevent further hazard.

Initiating policies and regulations that govern petroleum contamination is important. This would enhance the authorities' ability to monitor and address issues in accordance. Prevention of pollution from petroleum should focus on the outlet where they are sold, that is, the gas or service stations. With the operational nature of gas stations, it is cited as a potential source of both soil and groundwater contamination. Measures should be followed for the proper layout for both monitoring of sources of contamination and in-situ remediation. Storage of petroleum could be a major source of pollution when not properly done.[4] Locations of storage tanks, design, installation, and monitoring and tank closure are factors to be considered. Also, cost-efficient remediation technologies that can be used for petroleum contamination.

Underground storage of liquid petroleum products, such as motor fuel and gasoline, presents a potential threat to public health and the environment. Preventing tank spills and leaks are especially important because gasoline, diesel and fuel oil can move rapidly through surface layers into ground water. Vapors from an underground leaking to basements or other underground structures have the potential to

[2] https://www.epa.gov/oil-spills-prevention-and-preparedness-regulations

[3] https://www.epa.gov/.../leaking-underground-storage-tanks-corrective-action-resource

[4] https://www.epa.gov/.../leaking-underground-storage-tanks-corrective-action-resource

explode (Al-Megren et al. 2009). Petroleum fuels contain solvents such as benzene, toluene, and xylene, as well as additives and organic lead compounds.

With the operational nature of gas stations, it was identified as a potential source of both soil and groundwater contamination. Monitoring of storage tanks by taking soil and gas measurements from monitoring wells is seen as a good method of detecting leakages from USTs. It has been discovered that most of the soil and groundwater pollution is as a result of leakages from storage tanks (underground and aboveground), pipelines and delivery vehicles.[5]

Measures should be followed for the proper layout of gas stations for both monitoring of sources of contamination and in-situ remediation. The methodology used in relation to environmental protection was studied. It entails approaches that petroleum corporations use to monitor and prevent pollution. It can be modified and adopted by developing countries, especially oil-producing nations. Environmental degradation as a result of petroleum pollution can be costly. Further research in this field is necessary to make a roadmap for environmental protection.

Petroleum is composed principally of hydrocarbons, containing hydrogen and carbon. The elements hydrogen and carbon together (occurring as hydrocarbons or related compounds) constitute about 97% of petroleum. Volatile monoaromatic (single-ring) compounds found in crude oil are benzene, toluene, ethylbenzene, and xylene (BTEX) (Nerantzis and Dyer 2010). The different compounds and their structures are important for understanding the fate and effect of releases of petroleum products into the environment. Other additional properties are the media, capillary pressure, permeability, saturation, and residual saturation. Site-specific physical conditions such as depth of groundwater, the volume of the release, direction of groundwater flow influences dispersion of petroleum products (EPA 2013).

Polycyclic aromatic hydrocarbons (PAHs) are a persistent organic contaminant. They are mutagenic and carcinogenic, thus toxic. The impact of petroleum hydrocarbons on living organisms can be biochemical, cellular, organismal, physiological and behavioral responses; population, community structure and dynamics alterations. Impairment of behavioral, developmental and physiological processes may occur at low pollution concentrations.

Petroleum contamination can be a source of groundwater pollution. Petroleum in or on water is harmful and, in some cases fatal to aquatic life. Benzene, a carcinogen, is in gasoline and also contains zinc, sulfur, and phosphorous.[6] Methyl tert-butyl ether (MTBE) has the potential to contaminate groundwater. Spills and leaks from pipelines, underground and aboveground storage tanks are major sources of contamination. Petroleum contamination of groundwater can be in the form of Non-Aqueous Phased Liquids (NAPL) which flows on top of the groundwater or Dense Non-Aqueous Phased Liquids (DNAPL) which seeps down below.

Petroleum fuels contain a number of potentially toxic compounds, including common solvents such as benzene, toluene, and xylene, additives such as ethylene dibromide (EDB) and organic lead compounds. EDB and benzene are carcinogenic,

[5] https://www.epa.gov/.../leaking-underground-storage-tanks-corrective-action-resource

[6] https://www.cancer.org/cancer/cancer-causes/benzene.htm

cancer-causing agents in laboratory animals. Contamination of groundwater can occur from leaking underground storage tanks, especially when they are not installed properly, faulty design and material.

Many gas stations are located at arterial roads while others at the collector and local roads. They have valves to be able to transfer fuel from tank trucks into underground storage tanks. The valves should be properly sealed to prevent overflow. Spills should also be avoided. A leaking underground storage tank is a source of soil contamination. New design guidelines suggest that underground tanks be double walled to prevent fuel leakage. Product overfilling, leaking connections and free product release are a source of contamination. In order to prevent soil and groundwater contamination, gas stations should be constructed in a manner that will allow for the monitoring of underground storage tanks.

An UST is a tank and any underground piping connected to the tank that has at least 10% of its combined volume underground. Underground storage tanks leakage prevention can be achieved through regulations that govern installation and maintenance. Petroleum Pollution Prevention Regulation to address oil spill prevention provisions is vital. The regulation should address prevention of oil spills from aboveground and underground storage tanks. Gas or service stations should be regulated requiring a prepared facility plan for pollution prevention. It contains facility's design, operation and maintenance procedures for spills prevention, measures to control, contain, clean up and mitigate the effects.

Petroleum contamination is widespread, posing serious environmental risks to surface and groundwater. The implementation of remediation options involves stakeholders in decision-making processes. Petroleum contaminated site remediation is a multi-stakeholder decision-making process. The purpose of petroleum remediation is to protect human health and the environment by minimizing impacts on soil and water. Site conditions such as types of soils, topography, depth to groundwater, impacted versus non-impacted ground water and population affected should be assessed. Regulatory requirements should be considered with economic limitations. Availability of the cleanup technology is paramount, identifying in situ treatment or ex situ removal. Commonly used types of remediation are land farming, excavation, bioremediation, and volatilization.

Using instruments to take measurements from monitoring wells would help to detect leakages from USTs. Recording, analyzing and interpreting the data helps to know the behavior of contaminants if present. A collection of gas samples from monitoring wells can identify the type of petroleum compound through laboratory analysis using gas chromatogram and mass spectrometer (GC/ms). In order to carry out this research successfully, field trips to gas or service stations, remediation facility and a laboratory analysis of gas samples were done. Monitoring USTs for leakages through measurement from monitoring wells in gas stations was conducted. The instruments used are, combustible gas indicator, interface meter and a vacuum pump to monitor soil and groundwater contamination.

The prevention of petroleum pollution of soil and groundwater should be emphasized. It is relevant to manage storage and dispensation places where petroleum handling is done especially at gas stations. They are located within communities,

potentially having adverse and immediate effects within its periphery. Two gas or service stations were visited for monitoring monthly, for three consecutive months. Measurements were taken from monitoring wells to examine the level of petroleum contamination. In the first month, almost both stations were not at risk of contamination. The measurements were for both the underground storage tanks and line area (pipes from the tank to gas dispenser) to monitor pollution shown in Appendices III and IV.

Procedures in detecting leakages from UST by taking measurements from underground storage tanks were adhered to. It is conducted monthly to detect leakages from underground storage tanks for appropriate solution to protect soil and groundwater. During the operation of monitoring gas stations, samples were collected to identify the type of petroleum contaminants present. Identifying the type pollutant, a remediation technology can be chosen for clean-up. Monitoring UST for early detection of leakages is important in environmental and human health protection. The combustible gas indicator is used for detecting combustible gasses like gasoline; interface meter is used for the detection of free flow product in ground water. A gas sample collection kit can be used to take samples from monitoring wells that have a high level of petroleum compounds. Other instruments used are photoionization detector and dip stick. Figure 9.1 illustrates a procedure in monitoring gas stations for possible contamination.

The process of environmental protection should be in conformity with regulations as highlighted in Fig. 9.1. Integrated approaches include monitoring, sampling, proper design and installation to prevent petroleum contamination. Gas stations are urged to install soil gas monitoring wells consequently. Inventory is taken and the records archived. It is important that standards are followed and possible contaminants are not above acceptable levels. Management of possible sources is important in preventing petroleum contamination.

The service stations at which measurements was done by taking samples from monitoring wells are named A and B. In station A, there are 14 monitoring wells, 9 around USTs and 5 along the delivery lines to the dispensers. Station B has 11 monitoring wells, 8 around USTs and 3 in the delivery lines. All of the monitoring wells were in good conditions. Only monitoring wells along the pipelines to the dispensers have high readings, from which gas samples were taken for analysis. The gas chromatogram (GC) results from gas analysis helps to identify the type of petroleum compound present shown in Appendices V and VI. The nature of contamination within the station was also investigated. An increase of contamination was detected in the monitoring wells along the pipeline of service stations. The measurements taken from Station A shown in Appendix III increased in the third month of monitoring. The occurrence of such can be as a result of the frequent filling of fuel during dispensing or leaking pipeline. However, there was no severe contamination detected and that the measurements were below the acceptable level for both soil and groundwater. On identifying the high readings from monitoring well P2 in station A and P1 in station B, gas samples were collected and analyzed. Using gas chromatogram and mass chromatogram, the substances identified were butane,

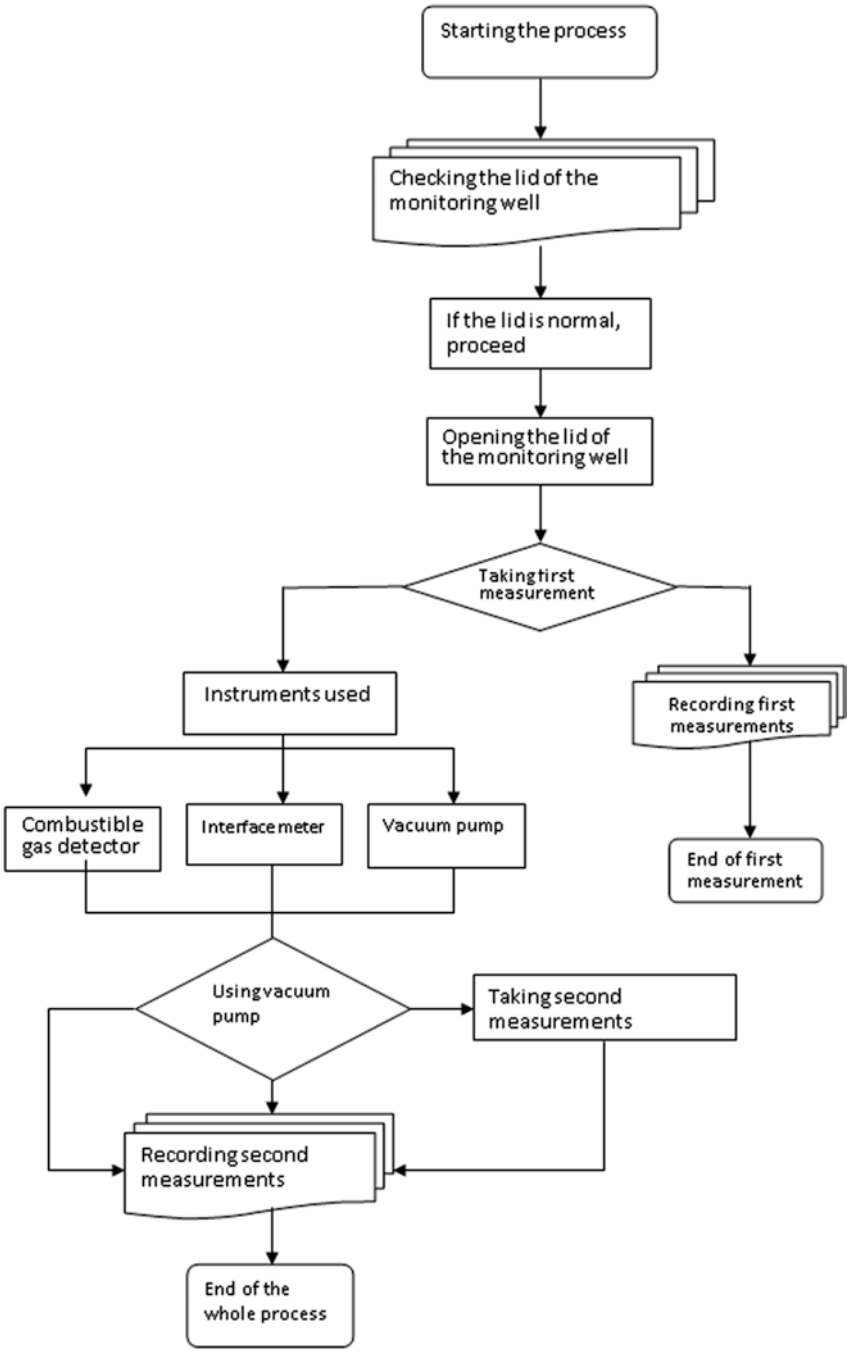

Fig. 9.1 Flow chart illustrating the procedures for underground storage tank leakage detection

methyl and pentane, all petroleum compounds. It confirms that part of both stations is contaminated.

Petroleum is composed principally of hydrocarbons; with little amounts of nitrogen, sulfur, and oxygen. The volatile monoaromatic (single-ring) compounds found in crude oil are often referred to as BTEX, or benzene, toluene, ethylbenzene, and xylene (Fathepure 2015). Understanding different compounds and their structures are important for assessing the fate and effect of releases of petroleum. A few quarts of gasoline in the groundwater may be enough to severely pollute drinking water. At low levels of contamination, fuel compounds in water cannot be detected by smell or taste, yet water may be polluted to the level that can affect human health.

The fate-and-transport of liquid petroleum products is determined primarily by the properties of the liquid and characteristics of the geologic media to which it is released. Important liquid properties include density, viscosity and interfacial tension. Soil properties that influence the movement of petroleum hydrocarbons include porosity and permeability (Hajabbasi 2016).

The term mass chromatogram refers to the representation of mass spectrometry data as a chromatogram, where the x-axis represents time and the y-axis represents signal intensity. The most common use of this data representation is when mass spectrometry is used in conjunction with chromatography such as in liquid chromatography, mass spectrometry or gas chromatography. This identifies the type of gas present through the molecular weight. Cleaning of sites contaminated with petroleum should be made to achieve the required standards. Treatment technology should be efficient, less time consuming and at a reasonable cost.

The strategies that would be set up to prevent and control petroleum contamination should be introduced in phases, to achieve certain targets within the short and long term. Sensitization of individuals dealing with the handling of petroleum would encourage adherence to the regulation. This can inspire responsibility in preventing petroleum contamination. Regulation dealing with storage tanks should include planning, design, installation and monitoring. Records of measurements will highlight the pattern in which petroleum hydrocarbon concentration are in the soil or groundwater if present. The standard at which petroleum compounds would be accepted should not be stiff, not injurious to health and the environment. Instruments such as photoionization detector, combustible gas indicator, and interface meter can be used to monitor pollution.

Decision makers informed judgments about the health risks of petroleum hydrocarbons and elements requires knowledge and understanding of the assessment activities. Designing and implementing relevant research will provide information for regulators to collaborate with the petroleum industry. Researchers and regulators share a common goal in protecting public health and the environment. Research on this subject should assess impacts of petroleum hydrocarbons contamination and clean up technologies.

References

Al-Megren, H., Al-Kinany, M. & Al-Drees, S. (2009). *Regulations for the storage of refined petroleum products*. nauss.edu.sa

EPA. (2013). *Introduction to in situ bioremediation of groundwater*. Office of solid waste and emergency response EPA 542-13-018 (https://cluin.org/download/techdrct/introductiontoinsitubioremediationofgroundwater_dec2013.pdf)

Fathepure, B. Z. (2015). Recent studies in microbial degradation of petroleum hydrocarbons in hypersaline environments. In *The Proceedings from Halophiles 2013, the International Congress on Halophilic Microorganisms*. Frontiers Media SA, p. 35.

Hajabbasi, M. A. (2016). Importance of soil physical characteristics for petroleum hydrocarbons phytoremediation: A review. *African Journal of Environmental Science and Technology, 10*, 394–405.

Jackson, R. B., Canadell, J. G., Le Quéré, C., Andrew, R. M., Korsbakken, J. I., Peters, G. P., & Nakicenovic, N. (2015). Reaching peak emissions. *Nature Climate Change, 6*, 7–10.

Nerantzis, P. C., & Dyer, M. R. (2010). Transport of BTEX vapours through granular soils with different moisture contents in the vadose zone. *Geotechnical and Geological Engineering, 28*, 1–13.

Chapter 10
Conclusion and Suggestions

Abstract Systems thinking, advocates thinking holistically, derived from the aphorism that "the whole is greater than the sum of its parts". This book uses a system thinking theory for a solution-based approach with development-oriented research for sustainable socioeconomic development. The international community, donor agencies, and governments have sustainable policies and ratification's for achieving Sustainable Development Goals. Corroborating Rio 20+ declaration, the SDGs Targets, Poverty Reduction Strategy Papers, the Bottom of the Pyramid (BOP) concept, Environmental Outlooks, Reproductive Health Policy, the EU directives, the IPCC findings and sustainable development according to the Brundtland Commission as a system can influence sustainable socioeconomic development.

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The socioeconomic impact of issues highlighted can be adopted to mitigate poverty. There are abundant renewable energy resources that can provide electricity for homes, schools, health centers and businesses. Governments should exploit these resources to move away from dependence on a centralized system that is not providing the direly needed energy for socioeconomic development. Access to energy is concentrated in urban areas that are connected to centralized grids. Remote villages are deprived of basic energy services. In Sub-Saharan Africa, only 8% of the rural population has access to electricity, compared with 51% of the urban population. Financial resources, legal institutional frameworks, and human resources are being identified as fundamental components for the dissemination of renewable energy. Innovative financial schemes would help people access renewable energy.

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Most urban communities are facing challenges with regard to environmental sanitation. This makes the prevalence of endemic diseases common. The prevalence of some disease pathogens, carriers and transmitters are cognizant with the occurrence of non-collection and management of municipal solid waste. Waste is not recycled, recovered and reused. Thus, resources are misplaced that could have been reused. The increase in volumes of unattended to solid waste with the associated risk to human health is a source of concern.

Recent studies conducted by Greenpeace, the Basel Action in Ghana, Nigeria, and other West African countries indicate the need to monitor and control the flow of used ICT products. The current situation of e-waste management in West African countries has serious environmental and ecological impacts that might hinder sustainable development. Manufacturers should be responsive to their customer' environmental concerns and needs. The current pattern is unsustainable and threatens all environmental media, exposing humans to heavy metals.

Due to the dispersed settlement of most rural communities, they lack physical access to health. Maternal and infant mortality is an issue that governments and NGOs are working relentlessly to address and achieving the developmental targets on health is slow. Safe drinking water is becoming a scarce commodity especially with the threats of droughts and floods as a result of climate change. Water-borne diseases are common causes of child mortality and morbidity in communities without access to clean drinking water. Access to water and sanitation are among the top priorities of the poor and directly contribute to poverty reduction and sustainable development. The World Bank developed a framework for water management that treats water as an economic good. Thus, the provision of funding in water infrastructure development to achieve the SDG targets is important. It has been shown that inequalities do exist in the health status and that, in general, the residents of rural communities are in poorer health. Possible strategies and solutions to the problems of access to health care in rural communities are discussed. Highlighting the situation of water supply systems presents challenges of providing health care in rural communities. The multi-stakeholder approach illustrated is feasible, appropriate and can be replicated. The model eases the healthcare burden for isolated communities located far away from health centers.

The occurrence of heat waves, floods, and drought and crop failure is an indication of the necessity of adapting to climate change. There is a high dependency on forest resources for energy, which can expose communities to the risk of drought or floods. Aridity might aggravate water scarcity. These can also lead to the loss of flora and fauna, causing ecological imbalance. Climate change forces communities in developing countries to adapt to the extreme and unpredictable weather. The present process of national-level planning for adaptation by developed and developing countries provides the first guide to its potential sustainability. A generic hierarchical method is used to assess the relative importance of identified categories and approaches of climate change adaptation. It creates a better understanding of climate change adaptation approaches and can be easily adopted. Broad-based development which recognizes the integral role of the environment and human

development alongside economic development can also assist in adapting to changing the climate.

The impact of environmental protection regulations, conventions and their consequence cannot be ignored. In recent years, a significant increase in municipal solid waste has been noted, and yet efficient systems for management are not developed. The waste management system should integrate collection, treatment, reuse, reprocessing and final disposal. Mandatory sorting of waste at household level would help greatly in making recycling activity successful.

With the nature of operations at petroleum related facilities, the possibility of soil contamination is very high. This book proposes preventive approaches to petroleum contamination of soil and groundwater. To decrease pollution potential, tanks should be placed within a secondary containment structure consisting of a dike and a pad. Above-ground piping must be made of steel and coated to prevent corrosion. Any below-ground piping may be either steel or fiberglass, but the steel piping must be coated and protected. Regulations for underground tanks should include a method of detecting leaks. Select tank location carefully to ensure that installation is easy and reliable leak detection.

Appendices

Appendix I: Survey Instrument – Clean Water Accessibility

Introduction

Dear Madam,

I would be pleased if you can help to answer the following questions. The survey is on the Access to Safe Drinking Water Supplies in the Western Division of The Gambia and its relations to the Millennium Development Goals. All responses are confidential, they will remain anonymous.

Section 1: General Information

Interviewers Name_____ Date Interviewed _____________.
Settlement Name _____ Questionnaire Number: (☐) (☐) (☐)

Section 2: Profile of Respondent

Questions Coding Categories Response

1. What is your age?
   <20 = 1, 20–30 = 2, 31–40 = 3, 40–50 = 4, over 50 = 5
2. What is your nationality? _____
3. Which tribe do you belong?
   Mandinka = 1, Wollof = 2, Fula = 3, Jola = 4, Sarahule = 5, Serrere = 6, Aku = 7, Other = 8
4. What is your Level of Education?
   Read only English or Arabic = 1, Write & Read English or Arabic = 2, Read, Write & Speak English or Arabic = 3, None = 4
5. What is your occupation?
   Farmer = 1, Civil servant = 2, Unemployed = 3, Business = 4, Skill craft = 5, Other = 6

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6. What is your marital status?
   Single = 1, Married = 2, Divorced = 3, Widowed = 4, Separated = 5

Section 3: Source of Water Supply

7. What is the source of your drinking water? ( )
   Open unlined well = 1, Opened lined well = 2, Covered well with hand pump = 3, Reticulation system = 4, River = 5
8. Is the source of water supply for drinking different from washing? ( )
   1 = Yes, 2 = No, If No, Skip to 10
9. If Yes, why are they different?

   _____

10. How far away (by number of compounds) is the source of your drinking water supply? ( )
    Within the compound = 1 1, Compound away = 2 2–4,
    Compounds away = 3 5–8, Compounds away = 4 9–12,
    Compounds away = 5 >13, Compounds away = 6
11. How far is the source of your other water supply, if different from above? ( )
    Within the compound = 1 1, Compound away = 2 2–4,
    Compounds away = 3 5–8, Compounds away = 4 9–12,
    Compounds away = 5 >13, Compounds away = 6
12. Do you pay for your water supply? ( )
    Yes = 1, No = 2, If No, Skip to 14
13. If Yes, how much in a month? ( )
    <D20 = 1, D20–D50 = 2, D50–D100 = 3, D100–D200 = 4,
    D200–D500 = 5, >D500 = 6

Section 4: Adequacy of Water Supply

14. Does the source of your water supply provide enough water for anyone who uses it? ( )
    Yes = 1, No = 2, If Yes, Skip to 16
15. If No, why?

    _____

16. In the last 2 weeks, do you join a queue to get water? ( )
    Yes = 1, No = 2, If No, Skip to 18
17. If yes, what is the usual queuing time like? ( )
    <2 minutes = 1, 2–5 minutes = 2, 6–10 minutes = 3, 11–20 minutes = 4,
    21–30 minutes = 5, >30 minutes = 6, Don't know = 7
18. How long does it take to fill your receptacle (service time)? ( )
    <2 minutes = 1, 2–5 minutes = 2, 6–10 minutes = 3, 11–20 minutes = 4,
    21–30 minutes = 5, >30 minutes = 6, Don't know = 7
19. Is this (service time) acceptable for your convenience? ( )
    Yes = 1, No = 2
20. Have you ever bought water for household use? ( )
    Yes = 1, No = 2, If No, Skip to 22
21. If Yes, why?

_____

Section 5: Reliability of Water Supply

If answer to question 7 of section 3 is either open unlined well, opened lined well or river then, respond to questions 22.

22. Is the water supply affected during the dry season? ( )
    Yes = 1, No = 2

If answer to question 7 of section 3 is either hand pump or reticulation system, then respond to questions 23–28.

23. Is the water supply regular? ( )
    Yes = 1, No = 2
24. How many times a week does the water supply not come as scheduled? ( )
    Once a week = 1, Twice a week = 2, Three times a week = 3, More than three time a week = 4, Don't know = 5
25. How frequent does your source of water supply break down? ( )
    Infrequently = 1, Once a month = 2, Once a week = 3, More than once a week = 4, Daily = 5, Don't know = 6
26. How much, in the last three months, do you pay towards the maintenance and operation of your water supply? ( )
    <D20 = 1, D20–D50 = 2, D50–D100 = 3, D100–D200 = 4, D200–D500 = 5, >D500 = 6
27. Are the spare parts and services readily available within the community? ( )
    Yes = 1, No = 2, If No, Skip to 29
28. If yes, can you afford to pay for those spare parts and services? ( )
    Yes = 1, No = 2
29. Do you have a reserve water tank within your households? ( )
    Yes = 1, No = 2

Section 6: Safety of Water Supply

If answer to question 7 of section 3 is either open unlined well, opened lined well or river, then respond to questions 30 & 31.

30. Do you treat drinking water before use? ( )
    Yes = 1, No = 2, If No, Skip to 32
31. If yes, how do you treat it? ( )
    Filtering = 1, Chlorination = 2, Boiling = 3, Herbal Medicine = 4

If answer to question 7 of section 3 is either hand pump or reticulation system, then respond to question 32

32. How often is the water tank cleaned? ( )
    Frequently = 1, Once a month = 2, Once every three months = 3, Once every six months = 4, Infrequently = 5, Don't know = 6

If answer to question 7 of section 3 is either open unlined well or opened lined well, then respond to questions 33 & 38.

33. Have you ever realized a change in the color/appearance of drinking water supply? ( )
    Yes = 1, No = 2, If No, Skip to 36
34. If yes, how long did this situation last? ( )
    Less than 6 hours = 1, 6–12 hours = 2, 12–18 hours = 3, 18–24 hours = 4, Over 24 hours = 5
35. Is the well decontaminated after? ( )
    Yes = 1, No = 2
36. Have you ever realized a change in the odor of your drinking water supply? ( )
    Yes = 1, No = 2, If No, Skip to 39
37. If yes, how long did this situation last? ( )
    Less than 6 hours = 1, 6–12 hours = 2, 2–18 hours = 3, 18–24 hours = 4, Over 24 hours = 5, Don't know = 6
38. Is the well decontaminated after? ( )
    Yes = 1, No = 2

Section 7: Water Related Diseases

39. Have you noticed diarrhea in children or any member of the household in the last two weeks? ( )
    Yes = 1, No = 2
40. Have you realized any skin rashes on any member of the household in the last dry season? ( )
    Yes = 1, No = 2
41. Have you noticed trachoma on any household member in the last dry season? ( )
    Yes = 1, No = 2
42. Have you been using the same source of water supply, after falling from/contracting diarrhea, trachoma, or skin rashes? ( )
    Yes = 1 No = 2, If No, Skip to 44
43. If yes, what kind of medication do you use to get cured? ( )
    Traditional = 1 Conventional = 2 Others Specify: _____ = 3 None = 4
44. What is the estimated volume of water collected per day? ( )
    Less than a pan = 1 1–3 pans = 2 4–6 pans = 3 7–10 pans = 4 over 10 pans = 5 None = 6

Section 8: For the Interviewer' Use Only

Please observe and respond to the following questions:

45. Is there a latrine within 10 m of well? ( )
    Yes = 1, No = 2
46. Is the nearest latrine on higher ground than the well? ( )
    Yes = 1, No = 2
47. Is there any other source of pollution within 10 m of the well? ( )
    Yes = 1, No = 2

48. Are the rope and bucket exposed to contamination? ( )
    Yes = 1, No = 2
49. Is the height of the parapet inadequate? ( )
    Yes = 1, No = 2
50. Is the parapet around the well cracked or broken? ( )
    Yes = 1, No = 2
51. Is the concrete apron around the well less than 1m wide? ( )
    Yes = 1, No = 2
52. Is the concrete apron around the well cracked? ( )
    Yes = 1, No = 2
53. Is stagnant water present within 2 m of the well? ( )
    Yes = 1, No = 2
54. Is the drainage channel cracked or broken, allowing ponding? ( )
    Yes = 1, No = 2
55. Is the fencing around the well inadequate to keep animals away? ( )
    Yes = 1, No = 2

Appendix II: Survey Questionnaire

Adaptation to Climate Change in The Gambia, Using Analytical Hierarchy Process

With increased climate threats and environmental disasters, this paper presents an analytic network process (ANP) approach to incorporate the issue of sustainable adaptation to climate change in the Gambia. The research evaluates 5 aspects and 25 major criteria pertaining to sustainable adaptation to climate change. Analytic Hierarchy Process (AHP) was selected for this study in evaluating the criteria for the best adaptation areas. Please read the directions below and select the most appropriate response by marking an X in the blank space ("□")! The measurement is nine-point scale. Thank you for your cooperation!

Adviser: Prof. Allen H. Hu
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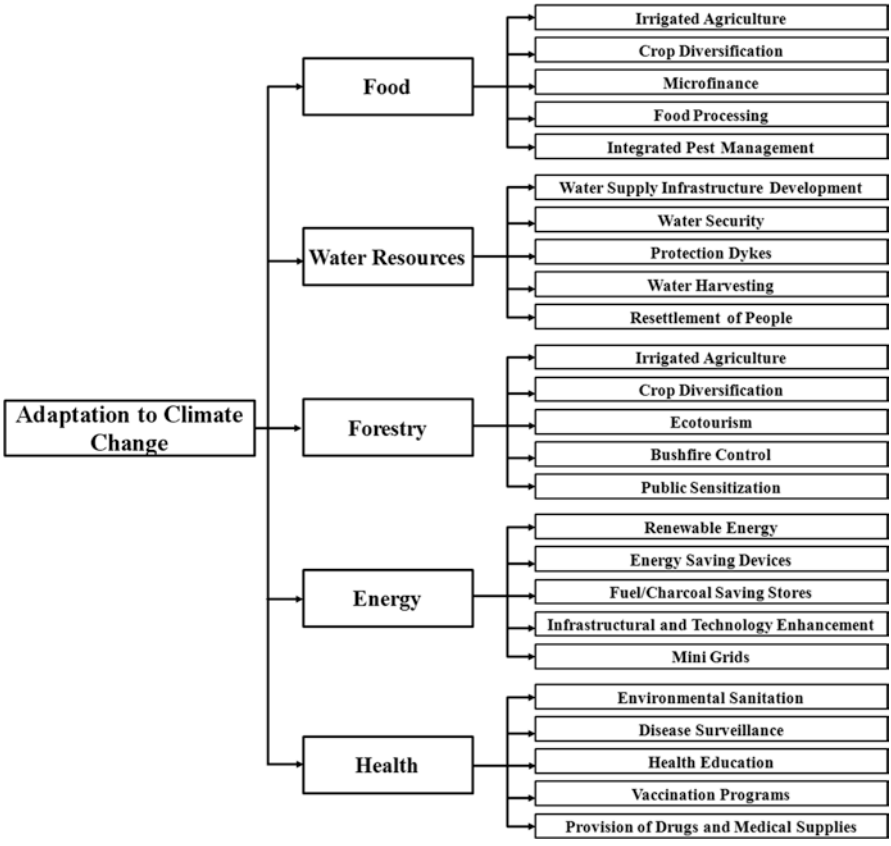
Institute of Environmental Engineering and Management
Corporate and Environmental Systems Management Laboratory

In this study, experts will be asked to respond to the relative weighting of each dimension via a pair-wise comparison matrix. A scale of 1–9 is used to compare the two components in this comparison. A score of 1 indicates that the two components have equal importance whereas a score of 9 indicates the overwhelming dominance of the considered component (row component) over the comparison component (column component). The numerical results that will be obtained can be used to detect high priority intervention for a sustainable adaptation to climate change in the Gambia thus mitigating risks to the livelihood of communities.

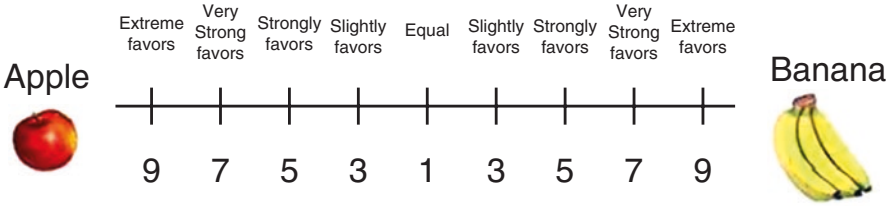
The Satty' Scale of Measurement for Pair-wise Comparison in AHP

Numerical values	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective
3	Weak Importance	Experience and judgment slightly favor one over another
5	Essential Importance	Experience and judgment strongly favor one over another
7	Very Strong Importance	An activity is strongly favored and its dominance is demonstrated in practice
9	Absolute Importance	The importance of one over another affirmed on the highest possible order
2, 4, 6, 8	Intermediate Values	Used to represent compromise between the priorities listed above



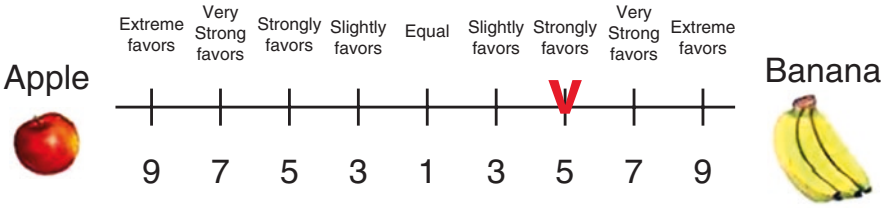
Please select the most appropriate response according to the scale of relative importance below by comparing items on the left side with the items on the right.

Example Suppose we have two fruits Apple and Banana. I would like to ask you, which fruit you like better than the other and how much you like it in comparison with the other. Let us make a relative scale to measure how much you like the fruit on the left (Apple) compared to the fruit on the right (Banana).



If you like the apple better than banana, you thick a mark between number 1 and 9 on left side, while if you favor banana more than apple, then you mark on the right side.

For instance, I strongly favor banana to apple then I give mark like this



According to the scale of relative importance to precede one pair wise comparison within 25 major criteria for sustainable adaptation to climate change, please select the most appropriate response for you in the blank space ("□")!

Aspect	9	7	5	3	1	3	5	7	9	Aspect
Food	□	□	□	□	□	□	□	□	□	Water Resources
	□	□	□	□	□	□	□	□	□	Forestry
	□	□	□	□	□	□	□	□	□	Energy
	□	□	□	□	□	□	□	□	□	Health
Water Resources	□	□	□	□	□	□	□	□	□	Forestry
	□	□	□	□	□	□	□	□	□	Energy
	□	□	□	□	□	□	□	□	□	Health
Forestry	□	□	□	□	□	□	□	□	□	Energy
	□	□	□	□	□	□	□	□	□	Health
Energy	□	□	□	□	□	□	□	□	□	Health

Based on integrating the categories and criteria identified from the literature on adaptation, threats to the livelihood of communities and suitable sustainable approaches were identified. These 25 criteria were determined and categorized into five main clusters. The application and analysis of ANP methodology is presented in the following steps. The first step in ANP method implementation is to construct the decision structure of adaptation strategies developed, based on the literature. This model has five aspects (see Figure below), consisting (1) Food security (2) water resources (3) Forestry (4) Energy and (5) Health. There are 25 criteria under the above-mentioned five aspects.

For the Dimension of Food

Against the background of projected climate change, adaptation options/activities in the agricultural sector can be linked to two general objectives: (1) enhancing food security, and (2) enhancing agriculture-based livelihoods (uplands/lowlands). In turn these can be measured by household income and food security. Rainfall variability, continued decline in per capita availability of land, further land degradation, social mutations and poverty effects make it increasingly necessary to seek out new and better solutions to climate hazards. Integrated Pest Management (IPM) is also highly appropriate in the face of expected changes in parasite ecology.

Criteria	9	7	5	3	1	3	5	7	9	Criteria
Irrigated Agriculture	☐	☐	☐	☐	☐	☐	☐	☐	☐	Crop Diversification
	☐	☐	☐	☐	☐	☐	☐	☐	☐	Microfinance
	☐	☐	☐	☐	☐	☐	☐	☐	☐	Food processing
	☐	☐	☐	☐	☐	☐	☐	☐	☐	Integrated pest management
Crop Diversification	☐	☐	☐	☐	☐	☐	☐	☐	☐	Microfinance
	☐	☐	☐	☐	☐	☐	☐	☐	☐	Food processing
	☐	☐	☐	☐	☐	☐	☐	☐	☐	Integrated pest management
Microfinance	☐	☐	☐	☐	☐	☐	☐	☐	☐	Food processing
	☐	☐	☐	☐	☐	☐	☐	☐	☐	Integrated pest management
Food processing	☐	☐	☐	☐	☐	☐	☐	☐	☐	Integrated pest management

For the Dimension of Water Resources

Global warming is exacerbating water stress by changing rainfall patterns, river flows, lake levels, and groundwater recharge. In some places water sources are becoming more depleted; other areas are being hit by floods. Climate change will lead to “decreased water availability for populations in many water-scarce regions, particularly in the sub-tropic” (IPCC (2001), Not only will water become scarcer, but the quality of available water will deteriorate. In all parts of the country, reliance on seasonal water bodies has shifted to more dependable ground and surface water sources.

Criteria	9	7	5	3	1	3	5	7	9	Criteria
Water supply infrastructure development	☐	☐	☐	☐	☐	☐	☐	☐	☐	Water Security
	☐	☐	☐	☐	☐	☐	☐	☐	☐	Protection Dykes
	☐	☐	☐	☐	☐	☐	☐	☐	☐	Water harvesting
	☐	☐	☐	☐	☐	☐	☐	☐	☐	Resettlement of people
Water security	☐	☐	☐	☐	☐	☐	☐	☐	☐	Protection Dykes
	☐	☐	☐	☐	☐	☐	☐	☐	☐	Water harvesting
	☐	☐	☐	☐	☐	☐	☐	☐	☐	Resettlement of people
Protection dykes	☐	☐	☐	☐	☐	☐	☐	☐	☐	Water harvesting
	☐	☐	☐	☐	☐	☐	☐	☐	☐	Resettlement of people
Water harvesting	☐	☐	☐	☐	☐	☐	☐	☐	☐	Resettlement of people

For the Dimension of Forestry

Natural forest and woodlands (including mangroves) cover approximately 46% of the country, with marked spatial differences. Amongst others, Bojang et al. (2005) report that contraction of forest area and degradation of forest quality owes more to human activities than any other causes. Nonetheless, direct and indirect impacts of climate on regeneration processes, as well as biomass productivity are nontrivial. Some ecosystems will be irreversibly damaged or lost. It will certainly result in much more flooding in low-lying areas, declines in food production, an increase in disease, and the extinction of plants, animals, and entire ecosystems. Likewise, species, habitats, and systems that have evolved over geological time are at risk of extinction or severe disruption this century.

Criteria	9	7	5	3	1	3	5	7	9	Criteria
Expansion of protected areas	☐	☐	☐	☐	☐	☐	☐	☐	☐	Propagation of Resistant Species
	☐	☐	☐	☐	☐	☐	☐	☐	☐	Ecotourism
	☐	☐	☐	☐	☐	☐	☐	☐	☐	Bushfire control
	☐	☐	☐	☐	☐	☐	☐	☐	☐	Public sensitization
Propagation of resistant species	☐	☐	☐	☐	☐	☐	☐	☐	☐	Ecotourism
	☐	☐	☐	☐	☐	☐	☐	☐	☐	Bushfire control
	☐	☐	☐	☐	☐	☐	☐	☐	☐	Public sensitization
Ecotourism	☐	☐	☐	☐	☐	☐	☐	☐	☐	Bushfire control
	☐	☐	☐	☐	☐	☐	☐	☐	☐	Public sensitization
Bushfire control	☐	☐	☐	☐	☐	☐	☐	☐	☐	Public sensitization

For the Dimension of Energy

Domestic/household energy consumption dominates that of all other end-uses, and more than 80% of this demand is catered by natural forest products (fuel wood, and charcoal to a lesser extent). A government ban on the production of charcoal in the early 1980s was meant to slow down the rate of forest destruction, encourage uptake of new fuel-saving technology, and spur the development of private and community

woodlots. In general, there is a noticeable shift away from fuel wood as a primary source of energy, and greater strategic use of petroleum products. Research into other forms of renewable energy and energy-use efficiency in industry and households is an essential investment in a more energy-secure future. At the regional level, energy resource sharing is a necessary strategy.

Criteria	9	7	5	3	1	3	5	7	9	Criteria
Renewable Energy	☐	☐	☐	☐	☐	☐	☐	☐	☐	Energy Saving Devices
	☐	☐	☐	☐	☐	☐	☐	☐	☐	Fuel/Charcoal Saving Stores
	☐	☐	☐	☐	☐	☐	☐	☐	☐	Infrastructural and technology enhancement
	☐	☐	☐	☐	☐	☐	☐	☐	☐	minigrids
Energy Saving Device	☐	☐	☐	☐	☐	☐	☐	☐	☐	Fuel/Charcoal Saving Stores
	☐	☐	☐	☐	☐	☐	☐	☐	☐	Infrastructural and technology enhancement
	☐	☐	☐	☐	☐	☐	☐	☐	☐	minigrids
Fuel/Charcoal Saving Stores	☐	☐	☐	☐	☐	☐	☐	☐	☐	Infrastructural and technology enhancement
	☐	☐	☐	☐	☐	☐	☐	☐	☐	minigrids
Infrastructural and technology enhancement	☐	☐	☐	☐	☐	☐	☐	☐	☐	minigrids

For the Dimension of Health

As global warming increases, it becomes clearer that it will lead to serious impacts on human health around the world. These effects will be direct and indirect. Indirect effects will happen because of the close relationship between climatic conditions and insects and rodent populations. This in turn will affect diseases such as asthma, as well as increase the range of vector-borne parasitic diseases like malaria and leishmaniosis. Food-borne diseases are likely to increase as a result of warmer temperatures. Water-borne diseases may also increase because of extra demands on diminished water supplies, which will in turn increase the risk of contaminated supplies reaching the public.

Criteria	9	7	5	3	1	3	5	7	9	Criteria
Environmental Sanitation	☐	☐	☐	☐	☐	☐	☐	☐	☐	Disease Surveillance
	☐	☐	☐	☐	☐	☐	☐	☐	☐	Health Education
	☐	☐	☐	☐	☐	☐	☐	☐	☐	Vaccination programs
	☐	☐	☐	☐	☐	☐	☐	☐	☐	Provision of drugs and medical supplies
Disease Surveillance	☐	☐	☐	☐	☐	☐	☐	☐	☐	Health Education
	☐	☐	☐	☐	☐	☐	☐	☐	☐	Vaccination programmes
	☐	☐	☐	☐	☐	☐	☐	☐	☐	Provision of drugs and medical supplies
Health Education	☐	☐	☐	☐	☐	☐	☐	☐	☐	Vaccination programmes
	☐	☐	☐	☐	☐	☐	☐	☐	☐	Provision of drugs and medical supplies

Criteria	9	7	5	3	1	3	5	7	9	Criteria
Vaccination Programs	☐	☐	☐	☐	☐	☐	☐	☐	☐	Provision of drugs and medical supplies

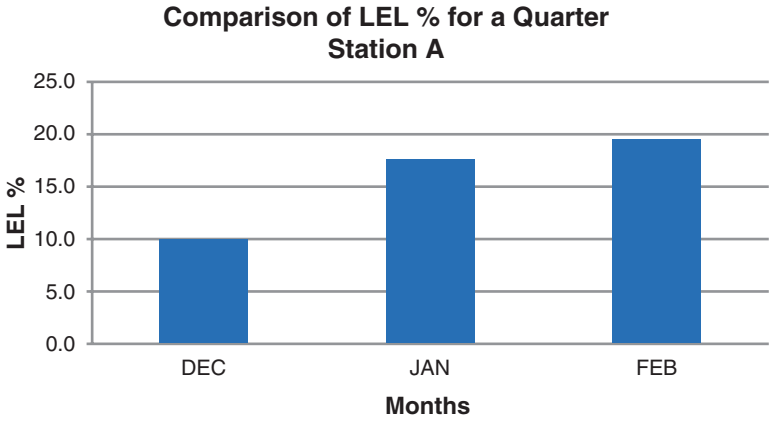
Personal Information

This section consists of six items related to your personal profile. Please answer the following questions. You are promised complete confidentiality. Thank you for your cooperation!

1. Your sex: ☐ Male ☐ Female
2. Your office/department name: ; Your position:_____
3. How long have you taken on work pertaining to adaptation to climate change or environmental management?
   ☐ Under 1 year ☐ 1–3 years ☐ 3–7 years
   ☐ 7–10 years ☐ 10–15 years ☐ More than 4 years
4. How long has your office been involved in adaptation to climate change activities?
   ☐ Never ☐ Under 1 year ☐ 1–3 years ☐ 3–5 years
   ☐ 5–10 years ☐ More than 10 years
5. Does your office have any overseas collaboration especially the UNFCCC?
   ☐ No ☐ Yes,☐Country or Area: _____

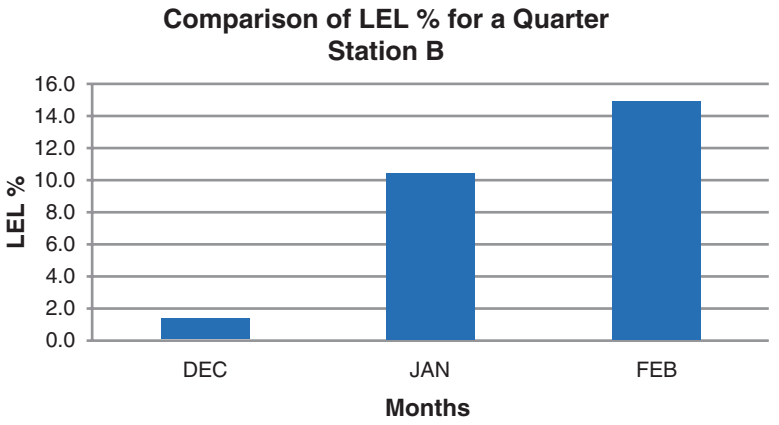
Appendix III

Gas Station Monitoring Results for Station A



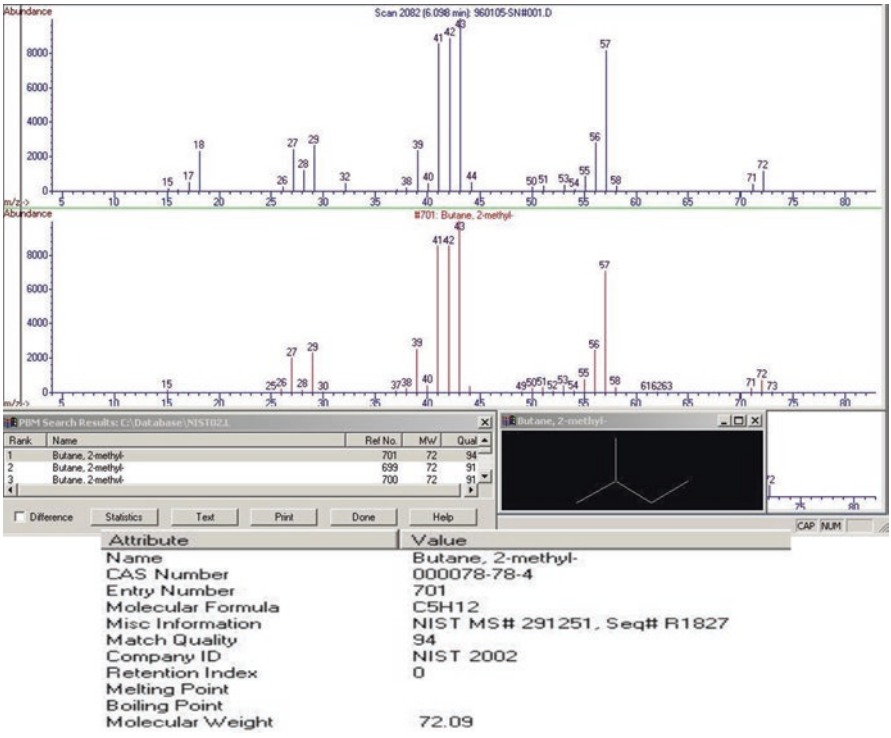
Appendix IV

Gas Station Monitoring Results for Station B



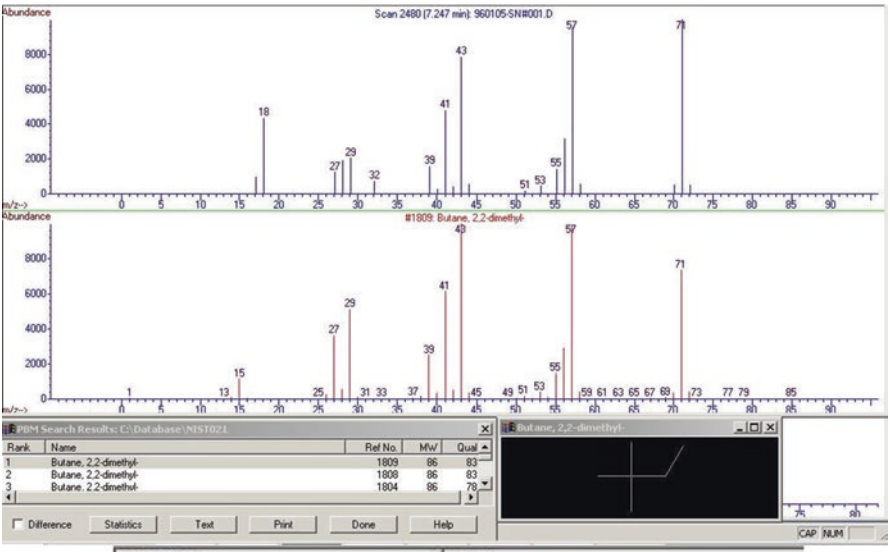
Appendix V

Gas Chromatogram Analysis of Sample Collected from Monitoring Well P2 in Station A



Appendix VI

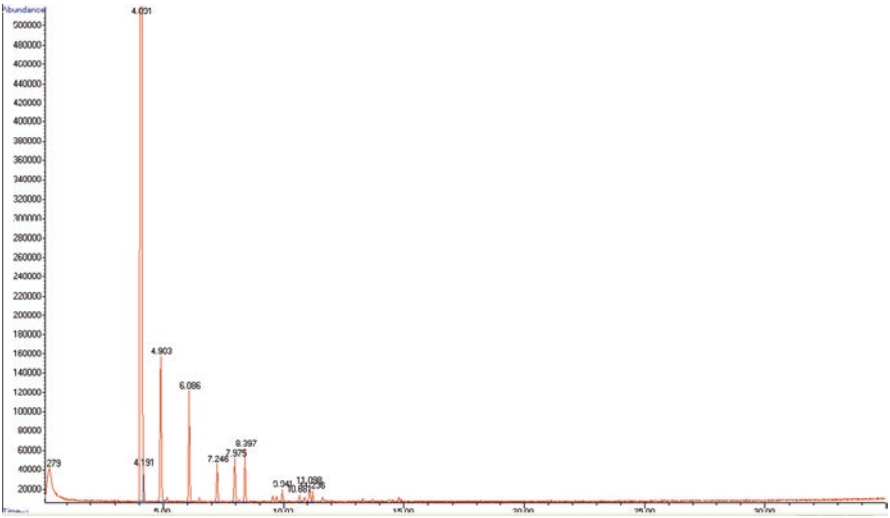
Gas Analysis of Sample Collected from P1 Monitoring Well in Station B



Attribute	Value
Name	Butane, 2,2-dimethyl-
CAS Number	000075-83-2
Entry Number	1809
Molecular Formula	C6H14
Misc Information	NIST MS# 563, Seq# R2139
Match Quality	83
Company ID	NIST 2002
Retention Index	0
Melting Point	
Boiling Point	
Molecular Weight	86.11

Appendix VII

Gas Chromatogram Analysis of Sample Collected from Monitoring Well P2 in Station A



Appendix VIII

Gas Analysis of Sample Collected from P1 Monitoring Well in Station