Giving all energy stakeholders a voice: Developing a theoretical framework for the uptake and sustained use of improved/clean biomass energy technologies

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ABSTRACT

Achieving Sustainable Development Goal 7 - to ensure universal access to affordable, reliable and modern energy services by 2030 – represents a considerable challenge. Currently, 40% of the global population do not have access to sustainable energy sources, and instead rely on burning biomass (wood, dung, agricultural waste) to satisfy their energy needs. Despite a long history of energy technology for poverty-alleviation across the globe many interventions fail at persuading end-users to continue using such technologies beyond an initial adoption phase. Whilst many champion sustainable energy solutions, most implementation and evaluation approaches do not consider long term sustained use. As a result, many end-user-orientated energy solutions, such as Improved Cookstoves (ICS), fall out of use once project partners depart. These failures often reflect the fact that energy-focused development initiatives are shaped by increasingly complex technologies rather than social methodologies that prioritise understanding end-user priorities and the complex contextual barriers to sustained use.

The global energy context is echoed in the focus country of this research Nepal. Nepal has a long history of International Development assistance, yet 65.8% of rural households still use firewood as their primary source of energy. Unfortunately, whilst 94% of Nepal's population has access to electricity (The World Bank, 2018), the supply is often unstable and the infrastructure not suitable for households to rely on electricity for their cooking needs (Clements et al., 2020). This results in only 29% of the population having access to clean cooking fuels and technologies (The World Bank, 2018). In addition to these objective factors, I have an established network of International Development energy contacts that could facilitate an easy and effective working environment across Nepal.

In this research I design, develop and present a novel qualitative implementation or delivery model, the Technology Implementation Model for Energy (TIME), for practitioners and policymakers that focuses on refining three core areas of energy technology implementation; to rethink how impact is defined, to understand differences between practitioner perception and end-user reality, and to champion a co-produced approach with all key stakeholders in the energy value chain or system.

TIME is the first energy technology implementation model to blend Social Enterprise, Appropriate Technology, behavioural change models utilised in the Water, Hygiene and Sanitation (WASH) and Health sectors, and International Development planning tools. This method promotes a values-driven approach centred around co-production, ownership, use of resources and equality. In addition, I focus on evaluating the Nepali biomass ICS sector in two parts, the first using the Market Map Tool and second, using TIME. The results of which have been published at Robinson et al. (2021b) and Robinson et al. (2021a) respectively. The application of these tools leads to insights into the sector such as, the role of 'stacking' ICS (using multiple energy fuels/technologies simultaneously), the impact of demand and supply side incentives, and policy changes to increase the sustained use of ICS.

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List of Abbreviations

AEPC – Alternative Energy Promotion Centre

AT - Appropriate Technology

BCM – Behavioural Change Model

CE – Circular Economy

CO – Chapter Objective

CRN – Child Reach Nepal

CRTN – Centre for Rural Technology, Nepal

DFID – Department for International Development (UK Government)

DHCD – Dhulikhel Hospital Community Department

EEM – Enabling Environment Matrix

EnDev – Energising Development

GCRF – Global Challenge Research Fund

ICS – Improved Cookstove

IWA – International Workshop Agreement

KS – Key Stakeholder

MM – Market Map

MoEWI – Ministry of Energy, Water Resource, Irrigation

MTF – Modified Theoretical Framework

P – Phase

PAN – Practical Action Nepal

Pr – Project

RBF – Results Based Finance

RETS – Renewable Energy Test Service

RO – Research Objectives

RRI – Responsible Research and Innovation

RTKC - Regional Testing and Knowledge Centre

SE – Social Enterprise

SPE – Strategic Planning Element

TIME – Technology Implementation Model for Energy

TLUD – Top-Lit Up-Draft

ToC – Theory of Change

TSF – Three Stone Fire

UN SDG – United Nations Sustainable Development Goal

WASH – Integrated Behavioural Model for Water, Sanitation and Hygiene

Chapter One - Introduction

"Poverty belongs only in museums where our children and grandchildren will go to see what inhumanity people had to suffer, and where they will ask themselves how their ancestors allowed such conditions to persist for so long" (Yunus and Webber, 2017)

1.1. Overview of Research

The launch of the United Nations (UN) Sustainable Development Goals (SDGs) in 2016 (United Nations, 2016) sought to create a unified approach to International Development agendas across all participating countries. This new roadmap of 17 goals to achieve a "Sustainable Future for All by 2030" (United Nations, 2016) championed the eradication of poverty and hunger, reduced inequalities, access to education, and climate action to reduce the global carbon emissions as well as SDG7 – Sustainable Energy for All. SDG7 seeks to ensure "access to affordable, reliable, sustainable and modern energy for all" (United Nations, 2016) and champions three core elements: increasing energy access, providing sustainable energy, increasing energy efficiency. Yet, despite this roadmap to a sustainable future, 40% of global population does not have access to clean fuels and technologies for cooking (The World Bank, 2018). These 2.6 billion people are exposed to household air pollution daily which results in a number of irreversible respiratory health issues responsible for up to 4 million deaths per year, with 20% of these being children under the age of 5 (The World Bank, 2018). These issues are especially relevant in the context of COVID-19, where underlying respiratory issues are one of the distinguishing factors between life and death. Taking this into account, the underlying question of this research is: how can practitioners and policymakers use poverty alleviating energy technologies more effectively to solve the energy problem?

Qualitative and Qualitative methods provide the conceptual background for identifying complex socio-cultural, environmental and financial contextual factors that often overrule the technical performance of ICS. Quantitative methods provide general trends through large data sets which do not take into account complex contextual factors but can be conducted without direct contact with users and at low

cost through readily available Government Surveys, such as the National Household Survey in Nepal (National Planning Commission, 2018). Qualitative research methods (Creswell, 1997b) use tools such as semi-structured interviews which require direct contact with users and investment for engineers in developing interview skills, travelling to the location of the end-users plus time and translation costs. The benefits of balancing technical and contextual knowledge of ICS development can be an increase in the adoption and sustained use of ICS. However, whilst there is a growing body of literature identifying these contextual barriers, the research gap is in the integration of these barriers into the design and implementation of ICS technologies.

This research identifies four literature groups with the aim of creating a novel theoretical framework which can contribute to the integration of these contextual factors specifically for practitioners and policymakers, these are: Appropriate Technology (AT), Social Enterprise (SE), Behavioural Change Models (BCMs) utilised in the Health and Water, Sanitation and Hygiene (WASH) sector, and International Development Planning tools. As part of this process I also look to identify these complex socio-cultural, environmental and financial contextual factors to further the academic discourse in the Nepali energy sector. Furthermore, the exploration of novel technology implementation methods for poverty-alleviation which integrate complex contextual factors have application outside of the energy sector as detailed understanding of end-user preference is key in the adoption of all poverty-alleviating technologies.

1.2. Overview of Literature and Research Gaps

Whilst considerable literature exists on the technical development of energy technologies (Iyakaremye et al., 2019, Lindgren, 2020, Mehetre et al., 2017), there is limited discourse on the development of successful implementation models. Traditionally, engineering academic discourse focuses on technical development of poverty alleviating energy technologies rather than integration of end user preferences or the investigation of complex contextual factors that often act as barriers to adoption and sustained use. In the case of Improved Cookstoves (ICS) this has resulted in increasing complexity and cost but not adoption rates (Lindgren, 2020). Often, this focus on the technical development of ICS and the lack of alignment with

contextual cooking practices results in the end-users 'backsliding' (Jewitt et al., 2020) or retuning to traditional technologies such as a Three Stone Fire (TSF).

From an engineering perspective, generating and integrating qualitative feedback into energy technology development for poverty alleviation is a significantly under-researched area of literature and thus provides a significant research gap. This results in a misalignment of priorities between energy technology research/developer and the end-user created by these two processes being conducted on opposite sides of the globe as many end-users live in low-income environments whilst researchers/developers do not.

More specific research gaps include: limited research on how to translate barriers into enablers, what roles key stakeholders can play in this process and the absence of definitive implementation models in the ICS sector. Sesan et al. (2018) identify an opportunity to establish and improve ICS implementation models by integrating aspects of approaches from the WASH and more broad health sector as both sectors share many barriers and enablers to technology adoption and sustained use. In addition, Sesan et al. (2018) state behaviour change models such as of IBM-WASH, RE-AIM and others developed for use in the health sector can have significant value to ICS implementation. These research gaps highlight the need for an effective energy implementation tool that can be accessible to policymakers and practitioners.

1.3. Nepali Context

Situated in the Himalayan Region between China and India, Nepal is a country of diverse landscapes, cultures and traditions. A population of 29 million people is spread across 77 districts and three unofficial regions: the terai[1], the mid-hills (up to 2500m altitude) and the high hills (above 2500m altitude). The large diversity of landscape and difficulty of accessing remote communities has resulted in 123 registered languages which are tied to the presence of a traditional caste system. In the context of this research, the recent history of Nepal is comprised of three main events, the Nepali Civil War (1996-2006), the Earthquake of 2015 and the Indian Fuel Blockade that followed in 2016. These three events have resulted in a significant increase in the

[1] The hot flat region which borders India

number of International Development actors working in humanitarian aid, socio-economic development and providing basic services such as energy, water, education and food.

In Nepal around 65% of rural households use firewood as their primary fuel source (National Planning Commission, 2018). Nepal is above the global average on both Access to Electricity & Renewable Energy Consumption in terms of UN SDG7 (United Nations, 2016) as shown in Figure 1.1. However, the REC has decreased from 95.1% in 1990 (The World Bank, 2018) based upon the rapid urbanization of major cities and the increased market share of LPG gas as opposed to fuelwood. At 28% Nepal is significantly under the global average of 59% for Access to Clean Energy even though the Himalayas have vast potential for hydropower (Alama et al., 2017).

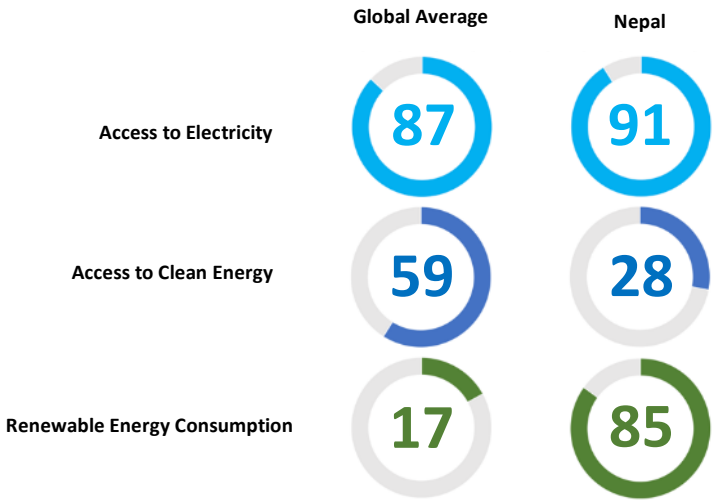


Figure 1.1: SDG7 Global Vs Nepal Comparison (Data provided by (The World Bank, 2018))

Whilst it is problematic to directly relate approximately 56,700 people every year dying from household and ambient air pollution (The World Bank, 2018) to traditional 'three stove fire' cooking methods (traditionally with wood or other available biomass), the fact that over 50% of Nepalese households cook with firewood (National Planning Commission, 2018) suggests that it is a large contributing factor to both micro and macro pollution. Efforts to promote transitions to cleaner energy sources include a longstanding policy of providing subsidies to promote the adoption ICS among rural households (Ministry of Population and Environment, 2016). The Renewable Energy Subsidy also gives varied support to a range of technologies including hydropower, solar power, solar thermal, biogas, wind energy, hybrid systems and biomass energy

by reducing costs at the user end. Significantly, however, the Renewable Energy Subsidy does not apply to LPG (Ministry of Population and Environment, 2016) and Nepal's long term aim is to promote a shift to the electrification of cooking facilities. Nevertheless, the country's Biomass Energy Strategy (Ministry of Population and Enviroment, 2017) highlights biomass as a key contributor to the country's energy needs in the short and medium term as reflected by the installation of 1.3 million ICS of tier 2 and above in households compared to 365,000 biogas units and 600 solar cookers.

This research is focusses on Nepal for three important reasons. Firstly, there are a number of existing relationships with academics and practitioners in the alternative energy sector through University of Nottingham and previous energy projects. These key energy stakeholders include Practical Action Nepal, the Centre for Rural Technology Nepal, Kathmandu University Mechanical Engineering Department, ICIMOD, the Government of Nepal Alternative Energy Promotion Centre, Live to Love International and a number of ICS manufactures. This range of key stakeholders provided vital access to important stages of the biomass energy value chain as well as pre-established trusted partnerships to efficiency create field-based research opportunities.

Secondly, Nepal has an underdeveloped energy market with limited academic discourse set against a rigid Governmental Policy Structure looking to promote energy solutions. In addition, the 2015 earthquake and 2016 fuel blockade highlighted the importance of biomass in rural energy consumption which has refocused the International Development community's effort on sustainable energy access.

Thirdly, the limited academic research on the Nepali biomass energy sector is set against an overdeveloped International Development sector where there is a long history of ICS interventions at various scales, from local organisations to national cookstove programming. Yet despite this history, 65% of rural households, accounting for 20 million people, still use biomass as their primary source of energy. This fact, intertwined with the diverse geography, people and cultures, creates an ideal environment for exploring the complex socio-cultural, environmental and financial

contextual factors that act as barriers to the adoption and sustained use of poverty alleviating energy technologies in Nepal

1.4. Case Studies

This research draws data from three case study groups, the Top-Lit Up-Draft (TLUD) ICS project, five Global Challenge Research Fund (GCRF) Primary Investigators and Practical Action Nepal's (PAN) Results Based Financing (RBF) Project. The TLUD project provides the data for Chapter Three & Four, the GCRF Primary Investigators for Chapter Four and the PAN RBF Project for Chapter Six. The TLUD ICS and PANs RBF projects provide direct access and primary evidence for the Nepali Biomass ICS sector that contribute to the research aims and objectives. Whilst the GCRF projects are not based in Nepal they will provide sector-wide methods of best practice in order to effectively and efficiently shape the proposed theoretical framework. This section gives an introduction and background information for these three case studies.

1.4.1. The TLUD Project: Do institutions influence cooking behaviours in Nepal?

In 2016, the University of Nottingham[2] and Live to Love International developed a novel natural draft Top-loaded Up-Draft (TLUD) ICS for rural Nepali Institutions, with the field tests funded by the Global Challenges Research Fund. Many solutions in the form of ICS have been developed, however they have only been affordable to a small proportion of potential users. The vast majority of these ICS are aimed at middle-income users in urban areas who pay for their fuel, with less emphasis placed on giving away stoves to rural dwellers who typically collect firewood at no financial cost, but at considerable inconvenience and risk. Whilst the household ICS market is saturated, these ICSs have limited use amongst large families and institutions such as schools, restaurants and monasteries, with most users retaining their inefficient traditional stoves to heat water for bathing and to cook for extended families.

Between 2017 and 2020, I conducted a pilot study consisting of 10 TLUD ICS across a number of rural institutions. The TLUD ICS were distributed through a diverse range of pilot sites across two regions; Langtang National Park and Kathmandu Valley, which included schools, farmers and monasteries. The aim of this pilot was to; provide

[2] As part of my MEng Project at UoN

technical feedback on the usability of the TLUD, understand the role that institutions play in influencing the adoption of both household and institutional ICS, and determine the complex contextual factors which acted as barriers and enablers to TLUD adoption and sustained use. A journal paper under review at Energy for Sustainable Development titled, "*Cooking for communities, children and cows: lessons learned from institutional cookstoves in Nepal"* provides further detail on the results of this pilot. This project contributed greatly to my understanding of technology implementation as well as the role of complex contextual factors in overriding a technologically superior product when compared to traditional technologies as well as highlighted the lack of established methodologies in the energy sector based around energy technology implementation. This provided the foundational understanding that was taken forwards into this research.

1.4.2. GCRF Primary Investigators

GCRF supports "cutting-edge research that addresses the challenges faced by developing countries" (Engineering and Physical Sciences Research Council, 2015) through three objectives, (1) promote challenge-led disciplinary and interdisciplinary research, (2) strengthen capacity for research both in the UK and developing countries and (3) providing an agile response to emergencies where there is an urgent research need. The GCRF portfolio contains 882 projects at a cost of 824,742,658GBP as a part of the UK Government Overseas Development Aid budget. Further information about GCRF can be found in Chapter Four. Determined through a systematic review of the 882 projects, five primary investigators were asked during the interviews to share their experience in designing, implementing and evaluating poverty alleviating technologies from a range of sectors as a means to establish the viability of an early version of TIME. These primary investigator interviews will provide a low-cost method of evaluating the theoretical frameworks applicability due to the limited funding for overseas travel.

1.4.3. Practical Action Nepal's Results Based Finance Project

Practical Action is an international development charity established by E.F. Schumacher in 1966. Schumacher "proposed a shift in emphasis towards 'intermediate technologies' based on the needs and skills of people in developing

countries" (Practical Action, 2021). This means that Practical Action focus on small-scale technology-based solutions to poverty alleviation across their global portfolio of working countries. Practical Action Nepal (PAN) focus on improving farmers' livelihoods, creating natural disaster shock resilience and building energy access. As part of PANs energy programs, Results Based Financing for Improved Cookstove Market Development (RBF) looks to strengthen the supply and demand of ICS through a number of means tested incentive mechanisms. The balance of market mechanisms and end-user behavioural change campaigns provide a multi-dimensional project strategy that is particularly suited to this research and specifically the evaluation of a novel theoretical framework. In addition, the inclusion of this research in RBF provided new insights into the working mechanisms of the project that allowed PAN to increase the efficiency of programming. The results of this process can be seen in Chapter Six.

1.5. Contribution of Research

This research asks the question, how can practitioners and policymakers use poverty alleviating technologies more effectively to solve the energy problem in Nepal? My aim is to develop an approach to energy technology implementation which results in a better understanding of the complex socio-cultural, environmental and financial contextual barriers faced by the key biomass energy stakeholders in Nepal.

This research will provide a significant contribution to the energy technology for poverty alleviation literature in two work streams, first, the exploration of contextual barriers to energy technology implementation in Nepal in Chapters Three & Six and second, the development of a technology implementation model that satisfies the research gaps.

There is also potential to build on the foundations that Social Enterprise (SE) and Appropriate Technology (AT) as existing technology implementation models with some existing application in the International Development sector. The existing body of literature on AT is currently focused on technologies rather than the dissemination methods (Sianipa et al., 2013, Bakker, 1990, C.A. Joshi, 2016), moreover Patnaik and Bhowmick (2018) state "appropriate technology is yet to be linked with sustainable development and innovation in the context of emerging economies (p.8)". There is still a significant challenge in affectively targeting vulnerable populations, such as

people in extreme poverty and in inaccessible regions, to adopt and sustainable use poverty alleviating technologies. Whilst technologies for these purposes are becoming affordable and accessible to the bottom of the pyramid (Agarwal et al., 2018, Linna, 2012), their uptake remains remarkably low. SE provides an alternative dissemination method that can benefit the entire value chain whilst concurrently providing access to basic technologies, self-regulated by free market choice (Shrimali et al., 2011). Alter (2002) cites examples of effective social enterprise dissemination methods to provide services, such as micro-finance, to vulnerable populations. This research looks to contribute to the literature by building on these approaches to explore the validity and versatility of AT & SE models to close the identified research gaps in Nepal as well as furthering the academic discourse on energy technology implementing through the lese of AT & SE.

This research also looks to contribute to the International Development sector planning tools as a step away from models, such as the LogFrame (Freer and Lemire, 2019) and Theory of Change (Valters, 2014), that do not promote or integrate end-user preferences. These top-down models driven by International Development actors promote the interests of the funding partners rather than representing the needs of the intended beneficiaries.

This research also champions an interdisciplinary approach where the inputs, activities, outputs, outcomes and impact of energy technology interventions are co-produced with all members of the energy value chain and creates novelty through the unique combination of the four key literature groups, AT, SE, Health and WASH BCMs, and International Development Planning tools.

The final anticipated contribution of this research is through challenging the existing narrative around technological development by focusing on a co-produced approach to energy technology implementation in low-income environments, the importance of understanding the difference between perception and reality, and the importance of defining impact. These recommendations look to provide a step-change in thinking from traditional engineering solutions and if adopted by policymakers and practitioners would likely result in the increased adoption and sustained use of poverty alleviating energy technologies.

1.6. Research Aim and Objectives:

The overarching aim of this research is to develop an approach to energy technology implementation for Nepal's in-country practitioners and policymakers to better understand the contextual barriers faced by the key biomass energy stakeholders. This aim is divided into four research objectives:

1. Establish the knowledge gaps in the existing technology implementation literature to develop a novel theoretical framework that can analyse the socio-cultural, environmental & financial barriers to the sustained use of poverty alleviating technology.
2. Evaluate the theoretical framework against existing projects which fit the poverty-alleviating technology criteria.
3. Use the theoretical framework to evaluate a poverty-alleviating technology project in the Nepali biomass energy sector resulting in an understanding of both the barriers to sustained use & theoretical framework applicability.
4. Outline the potential suitability of the theoretical framework for other country markets and sectors.

Figure 1.2 (p.23) provides a graphical representation of the research methodology, integrating the four research objectives as well as signposting the process against the SDGs and relevant literature groups.

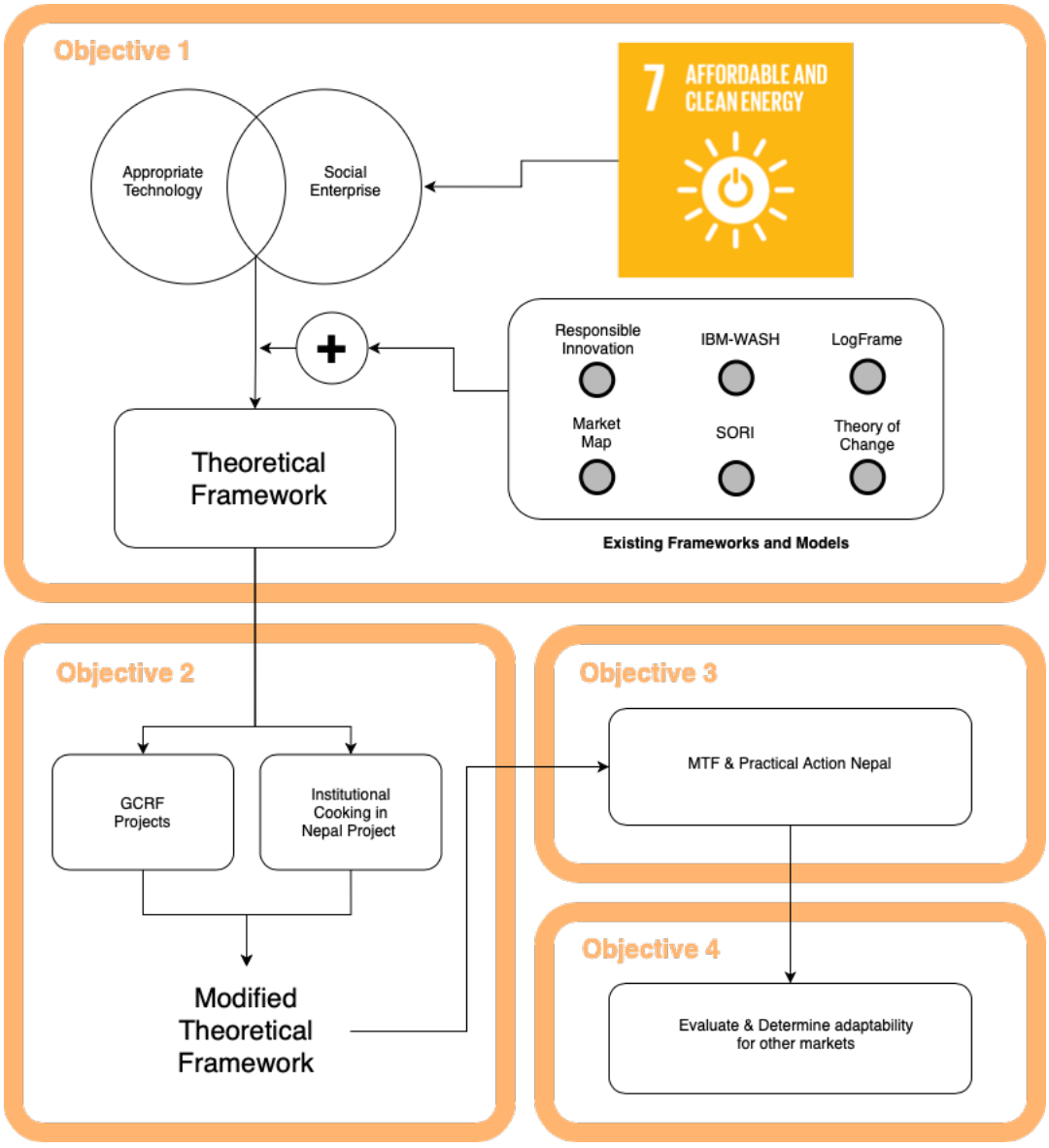


Figure 1.2: Research Design

1.7. Structure

This section outlines the structure of the thesis. Chapter Two reviews the literature groups associated with the implementation of energy-based poverty alleviation technologies paying particular attention to the ICS sub-sector. It Identifies common barriers and enablers for the adoption and sustained use of ICS and assembles these common factors into socio-cultural, financial and environmental groupings. These range from willingness to pay, affordability of technologies and access to financial institutions, to stacking (use of multiple technologies concurrently) of technologies, the historical role of cooking and type of food cooked. This chapter also considers existing frameworks for understanding complex contextual factors from three perspectives, the institutional, the international development practitioner and the

social scientist. These three perspectives of technology implementation highlight the Responsible Research and Innovation Framework, Logframes & Theory of Change and various behavioural change models for Health, WASH and ICS. The chapter concludes by outlining a number of energy technology implementation models for low-income households such as, the market map, appropriate technology, social enterprise and the circular economy, all of which have particular relevance to the ICS sector.

Chapter Three applies the Market Map tool to the Nepalese biomass ICS sector highlighting existing weaknesses in government policy and biomass cookstove market chains, as well as providing insights into a development practitioner implementation tool. The chapter explores the effectiveness of the market map, designed for East Africa's ICS sector (Stevens et al., 2019), in Nepal as well as co-developing a revised market map for Nepal's biomass ICS sector. I also review cookstove-related policy documents and regulatory frameworks from the Government of Nepal and analyse findings from the project through 31 semi-structured interviews. The results indicate that although government policy actively promotes biomass ICSs, this often results in cookstove 'stacking' rather than the sustained and exclusive use of clean cooking solutions necessary to promote health benefits. Attention is also focused on the underdeveloped nature of the institutional cookstove market and barriers to adoption and sustained use specific to the Nepali context. The chapter concludes by highlighting the usefulness of market maps and presenting a new monitoring and evaluation element for identifying barriers to clean cooking uptake and facilitating product improvement by integrating end-user feedback.

Chapter Four identifies key themes from the four core literature groups, appropriate technology, social enterprise, Health and Water, Sanitation and Hygiene Behavioural Change Models and International Development practitioner tools, integrating these themes with the key learnings from Chapter Three. The combination of evidence and practice-based paradigms results in four factors key to the adoption and sustained use of energy technologies: co-production, ownership, utilisation and equality. The resulting theoretical framework is divided into two elements, the strategic planning element and the enabling environment matrix. In addition, I also introduce a series of qualitative research methods and outline the theoretical framework methodology for

the first of two case studies. The first case study consists of five Global Challenge Research Fund projects, the results of which are presented in Chapter Five, the second, PANs RBF project. The results of which along with modifications to the methodology are presented in Chapter Six. The chapter concludes by outlining a number of limitations associated with qualitative research methods as well as limitations specific to the theoretical framework.

Chapter Five applies the novel theoretical framework to five Global Challenge Research Fund projects identified from a systematic review of 882 projects. These five projects are evaluated through a series of semi-structured interviews with Primary Investigators to determine the effectiveness of the theoretical framework in identifying complex contextual issues that often act as barriers to energy technology adoption and sustained use. In addition, I complete a self-evaluation of the TLUD project to utilise the framework on a smaller scale project. This chapter presents the results of the semi-structured and self-evaluation interviews and additionally, makes methodological and structural changes to the framework. The resulting Modified Theoretical Framework is presented to be applied to a 'live' project in the Nepali biomass ICS sector in Chapter Six.

Chapter Six introduces the second case study and applies the modified theoretical framework to PANs RBF Project between January and April 2020 in line with research objective three. The aim was to identify and understand end-user barriers and enablers to determine engagement strategies that would improve the programming. In addition, I clarify the roles and relationships of key stakeholders in the context of end-user behavioural change. I conducted 31 semi-structured interviews with a range of key stakeholder groups in Nepal and at various field sites in the Himalayas. The results generated a number of recommendations for PAN that were divided into five groups: Communication, the impact of incentives, understanding why end-users purchase ICS, the reusability of market chains and adoption vs. sustained use. This chapter also develops the Modified Theoretical Framework with suggestions for future work and changes its name to the Technology Implementation Model for Energy.

Chapter Seven evaluates the main findings from this research against the four research objectives. I discuss the two concurrent research streams; first, the development of a theoretical framework to integrate complex contextual factors into the implementation of poverty-alleviating energy technologies and second, identifying specific contextual barriers to ICS implementation in Nepal. Additionally, this chapter explores the impact of COVID-19 on the research objectives, as research objective four was not completed due to travel restrictions. This chapter also presents the three research recommendations: a co-produced approach to energy technology implementation, understanding the difference between key stakeholder perceptions and end-user reality, and re-defining impact. Finally, the chapter identifies a number of limitations to the research and presents areas for future work, including the development of a user guide to aid practitioners and policymakers in implementing TIME.

Chapter Two - Engineering in Development and the Social/Technical Divide

2.1. Introduction

The 17 UN SDGs frame the global energy context against a history of International Development interventions which have seen limited success in achieving sustainable change to "leave no one behind" (United Nations, 2016). Energy access is prioritised in SDG7 which seeks to "Ensure access to affordable, reliable, sustainable and modern energy for all" with target 7.1.2 promoting "universal access to clean fuels and technologies for cooking." The history of cookstove interventions has evolved in response to shifts from a desire to increase combustion efficiency whilst reducing deforestation and drudgery associated with wood collection (Mehetre et al., 2017), towards a focus on reducing the health and environment-related concerns associated with reducing household air pollution and black carbon emissions (Tielsch et al., 2014, Lindgren, 2020, WHO, 2020).

Reflecting the twin emphases on addressing health and environmental concerns, cookstove performance is evaluated using an internationally standardised testing methodology devised by the International Workshop Agreement (IWA) which catagorises them into 5 tiers with Tier 0 representing a traditional open fire and tier 4 an electric hob (International Organization for Standardization, 2012). The categorisation process reflects a range of factors including their production of high and low power carbon monoxide, high and low power particle matter, combustion efficiency, specific combustion efficiency, time taken to boil and simmer a predetermined volume of water and safety considerations (International Organization for Standardization, 2012). Despite recent efforts to promote clean cooking solutions, the uptake of higher tier systems in many low- and middle-income countries has been slow (Mobaraka et al., 2012, Hewitt et al., 2018).

In this chapter I review the literature focussing on low adoption and sustained use of ICS as an example of an energy sub-sector that has seen low demand and requires complex behavioural understanding for successful implementation. Emphasis on the IWA tier systems has pushed the global cooking sector to improve the technical

performance of cooking solutions rather than increasing the useability based on complex contextual issues that end-users often quote as the barriers for adoption and sustained use. This focuses the metrics of success away from sustained use and towards technical performance. These issues of low adoption rates are especially relevant in the case of Nepal, despite long standing programs from international development partners as well as an extensive Government of Nepal policy framework. These complex contextual barriers and enablers to ICS adoption and sustained use, also called behavioural determinants in a range of Health and WASH behaviour change models, have been identified across the globe, yet there is no universal energy implementation model which will help transition overcome the barriers and utilise the enablers.

In section 2, I look to further understand what is meant by complex contextual barriers by identifying a range of literature sources that present these factors in the ICS sector. By understanding the common barriers presented by Rehfuess et al. (2014), Stanistreet et al. (2014), Quadir et al. (1995) and Mehetre et al. (2017) etc. the process of transforming the barriers into enablers can begin. However, there is a distinction between factors that influence adoption and sustained use as discussed by Jürisoo et al. (2018) who state “the primary factors influencing initial purchase do not motivate people to use the stove regularly in the longer term (p.164)”. This distinction is important to take into considerations throughout this research.

In section 3, I consider the frameworks for capturing complex contextual factors from three perspectives, the institutional, the development practitioner, and the social scientist. The response of the institutional research community was the introduction of a research framework, the Responsible Research & Innovation (RRI) framework (Engineering and Physical Sciences Research Council, 2013). As discussed in section 3 this framework challenges the researcher to think about the unintended consequences of innovation. However, this framework is directed at high-income country research and as stated by Hartley et al. (2019), whilst the framework is applicable to low-income innovation it is yet to be applied in this context. This may be due to the focus of the framework on encouraging reflection from the perspective of

the researcher rather than the end-user (in the case of this research rural Nepalis) which could lead to incorrect assumptions around end-user priorities.

From the perspective of the International Development (ID) sector, there are a number of planning tools which help integrate contextual issues, however models such as Logframes (Freer and Lemire, 2019), Theory of Change (Stein and Valters, 2012) and the Market Map (Practical Action Consulting and EUEI PDF, 2015) often do not see extensive use outside of NGO 'cliques' due to the cost associated with a detailed planning processes. This has resulted in the ID sector transitioning to market based approaches such as the popular Results Based Financing (RBF) models (DFID, 2015a), however the benefits of this method of implementation are highly contested. Part of this planning process is identifying the barriers and enablers that discourage and encourage end-users to transition to an improved or appropriate technology or bridging the chasm as shown in Figure 2.1 as the gap between early adoptors and early majority. This results in interventions that can be tailored to the specific context; a key point echoed by the Shell Foundation (2018). In this study's chosen sector, ICS, these are traditionally divided into social and technical groupings. However, in reality this division underrepresents the complexity of the socio-cultural, financial and environmental contextual issues that contribute to the adoption and sustained use of improved technologies. Identifying these barriers and enablers is central to understanding the end-user behavioural change that occurs when implementing technologies.

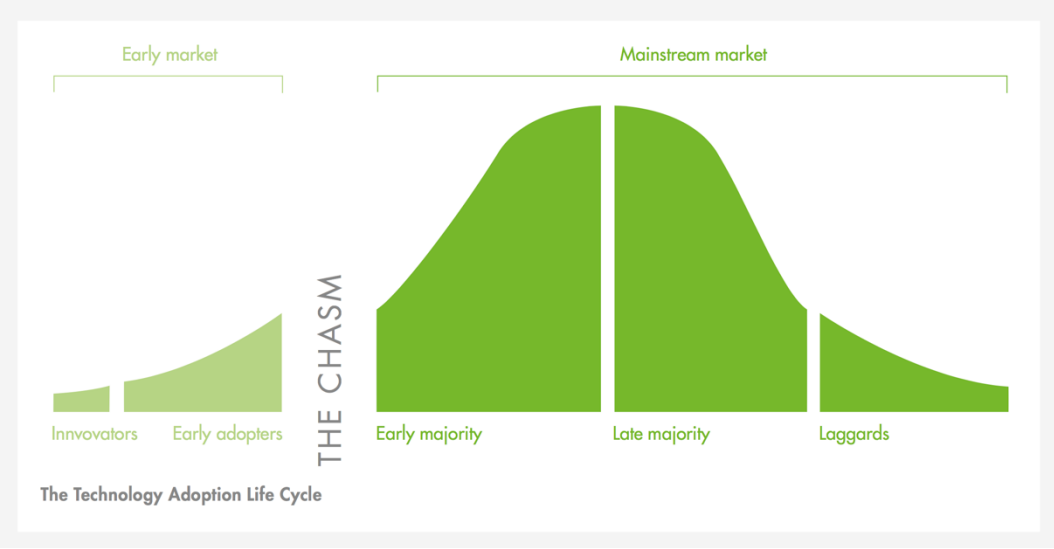


Figure 2.1: Rogers' "Diffusion of Innovation" Model (Shell Foundation, 2018)

As part of the social scientist approach there are a number of behavioural change models (BCMs) that have been adapted for use in the WASH sector which I shall present in section 3 to help researchers understand this transition. For example, the BCMs which integrate a range of health behavioural change theories and models relevant for the WASH sector have significant value to the ICS sector and a number, including IBM-WASH (Dreibelbis et al., 2013) and RE-AIM (Glasgow et al., 1999), have already been applied to ICS interventions (Quinn et al., 2018, Rhodes et al., 2014).

Section 4 considers a number of energy technology implementation models, the first of which is an internationally recognised engineering approach, Appropriate Technology (AT). AT is an engineering design movement founded by Schumacher (1973), there have been a number of modern interpretations by Joshi and Seay (2016), Patnaik and Bhowmick (2018) and Feige and Vonortas (2017), which all refer to low-cost, small-scale, easy to construct technologies. However, these modern interpretations also stress the importance of the process being operated by, or co-produced with, individuals from the targeted community. In an effort to build in elements of participation which can be seen throughout the WASH models considered later in this section. Whilst highlighting the core themes from AT, I also bring in other supporting approaches including the Swadeshi Movement (Gandhi, 1969, Bakker, 1990) and the Basic Needs Approach (Rimmer, 1981), which both add value to creating a participatory narrative in community based technology interventions. This section also identifies Social Enterprise (SE) as a model that could benefit the implementation of poverty alleviating technologies due to its focus on ownership, poverty alleviation and micro-economic development, which are concepts valued by technology end-users. SE could act as the transforming mechanism for barriers to enablers of energy technology sustained use.

The final section, section 5, presents the research gaps that have been identified throughout the review of the relevant literature groups and builds the case for a novel energy implementation model that can be used in the ICS sub-sector.

2.2. Barriers & Enablers for the Adoption and Sustained use of Energy Technology

High demand from governments and international development organisations for cookstove programs has led to a multitude of unsuccessful and damaging ICS interventions which commonly do not take into account ICS user priorities (Khandelawal et al., 2017). Hanna et al. (2016) state that "this big push for improved cooking stoves has occurred despite surprisingly little rigorous evidence on their efficacy on health and fuel use in real-life settings (p.81)". This failure is attributed to low demand for improved cookstoves (Mobaraka et al., 2012), which has resulted in a body of literature exploring the barriers and enablers for ICS adoption and sustained use. However as discussed throughout this research, the problem is systemic; not only do researchers need to adopt a more user-focussed approach (as research is traditionally undertaken in silos) but, fundamentally the technologies do not satisfy end-user needs. Mobaraka et al. (2012) discuss this in detail, "many of the technologies currently being marketed around the world are actually not "improved" in terms of fuel savings, emissions reduction, or other attributes that household's value most (p.10819)" highlighting that price reductions alone will not lead to high adoption rates. The problems unfortunately do not end with dissatisfied end-users, there are also a lack of adequate scaling routes to satisfy the global need (Quinn et al., 2018) if indeed there was a cooking technology that would satisfy all end-user needs.

2.2.1. Barriers and Enablers

There are a number of systematic reviews that set out the common barriers and enablers for ICS adoption from a range of perspectives. Rehfuess et al. (2014) provide a systematic review from a health perspective of large-scale uptake of ICS identifying 31 factors from 57 studies across Africa, Asia and Latin America stating that all are critical but none "guarantee success" with the relevance of each factor changing in different contexts. It is no surprise that despite the complexity of the problem, the barriers to adoption stated in Quadir et al. (1995) are similar to barriers to adoption found in Rehfuess et al. (2014) even after the numerous changes of ICS dissemination focuses (fuel saving, environment, time saving, health etc.). In other systematic reviews of this sector, Stanistreet et al. (2014) focus on the qualitative data associated with household uptake of ICS, whilst ICS for sustainable development are presented

by Mehetre et al. (2017) and Palit and Bhattacharyya (2014) with Kshirsagar and Kalamkar (2014) providing an overview of the biomass ICS literature. Section 2.2 concludes with a summary table (Table 2.1 p.39) that outlines the barriers and enablers from the systematic reviews along with a number of other relevant literature sources.

Looking more closely at a common barriers and enablers for improved cookstove uptake, Figure 2.2 divides these factors into seven categories (fuel and technology characteristics, household setting and characteristics, knowledge and perception, financial, tax and subsidy aspects, market development, regulation and standards, programmes and policy mechanisms) with the most important factors influencing adoption being fuel savings, impacts on time, smoke, health and safety, stove costs, subsidies and demand creation. Continuing through this section I shall group the common barriers and enablers to mirror the pillars of sustainability - financial, environmental and socio-cultural groupings.

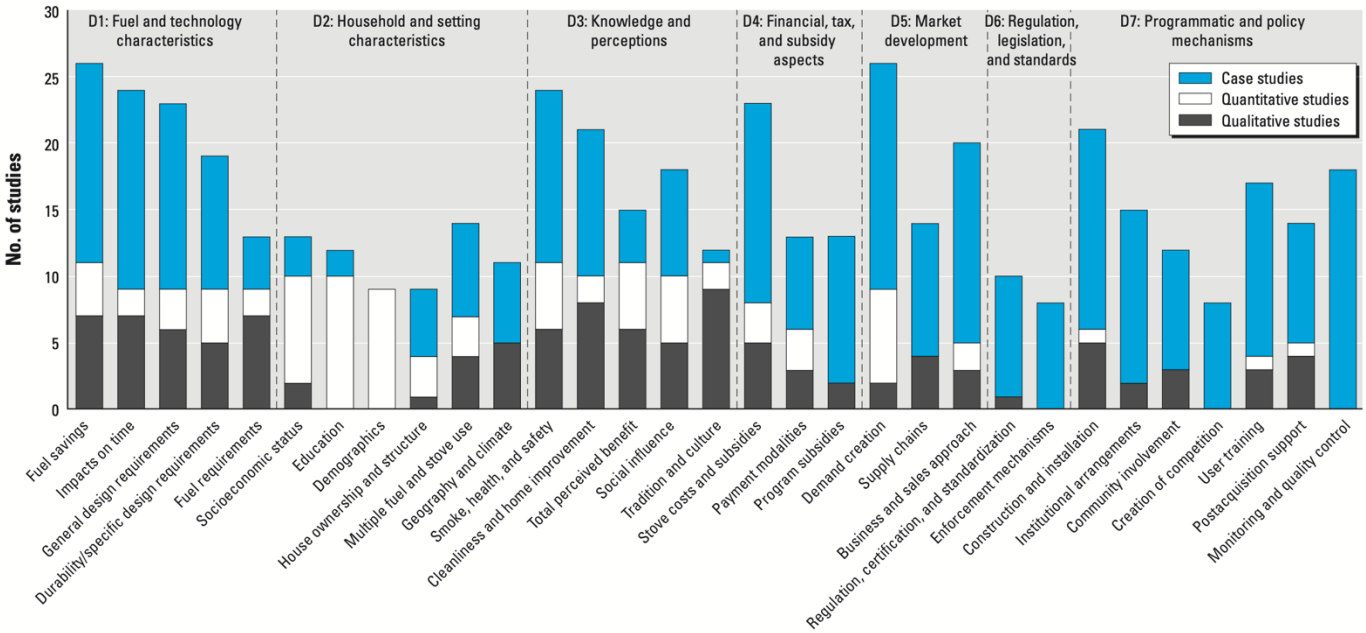


Figure 2.2: Factors influencing uptake of ICS (Rehfuess et al., 2014)

2.2.1.1. Financial

Financial barriers encompass a wide range of factors throughout the ICS value chain, from enterprises (Hewitt et al., 2018) to end-users. Financial barriers do not only capture the affordability of ICS over the product's life time but also capture willingness to pay, access to financial institutions, household financial priorities and on-going

support for maintenance costs as illustrated in Rehfuess et al. (2014). A single financial factor or multiple can determine the fuel choice for end-user cooking needs, for example, as stated in Das et al. (2018) some users switch to charcoal due to the lower price point however, as their research shows, in terms of time expenditure it is more effective to use firewood as the energy/financial cost of creating the charcoal is greater than firewood over the life of the ICS.

Hewitt et al. (2018) suggest a three-phase approach for satisfying the complex financial barriers: Supply chain financing, carbon financing, end-user finance. Nnaeme et al. (2020) tackle the end-user finance deficiencies through direct cash transfers which they state has an impact of improved livelihoods. In addition, another method aimed at reducing the financial barriers are subsidy programs throughout the ICS value-chain, either nationally funded such as the Nepal Renewable Energy Subsidy (Ministry of Population and Environment, 2016) or funded through international development organisations such as the Energising Development Fund (EnDev, 2020). Whilst national subsidies do promote the adoption of ICS, funds such as EnDev couple this subsidy with a market chain strengthening strategy to improve both demand and supply side aspects. Finally, carbon credits have gained momentum in the ICS sector and may present opportunities, challenges and unknowns (Freeman and Zerriffi, 2015), however, developed countries offsetting their carbon emissions in developing countries creates an ethical and moral dilemma linked to colonial histories of exploitation (Bachram, 2004, Lyons and Westoby, 2014).

2.2.1.2. Environmental

The environmental impact of an improved cooking technology is dictated by the technical performance of ICS. The impacts occur both on a personal and global scale. The production of CO_2, CO, PM and Black Carbon contribute to the greenhouse gases associated with global warming and personal end-user health issues such as chronic obstructive pulmonary disease and Lung Infections. Unfortunately, whilst many traditional stove users understand that inhaling smoke regularly is not beneficial, the long-term health benefits of ICS are difficult to grasp and, as Hanna et al. (2016) discuss, these long term benefits diminish if the ICS are not maintained.

As Afrane and Ntiamoah (2012) discuss, end-users in low-income settings are often far less interested in global environmental benefits than in personal health benefits as "human health aspects affect their economies directly in terms of the pressure on their health facilities and reduced national productivity (p.305)", whilst the global context does not affect the cookstove end-user. This is not surprising as the majority of low-income countries do not significantly contribute to global warming, yet, are the first to see the impacts hence it is difficult to see how a change in personal behaviours would affect the global context. For example, Nepal makes up 0.025% of global CO_2 emissions at 9105kt per year (The World Bank, 2018) and, due to the proximity of the Himalayas, sees the direct impact of rapidly melting glaciers (National Geographic, 2019). Afrane and Ntiamoah (2012) suggest that by presenting the life-cycle costs, environmental impacts as well as monetising the emissions of the ICS, end-users can make informed decisions about technology adoption and overcome these barriers.

Linking directly to the environmental management of resources, another technical barrier is the availability of improved fuels, which often are more expensive or require time investment by the end-user, as explored Das et al. (2019). In Ghana, Agbokey et al. (2019) describe the reluctance of ICS users to discard their traditional three stone fires as if LPG was not provided free of cost, ICS users would revert to this lower cost solution. This links to the acknowledgement that improved fuel cost and availability influences ICS choice (Malakar et al., 2018). The availability of free firewood consumed unsustainably will cause increased interest in other fuels, however this can lead to a vicious cycle of consumption where neither fuel is managed effectively.

2.2.1.3. Socio-Cultural

The question that rises repeatedly in the literature is, does the ICS satisfy the end-users need? The answer to this question is multi-dimensional, as differing contexts have different needs (Rehfuess et al., 2014) and thus require different solutions. Rhodes et al. (2014) stress the importance of "locally produced or adapted" ICS as a move away from the "one-size-fits-all" approach. However, this method does require extensive training and capacity building in ICS design, manufacture and maintenance. To create locally adapted ICS a detailed understanding of the socio-cultural context is key. Other socio-cultural factors include, what is being cooked and how, who is doing

the cooking and/or firewood collection, the fuel availability and the role of existing cooking technologies (Ruiz-Mercado and Masera, 2015).

A phenomenon that encompasses these issues is technology stacking which refers to the use of multiple cooking technologies concurrently. This often involves households continuing "to use their existing stoves both to meet diverse cooking needs and address more specific deficiencies in energy access or stove characteristics (p.101340)" (Jewitt et al., 2020). Types of stacking include, "(a) seasonal alternation of fuels and stoves; (b) weekly alternation of stoves; and (c) simultaneous use of several stoves within a day (p.49)"(Ruiz-Mercado and Masera, 2015). Stacking was found in 69% of households in a study of 1200 households across three regions in Peru by Wolf et al. (2017). Nepal is no different as Acharya and Marhold (2018) state that "households' energy consumption behaviour is directly related to the availability of the energy sources and different household activities require different energy sources (p.1132)". They go on to suggest that "the use of renewable energy is not effective in lowering the use of fuelwood (p.1136)". Echoing Nepal et al. (2010) who state that this phenomenon of using multiple cooking technology leads to greater firewood consumption than simply using a three stone fire or traditional cooking method. Jewitt et al. (2020) link stacking to backsliding[3] (linked to the energy ladder model discussed below) when biomass is considered to be "more affordable, reliable, accessible or safer (p.101340)" than other improved cooking technologies. If the results of these studies show that ICS interventions add to existing technology stacks rather than displacing the traditional cooking technologies, it then becomes difficult to justify the interventions without better understanding the role of stacking. As Quinn notes, "It remains to be seen, however, whether clean cooking programs can be effectively designed to achieve the multiple goals they often cite (p.9)".

The Energy Ladder Model developed by Hosier and Dowd (1987) and contested in Masera et al. (2000), sets out a linear fuel switching model. This model states, as socio-economic status increases end-users switch from less improved to more improved cooking solutions and when the opposite occurs it is called "backsliding". However,

[3] Returning to unimproved technologies

Masera et al. (2000) argue that this oversimplifies the complex contextual issues that act as barriers to adoption. They suggest that this switching behaviour is multi-dimensional; transitioning from a single cooking technology to multiple, based on four factors, "(a) economics of fuel and stove type and access conditions to fuels, (b) technical characteristics of cookstoves and cooking practices; (c) cultural preferences; and (d) health impacts (p.2083)". This fits into the stacking model and the interconnected nature of cooking technology to other aspects of end-user daily life. Namagembe et al. (2015) state, "those who did use the TLUD [Type of ICS] consistently still used other stoves for more than 90% of their cooking events (p.80)" meaning that their ICS was used for less than 10% of the cooking events and even less for total energy needs.

Stacking, backsliding & climbing the energy ladder are behavioural processes that depend on a number of factors. Lam et al. (2017) link seasonality to these behavioural processes, and not only discuss fuel wood consumption in Nepal but how seasonality and altitude is related to cooking and non-cooking needs. They note that, in winter, 45% of fuel was used in larger, unimproved supplemental stoves; the implication being that 45% of energy needs are not accounted for under the existing government policy systems. Figure 2.3 (p.37) illustrates this relationship between elevation, season, stove and end-use. The division of non-cooking/cooking needs better reflects actual cooking behaviours than the one-dimensional main fuel use that the Government of Nepal Household Survey (National Planning Commission, 2018) collects data on. This results in stacking as an under-measured phenomenon, for example the Annual Household Survey (National Planning Commission, 2018) utilised by Acharya and Marhold (2018) only accounts for primary cooking fuel and does not account for multiple fuel use. Jewitt et al. (2020) stress the importance of monitoring "system stacks" over space and time to better understand the long-term implications of ICS interventions which echoes Rehfuess et al. (2014) and their emphasis on the ICS adoption versus sustained or exclusive use.

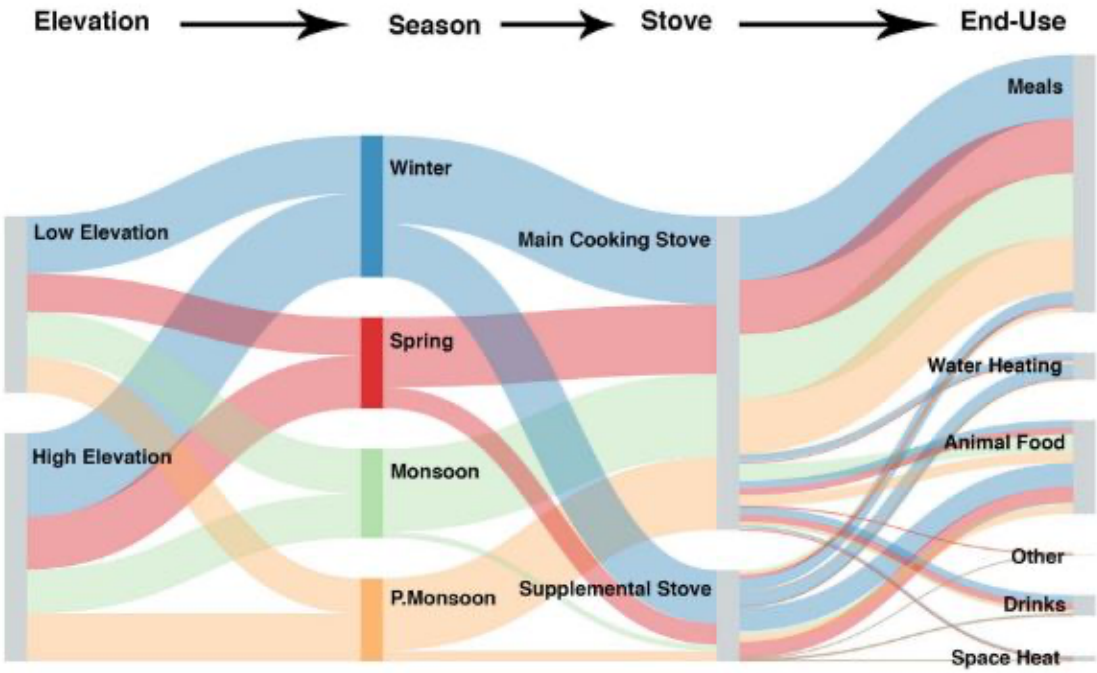


Figure 2.3: Seasonal Household Cookstove Use (Lam et al., 2017)

As discussed in Jagadish and Dwivedi (2018) the adoption of ICS is transitory with no clean break in the use of one technology as "each cookstove occupies a niche, fulfilling a specific need (p.50)", again resulting in stacking based upon the convenience of each technology. This is also supported by Rhodes et al. (2014) who show, convenience is defined differently in each contextual setting which can lead to different successes and failures of the same ICS. However this need is not required to revolve around the primary use of the cookstove, Rhodes et al. (2014) state many stove users use the ash as a secondary product for other uses which can also drive their decision making process. Whilst Jagadish and Dwivedi (2018) do not directly engage with the difference between adoption and sustained use in their analysis, their work highlights that adoption does not result in use in or after this transitory period. This confusion between what is meant by adoption and sustained use caused researchers, such as Namagembe et al. (2015), to claim data associated with sustained use occurring over their three month data collection period. Troncoso et al. (2007), by contrast, suggest sustained use occurs when the "the user becomes independent in the management and maintenance of a new technology (p.2800)".

2.2.2. Integrating End-User Perspective

Including end-user perspectives in ICS programs is recognised as an important factor for the adoption of ICS (Rehfuess et al., 2014), but end-users are often seen as a part

of the ICS value chain not as a key component. This role must be elevated to active participation rather than passive participation, as has been the case in the health behaviour theories adapted for the WASH sector through behavioural change models such as the Health Belief Model (Rainey and Harding, 2005). The integration of contextual social factors into ICS interventions, as argued by Malakar et al. (2018), is central to successful ICS interventions. Malakar et al. (2018) also cite "focus only on supplying modern fuels […] and implementing [cooking projects] as standalone projects (p.225)" as the core reasons for the failure of end-user adoption and sustained use. However, even with this focus on the barriers to adoption and sustained use, there is very little research on how to subsequently integrate these factors into future research. Whilst Jan (2012) identifies, "reduced participation of women in household decision making processes (p.3021)", the author does not suggest how to mitigate this barrier in future program design – translating a barrier into an enabler. Palit and Bhattacharyya (2014), meanwhile, acknowledge "there is a large data and knowledge deficit on this issue of cookstove adoption. Significant research is required in order to strengthen evidence-based action/policy [and] the role that different actors could play for enhancing ICS dissemination [as well as] the market potential for clean cooking fuels and technologies is not well understood (p.9)". Likewise, Stanistreet et al. (2014) state that little is known about successful implementation methods and as a result research needs to identify the factors that influence uptake. Whether the failure of these studies to create enablers out of barriers is due to funding constraints or a focus on producing research over impact, none of the literature sources stated here modify their approach based upon the results of their study. This may reflect the fact that barriers are contextually specific; an issue echoed in other parts of the ICS sector, such as solar cooking (Iessaa et al., 2017) along with other poverty alleviating technology sectors such as WASH which have similar problems stemming from similar root causes.

2.2.4. Summary Table of ICS Barriers & Enablers

Table 2.1: ICS Barriers & Enablers Identified by the Literature Review

Research Paper	Data Collection Method	Data Analysis Method	Focus Country	Barriers	Enablers
(Agbokey et al., 2019)	Qualitative Study	Theming in Nvivo (QSR International, 2019)	Ghana	safety, financial constraint (cost), non-availability of spare parts on the open market to replace faulty stove accessories, stove size and household size	convenience of clean cookstove use, reduced firewood usage, less smoke emission and associated health problems resulting from indoor air pollution and time for firewood gathering and cooking, good smell and taste of food
(Afrane and Ntiamoah, 2012)	Qualitative Study	Life Cycle Analysis	Ghana		Human Health Aspects, Reduction in Smoke
(Acharya and Marhold, 2018)	Government Household Survey	Multiple Discrete Continuous Extreme Value (MDCEV) Model	Nepal	Low Levels of Education	Ownership of information and communication technology
(Bhojvaid et al., 2014)	Semi-Structured Interviews/Focus Groups (11 villages)	-	North - India	Previous ICS Experience, High Cost of Use, Lack of ICS experience	
(Das et al., 2019)	Survey Data	General Statistical Analysis	Nepal	Time & Energy Requirement for ICS	
(Hewitt et al., 2018)	Semi-Structured Interviews	Thematic Analysis in NVivo	Kenya & Uganda	Finance throughout the ICS value chain	
(Jagadish and Dwivedi, 2018)	Focus group discussions, semi-structured interviews along with freelisting technique, and participant observation	Cultural Consensus Analysis	India Himalayas	Lack of other fuelwood options, poor infrastructure, costs associated with heating	Summer only use of ICS (as no heating required), Stacking, multi-use of traditional technologies
(Jan, 2012)	Survey Data (100 houses)	Regression Analysis	Pakistan	lack of education of the household members, especially women, reduced participation of women in household decision making processes, low income of the household, lack of knowledge of health and environmental hazards	Household Income, Education

				associated with inefficient use of biomass, insufficient funds allocated by governments and NGOs for such programs, and poor monitoring system for the long-term stove use and adoption patterns, motivation from users	
(Jewitt et al., 2020)	Qualitative Methods	Thematic Analysis in Nvivo	Nigeria	Properties of smoke – preserving food and signalling food security.	Economic and Access Considerations linked to spatio-temporal variations in fuel cost, availability and service quality coupled with socio-cultural and utilitarian influences on cooking practices. Backsliding
(Kshirsagar and Kalamkar, 2014)	Systematic Review		Global	Existing Institutional infrastructure, ICS price, Government Policy, Improved cookstoves do not usually serve the additional local needs fulfilled by traditional stoves such as lighting, space heating, food smoking, repelling insects, drying of a thatched roof, providing a social gathering place and burning multiple fuels, Technical issues with ICS.	Financial Services, Cash Transfer Scheme, Women Participation,
(Lam et al., 2017)	Mixed Methods Approach (Seasonal Kitchen Performance Test, and end-user discussions)		Nepal	Seasonality, Altitude, Stacking,	Cooking & Non-cooking needs, Distance to Protected forest area, utilisation of waste ash and charcoal.
(Malakar et al., 2018)	Qualitative Approach	Theories of Practice	India	Cooking with solid fuels is intertwined with structural elements, such as established traditions, traditional income generating practices, gender norms, and a sense of belonging	
(Masera et al., 2000)	Mixed Methods (Case Study Data in Kitchen Performance Test & Large Survey)		Mexico	Stove Investment Barrier as part of larger decision to upgrade house infrastructure.	Government investment in rural road and service infrastructure, the local cultural and economic circumstances of households. At the village level, fuelwood scarcity, the increasing monetization of the household economy, and the influence from urban centres, motivate households to look for other cooking options.
(Mobaraka et al., 2012)	Stated & Revealed	Unadjusted and Adjusted Linear-	Bangladesh	Air-Pollution not high priority, non-health considerations dominates household decisions, non-traditional	

	Preference Approaches	Regression Analysis		cookstoves are valued less than other essential goods and services.	
(Namagembe et al., 2015)	Mixed Methods (Household Survey + 8 Focus Group & 10 interviews	-	Uganda	Purchase price barrier, combined with the cost of processed wood, effectively eliminated the cost savings from its significant fuel efficiency.	ICS cook efficiently, cook quickly, reduce smoke, and produce charcoal
(Palit and Bhattacharyya, 2014)	Systematic Review		South-Asia and Sub-Saharan Africa	More emphasis on technical design of stoves to achieve higher thermal efficiency and lack of sufficient attention to consumer perspectives such as user-friendliness, purchasing capacity, income variability of rural households as well as to local capacity development of market players and stove builders	Stronger stakeholder partnerships, knowledge sharing, and satisfaction of user requirements through appropriate designs and diversified financing options
(Rehfuess et al., 2014)	Systematic Review		Global	Contained in Figure 2.2 (p.32)	
(Rhodes et al., 2014)	In-Depth Interviews & Direct Observation	Grounded Theory, Coding & Contextualising with IBM-WASH	Peru, Nepal, Kenya	Reliance on imported materials, increased cooking time, little knowledge of the smoke risk to health, available resources, no room for adjustment in cooks routine, socio-economic position.	Convenient Design & Logistical ease of use, convenient maintenance & repair, stacking required to meet energy needs, ash as a valuable commodity, maintaining tradition, aspirations,
(Stanistreet et al., 2014)	Systematic Review		Asia, Africa & Latin-America	User and stakeholder perceptions and highlight the importance of cost, good stove design, fuel and time savings, health benefits, being able to cook traditional dishes and cleanliness in relation to uptake.	Creating demand, appropriate approaches to business, and community involvement
(Stevens et al., 2019)	Qualitative Methods	The Market Map Model	East-Africa	Access to Finance, Customer Trust, Transport Costs, No electricity support, public awareness, clean cooking not prioritised, seasonal demand, lack of business capacity	More focus from policy makers on ICS, Increase Consumer Demand.
(Wolf et al., 2017)	Household Survey (1200)	Multivariable Logistic Regression Model	Peru	Pots being too large for ICS, Knowledge of ICS	Access to Maintenance

2.2.5. Other Sectors

Identifying barriers and enablers is common to a number of sectors: biogas (Clemens et al., 2018), solar energy (Sharma et al., 2020, Blimpo et al., 2020), water purification (Rainey and Harding, 2005), sustainable water and sanitation solutions (Buck et al., 2017, Hulland et al., 2015) and many more; most of which consider in detail how various behaviours influence the uptake of poverty alleviating technologies as many share the same barriers and enablers. The Health and WASH sectors are applicable to this research due to the cross-over with ICS, for example, Rhodes et al. (2014) apply the IBM-WASH model (Dreibelbis et al., 2013) and Quinn et al. (2018) apply the health based RE-AIM model to the ICS sector, both of which were developed for WASH applications. Sesan et al. (2018) state the commonalities between sectors, such as "the importance of the enabling environment [and] community focussed-approaches" but identify a lack of "cross-learning [and] knowledge exchange (p.1)". WASH literature leans towards a more 'software' based approach, such as in Lilje and Mosler (2017), than the 'hardware' approach favoured by most researchers in the ICS sector chasing improved efficiencies rather than sustained use. Traditionally referred to as 'factors influencing adoption and sustained use' in the ICS sector, the behavioural change literature focused on end-users refers to these barriers and enablers as behavioural determinants, which are further grouped to help understanding such as the 'technological, psychosocial and contextual' grouping in Dreibelbis et al. (2013).

2.2.5.1. Water, Sanitation and Hygiene

Buck et al. (2017) categorised WASH interventions into four main elements or approaches, (1) community-based approach, (2) social-marketing approach, (3) sanitation and hygiene messaging, (4) elements of psychosocial theory, and state a number of factors which are important, including "length of the intervention; visit frequency; use of short communication messages; availability of training materials; kindness, respect, status and accessibility of the implementer; recipient awareness about costs and benefits and their access to infrastructure and social capital (p.6)". The review also determined that these approaches did not have a consistent impact on the health of participants however, the communication-based approach has the most consistent positive impact on WASH behaviours.

Dreibelbis et al. (2015) utilised a qualitative approach to determine “the important role that existing behavioural patterns play in determining latrine uptake and the importance of perceived convenience in decisions to use available facilities (p.31618)” as well as identifying behavioural determinants such as the impact of “Direct exposure to both toilets and individuals using toilets (p.31618)” or the role that existing belief systems held around traditional processes can have on technology use. Dreibelbis et al. (2015) also suggest a stacking of sanitation behaviours due to convenience – a phenomenon shared with the ICS sector - “Among the 543 individuals that reported access to a functional latrine, 128 (24%) reported engaging in open defecation at least once in the seven days prior to data collection (p.31618)”. Even if users had access to an improved latrine, traditional practices prevailed.

Hulland et al. (2015) divide determinants into three categories (sub-categories in brackets), (a) understanding sustained adoption (measuring outcomes), (b) behavioural factors (psychosocial, technological, contextual), (c) programme characteristics (communication strategies) to aid understanding of determents. This research also identifies a common problem that is reflected in the ICS sector in that “most behaviour change models only describe or examine initial adoption, but do not consider the factors that influence sustained adoption, particularly beyond the end of behaviour change project activities (p.4)”. This view is supported by Dwipayanti et al. (2017) who state that each part of the project cycle has its own set of determinants each of which needs to be overcome to have sustained use of a WASH technology, and Ssemugabo et al. (2020) who champion a “multi-faceted approach targeting all stakeholders (p.227)” rather than the traditionally divided demand side and supply side interventions. Additionally, this system wide approach requires a detailed understanding the difference between habitual behaviours (water purification and latrine use) and non-habitual behavioural (maintenance or cleaning) when understanding the behavioural change mechanisms of the end-user (Hulland et al., 2015).

The WASH literature also explores a number of socio-psychological determinants, such as social norms, action knowledge and perceived self-efficacy (Lilje and Mosler, 2017) as well as how the water tastes and the perception of cost and benefits of

purifying water – all with correlating the determinants in the ICS literature. Lilje and Mosler (2017) acknowledge that contextual behavioural determinants are important such as infrastructure, availability of resources, storage and cleaning materials as they "partially explain the variance in current behaviours", but a "population-tailored approach (p.20)" is key when designing safe water consumption interventions. This shares stark similarities with the locally produced or adapted ICS approach of Rhodes et al. (2014).

2.3. Frameworks for Understanding Complex Contextual Factors

Having identified common barriers to the adoption and sustained use of energy technologies, specifically focussing on the ICS sub-sector, I now focus on the existing frameworks that been created to identify the complex systems that accompany a focus on poverty alleviation. I have chosen to include three perspectives, the insitutional researcher, the international development practitioner and the social scientist in an effort to capture core mechanisms linked to energy technology implementation. Including sectors outside of energy allows a transdisciplinary research element which builds the contribution of this research, as reinforced by Brennan and Rondón-Sulbarán (2019).

2.3.1. The Institutional Researcher

Given the global context of the SGDs and the emergence of trans-disciplinary research methods (Brennan and Rondón-Sulbarán, 2019, Lambe et al., 2020) it is crucial that researchers understand the impact of their work, not only on their research discipline but also on the wider global community. However, as researchers have traditionally worked in silos or specific work streams, there is limited appreciation for the importance of the contextual factors contained within a wider system (Lambe et al., 2020). This results in the social/technical divide of technology development as highlighted by the ICS sector in section 2.2. Brennan and Rondón-Sulbarán (2019) approach trans-disciplinary research, a more inclusive research methodology, from a Knowledge Typology perspective, integrating the LogFrame and Theory of Change (ToC) models discussed in section 2.3.2. Building on this theme of creating interdisciplinary and connected research teams the Responsible Research and Innovation Framework (RRI) focuses on the philosophical approach of technology

innovation, creating a set of parameters that the innovator(s) must remain within across research disciplines to ensure that the purpose as well as the product is developed responsibly. Whilst a number of definitions of Responsible Innovation are available, here I shall focus on the definitions given by Owen et al. (2013) where "responsible innovation is a collective commitment of care for the future through responsive stewardship of science and innovation in the present (p.36)", and the UK's Engineering and Physical Sciences Research Council:

> "Responsible Innovation is a process that seeks to promote creativity and opportunities for science and innovation that are socially desirable and undertaken in the public interest. Responsible Innovation acknowledges, that innovation can raise questions and dilemmas, is often ambiguous in terms of purposes and motivations and unpredictable in terms of impacts, beneficial or otherwise. Responsible Innovation creates spaces and processes to explore these aspects of innovation in an open, inclusive and timely way. This is a collective responsibility, where funders, researchers, stakeholders and the public all have an important role to play. It includes, but goes beyond, considerations of risk and regulation, important though these are." (Engineering and Physical Sciences Research Council, 2013)

The reason for this choice is twofold; first, Owen et al. (2013) devised the RI framework. Second, RI is used by the UK based research councils to promote innovation surrounding global social needs through GCRF. Stilgoe et al. (2013) positions the framework for RI thorough the cornerstones of care and responsiveness in order to make "explicit the need to connect with cultures and practices of governance (p.1576)". The aim is for this to result in the protection of society from the harmful unintended consequences of innovation (social, environmental or health) by challenging the innovator to reflect on what sort of future they want to see in the world. In this area, typical regulation is limited as it is impossible to predict unknown innovation and subsequently regulate due to not knowing what the potential impacts (either positive or negative) could be. Yet, is it the researchers' responsibility to mitigate for risks that are not foreseen, or will "an inability to 'reasonably foresee' [..] allow us to escape moral accountability for our actions (p.1569)" (Stilgoe et al., 2013). Factors such as moral Luck, rational justification & Kantian morals, as discussed by Williams (1981) are all subject to discussion in the literature.

RRI asks the researcher to consider four dimensions: anticipation, reflexivity, inclusion and responsiveness. These four dimensions of RI emerge from responses to questions set out by Macnaghten and Chilvers (2014) in the three models of public engagement,

the ‘upstream’ model, the ‘honest broker’ model and the ‘issue advocate’ model. The first dimension, anticipation, is an attempt to improve foresight when it comes to desirable outcomes of technological development. Reflexivity does not only involve the self-critical approach of the researcher but suggests that reflectiveness is a multilevel process involving key actors and institutions as well. This links with the third dimension – Inclusion. Traditional innovation methods involve a top-down or centrally powered approach where decisions are made independent of end-user input. Inclusive methods manifest in participatory approaches, where stakeholders are actively involved in the innovation process. The final dimension builds on the information provided by the previous dimensions - Responsiveness. This allows the researcher to act taking the most appropriate roadmap to development.

However, Owen et al. (2013) and Stilgoe et al. (2013) have not designed this framework to apply to low-income innovation contexts. Hartley et al. (2019) highlight this by stating, “RI has the potential to direct low-technology innovation toward global challenges in the Global South, yet this possibility remains largely unexplored (p.143)”. Yet, this area of novelty is party explored by EPSRC through the recently established GCRF to “to support cutting-edge research that addresses the challenges faced by developing countries” (Engineering and Physical Sciences Research Council, 2015) with such projects as Hartley et al. (2019). The EPSRC has modified the RRI framework developed by Stilgoe et al. (2013), to Anticipate, Reflect, Engage and Act – embodying the same philosophy but reducing complexity, this is the values-driven version of the framework this research shall consider going forward.

	Researcher activity
[A]nticipate	*Describe and analyse* intended and unintended impacts (including economic, social, environmental impacts). Think about and imagine possible trajectories: What else might the research lead to?
[R]eflect	*Reflect* on the purposes, motivations and potential impacts (what is known) as well as uncertainties, risks, assumption, areas of ignorance, dilemmas (what is not known). Question existing framings and understand others' framings. Reflection requires openness and leadership and must be institutionally embedded.
[E]ngage	*Open up* 'Anticipate' and Reflect' to a wide range of publics, stakeholders and institutions and debate them in an inclusive way to allow for the re-framing of issues. Engagement needs to be institutionally embedded. Engagement should be held early enough to be constructive but late enough to be meaningful and should be driven by normative (the right thing to do) and substantive (improves nature and trajectory of innovation) motivations.
[A]ct	*Take action* to allow these processes to influence the direction, trajectory and pace of the research and innovation process, responding to a wide range of publics, stakeholders, social needs and societal grand challenges.

Figure 2.4: RRI Framework (Engineering and Physical Sciences Research Council, 2013)

2.3.2. The International Development Practitioner

A number of planning tools are available to help development practitioners effectively manage project or programme cycles as well as integrate contextual factors into their programs (Red Cross, 2010, COOP Africa, 2010, Bond Project Management Group, 2016, UK Civil Service, 2015). These tools include planning mechanisms such as the Logical Framework or LogFrame (Freer and Lemire, 2019), as well as tools to map the change process, such as the Theory of Change (ToC) (Valters, 2014). In addition to these, market-based financing mechanisms allow development practitioners to mitigate a number of financial barriers whilst also championing user choice through Results Based Financing (DFID, 2014). Whilst this literature is presented within section 2.3 it also has relevance to section 2.4 where I present specific energy implementation models for low-income households.

The LogFrame is designed "to demonstrate how parts of a program fit together, neatly and logically, and how a series of program activities will lead to a specific set of program objectives (p.337)" (Freer and Lemire, 2019), through a number of planning steps shown in Figure 2.5 (p48). There are limitations to logframes, some are general to planning frameworks such as "it can often be created in a mechanical or bureaucratic way rather than as a practical, logical and flexible tool to determine the key elements of a potential intervention (p.5)" (Red Cross, 2010). This linear approach to behavioural change of end-users fails to capture the complex behavioural processes that occur. Additionally, the inflexibility of identifying indicators, often facilitated by the SMART Criteria (Specific, Measurable, Achievable, Relevant, Time-bound), at the beginning of the project processes by practitioners who do not have detailed knowledge of the context can lead to project failure. As the indicators are developed by the implementing organisation, when failure occurs this can be attributed to external factors that are outside the control of the practitioner. This is illustrated by Venugopal (2018) in a number of World Bank Projects, the "project scope was well beyond the Government's implementation capacities, and implementation was delayed because of poor project preparation, inexperience and rapid turnover of Government staff, and lack of timely availability of counterpart funding (p.241)", resulting in a lack of organisational accountability around failure. The final limitation

is a lack of cyclical learning, such as the reflect element of RRI, but there are other evaluation tools that utilise this – DFIDs 'test-learn-adapt' strategy (DFID, 2015b), Practical Action's 'Framework For Change' (Inspire – learn – demonstrate) or DFIDs "planning-action-reflection" (Hamilton et al., 2000).

Objectives (What we want to achieve)	**Indicators** (How to measure change)	**Means of verification** (Where/how to get information)	**Assumptions** (What else to be aware of)
Goal The long-term results that an intervention seeks to achieve, which may be contributed to by factors outside the intervention	**Impact indicators** Quantitative and/or qualitative criteria to measure progress against the goal	How the information on the indicator(s) will be collected (can include who will collect it and how often)	External factors beyond the control of the intervention, necessary for the goal to contribute to higher-level results
Outcome(s) The primary result(s) that an intervention seeks to achieve, most commonly in terms of the knowledge, attitudes or practices of the target group	**Outcome indicators** Quantitative and/or qualitative criteria to measure progress against the outcomes	As above	External factors beyond the control of the intervention, necessary for the outcomes to contribute to achieving the goal.
Outputs The tangible products, goods and services and other immediate results that lead to the achievement of outcomes	**Output indicators** Quantitative and/or qualitative criteria to measure progress against the outputs	As above	External factors beyond the control of the intervention, necessary if outputs are to lead to the achievement of the outcomes
Activities The collection of tasks to be carried out in order to achieve the outputs	**Inputs** The materials and resources needed to implement activities	**Costs (and sources)** The summary costs for each of the identified resources/ activities; sources of income can also be specified	External factors beyond the control of the intervention, necessary for the activities to achieve the outputs

Figure 2.5: Logical Framework (Red Cross, 2010)

These limitations have led to the creation of the ToC, or theory of action (Marua et al., 2018, Valters, 2014, Stein and Valters, 2012) which considers the internal process of change (Freer and Lemire, 2019) as outlined in Figure 2.6 (p.49). The ToC is a tool designed to facilitate a better understanding of change by enabling "stakeholders to present and test their theories and assumptions about why and how impact may occur (p.344)" (Marua et al., 2018). By linking objectives to goals verification occurs through if-then causality and the identification of assumptions. Stein and Valters (2012) define ToC as representing "an increased desire for organizations to be able to explore and represent change in a way that reflects a complex and systemic understanding of development (p.3)". However, the ToC has limited ability to model the wider contextual factors that influence the adoption and sustained use of technologies which has resulted in a number of difference interpretations of ToC.

Summary Statement	One sentence describing the expected link between the intervention, the change process and the ultimate goal, often given as an "If…then…" statement.
Problem Statement	Identify the problem and examine its underlying causes
Overall Goal	Following from the problem statement, an identification of the goal to be achieved and how success will be identified[76]
Change Process	Identify the mechanism of change linking the inputs to short-term output/outcomes and long-term goal[77]
Change Markers	Identify milestones, indicators or other tools to assess/measure extent of change
Meta-Theory	Define the underpinning theory that justifies the chosen change process
Inputs	Actions intended to catalyse the change process and corresponding timeline for change
Actors	Identify the actors in the change process, define their roles and relationships
	- End-users / Intended beneficiaries[78]
	- Implementing actors
	- Spoilers
	- Points of collaboration with other agencies[79]
	- Additional external stakeholders
Domains of Change	If applicable, identify various strands or thematic areas that must be addressed in order to achieve the change, potentially articulated as sub-theories
Internal Risks	Identify potential impacts of the programme that may undermine its success
Assumptions	Identify beliefs, values, and unquestioned elements for each step of the change process
External Risks	Identify external risks to the programme with the potential to undermine its success and outline plans to overcome them
Obstacles to Success	Identify obstacles likely to threaten the change process and outline plans to overcome them[80]
Knock-On Effects	Identify the potential unintended consequences of the project, both positive and negative

Figure 2.6: Theory of Change Methodology Outline (Stein and Valters, 2012)

Marua et al. (2018) use ToC in an agricultural context and outline the limitations which include; (i) different interpretations of ToC, ii) incoherence in relationships among the constituent concepts of ToC, (iii) confused relationships between ToC and the Logframe which is still a dominant design tool and (iv) necessary skills and commitment for enacting ToC.

The final model which is currently the centre of many international projects or programs, especially in the energy sector (EnDev, 2020), is Payment by Results (DFID, 2014) or payment by outcomes. This method looks to the delivery organisation to pay the initial cost of the intervention and then claim back the cost on completion, a low-risk strategy for the funder. However, this puts pressure on the delivery organisation to have the correct results – a high risk strategy for the delivery organisation if the goals are not reached to the funders expectations (DFID, 2015a). DFID has developed this method to increase the participatory nature of the interventions. Results-based financing looks to transition organizations away from donor requirements and towards more accurately representing stakeholder views, despite additional pressure to produce pre-determined impact.

2.3.3. The Social Scientist

The technical-social divide in technology implementation is amplified by the ICS sector as “affordable and technically optimized stoves are not enough to create acceptance in the society. We need to identify and unite the decisive socio-cultural, natural, and local resource conditions, with economics and modern technology (p.600)” (Kshirsagar and Kalamkar, 2014). This balancing act between designing for the complex context and what is technically best, coupled with the ICS developer traditionally being situated around the world from the ICS end-user has been a leading cause of the failure of ICS interventions. The WASH sector has reacted and mobilised around these similar issues of discarding improved technologies more effectively than the Energy sector with a number of behavioural change models (derived from more general health behavioural theories) of which a few have been applied to the ICS sector, such as RE-AIM (Quinn et al., 2018) or IBM-WASH (Rhodes et al., 2014). Behavioural Change Models (BCMs) stem from the distinction between ‘Hardware’ and ‘Software’ when implementing a new technology with hardware defined at the physical infrastructure or technology and software as the socio-economic barriers and enablers to adoption and sustained use. This section looks to interact with a number of these models from WASH and ICS, identify relevant parts and understand how they interact with one another.

2.3.3.1. BCMs in ICS

Namagembe et al. (2015) suggest a number of end-user orientated behavioural change strategies to increase the correct and consistent use of TLUD ICS in Uganda, however even with these behavioural change aspects the use of their ICS made up less than 10% of the end-user cooking events, even when community involvement from the start was stressed. Namagembe et al. (2015) do not acknowledge the role of gender at the cooking demonstration events although this is echoed throughout the ICS literature and is crucial for the end-users (traditionally women) to be at the cooking demonstrations as well as the financial decision maker (traditionally male). This is reinforced by Sesan et al. (2019) who state that women are under-represented at every level of the ICS value chain even if in some cases, such as in Troncoso et al. (2007), men are the primary fuelwood collectors. Cookstove demonstrations seem to

be the central mechanism for end-user behavioural change around cooking however as stated by Hulland et al. (2015), these are community level promotions and are not directly targeted at households. Stanistreet et al. (2014) stress the importance of interacting with a number of societal levels, in addition to directly targeting households, in successful interventions aimed at influencing behaviours, "Since factors within and across domains and at different levels interact, this suggests that the connection between household, community, programme and societal levels is important (p.8246)".

2.3.3.2. BCMs in The Water, Sanitation & Hygiene Sector

WASH provides an interesting range of BCMs that have many cross-sector applications. Sesan et al. (2018) suggest that the energy sector is in fact lagging behind WASH when it comes to innovative solutions to uptake and sustained use. In the WASH sector, demand-led software interventions intent on changing perceptions around sustainable sanitation have displaced traditional hardware interventions. These models "understand and consider the range of factors that influence a particular behaviour" or "improve the effectiveness of interventions aimed at changing the behaviour (p.2)" (Devine, 2009), which are key aspects in "sustainable and scalable (p.4)" solutions (Figueroa and Kincaid, 2010). For example, models such as the Behavioural Settings Theory (BST) (Curtis et al., 2019) look to understand the influence of environment on WASH behaviours, highlighting the role of self-reporting, unconscious behavioural drivers and categorising these behaviours into typical and variant. Whilst the BST focuses on the interaction between environment and user, the Domestication Theory (Gaybor, 2019) looks to understand how technologies and users co-shape each other, linking identity with use and building knowledge from the understanding that people who run projects/develop technologies are not the same as the people who use technologies.

The transition to software-led approaches is likely to be reflected in the energy sector as many of the barriers to adoption and sustained use are similar (Sesan et al., 2018). Key in the WASH BCM design is a "multi-level, multi-message strategy (p.5)" (Figueroa and Kincaid, 2010) to capture behavioural determinants as failure to capture these behavioural determinants can result in project failure (Roger, 1995). O'Reilly and Louis

(2014) define successful technological adoption around three core factors: "(1) multi-scalar political will on the part of both government and NGOs over the long term; (2) proximate social pressure, i.e., person-to-person contact between rural inhabitants and toilets; (3) political ecology (p.43)", where the political ecology refers to the wider societal context. It must be noted that none of these factors emphasize the technology itself although historically technical development has been prioritised over adoption models, as Jewitt (2011) notes for the bio-gas sector. The importance of interpersonal communication when promoting the adoption of water treatment technologies is also stressed by Wood et al. (2012). This is ever more apparent in the ICS sector, where decades of technological development have not overcome the barriers to adoption (Agbokey et al., 2019, Hewitt et al., 2018, Palit and Bhattacharyya, 2014). An emerging theme in current energy research methods is that although "technical equipment is good, knowledge is better (p.13)" (Siemens Stiftung, 2017).

A systematic review by Dreibelbis et al. (2013) identified and evaluated a number of existing WASH BCMs which are developed from more general health behaviour theory. These are: the Health Belief Model (Becker et al., 1974), the Hygiene Improvement Framework (Environmental Health Project, 2004), Jenkins Adoption Model (Jenkins and Scott, 2007), the SaniFOAM Framework (Devine, 2009), Communication Model (Figueroa and Kincaid, 2010) and general wash models (Curtis et al., 2011, Mosler, 2012, Wood et al., 2012). Dwipayanti et al. (2017) present further factors of sanitation adoption, usage and maintenance as well as a number of behavioural change frameworks that facilitate the translation of these factors into interventions.

Personal Preference, Perception or Motivation is cited in six out of the eight models. Some, such as Devine (2009), explore the cultural beliefs and attitudes behind these factors whilst others, such as Jenkins and Scott (2007), use this theme as a guide to perceptions of existing sanitation hardware. Within the personal level some look at the individual's behavioural change (Figueroa and Kincaid, 2010), others look at the whole value chain and try to promote systemic change (Curtis et al., 2011). Other levels that emerge from the frameworks are habitual, community, institutional, policy, environmental/context. All these levels are utilised in subtly different ways depending

on the context or technology. Maintenance is directly considered only once, and implied once. Wood et al. (2012) reference maintenance as a path to sustained use whereas in Environmental Health Project (2004), maintenance is implied under "Access to Hardware: water supply systems (p.10)". Maintenance contributes a significant cost over the lifecycle of the technology and is often neglected as stated in Edgerton (2008). This review by Dreibelbis et al. (2013) effectively identifies the factors that were not emphasised in previous models, utilising the information to create the Integrated Behavioural Model for Water, Sanitation and Hygiene (IBM-WASH) as seen in Figure 2.7.

Levels	Contextual factors	Psychosocial factors	Technology factors
Societal/Structural	Policy and regulations, climate and geography	Leadership/advocacy, cultural identity	Manufacturing, financing, and distribution of the product; current and past national policies and promotion of products
Community	Access to markets, access to resources, built and physical environment	Shared values, collective efficacy, social integration, stigma	Location, access, availability, individual vs. collective ownership/access, and maintenance of the product
Interpersonal/Household	Roles and responsibilities, household structure, division of labour, available space	Injunctive norms, descriptive norms, aspirations, shame, nurture	Sharing of access to product, modelling/ demonstration of use of product
Individual	Wealth, age, education, gender, livelihoods/employment	Self-efficacy, knowledge, disgust, perceived threat	Perceived cost, value, convenience, and other strengths and weaknesses of the product
Habitual	Favourable environment for habit formation, opportunity for and barriers to repetition of behaviour	Existing water and sanitation habits, outcome expectations	Ease/Effectiveness of routine use of product

Figure 2.7: IBM-WASH (Dreibelbis et al., 2013)

IBM-WASH allows the researcher to analyse the end-user behavioural change process in term of habitual change which "requires significant repetition across space and time (p.5)" (Dreibelbis et al., 2013). This habitual element is not considered in the majority of existing models. Multi-level and multi-dimensional structure allows in-depth exploration of the relationships between factors and levels as well as inter-level interactions with Dreibelbis et al. (2013) noting, "we modified our presentation to a matrix format, focusing on relationships between and amongst determinants rather than causal pathways (p.9)". The matrix format also allows easy translation to the development of monitoring and evaluations plans as appropriate indicators will be identified as the matrix develops over a number of levels. This has resulted in Hulland et al. (2015) utilising the IBM-WASH as a tool to collate and categorise systematic review data.

2.4. Energy Technology Implementation Models for Low-Income Households

In the *Wealth of Nations (Smith, 1776)*, the handbook of modern capitalism, Smith talks of the invisible hand of capitalism distributing capital wealth throughout modern society. The reality, in the 250 years since publication, is an ever-widening wealth gap (Yunus and Webber, 2017) with large proportions of society being unaccounted for in this traditional model of development as 45% of the global population still live on less than $5.50 USD a day (The World Bank, 2018). In the context of energy implementation models for low-income peoples, these traditional mechanisms based on a purely capitalist model do not satisfy the technology users' needs due to the lack of spare capital for investment. In this section I consider a number of models that take into account the wider societal context and rely less on traditional capital focussed market mechanisms. The Market Map (MM) (Practical Action Consulting and EUEI PDF, 2015) utilises a combination of demand and supply side interventions whereas AT (Schumacher, 1973) looks to lower the unit costs of improved technologies by shaping them to local context. Social Enterprise (Yunus, 2003) modified the traditional capitalist approach to value social gain whereas the circular economy utilises existing market mechanisms with a better understanding of the technologies impact over its lifecycle. I also consider a number of less well-known models. In addition to this, the international development practitioner models contained in section 2.3.2 also have application as implementation models. These models provide the literature foundations of the energy implementation sector.

2.4.1. The Market Map

Given the transition of the International Development sector away from charity giveaways to a more market-based approach to technology implementation, Market Mapping looks to not only identify complex change mechanisms but also takes into account the wider context and other influencing factors. The market map tool, developed by Practical Action Consulting and EUEI PDF (2015), is designed to analyse access to energy markets resulting in the design of interventions that improve access, satisfy demand and close market gaps. This framework is directly aimed at SDG7 in low-income countries as applied by Stevens et al. (2019), however this does not restrict its use to the energy sector. The market map process is divided into two stages,

first, market system mapping and second, the identification and analysis of potential supporting interventions. In the first stage, markets are divided into three levels to facilitate systematic analysis of market gaps, key actors, stakeholders and beneficiaries, shown in Figure 2.8.

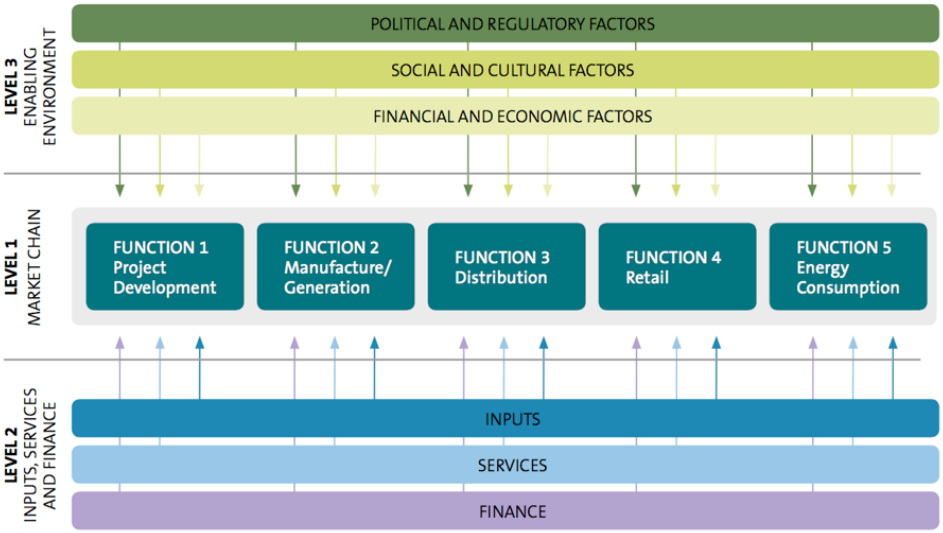


Figure 2.8: The Market Map (Practical Action Consulting and EUEI PDF, 2015)

The first level, the market or value chain, contains all the functions and actors associated with a product going to market including development, manufacture, distribution, retail and consumption. Extra, poorly defined or poorly linked steps in this process can negatively influence the effective and efficient dissemination of technologies and the overall success of interventions. The second level contains the inputs, services and finance (support services) that connect and support the market chain and typically include materials, quality testing services, transport and finance. Some elements or actors are responsible for more than one function and together these inputs are of critical importance in the effective working of the market chain. The third level is the enabling environment. This level analyses the wider context though sub-dividing into political and regulatory factors, social and cultural factors and financial and economic factors that influence the market chain largely focusing on the adoption of technologies through the purchasing power of end-users. The Market Map has been applied in east Africa by Stevens et al. (2019) and is considered in the Nepali context by this research in Chapter Three and the accompanying journal paper (Robinson et al., 2021c).

2.4.2. Engineering and Appropriate Technology

Whilst the Market Map Tool focuses on creating and defining the value chain as well as user demand for a technology, AT focuses on the design of the technology itself from a technical engineering perspective. Schumacher (1973) is seen as the founder of AT, however, there other academics and practitioners that have had significant influence on the development of the AT literature. Table 2.2 outlines the core principles of the AT movement as set out by Schumacher (1973) and summarised by Carr (1985).

Table 2.2: Core Principles of Appropriate Technology (Carr, 1985)

No.	Core Value
1	Low in capital costs
2	Use local materials whenever possible
3	Create jobs, employing local skills and labour
4	Are small enough in scale to be affordable by a small group of low income
5	Can be understood, controlled and maintained by locals wherever possible, without a high level of education.
6	Can be produced out of a small metal-working shop, if not in a village itself.
7	Involve decentralised renewable energy sources
8	Involve a knowledge transfer to the people using the technology to allow further innovations.
9	Flexible so that they can continue to be used or adapted to fit changing circumstances.
10	Practical Plans can be obtained free or at low cost and no further payment is involved.

Recent interpretations of AT echo many of the principles stated by Schumacher (1973) referring to a product centred approach where low-cost, small-scale, easy to construct technologies, are of central importance but the modern interpretations also stress the

importance of the process being operated by, or co-produced by, individuals from the targeted community (Feige and Vonortas, 2017, Patnaik and Bhowmick, 2018, Sianipa et al., 2013, Seay et al., 2012).

Under Schumacher's definition, AT (or Intermediate Technology) is for labour-surplus societies where retaining rural productivity is key to relieve pressure on the major urbanising cities. This phenomenon he defines as Dualism, the "twin evils of mass unemployment and mass migration (p.143)" (Schumacher, 1973). Schumacher (1973) states this duality is caused by the inappropriateness of complex technical solutions due to a misalignment or misunderstanding of barriers to technology adoption. This results in less employment opportunities for rural populations, forcing migration to industrialised urban areas. This issue is especially relevant in 2021 due to the mass migration in Nepal for employment (Jaquet et al., 2016). Grieve (2004) also supports AT as the solution for the dualism however, he does state that the introduction of labour-intensive technologies has gone out of fashion. This echoes other modern interpretations of AT, suggesting capacity building exercises coupled with AT solutions as a successful approach to technology adoption, creating a multi-dimensional approach rather than the product centred approach of Schumacher.

Following this multi-dimensional approach, Joshi et al. (2018) state, "[AT] must be low cost, economically viable, socially acceptable, and not adversely impact the environment, and also produce a product that has a ready local market (p.3)", similar to the socio-economic approach taken by Willoughby (1990) who looks to customise technologies to the an individual region at a specific time. Carr (1985) also considers that social acceptability is an evolving factor through space and time, as technologies are flexible and adaptable to fit changing circumstances. Reflecting the phase shift in WASH BCMs, the question, appropriate to what? (Willoughby, 1990) is central to the social acceptability of a technology. This echoes a similar question across the participatory methods literature, participation for who? (Estrella et al., 2000). Contrasting strategies for determining the answers to this question result in different conclusions; Pattnaik and Dhal (2015) focus directly on academic discourse and Joshi and Seay (2016) focus wholly on implementation whilst Feige and Vonortas (2017) focus on AT as a policy tool to enable technologies to succeed. When designing for a

context, Seay et al. (2012) integrate the flexibility of tolerances into the design of a plastic to fuel conversion system due to variance of manufacture with simple, readily available tools. This being said, academic discourse also has valuable lessons in identifying novel areas of research. Patnaik and Bhowmick (2018) state “appropriate technology is yet to be linked with sustainable development and innovation in the context of emerging economies (p.8)”. However, Seay et al. (2012) link AT to sustainable development through the design and implementation of appropriate bio-diesel and bio-char solutions – “for engineers in particular, sustainability has come to refer to the goal of designing, operating and maintaining products and processes in a manner that is economically viable, environmentally benign, and beneficial to society (p.38)”.

De-centralisation or federation of industry is another core theme for Schumacher (1973). However, it is not explicitly stated in the AT principles. Joshi et al. (2018) outlines the benefit of this contextually specific process, “our assertion that locally managed decentralized solutions—targeting waste where it is generated rather than focusing on centralized processing—may be more effective in communities where governmental waste solution efforts are minimal (p.4)”. This focus on empowering individuals rather that institutional systems could result in centralised and decentralised industries complementing or competing against each other.

Parallel to the AT movement is Gandhi’s social philosophy for development, Swadeshi. Bakker (1990) argues that new meaning is given to the concept of AT and basic needs when seen next to Gandhi’s social philosophy. Bakker (1990) continues to state this new meaning is derived from Gandhi’s equity, justice and community-based approaches, which retain the dynamic equilibrium of community as well as promoting positive development – a early approach to mitigate the unintended consequences of development intervention. The Swadeshi philosophy can complement this research through the Economics of Justice (Gandhi, 1969) and the “utilisation of local resources in the best way possible way (p.60)” (Bakker, 1990). Swadeshi shares many values with the qualitative Basic Needs approach to development as outlined by Rimmer (1981). However, the Basic Needs approach is seen as a reimagining of previous approaches to development, the “approach of the late 1970s is therefore of the nature of a

counterrevolution, but the insurgents appear curiously ignorant of the history of their cause (p.216)" (Rimmer, 1981). This approach is itself derived from the Ideology of the Living-Standards movement in the late 1930s following the Great Depression and the era of unemployment (Lucia, 2010).

2.4.3. Social Enterprise as a Technology Dissemination Tool

Another perspective on the transition to market based approaches which has replaced the giveaway/partially subsided methods as outlined in Bailis et al. (2009), is SE. Programs, projects or interventions that exist in the intersection between business and charity are known as social business or Social Enterprise (SE). SE could, when applied correctly, provide another innovative method of energy technology implementation. The following section outlines SE as a dissemination tool as well as a number of evaluation tools specific to this sector.

Starting at the beginning: The core principles of the SE philosophy are stated

Table 2.3. These are derived from Muhammad Yunus's field tests for micro-loans in rural Bangladesh in the early 1970s (Yunus, 2003). Accompanying these principles are 16 Decisions (Grameen Bank, 2019b) and 10 Indicators (Grameen Bank, 2019a). The 16 Decisions are the core values that every member of Grameen must uphold and range from growing vegetables, educating children, using pit latrines to not inflicting injustice and always being ready to help each other. The 10 indicators show when a family have transitioned from poverty by fulfilling the 10 indices, such as drinking pure water, sources of additional income and the ability to take care of family health, an example of a multi-disciplinary multi-level interventions. Whilst Yunus's work was pioneering, the novelty is debated as the American non-profit sector were using non-profit business ventures to "create job opportunities for the disadvantaged, homeless and other at-risk people (p.1)" (Alter, 2002) in the 1970s. These independent cases were the beginnings of the social enterprise movement.

Table 2.3: Core Principles of Social Enterprise (Yunus and Webber, 2017)

Principle Number	Social Business Principle
1	Business objective will be to overcome poverty, or one or more problems (such as education, health, technology access, and environment) which threaten people and society; not profit maximization.
2	Financial and economic sustainability.
3	Investors get back their investment amount only. No dividend is given beyond investment money.
4	When investment amount is paid back, company profit stays with the company for expansion and improvement.
5	Environmentally conscious.
6	Workforce gets market wage with better working conditions.
7	Do it with joy (http://www.grameencreativelab.com/node/21).

Alter (2002) provides a generally accepted definition, "revenue-generating activity founded to create positive social impact while operating with reference to a financial bottom line (p.5)". This is similar to general business principles of understanding customer needs to "subsequently adapt market offerings to gain competitive advantage (p.235)" (Agarwal et al., 2018). In 1996, The Roberts Foundation Homeless Economic Development Fund (1996) defined SE as, "a revenue generating venture founded to create economic opportunities for very low income individuals, while simultaneously operating with reference to the financial bottom-line." In this research, we are looking for principles that differentiate SE from traditional non-profit and profit-making industries. The first differentiating factor is the existence of a double bottom line (Alter, 2002), where social and financial objectives are equally weighted. This concept is further explored by Norman and MacDonald (2004) with the introduction of environmental performance to produce the Triple Bottom Line, echoing AT where environmental, financial and social sustainability are core themes. However, Norman and MacDonald (2004) go on to persuade readers that the Triple Bottom Line is in fact a "good old-fashioned single bottom line plus vague

commitments to social and environmental concern (p.256)" resulting in organisations hiding behind a smokescreen of buzzwords and vague reporting, a concern that is shared by Cornwall and Brock (2005). However, these three values, as outlined by Joshi et al. (2018) and the SDGs (United Nations, 2016), provide the basis for true sustainability.

The result of multiple business objectives allows a greater number of enterprise structures. Alter (2006) summaries these models into, an employer, a customer, a seller, a for-profit subsidiary, a social-purpose business, a non-profit organisation – all the example projects are in high-income countries. This flexibility in structure is reflected by the flexibility in purpose as illustrated by Figure 2.9.

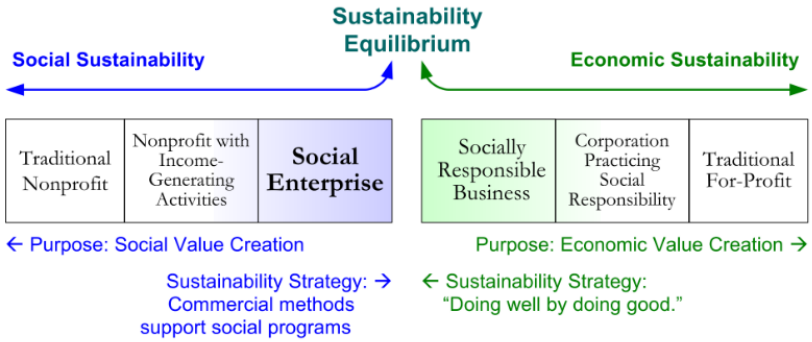


Figure 2.9: Enterprise Orientation & The Hybrid Spectrum (Alter, 2006)

The existence of a large number of structures and purposes highlight the importance of correct ownership structures. Yunus and Webber (2010) divide ownership into Type I and Type II; Type I is a "non-loss, Non-dividend Company devoted to solving a social problem and owned by investors who reinvest all profits into expanding and improving the business" (p.1), Type II is a "profit-making company owned by poor people, either directly or through a trust that is dedicated to a predefined social cause' (p.2). Schumacher (1973) expands on this Type II ownership, using the Scott Bader Commonwealth, the holding company for Scott Bader Co LtD, as an example. The commonwealth was owned by the employees and receive up to 40% of the profits (This was spilt further as 50% bonuses and 50% given to a charitable cause) the remaining 60% was retained for taxation and self-finance (expansion etc.). This model kept management accountable to the employees and ensured that the four tasks (economic, technical, social and political) of the company were of equal importance. The creation of this model allowed innovation whist also retaining structure. Another

key measure of success for the Scott Baker Commonwealth was the equality of all objectives. All objectives were of equal importance and economic gains were not at the expense of social, political or technical gains.

Continuing with the business orientated themes, SE can give clear focus on objectives that traditional non-profit models can lack resulting in instigating an investment mind-set (Alter, 2006). This involves an openness for all types of investment funding from fully philanthropic to fully commercial as outlined by Shortall and Alter (2009). However, this requires the integration of effective monitoring and evaluation tools to be built into core operational processes, currently these systems do not capture the social aspects of SE. Tranfomative Social Innovation Theory (2017) stress the importance of using multiple evaluation methods to capture all of the relevant data, as a single one does not exist. There are two significant formative and evaluative tools for SE, Social Return on Investment (SORI) and the Social Enterprise Balanced Scorecard (SEBS).

SORI is a tool that accounts for the "social, economic and environmental value that results from activities (p.6)" (The SORI Network, 2015) and was developed by the UK Government. This tool is a framework designed to capture in-tangible value in a tangible way by equating outcomes to a prescribed value. This method has been applied in middle and high-income countries. Whilst SORI has an application in low-income countries, the complexity of the reporting limits its use. SORI has two uses, evaluation and forecasting, evaluation uses data captured from activities and forecasting utilises previous research to map future outcomes. The principles of SORI are as follows: involve stakeholders, understand what changes, value the things that matter, only include what is material, do not over-claim, be transparent, verify the result.

Pioneered by Somers (2005), SEBS is based upon a concept for strategic management by Kaplan and Norton (1996) in which they state "building a scorecard can help managers link today's actions with tomorrow's goals (p.2)", similar to the goals of the SORI forecasting tool and Logframes discussed in section 2.3.2. However again, the SEBS tool has been created for a high-income market, the UK, and whilst it does have an application in low/middle-income markets it is a complex tool that relies on a

detailed understanding of the processes involved. The objective of SEBS is to show how an organisation adds value to its stakeholders. This is done by integrating the social goals into all of the organisations' perspectives as seen in Figure 2.10. This transfers the social goals from, traditionally a bottom-line position, to one integrated throughout the organisation's objectives.

Perspective	Social goal	Objectives	Measures	Achievements
Financial sustainability	Minimise eco-footprint	Use corporate buying power to purchase ethically	% of ethical purchases	95% of purchases sourced from ethical suppliers
Stakeholder				
Internal process				
Resources				

Figure 2.10: Balanced Report Card (Somers, 2005)

Lastly, traditional SE has focussed on the creation of micro-enterprises that provide basic needs services in markets that are occupied by state or government organisations, such as banking and healthcare. Bradach (2003) suggests that due to the social nature of the interventions it is difficult to replicate an idea in a different social environment such as a different town or country; reinforcing the importance of context. Gabriel (2015) devises four scaling routes: influence and advise, build a delivery network, form strategic partnerships and grow an organisation to deliver. The routes all share a collaborative nature, however, Gabriel (2015) recognises that "scale isn't appropriate in every case (p.1)a" and some innovators are not willing to collaborate. As AT is not a service, it has the potential to bridge the contextual gaps that are traditional barriers to scale.

2.4.4. The Circular Economy

The Circular Economy (CE) concept is rooted in Life Cycle Analysis, where a product's lifetime impact on the environment is evaluated (Rao, 2007) with the aim of creating a circular pathway for products that ensures the re-utilisation of all components at the end of life. This connects into themes of utilisation, resource management, maintenance and contextual design thinking as identified key to the sustained use of ICS. CE promotes "system innovations that aim to design out waste, increase resource-

efficiency, and achieve a better balance between economy, environment and society (p.1)" (Kristensen and Mosgaard, 2020). CE differs from LCA in a number of ways; first, Life Cycle Analysis is an analytical tool where are CE is a design philosophy. Second, CE considers the social impacts of a product whereas Life Cycle Analysis only considers financial and environmental impacts. The circular economy is measured over three levels; macro (global, national, regional, city), meso (industrial symbiosis, eco-industrial parks), and micro (single firm, product) (Kristensen and Mosgaard, 2020). Figure 2.11 shows a typical circular economy for a plastic bottle, the aim being to minimise or negate any waste materials at the end of the product life.

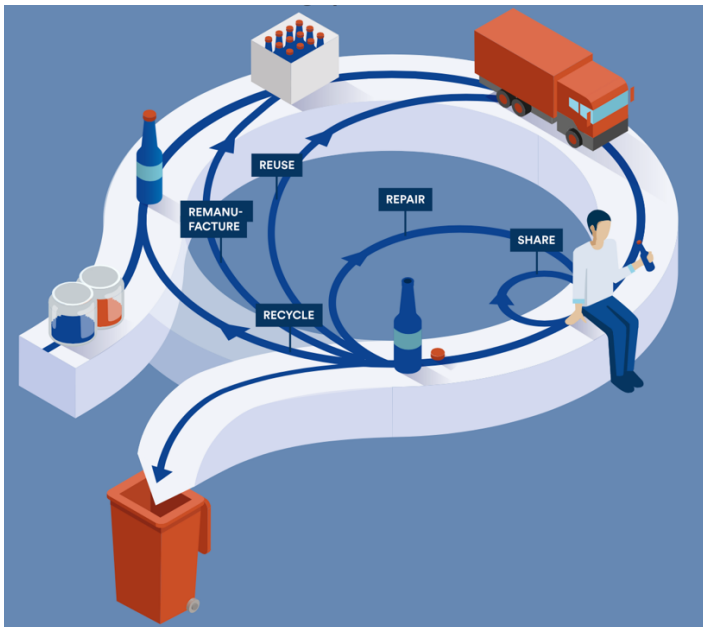


Figure 2.11: The Circular Economy (European Comission, 2016)

2.4.5. Other Market Models

There are a number of smaller and less frequently utilised frameworks contained within the SE and the market orientated literature. This next section summarises these different approaches.

2.5.4.1. Finance

Urban and George (2018) define four metrics to help impact investors and create an empirical model that connects the metrics: Social Impact, Innovativeness of Solution, Expandability/replicability and sustainability.

2.5.4.2. Assessment

Yang et al. (2014) build a performance assessment model for how social enterprises view social value creation. They present it as a questionnaire and weighted the results using an Analytic Network Process with the aim of helping achieve performance benchmarks. Siemens Stiftung (2016) built a SE Self-Assessment tool where the implementation manual headings are: Mission & Vision, Financial Resources, Organisation (structure), Marketing & Sales, Value Chain Integration and Networking, Innovation, Scaling, Risk Management, Ethics & Accountability, Social & Environmental Impact, Impact Assessment. As this is a self-evaluation tool it does not ask what the organisation does in these areas but how it feels it performs. The questions could be modified to provide information rather than feedback. Social Impact measurement for Local Economies (SIMPLE) developed by Social Enterprise London (2019), is a tool similar to SORI and SEBS. It identifies external/internal drivers, mission & values, activities and stakeholders under the 5 stage proves of: SCOPE IT, MAP IT, TRACK IT, TELL IT, EMBED IT. This is not dissimilar to the RRI framework in identifying responsible paths of innovation then acting upon the learned outcomes.

2.5.4.3. Monitoring

Foundation for Social Entrepreneurs (2019) divides monitoring data into three categories, Input indicators (financial, human, technical & intellectual), output indicators (direct outputs the inputs have achieved) and evaluation indicators (outcome indicators[4] and impact indicators[5]). This is represented by the process – Inputs -> [organisational process] -> outputs -> outcomes -> impact – seen in many development orientated project design guides (Red Cross, 2010, COOP Africa, 2010) which will be analysed further in the next section.

2.5.4.4. Communication

Estrella et al. (2000) stress the importance of including of non-verbal communication methods. For example, the SDGs are in pictorial format so that “they can be

[4] short-term differences to beneficiaries.
[5] Intended/unintended medium to long-term differences made to beneficiaries.

understood in the villages, the slums, the places where poor people live and work and fight for their survival (p.144)" (Sachs, 2015).

2.6. Knowledge Gaps & Opportunities

Throughout this chapter a number of strategies for technology implementation have been outlined as well as a number of barriers and enablers for the successful dissemination of ICS, highlighting throughout the social/technical divide in technology implementation. To understand these complex contextual issues the literature identifies a number of barriers and enablers for the adoption and sustained use of ICS. These range from financial barriers, such as willingness to pay, affordability of technologies and access to financial institutions, to socio-cultural barriers, such as stacking of technologies, the historical role of cooking and type of food cooked. This leads to identifying actual causality before building policy frameworks on assumptions which, as Simon and Peterson (2019) state, can create idealised narratives for ICS dissemination. By understanding the range of these factors it dictates what an implementation model would need to capture to, first, address the gap in the literature and second, be effective in theory and practice.

The institutional, international development practitioner and social scientist perspectives have provided a number of design philosophies, top-down research methods and a series of planning tools. Whilst AT, RRI, Logframes, ToC and Results based financing all contain aspects that add value to ICS implementation models, none of these models integrate end-user preferences into the strategic design of interventions or ground the intervention in the wider context. This results in low adoption rates of poverty alleviating technologies as the complex socio-cultural, environmental and economic contextual factors have not been considered. However, the market map model, whilst still being a top-down method, integrates a number of wider contextual issues and provides a starting point for further development.

Whilst ICS implementation models are very limited, the WASH sector has created and adapted a number of BCMs from more general health theories that begin to satisfy these factors by understanding the change mechanisms that influence the adoption and sustained use of WASH technologies. As ICS and WASH share many implementation barriers, ICS can learn from the successes and failures of WASH BCMS

as well as the way in which models such as IBM-WASH categorise behavioural determinants, enabling more direct strategy modifications. These BCMs when considered in the context of the Market Map have the potential to provide more successful approaches to ICS adoption and sustained use.

Finally, SE connects into the discourses as themes, such as ownership, purpose, need and equality coupled with a business orientated approach, provide a novel approach to ICS implementation and when complimented by the other literature cited here 68rovide a non-traditional approach to a traditional problem.

To conclude, whilst there is significant research surrounding the identification of the barriers and enablers to successful implementation, there is limited research on how to translate these barriers into enablers and what roles key stakeholders can play in this process. This results in a lack of definitive implementation models in the ICS sector. Supporting the work of Sesan et al. (2018), there is an opportunity to establish and improve ICS end-user orientated behavioural change models by integrating aspects of IBM-WASH, RE-AIM and other WASH models as well as building on the foundations that social enterprise and appropriate technologies give as technology implementation models. The Market Map model also provides a starting point linking into the ever more market-orientated international development sector.

Chapter Three – Understanding the current market enablers for Nepal's Biomass Cookstove Industry

3.1. Introduction

Reflecting the transition of the global biomass energy sector to more market orientated mechanisms and the inclusion of Social Enterprise in this research, this chapter aims to further understand Nepali biomass ICS sector through the market map tool (Practical Action Consulting and EUEI PDF, 2015). In addition to the importance of this work in the context of the global International Development energy sector, by understanding and generating new insights into the Nepali Biomass Energy sub-sector, the application of the market map will also develop understanding of what is required from a practitioner orientated implementation model. This chapter continues the narrative presented in Chapter Two around determining the complex context factures that influence the adoption and sustained use of biomass ICS in Nepal.

The market map provides an existing internationally recognised framework to aid in understanding the Nepali biomass ICS sector. There are a number of advantages to using this model, first, the market map can be sub-sector specific (Nepal -> Energy -> biomass -> ICS) focusing attention on specific key roles in the value chain whilst also identifying and integrating a number of wider contextual factors into the implementation of poverty alleviating energy technologies. In addition, this application of the market map builds upon work by Stevens et al. (2019) in the East Africa biomass ICS sector as well as having novelty in Nepal and the Nepali Biomass ICS Sector. Focusing on these novel aspects, this chapter provides the basis for a paper published by Development in Practice (Robinson et al., 2021c). The journal paper focuses specifically on the application of the market mapping framework to Nepal's institutional as well as household biomass ICS sectors as well as the use of participatory approaches to co-develop an ICS market map with key stakeholders. This process resulted in the addition of a monitoring and evaluation function to the market map framework which has not been seen in previous market map applications (Stevens et al., 2019). The practical experience of implementing the market map builds the case to satisfy research objective two which looks to create a practitioner orientated energy-technology implementation model.

The integration of the TLUD Project[6], where I designed, manufactured and implemented a novel institutional scale biomass ICS in the Nepali biomass ICS sector between October 2017 & April 2020, allows access to the ICS value chain. This is through manufacturers, distributors, designers, government officials and data from actual end-users about institutional and household cooking needs. Additionally, I integrate my own experience as an ICS designer/distributor in the Nepali biomass ICS sector. Furthermore, there is value in applying the framework to the TLUD project to enable insights for future data collection and understanding of the market map tool. This process also provided an introduction to the practical application of qualitative research methods; a skill that will be of central importance through the rest of this research in understanding lived experiences of ICS users allowing the discovery of complex contextual barriers to energy technology implementation in low-income environments.

The overall aim of this chapter is divided into two parts, first, to understand specific market enablers for, and barriers to, the adoption of both household and institutional biomass-fuelled ICS in Nepal, which results in a better understanding of how to create markets for them. Second, to understand the core mechanisms of the market map tool which enables the creation of a more effective implementation model. My objectives for this chapter were to:

1. explore the effectiveness of market maps designed for East Africa's ICS sector (Stevens et al., 2019) for identifying currently underdeveloped household-scale biomass-fuelled ICS market sections in Nepal that would benefit from market-based interventions.
2. draw on semi-structured interviews and participatory research with a range of key stakeholders to co-develop a revised market map for Nepal's biomass ICS sector.
3. conduct a parallel process for institutional-scale biomass ICSs and integrate this into my co-developed market map.

[6] Further information about the TLUD Project can be found in Chapter One.

4. draw on the co-produced market map to inform policy and regulatory frameworks relating to biomass-fuelled ICS in Nepal
5. identify core elements of the market map tool which can then be taken forwards into the next chapters.

The rest of the chapter is structured as follows: Section two provides additional detail on using the market map to promote ICS and the methodological steps as set out by Practical Action Consulting and EUEI PDF (2015). Section three provides an explanation of the data collection and analysis methodology while Section four sets out phase one of the market map, satisfying research objectives two and three. Sections five and six satisfy research objectives one and four by providing a discussion of phase two of the market map and bringing these results together in the market map conclusions. The final section, Section 7, provides conclusions on the effectiveness of the market map as a tool to understand the complex contextual factors that influence the adoption and sustained use of poverty alleviating energy technologies.

3.2. Market mapping to promote ICS

To help promote the adoption of clean cooking solutions, market assessments have been promoted in East Africa by the Clean Cooking Alliance to better understand barriers to the uptake of clean fuels and stoves and how to create markets for them (Accenture Development Partnerships, 2012). Stevens et al. (2019) applied market mapping techniques to the ICS sector in East Africa to enable market-based comparisons to be made between countries. Building on their approach, this chapter applies Market Mapping techniques to the Nepali biomass ICS market. Whilst this approach shares some similarities with other models (Clean Cooking Alliance, 2011), the market map has two core differences. First, the demand and supply elements are separated with the understanding that demand drives the value chain through various contextual factors (social, financial, economic etc.). Second, the market map focuses on a particular market segment. In this example the focus is on the Biomass ICS sector, not the entire energy sector.

The mapping process is divided into two stages comprising of market system mapping, shown in Figure 2.8 (p.55), followed by the identification and analysis of potential supporting interventions. During market system mapping, energy sector markets are

divided into three levels to facilitate systematic analysis of market gaps, key actors, stakeholders and beneficiaries. The first (middle) level is the market or value chain which contains all the functions and actors associated with a product going to market including development, manufacture, distribution, retail and consumption. Additional weakly defined or poorly linked steps in this process can negatively influence the effective and efficient dissemination of technologies and hinder the overall success of cookstove intervention initiatives. The second (bottom) level contains the inputs, services and finance that connect and support the market chain. Inputs typically include materials or products as well as labour or the manufacturing capability needed to deliver the products. Services include processes that are required for products to be sold and distributed by a number of different actors, public or private. Contained within finance is access to financial institutions such as traditional or community banks which provide loans to enable users to purchase the product. Some elements or actors are responsible for more than one function and together these inputs are of critical importance in the effective working of the market chain. The third level (top) is the enabling environment which is sub-divided into political and regulatory factors, social and cultural factors, and financial and economic factors that influence this market chain. These must all be accounted for in the development of business or market orientated proposals. In the case of ICS, these help to capture how country-specific regulations, standards and policies (including subsidies, quality testing requirements, regulations on the use of particular fuels) along with socio-economic and cultural factors (e.g. affordability relative to existing stoves/fuels or locally-specific cooking practices and preferences) influence demand and affect ICS markets.

3.3. Data Collection & Analysis

The methodology for mapping the Nepali biomass ICS sector was primarily qualitative and involved 31 semi-structured interviews, direct observations and informal interviews with 24 stakeholders in Nepal's ICS sector to explore biomass ICS markets at both household and institutional scales. The focus covered all biomass cookstoves in use in Nepal, including, but not limited to, traditional TSF and both locally produced and imported metallic and mud-based ICS with a range of efficiencies and emissions ratings, in both the institutional and household cookstove markets. In order to understand barriers to the adoption of improved biomass cookstoves, I also explored

the use of other fuel and stove combinations such as LPG, kerosene and electric which were often used (or 'stacked' (Masera et al., 2000)) alongside both unimproved and higher tier biomass stoves to meet users' cooking preferences and requirements.

This primary data was obtained in three main segments to populate the three levels and multiple sub-levels of the market map seen in Figure 2.8 (p.55). The first segment focused on exploring the policy and regulatory frameworks influencing Nepal's household and institutional biomass ICS sectors. In addition to reviewing Nepalese Government policy documents and ICS regulatory frameworks, I conducted seven semi-structured interviews with seven key stakeholders (government policy representative, national cookstove tester, national cookstove design centres, manufactures, distributors and a non-governmental organisation) in the ICS sector and biomass stove value chain to provide the level one segments for constructing the Market Model. This process represented both institutional and household actors as they share the value chain.

The second segment focused on the institutional ICS sector and was informed by a pilot study looking at the design, implementation and evaluation of an Institutional TLUD ICS; the key results of which are presented in a paper submitted to Energy for Sustainable Development (Energy for Sustainable Development, 2020). The pilot study was conducted between October 2017 & April 2020 using a participatory approach in which I co-designed, manufactured and tested a Natural Draft Institutional TLUD Gasifier with the Centre for Rural Development Nepal, according to Nepal's Interim Benchmark for solid biomass cook stoves (NIBC, 2016). Following the testing process, I and Nepali project partners placed 10 TLUDs at a series of institutions comprising dairy farmers, high altitude Buddhist retreat centres, schools and small businesses and collected feedback on longer term performance and sustained use at around three months, one year, and 2 years after first use. This included 24 semi-structured interviews with 11 TLUD users and 6 community members from the area surrounding the pilot sites plus progress updates from the Nepali project partner and research assistants. Whilst the TLUD pilot focused on the institutional ICS sector, all of the pilot sites have access to household-scale biomass ICS enabling user perspectives from the household sector to be noted and integrated into the results. This chapter also draws

on my direct experience of the manufacturing and testing process coupled with data collected through a combination of direct observation, semi-structured interviews and informal discussions with TLUD users and ICS stakeholders (details of which were recorded in a field diary and supported with photographs) to obtain different perspectives on ICS use. These stakeholders included staff at the Centre for Rural Technology, Nepal (CRT/N), Child Reach Nepal (CRN), Kathmandu University, Alternative Energy Promotion Centre (AEPC) and Dhulikhel Hospital Community Department (DHCD).

The third segment involved working with a number of key stakeholders to co-develop an early draft of the market map and identify key barriers to biomass-based ICS development and uptake in Nepal with the aim of reducing bias and grounding the research with stakeholder voices. This involved presenting initial findings from the pilot study and seeking feedback from government officials, staff from international and national non-governmental organisations, private sector representatives and academics from around the globe at the 2019 ICIMOD Indoor Air Pollution Conference in Kathmandu. This feedback was in accordance with the ethical clearance granted in advance of the study by the University of Nottingham. Informed consent was obtained from all participants and the information they gave was anonymised.

The data obtained from the first two segments was analyzed qualitatively employing an inductive theming and coding approach using Nvivo12 (QSR International, 2019) to help identify site-and method-specific themes as well as those present across the different sites and methods. I designed this approach to explore and interpret key barriers to adoption for different technologies in different contexts and enhance understandings of how these were underpinned by prevailing social practice and cultural norms, as well as economic and pragmatic factors (Malakar et al., 2018, Jagadish and Dwivedi, 2018, Jewitt et al., 2020). While a combination of approaches was used to reduce the chance of systematic bias, it is important to acknowledge researcher positionality. I facilitated the production and distribution of the institutional TLUDs as well as well as the monitoring, evaluation and data collection from the pilot study as TLUDs were a novel technology in the Nepalese cookstove market. My relationship with the technology was made clear to users at the start of

the study when visits were made to the pilot sites prior to the dissemination of the TLUDs. I also made efforts during these visits to build trust, encourage transparency and foster an environment in which the users could give honest, open feedback to myself, research assistants or the Nepali project partners. However, I acknowledge a risk of 'social desirability' bias (Sovacool et al., 2018) in the TLUD pilot interviews linked to the my 'outsider' status and involvement in the design of the TLUD (explored further in section 6.2.4 (p.170)). In an effort to reduce this, semi-structured interviews were undertaken in collaboration with either a research assistant (as an interpreter and translator) or an additional researcher who had no previous involvement in the TLUD. To further reduce the potential for bias, I triangulated interview data with direct observation coupled with feedback and photographs from the Nepali project partner and end users. The direct observation was structured to note evidence of the nature and frequency of TLUD use such as general condition, heat from recent use, soot deposits, ash build up and firewood stacks or appropriately sized pots located nearby.

3.4. Phase one: Market System Mapping – Biomass Market Map Development

In order to develop a biomass ICS market map for Nepal that captures the entire biomass energy chain and includes monitoring and evaluation aspects, some adjustments needed to be made to the original market map structure (Practical Action Consulting and EUEI PDF, 2015). These adjustments drew from discussions and interviews with key stakeholders which clarified the nature of Nepal's ICS market chain, the testing process, allocation of ICS subsidies, broader regulatory frameworks governing ICS, key bottlenecks and user priorities. These discussions also highlighted monitoring and evaluation as a key market segment as national organisations routinely bid on tenders for the monitoring and evaluation aspects of government projects. However, I recognise that by adding this additional element it may alter the flexibility of the overall system. Although the household and institutional aspects of the improved biomass cookstove industry are considered separately by the Government of Nepal Alterative Energy Promotion Centre (AEPC), I consider them both in one market map in order to simplify a complex system.

3.4.1. Level 1: The ICS market chain

Both function one (project development) and two (manufacture) can be subdivided into international and national value chain segments with testing and approval processes taking place in both. Participant observation at Renewable Energy Test Service (RETS) indicated that international organisations develop and test their biomass ICSs outside of Nepal and tend not to modify the design to account for local social, cultural and financial factors. Many of these designs are replicated by local manufacturers, the most common of which is a continuous loading single pot rocket type cookstove which makes up 72.3% of Nepal's Government Approved Cookstoves (Renewable Energy Test Station, 2019). This system of replication further exacerbates the lack of contextual design and has a significant impact on sustained use, resulting in complex, expensive and less well adapted ICS (Stanistreet et al., 2014, Malakar et al., 2018, Jagadish and Dwivedi, 2018). For example, in the household sector, the Mimi Moto imported cookstove uses wood pellets which are not widely available in Nepal and costs up to 10,000 Npr (100USD). In the institutional sector the InStove 60 & 100L cookstove has a very high thermal efficiency of 50% but retails at 850USD (InStove, 2016). Although these are technologically advanced tier 4 biomass ICS, their appropriateness in Nepal is questionable.

At the national level, a range of organisations including the Centre for Rural Technology Nepal, Regional Knowledge and Testing Centre, Kathmandu University and other small private engineering firms have developed household and institutional scale biomass ICS, although the number of stoves that they produce is relatively small due to the high cost of developing new cooking technologies (Renewable Energy Test Station, 2019). There are also some hybrid models which involve product design and testing by international research institutes outside Nepal followed by refinements to adapt the product to local needs during manufacture within Nepal; often undertaken by trained technicians from villages in which the initiatives are conducted. These processes are represented by S1, S2 & S3 in Figure 3.1 (p.77)**.**

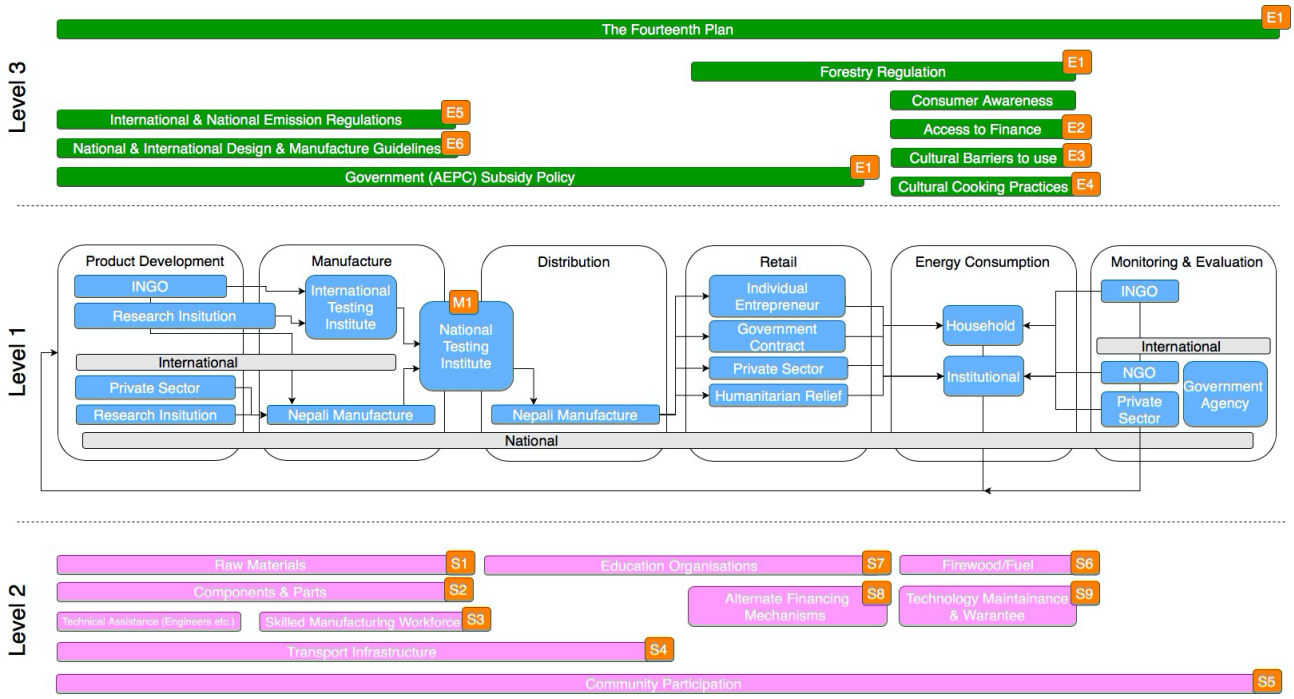


Figure 3.1: Nepal Biomass ICS Modified Market Map & Policy Framework

The methods of manufacture for the household and institutional biomass ICS sector include Nepalese Manufacture with Approved design (NM), International Manufacturer & Imported Product (IM) and Centrally Manufactured and Locally Assembled (CMLA) (Renewable Energy Test Station, 2019). An example of the latter which qualifies under the stove subsidy policy is the Hybrid Mud/Steel type ICS (for both household and institutional use) for which the steel components are manufactured in Kathmandu and the mud elements are built on site by builders pre-approved by AEPC. Regarding international ICS imports, India is the second biggest contributor to the market (44.7%), after Nepal (40.4%), whereas China has an unusually small market share (8.5%) (Renewable Energy Test Station, 2019). This could be due to the lack of road links between China and Nepal which increases the cost of importing alternative energy products from the Chinese market.

The process of government approval for all biomass ICS within Nepal is influenced by the Ministry of Energy, Water Resource and Irrigation (MoEWI - formally known as the Ministry of Population & Environment - MoPE) which sets government policy for strategy periods (E1). This policy is implemented through the AEPC which puts out tenders for new designs to fulfil MoEWI Policy. These include 100% cookstove subsidies for marginalised groups or government tenders for contractors to fulfil the

policy requirement (Ministry of Population and Environment, 2016). New biomass ICS designs are either tested directly through the RETS[7] or at the Regional Testing and Knowledge Centre (RTKC) for AEPC. However, stoves tested at RTKC must still be signed off by RETS (M1) if the model is being promoted under government programs. All submitted ICS designs must comply with Nepalese Government regulations for emissions, materials and safety as set out by MoEWI (E5 & E6), which include being tier 2 or above in the IWA Standards (Ministry of Population & Environment and AEPC, 2016). The National Standards contain information about material used, material thickness, etc. which can restrict cost whilst helping to ensure quality (Ministry of Population & Environment and AEPC, 2016). Significantly, however, for Institutional Cookstoves "larger than 20 kW firepower, the emission testing requirements are optional". There are 47 (at last update of the list) government approved biomass ICS which comply with the National Standards for manufacture and emissions; 45 of which are for household use and only two for institutional use. In addition, there are four biomass household-scale ICS that could be used in institutional settings as they are constructed with mud/stone and can be sized accordingly. The Renewable Energy Subsidy Policy is a key element in the market chain but due to its longevity, it has started to distort users' perceptions of the value of individual ICSs. If an ICS design complies with the policy and is subsequently certified, it is placed on the approved ICS list and made eligible for a subsidy subject to being manufactured using one of the pre-approved companies.

There are a limited number of institutional solutions for specific markets that lie outside of regular policy. The paper making and the milk-based sweet industries (see Figure 3.2 (p.79)) fall into this category and have been developed by AEPC to promote rural entrepreneurship and increase efficiency. One key informant spoke of an improved biomass cooking solution designed for the paper making industry that enabled it to increase productivity by 350%.

[7] The Government of Nepal official testing facility is independent from government but situated geographically very close to the Alternative Energy Promotion Centre (Government department of the Ministry of Energy, Water Resources & Irrigation).

Figure 3.2: Milk Sweet Industry (Left) & Paper Making Industry (Right)

Function 3 (distribution) and 4 (retail) are often undertaken by manufacturers with distribution costs being included in the initial product cost and varying according to the distance from the manufacturer and the accessibility of the destination community. In addition, APEC, after the certification of all stoves, sets the price for specific districts, reflecting distance from the manufacturer, to control uneven prices, keep competition amongst the suppliers and ensure the user gets value for money (Ministry of Population and Environment, 2016). Drawing on the semi-structured interviews, Figure 3.3 (p.81) outlines the methods of distributing ICS to beneficiaries and provides more detail on the connectivity between distribution and retail than it is possible to show on the market map. The first product pathway illustrated in this figure starts from a policy change at the MoPE or through identification of a technology sector which needs development. This involves evaluation/testing of a new technology by RETS and approval by the AEPC followed by the implementation partners collecting the subsidy for the project. Under this product pathway, end-user beneficiaries receive a certified technology which is later evaluated via a household survey conducted yearly by the National Planning Commission (National Planning Commission, 2018). For the manufacturer, the process of claiming the subsidy from AEPC requires the installer to take photographs of the beneficiary, installer, the installed cookstove and the beneficiary's Citizenship ID card. This is to ensure there is only one cookstove present, as the subsidy only covers one cookstove per household.

After all the documentation has been submitted to AEPC and approved, the manufacturer receives the subsidy which effectively requires them to work in negative equity whist waiting for the subsidy payment to be processed. As a means of quality control, the AEPC retains 5% of the subsidy amount for 1 year after installation; releasing it following a satisfactory independent evaluation or retaining it in the event of an unsatisfactory evaluation. Whilst this is a subsidy requirement, in reality retention of the 5% subsidy may not occur.

A second pathway starts with a rural community whose members draw a particular need to the attention of AECP, through a local government official, who reacts by either creating a new policy or tender to be bid on. From this point, the product follows the same pathway as above. A third pathway involves the identification of a community need by a private sector company (or individual entrepreneurs), which develops a technology, seeks approval by AEPC and provides a certified technology (which may or may not receive a subsidy) to beneficiaries. As the subsidy process requires a significant amount of bureaucracy for the manufacturer, in some cases private funding organisations, or more commonly international organisations, prefer to disseminate the technology without applying for a subsidy. The third pathway can therefore involve operating outside of government policy with beneficiaries receiving non-certified technologies direct from the developer/manufacturer. The advantage of this method is speed and simplicity, and it is sometimes used by organisations developing a new technology and building a case for approval through the AEPC.

The role of the AEPC is likely to change in the context of the new government's stance on the de-centralisation and federalism of power. AEPC will act as a facilitator, developing standards and policies, and the local arms (such as RIMREC) will provide the financial aid of the subsidy policy.

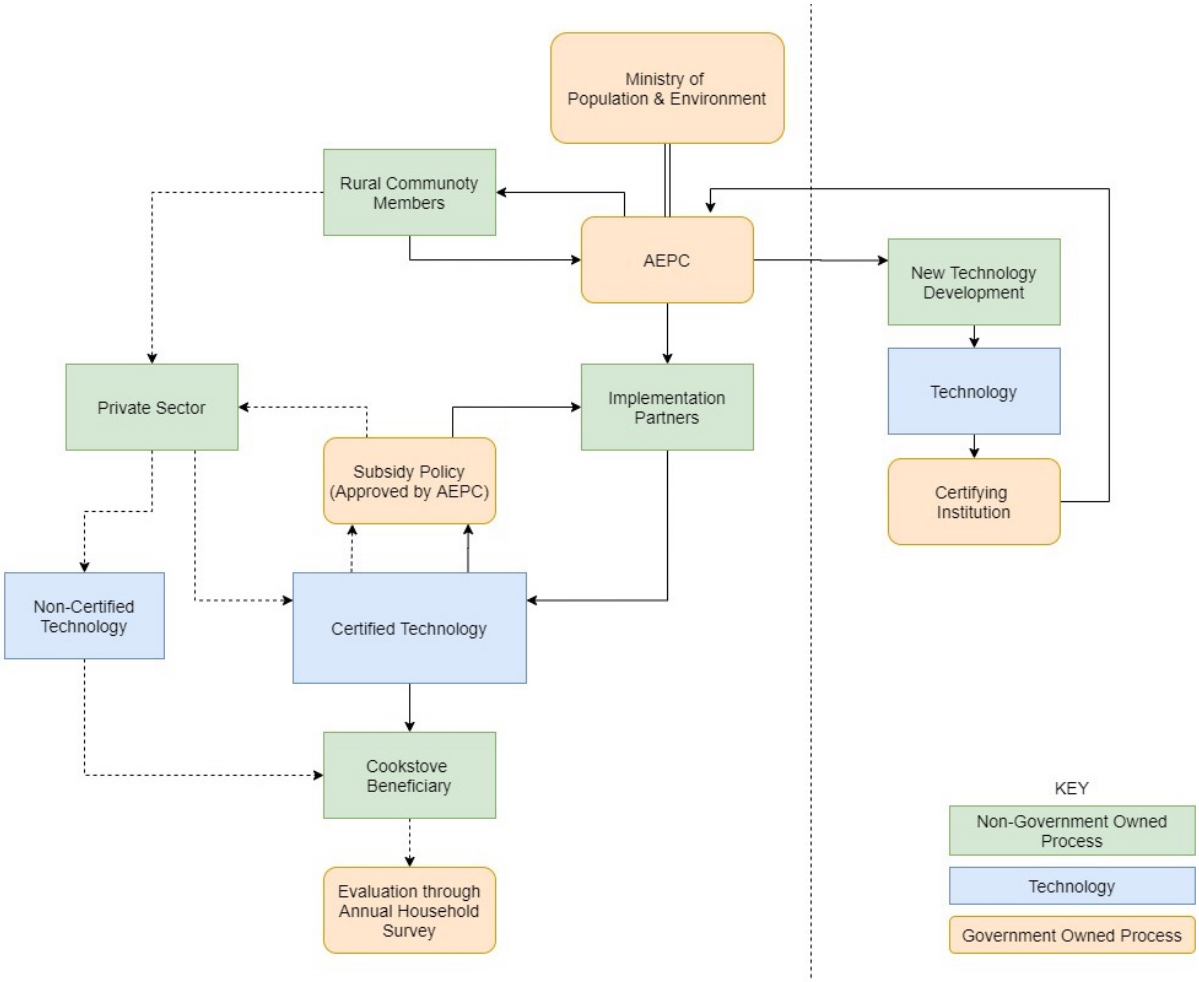


Figure 3.3: Biomass Cookstove Distribution Network

In order for manufacturers to take advantage of the government's Renewable Energy Subsidy policy for biomass ICS, cookstoves have to be produced by certified or formally registered manufacturers using approved designs and installed by an approved installer. The subsidy amount is a pre-determined percentage of the total cookstove cost (Ministry of Population and Environment, 2016) hence if the cost of the ICS increases, so does the monetary value of the subsidy up to a maximum of 50% of the total cost. This is done to ensure the final stove cost covers transport costs. Retailers can also set their own prices and the subsidy will cover a percentage, so if one retailer sets a higher price, the subsidy will rise up to a limit depending on where the user is situated. This means there is an opportunity to make money in the private sector as there are insufficient numbers of retailers to drive costs down through free markets and user choice, although this is slowly being negated by AEPC price limits.

The energy consumption function (5) is sub-divided in accordance with AEPC subsidy policy, where each policy group – hydropower, solar power, solar thermal, biogas, wind energy, hybrid systems or biomass energy – is split into household and institutional sectors. This is to enable tailored subsidy policies, as the cost of these interventions varies greatly. In this study, a household is defined as a non-commercial premises containing less than 10 people as the average Nepalese Household size is 4.5 with poorer households tending to have more (average 5.9) family members compared to 3.5 for the wealthiest group (National Planning Commission, 2018). The institutional category is categorised as anything that is not household and includes SMEs, schools, monasteries, military barracks, farms, etc. Although energy and biomass consumption statistics are not widely available for institutions, observations carried out in 10 rural institutions during the second segment of this study indicated the majority of rural institutions cook with firewood. According to data from the national household survey (National Planning Commission, 2018) most urban institutions use LPG; presumably due the lack of available fire wood for urban institutions and households. There are exceptions, however, as urban schools on average do not cook at all, whilst, as one TLUD pilot showed, some rural schools use a combination of methods which are cost driven. Figure 3.4 shows the 'main fuel used' results of the 2016/17 Annual Household Survey, and the breakdown of consumption by urban/rural location and by economic status. One interesting observation is the lack of electric stoves, despite Nepal's policy on electrification. Reflecting the views of all key stakeholders, the head of biomass projects in the AEPC suggested why this may be the case:

> *"there was a huge problem with load-shedding and also we have an issue with energy security and energy sustainability" (Interviewee 15 (AEPC) - Mar 2019).*

A TLUD pilot member added:

> *"… in my homeland, Dolpa, there is no LPG gas, no electricity, they only have two types of things for cooking, the cow dung and wood. So yearly*

they are cutting lots of wood for making fire" (Interviewee 8 (TLUD Pilot Member) – Mar 2019).

Finally, each year AEPC prequalifies competent companies to take part in the dissemination of ICS through the subsidy channels. In addition, the Rural Technology Producer Association Nepal (RuTPAN) - formed from private companies working in the sector - advocates for the sector and contributes toward the Alternative Energy Promotion Centre (AEPC) subsidy policy and delivery mechanism.

	Firewood	Cow dung	Leaves/ straw/ thatch	Cylinder gas	Bio-gas	Other	Total
Urban/Rural							
Urban	35.4	4.6	1.7	54.1	3.8	0.4	100
Rural	65.8	11.7	3.4	16.5	2.5	0.2	100
Consumption	**Quintile**					0.0	
Poorest	67.2	20.7	8.3	2.2	1.1	0.4	100
Second	71.7	12.6	5.2	7.7	2.8	0.0	100
Third	69.3	8.1	1.9	16.6	3.8	0.4	100
Fourth	49.3	4.8	0.4	41.4	3.7	0.3	100
Richest	19.8	2.0	0.0	74.5	3.3	0.4	100
Nepal	**52.4**	**8.5**	**2.7**	**33.1**	**3.1**	**0.3**	**100**

Figure 3.4: Percentage Distribution of Households by Main Fuel used for Cooking (National Planning Commission, 2018)

Function 6, Monitoring & Evaluation (M&E), is an aspect of the value chain that has not previously been included in market maps. I have included it here as it contributes a significant proportion of the project cost and for some energy sources such as micro-hydro, is required by the Nepalese Government to release funds[8] (Ministry of Population and Environment, 2016). For cookstoves, M&E is only required by the government if the initiative has been partially subsidised, so private sector projects outside of the policy are not required to partake in M&E.

In AEPC tendered projects there are multiple methods of M&E which include an internal review led by the AEPC M&E Team, a review led by an independent M&E Team and a review that is contained in the Subsidy Policy through documentation collected in the Household Survey. Significantly, however, it is unusual for any of these methods to monitor use over time to ascertain whether subsidised ICS remain in use

[8]10% of micro-hydro project fund are held by the AEPC until an independent evaluation (either privately funded or government) confirms the power unit has been built correctly.

a year after dissemination. Another limitation is that the annual household government survey tracks national statistics on *primary* cooking methods, which means that the tendency of households to use multiple cookstoves and fuels simultaneously (Masera et al., 2000) is not captured (National Planning Commission 2018).

3.4.2. Level 2: Inputs, Services & Finance

Raw material costs fluctuate regularly as Nepal relies heavily on imports; especially after the 2015 earthquake. In 2017, iron and steel imports from China and India[9] totalled 950 million USD while exports only accounted for 43 million USD (United Nations Comtrade Database, 2019). The cost of labour is low in Nepal and most biomass ICS manufacturing processes are done by hand which - although less time efficient - does reduce costs. The cost of engineering professionals is also low at both the product design and quality assurance stages with an average Nepalese engineer earning "around 15,000 USD per year" *(Interviewee 14 (cookstove engineer) – Feb 2019).*

As the quality of transport infrastructure varies greatly throughout Nepal (S4), the location of the end user has an important influence on the price of a stove, the total cost of which will reflect transport costs. Transport costs and infrastructure coupled with high fuel and vehicle maintenance costs therefore have a dramatic impact on stove distribution networks and on stove markets more generally as additional transport-related costs can make stoves unaffordable for more remote communities.

3.4.3. Level 3: Political and Regulatory Factors [enabling environment] (E1)

There are two key policies that influence biomass ICS markets: one being the Nepalese Government Renewable Energy Subsidy Policy (Ministry of Population and Environment, 2016) which enables the dissemination of subsidised biomass ICS as outlined in section 3.1 and the other being the Biomass Energy Strategy 2017 (Ministry of Population and Enviroment, 2017). The Biomass Energy Strategy dictates general strategy and outlines a commitment by the Nepalese Government to "focus on biomass energy to fulfil the energy needs on short and medium term" (p.1). Nevertheless, there is a realisation, due to the abundance of hydropower, that the

[9] India accounted for 95% of Nepal's Iron & Steel imports in 2017 (UN Comtrade Database 2019).

"longer term needs [will be] met by electricity reducing the consumption of biomass energy" (p.1) (Ministry of Population and Enviroment, 2017). These goals are echoed in the fourteenth Plan (2016/17) which "aspires to reach additional 9% of population with electricity from solar, hydro (mini and micro) and wind resources. The 14th plan also aims to promote 0.2 million units of biogas digester and 1.065 million units of improved cooking stoves" (p.6) (Alternate Energy Promotion Centre, 2018).

Additional policies promoting alternative energy technologies alongside the overarching government strategy and the Fourteenth Plan (National Planning Commission, 2016) are based around controlling deforestation, promoting forest enterprises, the environment and biodiversity, diversifying energy use through an emphasis on alternative energy (Ministry of Environment, 2006) and the reduction of harmful carbon emissions through the Climate Change Policy 2011.

3.4.4. Social, Cultural & Economic Factors [enabling environment]

Echoing studies elsewhere many users prefer to 'stack' different stove technologies for household cooking purposes according to fuel price, season, type of food being cooked, convenience and broader social practices regarding fuel and stove type (Jewitt et al., 2020, Masera et al., 2000, Jagadish and Dwivedi, 2018, Malakar et al., 2018). TLUD pilot users often had LPG and a traditional three stone fire in their household as well as a larger cookstove for preparing animal feed:

> *"[they use] firewood, they also use gas, They use both. People mostly who have animals still use firewood" (Interviewee 2 (TLUD Pilot Member) – Nov 2017)."*

This often makes it hard to assess the extent to which ICS displace 'traditional' biomass-based cooking systems. Direct observation in rural communities and interviews with ICS stakeholders indicated that the choice of stoves from within different users' cooking system stacks may vary over time or with the occasion for which cooking is taking place. A number of factors influence this decision, including social prestige, convenience and time saving:

> *"There is some social prestige with LPG, like if very important people are coming and if we are using the woodstove then there is smoke in the*

kitchen and that won't be comfortable for them. If their friends are there, their preference will be to cook fast on LPG … They don't want to discard this wood cookstove … their preference will always [be] to use wood as wood is easily available. But, if they have a guest or want fast cooking they would use the LPG." (Interviewee 13 (National ICS design centre) – Feb 2019)

Seasonality also has an important influence on user choice as a traditional three stone fire provides space heating in homes that lack alternative systems for generating warmth:

"It also gets quite cold at night [in the winter] so after the fire goes out the kids stay around the warm coal to make themselves warm"
(Interviewee 1 (TLUD Pilot Member) – Feb 2018).

However negative experiences of using ICS for heating can sometimes have extreme consequences; (Stanistreet et al., 2014, Malakar et al., 2018); especially when recounted by influential community members. As noted by a biomass ICS manufacturer:

"In one project, a woman was using the [biomass] metallic cookstove sitting on the floor. She went to stand up and put her hand on the cookstove and burnt it. She told the community it wasn't safe so the whole community discarded" (Interviewee 13 (National ICS design centre) – Feb 2019)

Some rural stakeholders made strong links between the Indian fuel blockade and 'backsliding' (Jewitt et al., 2020) by former LPG users to traditional open fires as the increase in LPG cost resulted in fuelwood becoming more cost effective:

"LPG is very expensive especially after the blockade it became very difficult as gas was going on the black market … so we had to find an alternative" (Interviewee 1 (TLUD Pilot Member) – Nov 2017).

Not only did this experience influence user choice during the blockade, it continues to influence stacking tendencies by users keeping old technologies in case the blockade

returns. At the same time, the potential to shift to improved household scale biomass-fuelled cooking systems seemed to be hindered by the lack of end-user engagement in the ICS value chain which was linked to the fact that changing an 'approved' design on the basis of user feedback could result in it not qualifying for subsidies without being retested; the cost of which can be up to 400USD. One way around this would be to involve communities in the creation of design parameters. This process was outlined in a key informant interview with the case of the Kathmandu University three pot ICS (KU3); a metallic biomass cookstove designed for use at high altitude for both heating and cooking – ICS1124 on the NIBC Approved Cookstove List (Renewable Energy Test Station, 2019). The community provided feedback on its design and performance following a pilot study which took place before the RETC testing commenced. Using this model more widely could help to address key socio-cultural and economic barriers within the enabling environment.

Finance has also traditionally been a barrier to ICS adoption (Hewitt et al., 2018, The World Bank, 2017) although the emergence of microfinance-schemes coupled with government subsidy programs has potential to overcome this barrier among potential users who want to purchase ICS but cannot afford the cost. This approach tends to be less effective where there are low levels of demand for ICS and/or where potential users are unable/unwilling to pay for them on account of competing financial priorities:

> *"when you do the user survey or [determine] willingness to pay, even for the household cooking they don't value [ICS]. They can buy mobile phones of 10,000 rupees without feeling like, 'okay my money is going' but if you want [the users] to pay 400 or 500 or 1000 rupees for the [biomass] stove then they don't want to." (Interviewee 16 (Microfinance Co-ordinator) – Jun 2019)*

Uptake can also be limited by potential users lacking the confidence to take out loans, not only for biomass ICS but for other business activities:

> *"when they [the community members] started participating in micro-finance, they are very shy in speaking their name […] Now they are asking*

for more money which means they have another type of empowerment, confidence building and [able to] explain themselves..." (Interviewee 16 (Microfinance Co-ordinator) - Jun 2019)

Financial barriers are also affected by potential users' past experiences with other biomass ICS actors such as NGOs, local distributors and local government representatives who have often provided biomass ICS free of charge. Not only can this distort the perceived value of ICS (e.g. when potential users see the same models for different prices) but it can also create an expectation that these products will be free of cost, which reduces their perceived value:

"If you wanted to make a sustainable technology for a rural community there must be some investment of the people." (Interviewee 13 (National ICS design centre) - Feb 2019)

A final theme affecting biomass ICS adoption had intersecting social, cultural and environmental dimensions and was linked to a desire to increase efficiency and time-saving benefits whilst reducing smoke and associated health impacts. This was apparent in the use of an institutional biomass stove for paper-making in a location close to the user's household:

"It is primarily cost driven as well as health also. Since the smoke goes here and there and comes inside [the house], if you have the chimney outlet it will not do this. That is one reason and another reason is time saving, in a week they could only do 1 or 2 burns but with this system they can do it daily. Larger time is being saved with this intervention." (Interviewee 14 (National cookstove tester & manufacturer) – Feb 2019)

However, this increase in frequency of cooking may also increase the volume of fire wood consumed, Nepal et al. (2010) highlight a similar theme when introducing ICS in the household cooking sector.

3.5. Phase two: Identification and Analysis of Potential Supporting Interventions

Stage one of the market map, the market system mapping (RO2&3), identified a series of market gaps and bottlenecks. Stage 2 of the market map which involves addressing

these market gaps with new interventions offers potential to address the cycle of failed biomass cookstove projects in Nepal and beyond (RO1&4). This section draws on interviews and discussions with key stakeholders to outline a series of market gaps and identifies potential supporting interventions to address them.

One of the most significant lessons learned from discussions that fed into the creation of the market map is that in Nepal, institutional cookstoves do not have to comply with national emissions regulations to qualify for the government subsidy so long as the firepower is above 20kW. This low hurdle of official approval reflects an attempt to increase the number of approved institutional solutions, as currently there are limited solutions and funding for institutional biomass ICS resulting in an underdeveloped institutional ICS market. This results in institutions using inefficient solutions that negatively impact community members in terms of household air polution-related health issues and contribute to black carbon emissions (Soneja et al., 2015, Smith et al., 2009). As the only two institutional ICS approved by RETS are rocket stoves with pot skirts to increase heat transfer (Bryden et al., 1997), there are opportunities for supporting interventions around low cost alternatives that outperform existing ICS whilst better meeting the needs of local cooks outlined in the social, cultural and economic factors section of 3.4.4.

The findings of this study also show that Nepal's subsidy program does not discriminate between nationally and internationally manufactured biomass ICS; even though the carbon footprint of both models differs significantly. Likewise, most end-users make no distinction between local or imported biomass ICS, as for them affordability is central to acceptability. Unfortunately, international manufacturers often prioritise combustion efficiency over cost and also fail to take local usability fully into account. This echoes similar research in India as well as West and East Africa (Hewitt et al., 2018, Agbokey et al., 2019, Palit and Bhattacharyya, 2014). A possible short-term solution would be subsidy incentives for local manufactures to reduce their manufacturing costs and increase the production quality, resulting in a biomass ICS able to complete commercially with the imported products.

With the importance of usability reinforced by the interviewees, cost and convenience come next in the list of priorities which often results in Nepalese institutions and

households[10] stacking multiple technologies to meet different cooking needs. For example, in one of the TLUD pilot sites, an open fire is used for rice and boiling water as these are energy intensive and unaffordable with LPG. LPG is preferred for preparing side dishes as it is faster, does not blacken cooking pots and is considered safer. This type of fuel and stove stacking tends to go unrecognised by the government subsidy policy, in part due to the one subsidised ICS per kitchen rule but also because the National Household Survey only captures data on 'main fuel use'. The impact of this is significant not only on the subsidised biomass and electric ICS markets but also on LPG markets as this fuel is excluded from the Renewable Energy Subsidy (Ministry of Population and Environment, 2016). This phenomenon of stacking is not exclusive to Nepal. Ruiz-Mercado and Masera (2015) and Namagembe et al. (2015) observed similar patterns in Mexico and Uganda.

Building on the cookstove stacking issue, the inclusion of monitoring and evaluation aspects of the project life cycle in the market map highlighted that the government closely monitors the distribution of biomass ICS but household surveys do not cover whether they are used exclusively or for an extended time. This causes major issues when biomass ICS become broken or discarded and, as the beneficiary does not qualify for another ICS, there is a tendency for them to 'backslide' to unimproved stoves, as seen in Jewitt et al. (2020). This is a drawback of the complex and overdeveloped nature of government policy which results in a slow and inflexible system requiring extended periods of time to change. An increased focus on tracking multi-dimensional aspects of stove use including the extent of fuel/stove stacking and whether biomass ICS use is sustained over time would increase understanding of the problem and provide evidence for the development of more sustainable solutions.

Another result of this complexity is the absence of local biomass ICS artisans from inclusion in current value chains. Currently, the failure of government and AEPC's subsidy and regulation processes to include the role of artisans significantly increases transport costs as technologies must be manufactured at central approved hubs. By integrating local artisans into the process, transport costs could be captured in the

[10] Institutional and Household cooking practices are generally reflective in practice but different in volume.

manufacturing cost of the product, thus reducing the price for the beneficiary. Local artisans may also have a better sense of locally specific end-user priorities. However, without sufficient training and engagement with end-users, the quality and acceptability of artisan-produced technologies may be low and, due to the higher number of artisans making fewer ICS, more difficult to monitor. Government policy must then encourage local artisans to manufacture high quality products either through financial incentives, by providing preferential access to high quality materials or training on manufacturing methods. This method could be self-regulating by biomass ICS users' choices regarding which ICS to purchase if there was more than one artisan in each community.

3.6. Conclusion

3.6.1. Market Map findings for Nepali Biomass ICS Sector

Unlike in many other countries where biomass cookstoves are largely ignored by governments (Stevens et al., 2019), Nepal has a government policy in place to promote biomass stove technologies and has produced significant numbers of cooking interventions for the household market. Its subsidy policies have been largely successful in both creating and sustaining a market which fosters alternative energy projects and the dissemination of household scale biomass ICS. The interviews also indicated that the government is willing to modify the subsidy policy to support specific institutional-scale ICS projects such as the milk sweet or paper making stoves. This implies there is scope for new policy that promotes institutional-scale technologies whilst improving cooking efficiency in settings such as schools, monasteries and small businesses. This policy could either be separate to the Renewable Energy Subsidy Policy or integrated as part of the biomass energy sub-section.

This chapter also shows how market maps can be a useful tool for highlighting key barriers to the uptake of biomass-fuelled and other ICS; especially in terms of identifying bottlenecks and complexities within the policy and regulatory framework. I highlight the need for a multi-scale, multi-institutional approach to better understand the needs of biomass ICS end-users. However, more exploration of the social, cultural and financial factors is needed as well as how these factors interact

with the difference key stakeholders in the value chain. In the case of Nepal, approaches include regulations in place for subsidy collection, multiple ministries working in similar industries and over-regulation of a market that fulfils a core need. The addition of a monitoring and evaluation element to the market map framework is particularly valuable for capturing the biomass-fuelled ICS lifecycle and also has potential to facilitate product improvements through the integration of end-user feedback. The monitoring and evaluation element also has scope to encourage more nuanced understandings of how success is measured in relation to promoting improved biomass stove adoption. Currently, Nepal's national cookstove statistics are measured by implementation (numbers installed) but the claim that "ICS have been installed in 1.3 million households" (Ministry of Population and Enviroment, 2017) is somewhat misleading in that it provides no indication of whether these ICS continue to be used. Such statistics also fail to reveal if improved biomass ICS have replaced existing stoves as the primary cooking system (rather than acting as additional stoves) or whether their use occurs year-round as opposed to seasonally (e.g. for heating purposes).

To address such issues, the National Planning Commission's yearly household surveys should seek information on how various types of subsidised ICS are used as part of wider household fuel and stove stacks during different seasons as this would give a clearer indication of the success of different ICS initiatives in reducing household air polution exposure and promoting transitions to clean cooking solutions.

3.6.2. The Market Map as a tool for mapping the ICS Sector

The market map outlined here provides a useful framework to build comparisons on, as well as to identify broader barriers to biomass ICS uptake, promote inter-country learning, enhance monitoring approaches and integrate end-user feedback into the future development of these stoves through a simple presentation method. However, there are a number of shortcomings of the market map tool that were highlighted during this implementation process.

First, whilst the market map integrates wider contextual factors, end-users' perspective is not integrated, end-users are valued as a customers but not as participants in the market mapping process. This results in a top-down view of value

chain where there is not equal attention given to the demand and supply elements. In addition, efforts to include socio-cultural, financial and environmental factors from the perspective of the practitioner, not the end-user, contribute to this top-down approach. The concept of differing perspectives, not only from the end-user but from other key stakeholders on the value chain is also not considered. When coupled with a lack of structured data collection methodology, the inclusion of qualitative research methods is optional which may result in minimal inclusion of end-users lived experience. Thus, it is the responsibility of the practitioner to give representative views.

Lastly, there is no identification of traditional international development planning elements such as purpose or expectations or the resulting impact of the work or any linking between the inputs, activities, outputs, outcomes and impacts (Bond Project Management Group, 2016) due to the sole reliance on transitional market mechanisms. These market mechanisms to not capture a large segment of rural Nepalis due to financial constrains associated with buying a new cooking technology.

3.6.3. Final Thoughts

Throughout this chapter I have explored the effectiveness of market maps designed for East Africa's ICS sector (Stevens et al., 2019) for identifying currently underdeveloped household-scale biomass-fuelled ICS market sections in Nepal that would benefit from market-based interventions. I have done this by drawing on semi-structured interviews and participatory research with a range of key stakeholders to co-develop a revised market map for Nepal's biomass ICS sector. I also conducted a parallel process for institutional-scale biomass ICS and integrate this into our co-developed market map. This resulted in a number of policy recommendations relating to biomass-fuelled ICS as well as a better understanding of the market map tool enhancing the understanding of the market map tool and specific elements which contribute to the creation of a more effective implementation model.

Chapter Four - The Development of a Theoretical Framework for the Implementation of Energy Technologies in Low-income Contexts

4.1. Introduction

The aim of this chapter is to build upon the experience of implementing the Market Map framework (Practical Action Consulting and EUEI PDF, 2015) and the literature identified in Chapter Two to create a novel theoretical framework that will capture complex contextual factors that have traditionally been seen as barriers to the adoption and sustained use of poverty-alleviating energy technologies. Additionally, this theoretical framework will assist practitioners and policymakers in developing viable mitigation strategies to these barriers – transforming barriers into enablers by outlining step by step process This echoes the three research gaps that Crosby and Noar (2010) suggest when developing new implementation models for sustainable sanitation, where "(1) theory is developed in an evidence-based paradigm rather than a practice-based paradigm, (2) a substantial majority of health behaviour theories exist at the individual level, thereby neglecting contextual realities that shape behaviour, and (3) ''accessibility'' levels of theory to practitioners may be quite low in comparison to the growing demands to prevent disease through expanding health promotion practices (p.259)".

Looking at the evidence-based paradigm, I identified a number of research gaps in Chapter Two including, first, limited integration of end-user preference into existing technology translation models which leads to limited understanding of the complex contextual factors to adoption and sustained use. Second, once the complex contextual factors are identified there is limited research on the translation of these barriers into enablers or into practical applications. Finally, the WASH sector presents a number of behavioural change models that ICS interventions can learn from as there are no BCMs designed specifically for ICS, only cross-sector applications of health and WASH behaviour theories. The novel theoretical framework developed in this chapter satisfies these research gaps by drawing on key themes from the Appropriate Technology & Social Enterprise, Health Theories and WASH BCMs specifically IBM-

WASH, existing development practitioner planning tools and the Market Map Tool. This all contributes to the evidence-based grounding of the novel theoretical framework.

When drawing on the practice-based paradigm, the experience of implementing the market map in the previous chapter showed the importance of understanding the multi-dimensional multi-actor approach to technology implementation which also allowed easy identification of key stakeholders in the value chain (manufacturers, distributors etc.). This approach also highlighted the importance of bringing together a range of data sources (quantitative & qualitative) into one framework. However, there were a number of drawbacks. Whilst the MM useful as a planning tool to help dictate policy, it lacks flexibility and adaptability in more practical settings as there is no focus on reflection or modifying the approach based upon end-user feedback. Next, the MMs market-based approach to poverty-alleviation relies on market mechanisms that do not account for the lowest income populations resulting in metrics rather than values-driven change. This metric/values divide also does not account for the actions needed to the promote a change in behaviours which results in the adoption and sustained use of poverty-alleviating technology. This results in the MM only mapping key stakeholder roles in terms of a segments in the value chain. Lastly, there is no systematic approach or defined methodology to gathering data, which makes direct comparisons of results from different contexts or markets difficult.

This chapter starts by identifying themes, common methodologies and framework structures from Appropriate Technology, Social Enterprise, Health and WASH BCMs, existing development practitioner planning tools and other relevant frameworks identified in the literature review. Next, I build on these themes, methodologies and structures as well as the outcomes from Chapter Three to develop a novel theoretical framework. Additionally, I present the conceptual background on the relevant qualitative methods approaches to data capture, analysis and presentation of results, also highlighting issues associated with ethics, positionality & interviewer bias. This chapter ends linking back to the aims and objectives of the thesis, stating how the framework will satisfy these whilst also identifying any methodological limitations that may impact the effectiveness of the framework. Furthermore this chapter provides

the theoretical underpinning for a paper submitted to Energy Research and Social Science titled "*TIME to Change: Rethinking Energy Access"*.

4.2. Identifying Themes

The theoretical framework developed in this chapter builds upon the implementation of the Market Map framework as well as incorporating themes or factors from other relevant frameworks identified in the literature review. Whilst a number of these frameworks were established outside of the energy sector, each can make a valuable contribution to the underlying theory. For example, IBM-WASH (Dreibelbis et al., 2013) is a behavioural change model focuses on end-users and framework users rooted in water, sanitation and hygiene technology uptake but has useful learnings for SDG7. Concurrently, the SORI evaluation framework (The SORI Network, 2015) enables organisations to quantify intangible outcomes based around wider societal contexts. This method of combining a number of established approaches echoes work by Owen et al. (2013) with the Responsible Research and Innovation framework and Dreibelbis et al. (2013) in developing IBM-WASH. In this section, I identify a number of relevant themes or factors that will contribute to the values, structure and methodology of the novel theoretical framework. These themes are rooted in the Appropriate Technology, Social Enterprise, Health and WASH BCMs, and Development Practitioners planning tool literature.

4.2.1. Themes from Appropriate Technology & Social Enterprise

Building upon analysis presented in the literature review, this section looks to extract a number of central themes common to AT and SE. These values will form the underlying structure of the theoretical framework and accompanying methodology. In Chapter Two, Table 2.2 (p.56) and

Table 2.3 (p.61) present the core principles of AT and SE as defined by Carr (1985) and Yunus and Webber (2017). These are the underlying values that all AT and SE projects, business or interventions must adhere by and thus define the operating procedures for the methodological approach to implementation. I identified five core themes from these principles: ownership, education, utilisation, flexibility and equality.

The first theme is **ownership**, shown in Appropriate Technology Principles (ATP) 2, 5, 6, 8 & 10 and Social Enterprise Principles (SEP) 1, 3 & 4. Through these principles, ownership is defined on a number of levels; societal, organisational, personal and inter-personnel. On a societal level, SEP1 refers to solving "problems which threaten people and society" and SEP3 states investors cannot receive "dividend beyond investment money". SEP1 reflects the multi-scalar nature of poverty alleviation in low-income contexts and recognises the importance of each actor within the multi-level model, of which investors (SEP3) are key. Whist both movements engage with societal issues around ownership, the ATPs are aimed directly at local, materials (ATP2), job creation (ATP3) and the transfer of technical knowledge (ATP5 & 10). However, the SEPs focus on societal transformations around workplace culture (SEP3, 4, 5 & 6) especially in SEP7, "do it with joy". This results in the SEPs influencing other organisations to adopt this workplace strategy[11] rather than the end-user approach of the ATPs directly integrating end-user preference on a technological level. The increased engagement of end-users has the potential to drive interest and lead to outcomes which empower the participants on a personal and inter-personal level, as seen in Dreibelbis et al. (2013). However, as Dickin et al. (2021) state, quantitively measuring empowerment is a complex and difficult process with no standardised approach.

The second theme is **education**. ATP 5, 8 & 10 utilise educational tools to transfer ownership of design to the end-users rather than the Intellectual Property of the product or service being retained by the designers or managers. This transfer of knowledge can empower traditionally low-skilled labourers to act as product innovators (Schumacher, 1973). The ATPs educational theme involves a knowledge

[11] Such as micro-finance members being stakeholders in Grameen Bank YUNUS, M. 2003. *Banker to the Poor: The Story of the Grameen Bank*.

transfer from a traditionally more to a less technically knowledgeable group within an organisation. This differs to the educational stance of the SEPs; SEP1, 5 & 6 look to educate the broader society coming into contact with the SE. Whist these different approaches to education do not correlate to the multi-level approach of behaviour model such as IBM-WASH (Dreibelbis et al., 2013) or the Market Map (Practical Action Consulting and EUEI PDF, 2015), both have multi-level impacts. For example, end-user education can promote more responsible or ethical practices (UNESCO, 2017). Whereas more general educational approaches promote awareness of the chosen area throughout the multi-stakeholder value chain. This difference in approach to the same problem is also reflected in the different technology implementation methods of IBM-WASH and Market Mapping as cited in Chapters Two and Three.

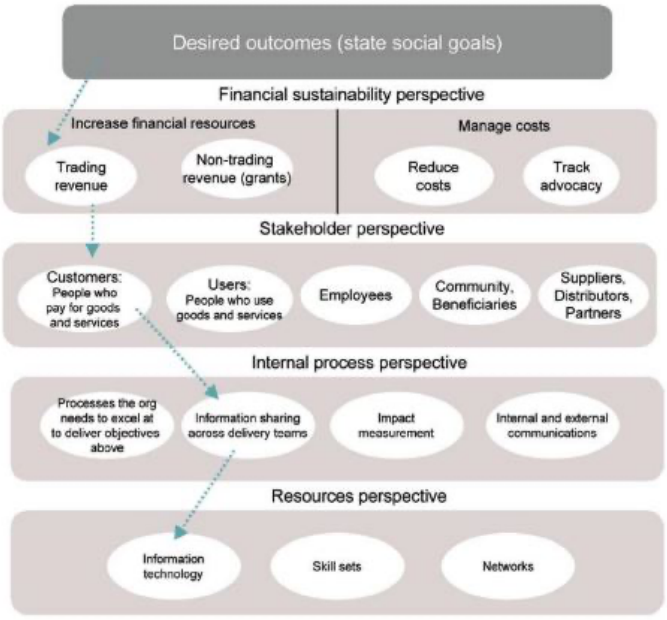
Utilisation is also a key theme in the principles. This is rooted in AT where Schumacher (1973) constantly reinforces the use of local and widely available materials. Similar to the educational theme, the SEP and ATP have differing approaches. ATP 2 & 7 focus on the utilisation of natural and human resources, whilst the SEPs focus on environmentally conscious practices (SEP5) applied to both physical and human resources. This utilisation of natural resources through environmentally sustainable methods is achieved with implementation of technology that either utilises resources more efficiently, or transitions dependence from finite to renewable resources. For example, the transition from a TSF to an ICS. This creation of opportunity in rural areas could alleviate the weight on rapidly urbanising cities, which can result in the "mutual poisoning" of the urban environment, a problem actively discussed in the literature (Schumacher, 1973, Sachs, 2015, Jaquet et al., 2016). AT3 & 6 touch on this issue by using local labour and businesses to manufacture appropriate products. This can occur as appropriate technology products require lower capital costs as no new equipment is needed (utilising existing materials and processes). Following on, the use of existing market or value chains can significantly increase the effectiveness of the dissemination method. Additionally, this is highlighted in the value chain segment of the Market Map framework.

Closely linked with utilisation is **Flexibility or adaptability**. The use of resources, workforce or markets in an environment where technical, social or political change

can result in the destabilisation of an initiative requires creative flexibility and adaptability. ATP9 refers to technical flexibility, ATP6 refers to processes on organisational, personal and societal levels, and ATP8 required an educational flexibility to modify tools to best fit local understanding. This flexibility with regards to context ensures local needs are suitably met. Estrella et al. (2000) suggest this process is difficult and as a result "needs to be integrated as part of project activities (p.151)". Finally, all principles promote the theme of **equality**. From the core objectives (SEP1), to the distribution of profit (SEP4), the use of local systems (ATP2, 3 & 6) and the nature of the activity (SEP7). The SE and AT principles promote inclusive, transparent and equal environments for the implementation of poverty alleviating technologies.

4.2.1.1. Themes from Social Enterprise Tools

SORI and SEBS were identified in the literature review as two enterprise analysis tools which are relevant to the research objectives. Both SORI and SEBS are formative and evaluative tools which map the strategic process, linking inputs, outputs, outcomes and impacts from a number of perspectives (stakeholder, financial, internal process perspective and resource allocation) - Figure 4.1 shows this process for SEBS. One element of the SEBS methodology that can be integrated into the theoretical framework is the multi-level stakeholder approach, similar to the system used in the IBM-WASH framework. Not only does this method capture the direct stakeholders but also the indirect; for example, in an organisation that employs at-risk individuals. The



impact is not only them, but also the employee learning, the family of the employee and the local community. The SEBS also integrates the social goals into every level of the organisation's objectives, creating a culture devoted to the accomplishment of social outcomes.

Figure 4.1: Social Enterprise Balanced Scorecard (with example) (Somers, 2005)

Elements of SORI are also relevant to the theoretical framework. The use of a "net present value" in determining SORI does allow the comparison of an intervention irrespective of capital size. The ability of SORI to effectively grow in scale with its user is an important trait to be reflected in the theoretical framework. But again, the question remains, similar to participatory methods, who does this benefit and who is SORI for? It could be argued that SORI is a tool for the organisation not the stakeholders. On the other hand, clarification of stakeholder views will allow the organisation to more effectively satisfy stakeholder needs. Thus, this tool has the ability to help clarify operational goals in the context of stakeholder views whilst retaining a structure that will satisfy investors or donors.

$$SORI\ Ratio = \frac{Present\ Value}{Value\ of\ Inputs}$$

The supporting SE literature (Alter, 2006, Gopalkrishnan, 2013, Laura Fry, 2008, Kim Alter, 2006) reflects the learnings from the more widely used models.

Whilst the circular economy is not a specific SE tool, it encompasses the values of SE from the perspective of a technology developer. The net carbon neutral life cycle of a product is critical in ensuring the sustainable use of resources. The manufacturing of new poverty-alleviating technologies must take into account socio-cultural, environmental and financial sustainability. This highlights that careful consideration of the impact of using specific resources is needed. The CE also uses a multi-tiered approach across the macro, meso and micro levels. This type of structured approach touches on the hybrid approaches discussed later.

4.2.2. Themes from Research Frameworks

There are four core factors in the RRI framework, Anticipate, Reflect, Engage, Act – these discussed extensively in Chapter Two. RRI provides the research academic with

a tool to shape the intended and unintended consequences of innovation. In this sub-section I shall highlight three themes that are relevant to the theoretical framework for energy-technology implementation. First, the reflective nature of RRI challenges the researcher to be flexible in their approach to innovation as complex contextual issue change thorough both space and time (Jewitt, 2011). Second, the focus on purpose, investigated through the "intended and unintended" consequences, is also key as incorrect assumptions of end-user preferences are a core failure in the ICS literature (Mobaraka et al., 2012). Third, the RRI framework encourages innovations that would not occur in the traditional regulatory environment. However, RRI promotes a top-down method (discussed in section 4.2.4) in which the technology end-users' perspectives are not well integrated.

	Researcher activity
[A]nticipate	*Describe and analyse* intended and unintended impacts (including economic, social, environmental impacts). Think about and imagine possible trajectories: What else might the research lead to?
[R]eflect	*Reflect* on the purposes, motivations and potential impacts (what is known) as well as uncertainties, risks, assumption, areas of ignorance, dilemmas (what is not known). Question existing framings and understand others' framings. Reflection requires openness and leadership and must be institutionally embedded.
[E]ngage	*Open up* 'Anticipate' and Reflect' to a wide range of publics, stakeholders and institutions and debate them in an inclusive way to allow for the re-framing of issues. Engagement needs to be institutionally embedded. Engagement should be held early enough to be constructive but late enough to be meaningful and should be driven by normative (the right thing to do) and substantive (improves nature and trajectory of innovation) motivations.
[A]ct	*Take action* to allow these processes to influence the direction, trajectory and pace of the research and innovation process, responding to a wide range of publics, stakeholders, social needs and societal grand challenges.

Figure 4.2: RRI Framework (Engineering and Physical Sciences Research Council, 2013)

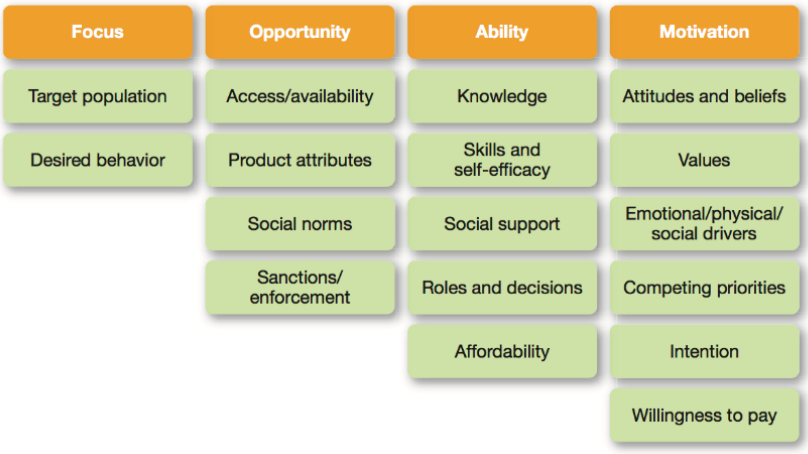
4.2.3. Themes from the Water, Sanitation and Hygiene Behavioural Change Models

The WASH sector shares many of the shortcomings, in terms of low adoption rates of improved technologies, as the energy sector, especially in the ICS sub-sector. Whilst there is limited research on ICS behavioural models, as supported by Rio et al. (2020), WASH has reacted to these low adoption rates by transitioning from hardware to software-based interventions rather than continuing with the same implementation methods and adjusting the purpose as seen in Chapter Two for the ICS sector. This means that there are a number of software-based approaches, which, rather than creating technologically advanced solutions, look to understand and influence the end-user decision making processes to increase adoption and sustained use. In this section, I focus on five WASH frameworks, three of which have been applied to the

ICS sector in their current format, from which I identify a number of themes that will be taken forwards into theoretical framework.

The Behaviour Settings Theory, developed by Barker (1968) in a health setting, and further adapted to WASH by Curtis et al. (2019), states that the setting is the primary driver for behavioural settings as, “All inhabitants of the tavern behaved tavern and all of the inhabitants of the drugstore behaved drugstore (p.2)” meaning that behaviours and settings are synomorphic. However the added complication, as seen by Curtis et al. (2019) when studying routine domestic water use in Nigeria, is that these synomorphic behaviours are unconscious and thus are not captured by qualitative interview methods; “Routine behaviours, though, are generally not governed by knowledge and belief, but by subconscious drivers and by automatic and learnt responses to the immediate social or physical environment in which behaviour occurs (p.1)”. Curtis et al. (2019) highlight the limited understanding of these sub-conscious behavioural drivers as a research gap and divide these into typical and variant behaviours.

SaniFOAM is used to analyze sanitation behaviors, such as ceasing to defecate in the open and building sanitation facilities by categorizing these sanitation behavioral determinants in three categories – “Opportunity: Does the individual have the chance to perform the behavior? Ability: Is the individual capable of performing it? Motivation: Does the individual want to perform it? (p.4)” (Devine, 2009). When these categories are combined with Focus, the framework is complete as shown in Figure 4.3. Devine (2009) also discusses the importance of elevating sanitation in the beneficiaries’ list of priorities; this is echoed throughout the energy and ICS literature.



However, as stated by O'Reilly and Louis (2014) SaniFOAM does not investigate or reflect on these behavioral determinants as they change in both space and time. Jürisoo et al. (2018) use SaniFOAM in an ICS context as part of the Cleaner Cooking Intervention framework determinants section, mapping the end-user journey from hearing about ICS to sustained use, concluding that these factors change during this journey, "the factors that motivate purchase of a new stove do not necessarily lead to its long-term adoption".

Figure 4.3: SaniFOAM Framework (Devine, 2009)

The Integrated Behavioural Model for Water, Sanitation and Hygiene (IBM-WASH) (Dreibelbis et al., 2013) is a matrix style tool which, similar to SaniFOAM, identifies sanitation behavioural determinants in three intersecting categories: contextual, psychosocial and technical. The contextual factor addresses the environmental conditions for technology implementation, similar to the BST, whilst the psychological factor focuses upon behavioural, social, or psychosocial determinants (Dreibelbis et al., 2013). Finally, the technological factor encompasses the specific attributes of the technology as well as the location. However, what differentiates IBM-WASH from SaniFOAM, is the mapping of these behavioural determinants across multiple levels of society: societal/structural, community, interpersonal/household, individual, habitual. This enables not only a multi-scale approach to behavioural determinants, as what is relevant on an individual level may not be relevant to the societal level, but also how these levels interact. For example, what is the impact of a societal level change on the individual level? As discussed by Dreibelbis et al. (2013) these five levels reflect the previous eight multi-level WASH behavioural change models which are all derived from more general health theories (Health Belief Model (Becker et al., 1974), the Hygiene Improvement Framework (Environmental Health Project, 2004), Jenkins Adoption Model (Jenkins and Scott, 2007), the SaniFOAM Framework (Devine, 2009), Communication Model (Figueroa and Kincaid, 2010) and general wash models (Curtis et al., 2011, Mosler, 2012, Wood et al., 2012)) identified in their research.

Table 4.1: What do the IBM-WASH Levels Include? (Dreibelbis et al., 2013)

Level	What's Included?
Societal/Structural	Broad organisational, institutional, or cultural factors which includes laws, policies, climate, geography, geology, and manufacturing and commercial distribution of products
Community	The physical and social environment in which individuals are nested, as well as the formal and informal institutions that shape individual experiences
Interpersonal/Household	Interactions between individuals and the people they intimately associate with (household members, close friends and neighbours), also roles and responsibilities in the household, household wealth, injunctive and descriptive norms, aspirations, shame, sharing access to a product, and behavioural modelling
Individual	Sociodemographic factors (age and gender, individual cognitive factors, and attitudes toward the product, hardware, or behaviour)
Habitual (nested within the individual)	Factors related to habit formation

IBM-WASH has been applied in both the WASH (Hulland et al., 2013) and ICS sectors (Rhodes et al., 2014). Hulland et al. (2013) utilise the methodological approach of the framework to guide their research and identify key behavioural determinants that influence the uptake and sustained use of a hand-washing station. Rhodes et al. (2014) apply the framework as a data analysis tool to contextualise results. They justify using IBM-WASH as "similar to water and sanitation interventions, improved cookstoves are household-based technological interventions that attempt to modify and/or replace existing behaviours and practices (p.10314)".

Next, developed by Glasgow et al. (1999) to evaluate the impact of health interventions RE-AIM has seen significant use and is defined in Table 4.2. In 2019 there were 120 RE-AIM publications across a number of sectors (RE-AIM, 2020). We shall focus on two relevant to energy, Quinn et al. (2018) and Clemens et al. (2018).

Table 4.2: RE-AIM Framework (Glasgow et al., 1999)

Dimension[a]	Level
Reach (proportion of the target population that participated in the intervention)	Individual
Efficacy (success rate if implemented as in guidelines; defined as positive outcomes minus negative outcomes)	Individual
Adoption (proportion of settings, practices, and plans that will adopt this intervention)	Organization
Implementation (extent to which the intervention is implemented as intended in the real world)	Organization
Maintenance (extent to which a program is sustained over time)	Individual and organization

[a]The product of the 5 dimensions is the public health impact score (population-based effect).

Quinn et al. (2018) use RE-AIM to coordinate and evaluate case studies related to scaling opportunities for clean household energy cooking solutions. Whilst the framework allows the authors to easily evaluate past interventions, it does not encourage the integration of end-user preferences into this process. As this study was evaluating a number of publications rather than the interventions in the field, no user-end preferences were directly considered. In contrast, Clemens et al. (2018) used the RE-AIM structure combined with "literature, internal documents, primary data from user surveys and interviews with sector stakeholders (p.23)" to analyse the success and viability of the Africa Biogas Partnership Program.

Finally, the Domestication Framework, as discussed by Gaybor (2019), contained a number of concepts surrounding technology implementation that are important to the development of the theoretical framework. First, technologies and users co-shape each other as the technology can shape the users' interactions with it and also the way in which the end-user utilises the technology shapes what it means to them - its identity. This evolution of use, acquiring of identity and the role of the relationship between end-user and technology is a concept not directly considered in the other frameworks. The domestication framework also highlights a problem seen throughout the technology implementation literature; people who run projects are not the same people using the technology, which leads to a basic misunderstanding of user need. "There are other uses and meanings of technologies in addition to those for which they were designed – ones that are assigned by users in the process of integrating them into their everyday life (p.112)" (Gaybor, 2019).

To summarise, the key themes that I shall take forward into the theoretical framework include:

Behavioural Settings Theory which highlights the role that setting plays in influencing sub-conscious behavioural decisions. Where handwashing is done has a significant habitual influence on the behaviour, irrespective of the hand washing technology.

SaniFOAM presents a capability-oriented approach, asking does the end-user have the opportunity/ability/motivation to sufficiently change their habitual behavioural patterns. However, the addition of the Focus factor does not have the same end-user integration and lacks sufficient end-user input. In fact, SaniFOAM has hints of a top-down approach to behavioural change. Whilst the end-user preferences are integrated, the implemented technology has already been deemed 'good' for the user group, rather than establishing actual need prior to implementing.

IBM-WASH looks to transcends the individual level (Dreibelbis et al., 2013) by promoting a multi-dimensional approach determining not only how each level plays a role in behavioural change but the effect of these levels interacting. This is achieved through the matrix format, as the causal pathways cannot capture the complex multi-level determinants of behavioural change. IBM-WASH engages more directly with the habitual level of behavioural change not seen in other frameworks. Dreibelbis et al. (2013) also focuses on practitioner accessibility, whilst this approach has its advantages and disadvantages, it does create a simple and adaptable tool for understanding complex issues associated with WASH behaviour change.

The key theme from RE-AIM is its direct engagement with the maintenance dimension, highlighting how programmatic needs evolve over time, however, this maintenance dimension is not directly targeted at the technology. As discussed extensively by Edgerton (2008) the maintenance of technology is a significant cost of sustained use and thus requires programmatic attention.

The Domestication Framework allows consideration of the evolving relationship between end-user and technology. This theme will be considered further in developing the theoretical framework.

Finally, whilst all capture complex contextual factors to different extents, it is the researcher's choice whether to integrate end-user voice and preferences; which may result in the downplaying of end-user voice. Finally, many WASH models focus

singularly on the behavioural determinants of sustained use and adoption. This research looks to echo the approach from IBM-WASH focussing on both the software and hardware elements of an intervention.

4.2.4. Themes from Development Practitioner Frameworks

Logframes and Theory of Change were identified in Chapter Two as two important planning tools which effectively link project cycle process. These models benefit from many years of usage and provide a number of themes that can be applied to this research. Firstly, these frameworks are applied over a number of key project stages using If-then causality to link levels and important factors whilst also identifying assumptions that may have either positive or negative effects on project outcomes. As seen in IBM-WASH, the relationship between levels and factors are important; ToC especially provides a robust method to identify these linkages. Unfortunately, these development practitioner frameworks promote participation but keep core decision processes centralised due to funding constraints. This does not give technology end-users a participatory role in the creation of inputs, activities, outputs, outcomes or impacts.

The Monitoring & Evaluation (M&E) segments of these frameworks are important for capturing the qualitative and quantitative outputs of interventions. The Red Cross (2011) outlines six Key Step for Project M&E, Table 4.3, which give a detailed approach to M&E. This is broadly representative of other quantitative & qualitative standardized M&E frameworks, such as the 8 Principles (Patton, 2016), MERL (Wash Advocates, 2015) and Impact Measurement (UNICEF, 2011). Osorio-Cortes et al. (2013) outline Seven Principles of Systematic M&E Framework; Indirectness of Impact, Depth of Impact, Network-driven Change, Unpredictability, Sensitivity to External Signals, Information Deficit, Sustainability as Adaptability. Themes of participation, cost-effectiveness, the difficulty of quantifying impact, and an improvement of systems feature through all these models. Formative Evaluation (double or triple loop - (Marua et al., 2018)) is a significant contributor to development evaluation – examples such as DFIDs ‘test-learn-adapt’ strategy (DFID, 2015b), Practical Action’s ‘Framework For Change’ (Inspire – learn – demonstrate) or DFIDs ‘planning-action-reflection’ (Hamilton et al., 2000).

Table 4.3: Six Key Steps for M&E (Red Cross, 2011)

No.	STEP	More Information
1	Identify the purpose and scope of the M&E system	Results, Process, Compliance, context, beneficiary, financial or organisational monitoring? Which part of the project cycle is being evaluated? Formative, summative, midterm or final evaluations? External or internal, participatory or joint? Real-time or meta evaluations? Thematic or cluster? Baseline or Endline? But this should be all set out in the logframe.
2	Plan for data collection and management	Building on the logframes, define how, when, where? Assess if there is data that already exists to reduce workload. Quant., Qual. or mixed methods. Plan for data management and data protection. Indicator Tracking Table & Risk Log Table.
3	Plan for data analysis	Robust is key (data verification). Where does the responsibility for data analysis lie? Planned vs actual, demographic, geographic and thematic comparison.
4	Plan for information reporting and utilization	Needs/audience, frequency, formats, people responsible. How information is disseminated. How will the reported data be used? Capture in decision, action and lesson learnt log.
5	Plan for M&E human resources and capacity building	How to build capacity in a M&E team, do the output and skills match? Where is the experience and how can it be best utilized. How much participation from beneficiaries?
6	Prepare the M&E budget	Integrate costs into program budget. Plan for cost contingency.

4.2.4.1. Top-Down, Bottom-Up & Hybrid methods

For effective analysis of existing development practitioner planning tools, it is important to understand the background of traditional low-income country Overseas Development Assistance in the form of top-down & bottom-up methods. In top-down approaches the information flow is from high to low-income countries which can lead to “rich people who have very little knowledge of poor people” (p.15) (Easterly, 2006) determining development strategy. Moyo (2009) reinforces this to the extreme, “it has often seemed to me problematic, and even a little embarrassing, that so much of the public debate about Africa’s economic problems should be conducted by non-African white men” (p.iv). Examples of where this approach has failed range from community to national and International scales. Internationally, the introduction of structural adjustment by the International Monetary Fund (IMF) in the 1980s (Stiles, 1999), nationally through the risk of donor dominance (Krantz, 2001) in Oversees Development Assistance. At the smallest scale, Hartley et al. (2019) cite the example of household ICS, where solutions are designed for efficiency rather than usability. The

resulting disconnection from local context has resulted in a growing body of literature around bottom-up development models.

The information flow in bottom-up models is from low to high-income countries, the opposite of traditional donor/beneficiary relationships. This allows greater participation from the key stakeholders in determining the most effective use of resources. Estrella et al. (2000) suggest that the stakeholders are the axis that all else should revolve around when integrating participation into programs, resulting in greater performance based accountability. Symes and Jasser (2000) take this one step further stating, "it is not sufficient simply to use participatory techniques. There must be a commitment to the philosophy of participation at all levels" (p.141). Methods, such as the DFID Payment by Results (DFID, 2015a) system, look to shift towards this outlook. However, if program results are not in line with targets then funding is not released resulting in the retention donor power seen in the top-down models. Accordingly the integration of project design, implementation and evaluation with participatory methods is crucial in program success (Khadha and Vacik, 2012). Conversely, there is an argument that a participatory approach doesn't benefit the stakeholders, it just increases the robustness of data collection for the funder. As an example is ICS programs where success is measured by number of stoves given out in adoption metrics rather than by sustained use as seen in many Clean Cooking Alliance (2011) programs.

Top-down and bottom-up strategies have significant differences, however, there is a space in which they interact. Hybrid methods are less common and look to utilise the fundraising capacity from top-down methods coupled with the identification of complex local social, environmental and financial structures seen in bottom up methods. Sachs (2015) champions this method through adding governance and self-regulation to the three pillars of sustainability across a number of levels framed by the top-down SDGs. This use of multi-level and multi-message strategies is reinforced by Figueroa and Kincaid (2010) stating that one level interventions, such as boiling water to kill germs, does not have the power to change behaviours.

4.3. Developing the Theoretical Framework

Table 4.4 summarises the key themes identified from the literature, this enables clear and concise identification of all themes. To enable the construction of the theoretical framework key words were compiled in

Table 4.5. This information is supplemented by the previous chapters learning from implementing the market map in the Nepali Energy context.

Table 4.4: Framework Themes

Framework/Model Name	Behaviour Outcome or Focus	Themes	Application to Theoretical Framework
		SE & AT Principles	
SE & AT Core Principles	Technological Behavioural Change	**Ownership, Education, Utilisation, Adaptability and Equality**	
		Social Enterprise Tools	
SORI (The SORI Network, 2015)	SE Forecasting and Evaluation Tool	Involve stakeholders, understand what changes, value the things that matter, only include what is material, do not over-claim, be transparent, **verify the result.**	Allows the comparison **irrespective of scale**. Grow in scale with its user. Clarify operational goals in the context of stakeholder views whilst retaining a structure which will satisfy investors or donors.
Social Enterprise Balanced Scorecard (SEBS) (Somers, 2005, Kaplan and Norton, 1996)	SE Evaluation Tool	Levels; Perspective, social goal, objectives, measures, achievements. Factors; financial sustainability, stakeholder, internal process, resources.	**Multi-level** stakeholder approach. Captures **direct and indirect** stakeholders. **Integrates social goals** throughout the organisation's objectives.
The Circular Economy	Life Cycle Management of Technology	Reuse, Recycle, Share, Repair, Remanufacture.	**Circular Design**. Sustainable utilisation of resources on environmental and social levels. **Multi-Level** approach.
Other SE Literature			**Non-verbal communication methods**. Communication **Language.** Orientation of a financial model from an **investor's perspective**.
		Research Frameworks	
Responsible Innovation (Engineering and Physical Sciences Research Council, 2013)	Moral obligation of researcher	Anticipate, Engage, Reflect, Act	The **reflective** nature of RI challenges the user to be flexible in the approach to innovation. Focus on **purpose**, analysed through the "intended and unintended" consequences. **Encourages innovations** that would not occur in the traditional regulatory environment.
		WASH BCMs	
Behaviour Settings Theory (Barker, 1968)	Understanding WASH behaviours	Stage, Infrastructure, Props, Roles, Routines, Competencies, Norms, and Objectives	The importance of **setting.**
SaniFOAM (Devine, 2009)	Analyse Sanitation Behaviours	Focus, Opportunity, Ability, Motivation	Integration of **Focus** as a factor, determining who and why.

IBM-WASH (Dreibelbis et al., 2013)	Adoption of low Demand, high impact Technology	Contextual, Psychosocial, Technological Factors across societal/structural, community, interpersonal/intrahousehold, individual, habitual levels.	**Multi-level**: change occurs if individual, household, community and structural levels are considered equitably. The **matrix format**. The power of **interpersonal connections.** Importance of **local context.** Linked between **maintenance** and sustained use.
RE-AIM (Glasgow et al., 1999)	Evaluating WASH	Reach, Efficacy, Adoption, Implementation, Maintenance	Integration of **maintenance** into sustained use.
Domestication Framework (Gaybor, 2019)	Understand domestication behaviours	Appropriation, Objectification, Incorporation and Conversion	The evolutionary nature of the technology/end-user relationship.
		Development Practitioner Frameworks	
Theory of Change (Stein and Valters, 2012)	Identifying causal links	Input, Activity, Outcome, Impact	Frameworks are applied over a number of key project stages. If-then causality linking inputs with impacts.
LogFrame (Freer and Lemire, 2019)	Project Planning Tool	Levels – Goal, Outcomes, Outputs, Activities. Factors – Objectives, Indicators, Means of Verification, Assumptions	Identification of **underlying assumptions** and importance of M&E
The Market Map (Practical Action Consulting and EUEI PDF, 2015)	Identifying Energy Market Gaps	Levels: value chain, inputs, services and finance (support services), enabling environment.	**Multi-level** and **multi-stakeholder** assessment of markets. Including **"enabling environment"** as a level.

Table 4.5: Themes and Levels from Literature

Identified Key Themes	**Levels**	**Structures** (iteration, cycle)
Encouraging Innovation	Personal/Interpersonal	Reflection
Ownership	Community	Purpose
Utilisation (of local resources – human and environmental)	Contextual	Adaptability
	Institutional	Circular Design
Equality	Governmental	Adoption/Sustained Use
Enabling Environment	Operational Scale	Non-verbal Communication
Maintenance	Monitoring & Evaluation	Methods
Social Goals		
Investors Perspective		
Internal Organisational View (through applying to TLUD project – self-evaluation?) & External Organisational View (through application to GCRF projects?).		
Multi-oriented evaluation.		
Assumptions		

4.3.1. The Theoretical Framework

In this section I present the first version of the theoretical framework in Figure 4.4 which will form the methodology for the first case study discussed in section 4.4.2. Throughout the rest of this section, I shall identify how each element of the theoretical framework relates to the structures and themes identified in the previous sub-sections as well as how it relates to the practical application of the market map. This grounds the novel theoretical framework to the existing literature by building upon the existing systems of energy technology implementation and additionally, introduces my own practical experience of technology implementation.

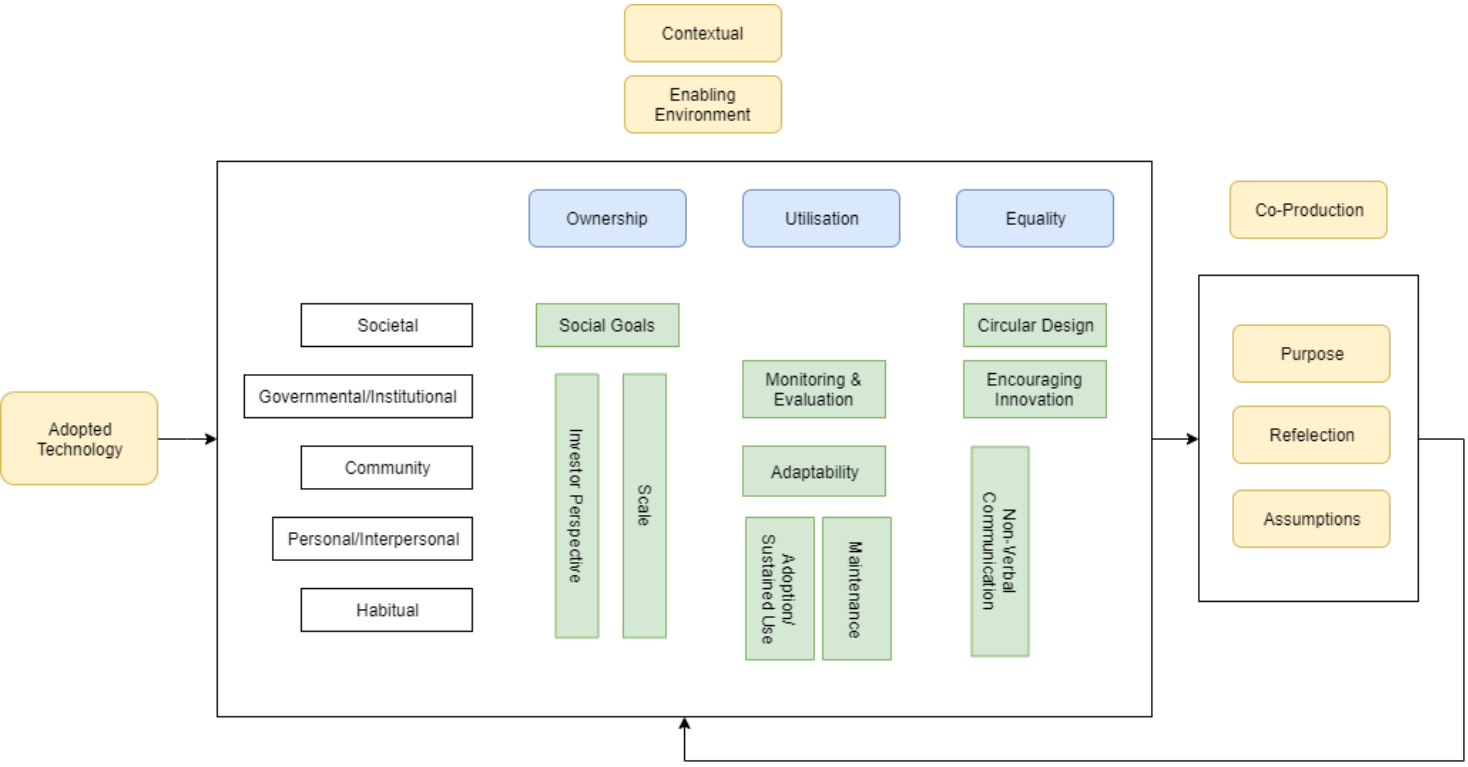


Figure 4.4: The Theoretical Framework

Central to the success of the previous technology implementation models identified in the literature is framework structure. Two traditional framework structures are matrices and causal pathways: matrices allow exploration of complex multi-level relationships (as in IBM-WASH) and causal pathways present linear steps to technology adoption (as in Theory of Change). Matrices are the most common structure in the models analysed throughout this chapter due to their ability to conduct multi-level analysis. Causal pathways are less common as presenting complex contextual relationships between levels and factors is more difficult. Hybrid structures are also less common, for example, the SORI analysis uses a causal pathway for the overall structure of the analysis but uses matrices when considering the individual steps such as the impact map. From a number of framework structure exercises (Figure 4.5) I created a structure that built upon the literature with, theoretically, the capacity to capture complex contextual data. This took the form of a hybrid structure containing two distinct elements, the enabling environment matrix (EEM) and the Strategic Planning Element (SPE). The relationship between these two elements is reflective (or cyclical) as information obtained in the SPE can inform the EEM and vice-versa (similar to the structure of the CE model).

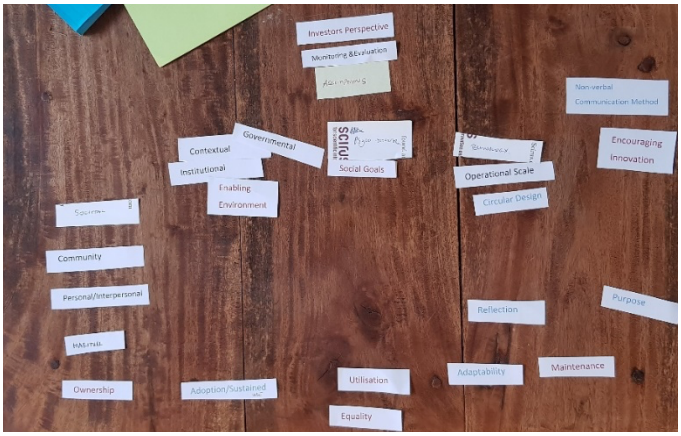


Figure 4.5: Framework Structure Exercises

4.3.1.1. Strategic Planning Element

The SPE takes inspiration from the development practitioner models, SaniFOAM and Domestication Framework in exploring the three sub-factors, purpose, reflections and assumptions from the perspective of the technology end-users. The SPE and central co-production factor translates real end-user needs into reality though the identification and clarification of the three sub-factors and linking these needs to the implementing partners goals. Similar to Logframes, Theory of Change and Results Based Financing, the SPE highlights the importance of including these end-user voices when integrating complex contextual factors into energy technology translation. These three sub factors expand the Focus element of SaniFOAM whilst also reflecting the bottom-up approaches presented in the participatory literature surrounding WASH interventions. As argued by Sesan et al. (2018) end-user priorities must be focussed on rather than implementing benefit-laden technologies. By communicating with technology end-users and understanding what really matters, interventions are designed to directly address user needs – a theme throughout SORI. This, hopefully, results in adoption and sustained use (Ruiz-Mercado et al., 2011) of poverty-alleviating technologies.

Directly related to understanding technology end-user needs is defining the Purpose of implementing the energy technology. As seen in the Chapter Two, the purpose of ICS interventions has evolved over the decades from improving the efficiency of burning wood to health due to the low uptake of these high impact technologies. This leads to ICS end-user confusion due to the lack of coordinated strategy especially

when exposed to multiple organisations with different purposes and a lack of clear communication. These implementing organisations, traditionally based in high-income countries, have the view, 'this technology is good for you' and do not ask, 'what are your needs?'. The disconnect between end-user and the implementing organisations priorities results from assumptions made with little understanding of the complex contextual issues felt by the end-users. Identifying these assumptions (what is known, what is not, prepared for unknown unknowns), such as ICS users only use one type of cookstove as stated in the linear energy ladder model (Masera et al., 2000), then becomes central to the strategic planning process. Assumption and reflection are linked, as in RRI, where researchers are encouraged to reflect and act upon the continual research learning process. The reflection sub-factor also arises from the understanding that no implementation model is perfect, continuous improvement is needed especially given that contextual factors evolve over time (Gaybor, 2019) due to, for example, a changing government renewable energy subsidy policy. The act of reflection can redirect incorrect assumptions or a confusing purpose back to accurately represent end-user needs.

Finally, the co-production lens which shapes the SPE considers not only what the end-user adds but what the other key stakeholders and the implementing organisation can add to the end users. A similar philosophy is found in SEBS, one key stakeholder does not drive the process, it is a collaboration between key stakeholders hence the 'co' element of co-production.

4.3.1.2. The Enabling Environment Matrix

As shown in Figure 4.4 (p.114), the EEM applies three key themes (ownership, utilisation and equality) across the matrix structure, similar to IBM-WASH (Dreibelbis et al., 2013) and the Market Map (Practical Action Consulting and EUEI PDF, 2015). The EEM section expands the enabling environment level of the Market Map, utilising a values-driven approach across the key stakeholder levels. The matrix structure allows analysis of how each level influences the key factors and also the interaction between the levels. These levels may represent societal groups or individual stakeholders depending on how the relevant project aligns with the framework. Whilst the market map assigns enablers to the key stakeholder value chain, it presents

the relationship between these stakeholders as a linear process from designer, manufacturer, distributors to customer, whereas in the theoretical framework all key stakeholder groups interact with each other not only the levels above and below. In terms of end-users this changes the relationship between the technology designers/manufactures from designing the best technology which is then implemented to a reciprocal relationship where the technology is balanced between actual user need and technological progress.

The theoretical framework contains a number of societal groups or levels. Given the success that IBM-WASH as had with its multi-dimensional approach to identifying behavioural determinants, for this first version of the theoretical framework I have utilised the societal groups directly from the matrix. The societal, governmental/institutional, community, personal/interpersonal and habitual levels provide sufficient details for the energy sector as supported by Rhodes et al. (2014). However, given the cyclical relationship between the EEM and SPE these groupings may change as a reaction to the changing relationships between end-user and technology, as seen in the Domestication framework, as well as changing societal needs, policy frameworks and implementing partners seen in the societal and habitual levels.

Whilst the Factors or determinant groups have been derived from the SE and AT literature as concepts key to the adoption and sustained use of technology, the matrix structure takes inspiration from IBM-WASH. However, the focus of the theoretical framework differs slightly. By directly engaging with ownership, utilisation of resources and equality rather than contextual, psychosocial and technical factors, actionable outputs for practitioners are easily implemented after identification of behavioural determinants. For example, the utilisation of existing community skills is central to technology buy in; if this process is not happening it can be easily identified and implemented. A similar argument can be presented around the “motivation, opportunity, and ability to purchase sanitation technology (p.4)” (Devine, 2009) in the SaniFOAM model with the link to actionable outcomes after identifying behavioural determinants.

I define the factors as follows:

Ownership – By considering what motivates a user to change their habits, a model can be designed to give the user ownership over the technology. Ownership is defined as the user buying into the technology through a carefully constructed program promoting sustained use resulting in the user feeling part of the design and/or implementation process (SE).

Utilisation – Utilising local resources, either people or materials. This both reduces the environmental impact of materials traveling large distances but also utilising local systems, such as manufactures, in an effort to; stimulate local micro-economies, employ local people, get user buy-in, facilitate effective maintenance, create local ownership of processes and technologies resulting in sustainability of use. This takes inspiration from the CE and AT, though instead of focusing on a product we are focusing on human centred interventions.

Equality – Financial, Environmental, Social Sustainability are central to the equality of interventions. This factor ensures that co-produced values or the perception of those values (WASH) are equitable and just for all (SE) across the entire project cycle (CE). This stretches from design, implementation, evaluation to the methods of communication in an effort to include all segments encompassed by community living. There will be no discrimination based upon race, caste, language, religion or nationality.

To summarise this sub-section, the theoretical framework is novel in a number of key areas:

- Builds upon concepts from other models to dive deeper into the mechanisms of behavioural change around energy technology adoption and sustained use. For example, the SPE expanding on the Focus element of SaniFOAM and the EEM building upon the enabling environment elements of the Market Map.
- The hybrid structure includes both multi-level and causal approaches that reflect and build upon the knowledge of the practitioner as the complex contextual factors evolve in space and time.
- The introduction of novel behavioural determinant groupings (ownership, utilisation and equality) that have not been explored in the literature before.

- Enables the indented audience (including partitioners and policymakers) to understand how the project fits into societal fabric and is influenced not only by decisions made in the project but outside the project.

4.4. Data Collection & Analysis Methods

In this section I address the qualitative research methods for the data collection, analysis and presentation associated with theoretical framework. This includes some brief background on qualitative methods, identifying the relevant approaches as well as issues associated with ethics, positionality and interviewer bias. The section concludes by summarising the chosen the theoretical framework qualitative methods and an introduction to the first case study.

4.4.1. Theoretical Background to Qualitative Research

Two approaches dominate the academic discourse around research methodology: quantitative and qualitative approaches. Mack et al. (2005) defines qualitative research as having the "ability to provide complex textual descriptions of how people experience a given research issue (p.1)". Reinforcing this view, Kielmann et al. (2012) use qualitative methods to obtain the "experiences […] knowledge and understanding [and] meanings (p.8)" that define an intervention – a more anthropometric approach. There are a number of established qualitative approaches to data collection and analysis: biography, phenomenological study, grounded theory study, ethnographic study and case study. Creswell (1997a) summarises these different approaches as follows:

> "A biographical study is the study of an individual and their experiences as hold to the researcher or found in documents and archival material […] a phenomenological study describes the meaning of the lived experiences for several individuals about a concept or phenomenon, exploring the structures of consciousness in human experiences […] the intent of a grounded theory study is to generate or discover a theory, an abstract analytical schema of a phenomenon, that relates to a particular situation […] ethnographic study is a description and interpretation of a culture or social group or system, typically through participant observation […] a case study is an exploration of a bounded system [by time and place] or case

over time through detailed, in-depth data collection involving multiple sources of information rich in context" (p.49-61).

In contrast to understanding the human experience through the language used, quantitative approaches are based upon identifying trends in large data sets through statistical analysis of surveys or big data gathered from a target demographic (Bryman, 2012). I shall focus on a phenomenological method as the lived experience (Creswell, 1997a) or as Arino et al. (2016) state, exploring the "uniqueness of an individual's lived situation which provides a first-person point of view (p.109)". The meaning behind behavioural decisions are of central importance to integrating complex contextual factors into technology implementation.

Also of central importance to method is the research approach. Bryman (2004) highlights the difference between deductive and inductive approaches to qualitative research in Figure 4.6. Deductive approaches start with a theory on society or the case study and the researcher seeks to prove or disprove the theory, in inductive approaches the theory is shaped by the observations or findings. In this research I have established the central research problem, limited integration of contextual factors into energy technology implementation in low-income contexts but not the solution, which shall be shaped by the findings - this suggests an inductive approach.

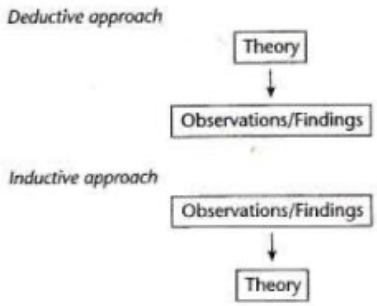


Figure 4.6: Deductive & Inductive Approaches to Data Collection & Analysis (Bryman, 2004)

As Arino et al. (2016) states there are also ontological considerations in terms of positivism and constructivist approaches: "researchers in the positivist tradition emphasize objective descriptions and explanations of reality, and aim at understanding why and how a phenomenon occurs [whereas] researchers in the constructivist tradition emphasize subjective interpretations of reality, and go in search of meaning (and its making), rather than natural law (p.110)". Whilst these two

categorisations are seen as the two extremes of the ontological approaches in reality they represent two ends of a continuum where a combination of approaches can be utilised to suit the researchers' needs (Bryman, 2004). Traditionally quantitative researchers needs are associated with a positivist approach and qualitative approaches are linked to constructivist approaches (Kielmann et al., 2012). As with any research approach, qualitative methods have a number of limitations or criticisms which are important to recognise. Bryman (2012) cites four main areas: the subjective nature of qualitative research, the difficulty of replicating results, problems of generalisation, and a lack of transparency.

4.4.1.1. Data Collection

The three prevalent qualitative data collection techniques are interviews, focus groups and observations. As discussed in Mack et al. (2005) and Kielmann et al. (2012) these tools can be presented in a number of ways, either unstructured, semi-structured or structured as shown in Figure 4.7. The difference between these interview methods is reflected by the open or closed nature of questions or observations (Kielmann et al., 2012). Closed questions generate yes/no responses whereas open questions generate narrative responses. Kielmann et al. (2012) represent this by different phrasing of the same question, "what is your level of education [closed]?" and "tell me about your schooling [open] (p.12)". With this research exploring the contextual factors of technology implementation, an open question approach is key in understanding the context specific perceptions of the participants or technology end-users.

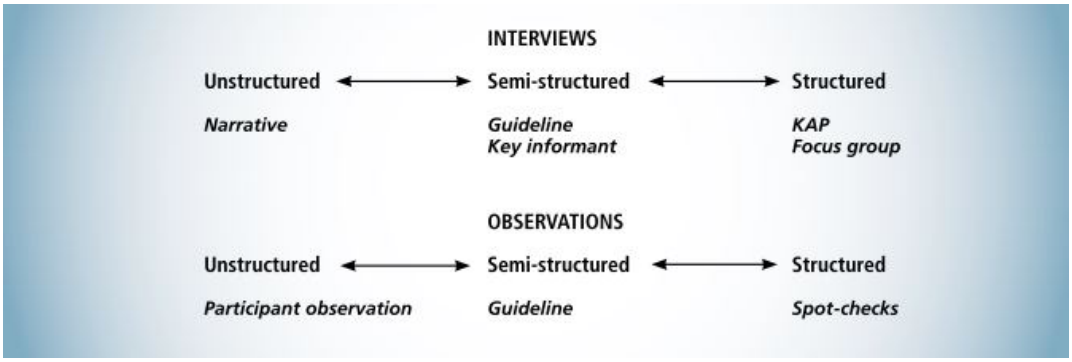


Figure 4.7: Interview & Observation Methods (Kielmann et al., 2012)

In this research, I initially looked to utilise two data collection tools, participant interviews and focus groups[12]. Participant interviews involved interviews with study participants to better understand their lived experience of phenomena and used a semi-structured format which allowed a balance of closed/open-ended questions around a specific topic or theme. A topic guide for these interviews was developed in conjunction with the themes identified earlier in this chapter, however specific semi-structured interview guides were developed for the two specific case studies discussed in section 4.4.2 and presented in Chapters Five and Six. As reinforced by Kielmann et al. (2012), this guide was not a questionnaire and the discussion was led by the participant with the interviewer following up on topics relevant to the specific study. Similarly, the questions contained within the guide did not necessarily follow the order written and the interviewer had to adapt and modify the question order depending on the participant. An important part of the semi-structured interview process was the informal conversations that surround the main interview; with either the technology-end user, family member or other interested community members in geographical proximity. These semi-formal conversations were often less constrained by the pressure of recording or the formality of interviews. However, across all interviews I recognise a gender bias in respondents' participation due to societal structures, for example men who do not cook talking about cooking due to their 'head of household' role, when, an informal conversation with the member of the family who actually cooks may have been far more beneficial. Additionally, the location of conversations are key. This should be either in a private or public place and the space may contain a number of other neighbours, family or community members. The central objective is to make the interviewee comfortable and to create a trusting, open and honest environment for discussion. It is also important to record the location of the conversation.

The second data collection tool which is closely linked to participant interviews is group interviews which, can be used either in conjunction or separate from participant interviews. The combination of these approaches can "increase the reliability and credibility of qualitative data, as research subjects provide comparable and

[12] Additionally observations are introduced in Chapter Six to the data collection methodology.

contrasting responses to the same interview questions (p.109)" (Arino et al., 2016). However, the interviewer must take into account that dominant community members may dictate opinion over more marginalised members. Group Interviews are either conducted with a natural group or focus group, organised by the researcher (Kielmann et al., 2012). In this research, natural group interviews were utilised for groups who do not feel comfortable or relaxed when discussing their energy needs with an 'outsider' in their natural setting (home, community centre etc.).

4.4.1.2. Data Validation

There are two methods of data validation, triangulation and respondent validation. When used as part of the research strategy, triangulation uses of multiple methods of data collection on the same topic to validate the findings. (Kielmann et al., 2012). For example, researchers can combine "observations with interview questions to determine whether they might have misunderstood what they had seen (p.386)" (Bryman, 2012). There are a number of observational techniques (covert, overt, structured, unstructured), I used overt semi-structured observations to validate the data as well as taking a number of contextual photos with the interviewee's permission and in line with the approved ethical guidance. For respondent validation, when possible, we provided the interviewee with the findings from the study and/or interview transcripts to validate the data (Bryman, 2012). This allowed the correlation of participant views with the research findings as it was crucial that the interviewers perception of the interviewees' perspectives was an accurate representation of their views.

4.4.1.3. Ethics

Ethical approval was granted for this research by the University of Nottingham Ethics Committee. The letter of approval can be found in Appendix A (p.219) . Ethical approval was particularly important in this study due to the nature of conversations between the researcher and participants. The Ethical approval ensured that all participants were adequately informed of their rights before the agreeing to take part in the study. This included: knowing the goals of the study and who was funding the work, making an informed decision about whether or not they wish to participate, leaving the study at any time if they do not wish to continue, knowing what would

happen to them during the study and how long it would take, knowing what would happen to the findings, privacy of personal information, know that there will be no payment for participating, to be treated courteously. In addition to this ethics process, each participant was given an information sheet and asked to sign a consent form prior to the interview to confirm that they understood their rights in the interview process.

4.4.2. Theoretical Framework Methods

Section 4.4.1 provides an introduction to the qualitative methods theory which underlines the methodology for the theoretical framework. In this section I shall present the specific methodological steps used for the case studies. For these steps, a purposive sampling method was used (Bryman, 2012) to enable the identification of specific case studies that have a variety of approaches to energy technology implementation. I chose two specific case studies that satisfied different framework development stages. Firstly, GCRF Primary Investigators (PI) who have significant experience in technology implementation for poverty-alleviation and would help in validating the relationship between theory and practice-based paradigms. Secondly, a range of participants from PANs RBF project, run in a number of districts in rural Nepal. This provided a 'live' project where the theoretical framework was used for the first time to evaluate a significant portion of the programming. This section continues to outline the methodology for the first case study, as the data collection and analysis methods will evolve between both case studies due to a development of the framework structure and accompanying methodology. The methodology for the Practical Action Project is presented in Chapter Six.

4.4.2.1. GCRF Primary Investigators Methodology

The five semi-structured PI interviews were conducted between October and December 2019. The participants identified by a systematic review of 882 projects (representing 824,742,658 GBP) based upon a number of inclusion/exclusion criteria contained in detail within the next chapter. These GCRF projects were chosen as there was easy availability of project information, most were based in the UK, and this method of testing required limited resources rather than the resource intensive testing in Nepal. However, the theoretical framework is a multi-stakeholder multi-

dimensional framework and by only interviewing one stakeholder, the primary investigator, only one perspective was presented in the results. Due to this small number of interviews I did not expect to reach theoretical saturation for the data (Bryman, 2012).

The semi-structured interview guide[13] reflected the theoretical framework composition with three sections. The first section gave an introduction and background to this research and its relevance to energy technology implementation models aimed at low-income households. We also discussed the background of the GCRF project. The first question "can you tell me about your GCRF project and your role in it?" was designed to 'break the ice' and allow the PI to feel comfortable talking about their project. However, in a number of interviews this question received long answers that had little relevance to the subject and required careful redirection back to technology implementation. The second section was designed to determine levels/factors from the perspective of the PI and in which of these levels/factors was the GCRF project was most engaged in. I asked direct questions about the societal levels that were engaged and factors or themes which determine the success or failure of their project, as well as what they thought were the most important levels or factors. The final part of this section focused on how these factors were integrated into the project process – a similar line of questioning from a different perspective. The third section cross-referenced the levels/factors identified by the PIs with the levels/factors identified in the literature review process and asked for feedback from the PIs. The interview ended with the PI's being given the opportunity to mention anything else they felt was important or any other questions they had for the interviewer. In addition to the PI interviews which externally evaluated the GCRF projects based upon the theoretical framework, I also applied the theoretical framework as a self-evaluation tool to the GCRF funded Nepal IIC project. This was conducted as a 'self-interview' and enabled the framework to be tested in this regard as well as on a project of significantly smaller capital size.

[13]GCRF Semi-Structured Interview Guide in Appendix B (p.215)

Using the software package Nvivo (QSR International, 2019) and an analysis framework determined by the theoretical framework structure, the interviews were coded into the enabling environment matrix. For example, if the interviewee discussed how to engage the academic community, the quote would be coded as [institutional (level)] and [Ownership (factor)]. This resulted in a matrix of supporting quotes which then provided the basis for modifying the theoretical framework.

Echoing the multi-level analysis approach in Ribeiro et al. (2017) the first level of analysis involved coding the interview transcripts into the analysis framework whilst also modifying the framework to capture any new nodes or sub nodes. Each coding point within the node represents a single project narrative point made by the interviewee. This means that if the interviewee made 5 points about ownership on a community level there will be 5 quotes in the [community, ownership] segment of the theoretical framework. Thus, allowing the researcher to see the distribution of talking points across the theoretical framework. This allows analysis of both what has been discussed, what has not, what is important and where the project focus has been.

Throughout this first analysis level, a number of modifications were made to the analysis framework; a Participation/Engagement sub-node was added as the way in which end-users were engaged was not adequately captured in the existing analysis framework. Utilisation was further divided into human and material resources allowing a better understanding of how resources were utilised locally, nationally and internationally. Institutions was split into a number of sub-nodes (1. Global Academic Community, 2. Government, 3. NGO, Business, Industry, Supply Chain) to allow a more in-depth understanding of what institutions are and what their role is in GCRF projects.

Table 4.6: Interview Analysis Framework before Analysis

	Node	Sub-node
Factors	Co-Production	Assumptions, Expectations (Researcher & User), Purpose, Reflection
	Equality	-
	Ownership	-
	Utilization	Human Resource, Material Resource
Levels	Societal	-
	Community	-
	Habitual	-
	Institutions	Global Academic Community, Government, NGO, Business, Industry, Supply Chain
	Personal, Interpersonal	-
	Other Frameworks	-

The second level of analysis was conducted after all the interviews had been coded. I then considered the interview transcripts from the perspective of the nodes, refining and if needed recoding the data to increase the robustness of the coding process. The refinement included removing any repeated statements, re-coding statements to better fit other factors and levels and checking for coding errors. The results are presented, along with the modifications to the framework and accompanying methodology, in the next chapter.

Whilst this section has set out a detailed operational qualitative methodology that supports the theoretical framework, in reality this process may not be linear. John (2002) discusses quantitative research methods as an incremental solving of the question, one step at a time with a number of blind alleys. This can also be applied to qualitative methods and I recognise that there may be unplanned and unpredictable parts to the data collection and analysis which may lead to novel discoveries throughout the technology implementation process. The flexibility of approach is also echoed by Mack et al. (2005), "qualitative methods are typically more flexible – that is, they allow greater spontaneity and adaptation of the interaction between the researcher and the study participant." In addition to this, whilst this qualitative method has been presented as linear steps, in reality the data collection and analysis

occurred concurrently, allowing for modification of the methods as the study progressed with the quality of data increasing as the process was repeated.

4.5. Conclusions & Limitations

The aim of this chapter was to create a novel theoretical framework from a combination of the theoretical and practical experience gained by implementing the Market Map in the Nepali biomass sector - as outlined by research objective one. As can be seen in sections 4.3 & 4.4, I have created a theoretical framework and defined the accompanying methodology, which is rooted in the qualitative methods literature. Additionally, I took into account the three findings from Crosby and Noar (2010), developing theories from evidence and practice, taking into account contextual realities and making the theory accessible to practitioners.

The literature groups (Appropriate Technology, Social Enterprise, Water, Hygiene and Sanitation Behavioural Models and International Development planning tools) contributed to the core themes of the theoretical framework, which are summarised in Table 4.4 (p.111) and

Table 4.5 (p.113). As well as identifying relevant themes from the literature, I built upon my experience in implementing the Market Map framework for the Nepali biomass market, as discussed in Chapter Three. Implementing the market map in Nepal also acted as contextual research for the application of the theoretical framework in the Chapter Six. This knowledge of the contextual issues faced across a number of key stakeholder groups as well as how to integrate socio-cultural, environmental and financial factors into a framework will remain of central importance going forwards.

The structure of the framework builds upon the hybrid matrix/causal pathway model. There is a causal cyclical relationship between the two main framework elements, the SPE and the EEM. The SPE aligns end-user needs with practitioner goals through three sub-factors: Purpose, Assumptions and Reflection. These take inspiration from the development practitioner planning tools which link project inputs, activities, outcomes and impacts. The EEM expands upon the enabling environment section seen in the market map with structural elements from IBM-WASH and the AT/SE core principles which result in prosperity for all. IBM-WASH contributed the societal levels or key stakeholder groups (societal, governmental/institutional, community, personal/interpersonal and habitual) whilst the AT/SE literature provides the behavioural determinant groups (ownership, utilisation, equality). The theoretical framework has application across formative and evaluative elements energy technology for poverty-alleviation implementation. Moreover, the framework evolves from understanding that alleviating poverty through technological implementation is a multi-dimensional, multi-stakeholder process and thus requires a solution that solves multiple issues simultaneously.

However, as with all research strategies reliant on qualitative methods for the data collection there are a number of limitations, these include: the subjective nature of qualitative research, the difficulty of replicating results, problems of generalisation and a lack of transparency. I have taken a number of steps around ethics, positionality and interviewer bias to mitigate these limitations as much as possible. In addition to the qualitative methods limitations there are also a number of limitations when applying this theoretical framework to real-world situations. Such as, the novelty of

this framework which has not been implemented in a real-world situation – the theory and practice do not often correlate. This framework also relies on the openness of technology-end users/interview participants due to the values, rather than metrics driven nature. This could result in distorted results if there is not an open, honest relationship between interviewer and interviewee. Finally, this theoretical framework builds on a number of concepts from a range of literature sources that are not traditionally combined.

In the next chapter I shall describe the process of conducting a systematic review to identify a number of Global Challenges Research Fund (GCRF) projects that fit the pre-determined energy-technology/poverty-alleviation inclusion criteria. I shall also set out how this first version of the theoretical framework was applied to these projects using the qualitative research methods that have been outlined in this chapter. This will then result in a development of the theoretical framework and the accompanying methodology as well as, hopefully, conformation that the theoretical framework developed in this chapter has significant value to practitioners and policymakers implementing energy-based poverty alleviating technologies.

Chapter Five - Theory in Practice: Applying the Theoretical Framework to Five GCRF Projects

5.1. Introduction

The aim of this chapter is to determine the relationship between theoretical background identified in Chapter Two and GCRF Primary Investigators (PIs) experiences in implementing poverty alleviating technologies to determine if the theoretical framework captures complex contextual factors effectively. In addition, this chapter looks to clarify the mechanisms contained within the theoretical framework for ease of practitioners and policymaker use. The aim falls under research objective two - Evaluate the theoretical framework against existing projects which fit the technology implementation criteria. The four objectives of this chapter are as follows:

1. Conduct a systematic review of GCRF projects and identify five projects which fit the pre-determined inclusion/exclusion criteria.
2. Interview the GCRF PIs using the theoretical framework and accompanying methodology, obtaining feedback on their experiences of technology implementation.
3. In addition, conduct a self-evaluation of the Institutional TLUD Project in Nepal using the theoretical framework.
4. Review the results and modify key factors or structures in the theoretical framework accordingly.

The theoretical framework, developed in Chapter Four, builds upon the social enterprise, appropriate technology, Health and WASH Behavioural Change Models and other International Development planning tools all contributing to the UN SDGs (United Nations, 2016). The SDGs aim to eradicate poverty by 2030 and a number of funds have been established to realise this target. The GCRF supports the SDGs from a research perspective funding “cutting-edge research that addresses the challenges faced by developing countries” (Engineering and Physical Sciences Research Council, 2015). The fund achieves this through three objectives, (1) promote challenge-led disciplinary and interdisciplinary research, (2) strengthen capacity for research both in

the UK and developing countries and (3) provide an agile response to emergencies where there is an urgent research need. GCRF had directly funded 882 projects at a cost of 824,742,658GBP as a part of the UK Government Overseas Development Aid budget at the time of this review in October 2019. The ODA budget represented 0.7% of UK Gross National Income (GNI) according to the target set by SDG17.2. The GCRF projects were diverse in nature and distributed across the globe, as shown in Figure 5.1.

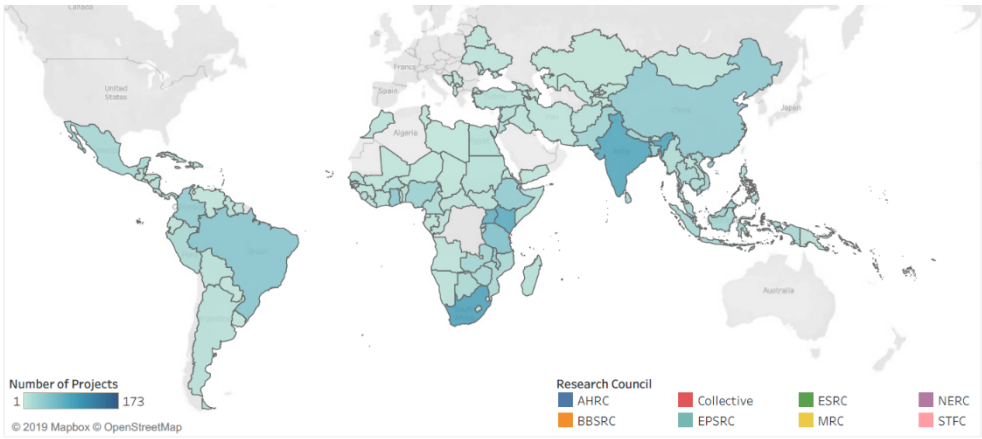


Figure 5.1: Countries of Focus for GCRF (Engineering and Physical Sciences Research Council, 2015)

GCRF has been the leading (UK based) global fund for promoting research that contributes to the SDGs. By integrating a number of these GCRF projects into my research, I could access the eight UK research councils, thus creating opportunities for learning outside of engineering promoting transdisciplinary and multi-sectoral research. In previous chapters I have discussed the need for inter-sectoral/disciplinary learnings. The global nature of funding leads into this transdisciplinary approach by integrating a wide range of contextual values and understandings across multiple countries. By evaluating the theoretical framework against these transdisciplinary projects, I sought look to increase its flexibility, resilience and robustness. GCRF's online platform also allowed easy access to PIs, as well as detailed project outlines, objectives, methods, results and future work. Lastly, in an effort to promote the values of Crosby and Noar (2010), a practical application of the theoretical framework ensured accessibility to both researchers and practitioners as well as developing a theory through a practical evidence base. The version of the theoretical framework used for this chapter is shown in Figure 4.4 (p.114).

The methodology for identifying five relevant GCRF projects was based upon a systematic review. Whilst originating in healthcare, systematic reviews have been used across a number of other sectors (Buck et al., 2017, Kshirsagar and Kalamkar, 2014, Torres-Carrión et al., 2018) as seen in Chapter Two when identifying barriers and enablers for ICS.

The systematic review in this chapter follows a similar methodology to Dreibelbis et al. (2013), Stanistreet et al. (2014) and Rehfuess et al. (2014), whilst building on the theoretical background presented by Khan et al. (2003) and Torres-Carrión et al. (2018). Khan et al. (2003) presents the five steps for conducting a systematic review: Framing questions for a review, identifying relevant work, accessing the quality of studies, summarising the evidence, interpreting the findings. Torres-Carrión et al. (2018) presents a three step methodology, Figure 5.2, which follows similar steps to Khan et al. (2003)

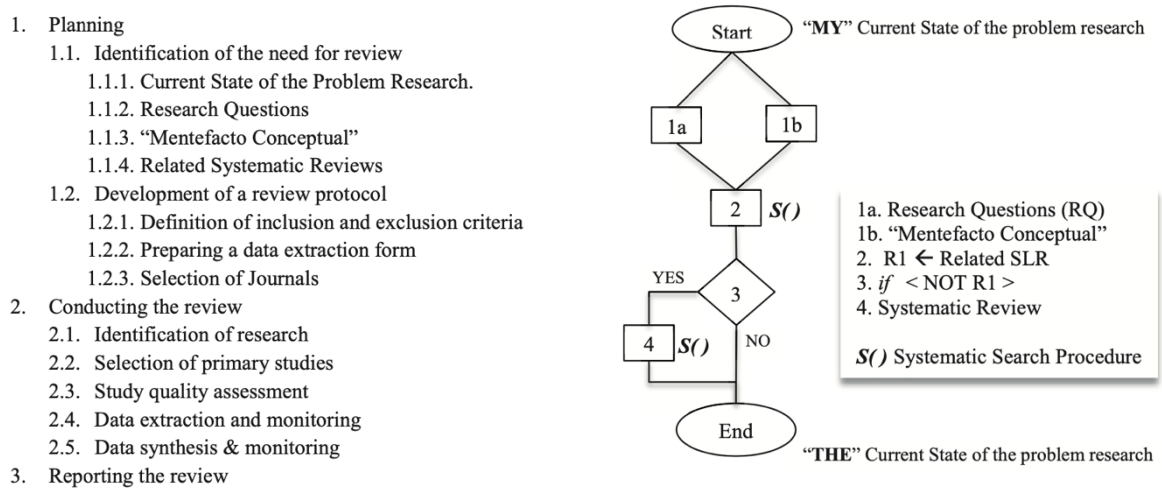


Figure 5.2: Macro procedure of Methodology (Torres-Carrión et al., 2018)

Dreibelbis et al. (2013) created a Behavioural Change Model (BCM) for WASH through the identification and systematic review of articles in PubMed, "through a combination of search terms associated with water, sanitation, and hygiene practices, with terms related to conceptual frameworks and models, and with names of key behaviour change theories and popular determinants referenced in existing water and sanitation research (p.2)". This search, considering terms relating to BCMs and constructs and terms related to WASH, was conducted through the full citation

information[14]. Grey literature from global health organisations was also considered. In terms of the GCRF project all the projects are retained in the grey literature space. Stanistreet et al. (2014) identify factions influencing uptake of ICS in low and middle income countries. Stanistreet et al. (2014) determine inclusion/exclusion factors dealing with initiative scale, use (household, commercial, institutional), adoption and sustained use and special distribution (urban or rural). The search terms were based around Intervention and uptake with studies "subsequently allocated to either the qualitative, quantitative or case study categories as appropriate (p.8231)". Unlike Dreibelbis et al. (2013), Stanistreet et al. (2014) identify time criteria (1980 – 2012) and screen the literature for quality appraisal. This methodological quality assessment was completed using 11 established criteria from Harden et al. (2009). Rehfuess et al. (2014) undertake a systematic review of barriers to large scale uptake of ICS using a similar method to Stanistreet et al. (2014) with search terms of interventions AND uptake. Rehfuess et al. (2014) also categorises literature into qualitative and quantitative approaches. The method from these three reviews, as well as the steps presented by Khan et al. (2003) and Torres-Carrión et al. (2018) formed the foundation for the GCRF systematic review in line with the objectives for this chapter.

Once the systematic review identified the relevant projects, the next step was to apply the theoretical framework methodology presented in Chapter Four to the five GCRF Projects, this includes: Semi-structured Interviews, data collection, analysis and presentation. The interviews with these five PIs resulted in further clarification and understanding of the mechanisms contained within the theoretical framework, whilst also either reinforcing of modifying the factors and levels contained within the framework. Further to increasing understanding of the framework itself (which resulted in a number of structural and methodological modifications), this framework application explored how the framework interacts with early, mid and late-stage research projects.

The structure of this chapter reflects the methodological steps outlines above; first, the aims of this review are identified. Second, the inclusion/exclusion criteria were

[14] Title, Abstract, Publication Date and Journal name.

applied to the 882 GCRF projects, based upon, technology, social orientation, SDG goals alignment, funding and suitability to the theoretical framework principles. All GCRF projects use a standardised template for funding calls, providing easy identification of inclusion/exclusion factors. The final 5 projects were then reviewed, key learnings identified, and primary investigators contacted. Section 5.3 presents the theoretical framework methodology and Section 5.4 presents the results of the semi-structured interviews and self-evaluation. Section 5.5 modifies the theoretical frameworks structure and methodology based upon the findings of previous chapters. Finally, Section 5.6 summaries the results.

5.2. Systematic Review: Inclusion/Exclusion Criteria

There are 882 GCRF projects on the online database[15]. All projects are post 2013 which means that they should integrate the RRI Framework (Engineering and Physical Sciences Research Council, 2013) into the project proposal and implementation methods. Given the theoretical framework has connecting roots to RRI there should be correlation between the theoretical framework and the project methodologies. The systematic review followed the following process.

Projects were immediately discarded if there was **zero award pounds.** The next selection criterion excluded **projects that did not align to SDG7** and its five sub goals. This resulted in 31 projects remaining. This means that 3.5% of GCRF projects had a focus on sustainable energy technologies and services. SDG7 as a percentage of the other 17 goals represented 5.9%. When considering budget, SDG7 aligned projects represented 4.48% of budget – a significant underrepresentation in both categories. In line with the theoretical framework, the search criteria were **Technology AND/OR Enterprise**[16] resulting in 13 remaining projects. Of these final 13 all were awarded as research grants by ESRC, EPSRC, NERC, BBSRC and AHRC at a value of £55,753 - £6,880,123 over a duration of 11 – 50 months with two of the projects closed and ten active. This represents a diversity of both size and duration. The aim was to reduce this number to 5 due to the initially limited number of projects that fit the selection

[15] All GCRF Projects - https://gtr.ukri.org/resources/classificationprojects.html?id=D640D1B8-B141-4DFC-BCD3-CEADD848A918&type=RCUK_Programme&text=GCRF#/csvConfirm

[16] Based upon the Appropriate Technology and Social Enterprise core principles outlined in Chapter Two.

critical and the limited amount time available to conduct interviews and analyse data. A detailed analysis of the published project overview, organisations, people, publications and outcomes led to the following conclusions:

- AH/S005897/1 was excluded as it focused on media based urban development, which was outside of the scope for theoretical framework.
- Duplicates were identified and discarded. For example, five projects considering electrical generation, distribution or connectivity (NE/S01344X/1, EP/P028829/1, EP/P032591/1, EP/R030243/1) were discarded.
- EP/R030294/1 considered development of techno-economic framework about policy and regulation at a government level and ES/S000941/1 created small-scale business models to increase energy access, both relevant projects.
- ES/P002617/1 and BB/S011439/1 both considered biomass energy generation; however, ES/P002617/1 reflected the government policy perspective as seen in EP/R030294/1 and was thus discarded.
- Two projects considered technology for safe drinking water. EP/P032427/1 aimed to develop low-cost technologies in collaboration with in-country NGO and, EP/P027571/1 applied the Integrated Participatory Technology Development (iPTD) to developing a water monitoring technology. The latter project had a larger scope for community participation thus EP/P032427/1 was excluded.
- ES/P005047/1 was an exercise in data collection for energy usage in forced displacement camps and as also excluded.

A graphical representation of this process is illustrated in Figure 5.3 with the project overviews contained in Table 5.1.

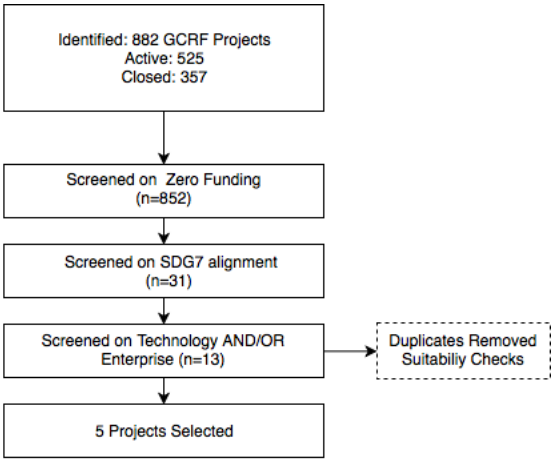


Figure 5.3: Project Selection Flowchart

Table 5.1: GCRF Projects post Systematic Review (all active)

Funding Org Name	No.	Title	Start Date	Duration (Months)	Award Pounds	Region
BBSRC	1	Bioenergy, Fertiliser and Clean Water from Invasive Aquatic Macrophytes	31/01/2019	35	1.71M	SSA
EPSRC	2	Sensors for clean water: a participatory approach for technology innovation	01/05/2017	35	1.18M	Oceania
NERC	3	Implementing innovative technology to tackle barriers in utilising human waste derived fertilisers in Sub Saharan African agriculture	01/11/2017	23	101K	SSA
EPSRC	4	TERSE: Techno-Economic framework for Resilient and Sustainable Electrification	01/05/2018	35	1.02M	East Asia
ESRC	5	Innovation and Scale: Enhanced energy access and local market development in sub-Saharan Africa	01/09/2018	17	677K	SSA

To show how these projects could help develop the theoretical framework, a deeper understanding of the characteristics of the selected projects was required. The next step was to extract the Inputs, Activities, Outputs, Outcomes and Impacts (IAOOI) from the standardised GCFR forms and development literature (Red Cross, 2010). This method of categorisation also shared a resemblance to the impact map section of SORI (The SORI Network, 2015) as well as logframes (Freer and Lemire, 2019) and simple Theory of Change (Valters, 2014) methods. The international development industry use IAOOI to simply map interventions with linear causality (p.51) (DFID, 2012). The limitations of this method are discussed in detail in Chapter Two. At this stage of analysis, the nuances of complex social structures could be overlooked as only a high-level understanding was needed, the results are shown in Table 5.2.

Table 5.2: IAOOI Analysis of Selected Projects

No.	Inputs	Activities	Output	Outcome	Impact
1	Water hyacinth, nutrient rich waste, immobilised microbial systems.	Biotechnology solutions	Biogas, nutrient recovery & clean water	affordable clean energy for cooking, refrigeration and power generation	reduction of carbon emissions contributing to SDG7
2	Academic Water purification knowledge	Integrated Participatory Technology Development (iPTD) model.	Monitoring system to catch unsafe water.	National Policy Change Less drinking of unsafe water Increase of awareness. Linkages across multiple levels of society, natural disaster resilience. Attract other organisations to help.	Reduction in diarrhoeal deaths
3	Paper based nutrient analyser, mobile phone app	translational and knowledge exchange to tackle barriers to use	Affordable fertiliser (faecal matter derived fertilisers). Social acceptance of use, safe disposal of waste, attract other organisations to the sector	Reduce use of chemical fertilisers, use of correct volume of fertiliser. Reduction of fertiliser costs.	Increase of agricultural yield, increase of income, reduction of poverty, increase in local water quality due to decreased runoff,
4	Academic Experience	User-engagement strategy	Supporting decision, policy and regulatory, micro-grids (on and off grid)	Electrical connectivity	Improved livelihoods through energy connectivity
5	Academic & Local Partner Experience	Scaling of locally driven business models, renewable off-grid solutions, community involvement, institutional regulation	integrated, actionable and transferable development strategies for the local renewable energy sector, identifying current barriers to scaling rural electrification and developing solutions, novel financing and revenue schemes, best practice guidelines,	Electrical connectivity, increase in revenue from SME energy generation firms,	Improved livelihoods through energy connectivity

The selected projects highlighted a range of qualitative and quantitative research methods across a number of different geographical locations– Sub-Saharan Africa, Oceania and East Asia. Most were either developing or establishing viability for technological interventions with high-budget, multi-dimensional implementation strategies utilising local partnerships to develop end-user interest. The diverse range of award pounds, from £101k to 1.71M, shows a diversity of scale which allowed the flexibility of the theoretical framework to be tested. SORI (The SORI Network, 2015), as an evaluation or formative planning tool, has the ability to function independently of funding size which is an attribute that I look to emulate in the theoretical framework. However, the selected projects did not encompass a small-scale project (<100k) which is why I included the GCRF funded TLUD Project in Nepal as discussed in the market map chapter. This had the double benefit of using the theoretical framework as a self-evaluation tool.

5.3. Framework Methodology Summary

The development of the theoretical framework methodology can be seen in detail in Chapter Four; the outline is as follows:

The first methodological step was data collection, I focused on the semi-structured interview as observational methods were not possible due to the interviews being held over Microsoft Teams (Microsoft, 2020) in accordance with the University of Nottingham's policy. The semi-structured interview guide, shown in the Appendix C (p.228), reflected the theoretical framework structure comprising of three sections: introduction and background, determining important levels/factors in the GCRF project, and cross-referencing of identified levels/factors with levels/factors identified in the Chapter Two and Four. The interview concluded with interviewees having the opportunity to talk about anything else that was deemed important and give feedback on the interview. The self-evaluation followed the same structure.

The interviews were coded and transcribed using Nvivo12 (QSR International, 2019) in two steps. First, coding the nodes determined by the level/factors in the strategic planning and enabling environment elements of the theoretical framework, second, considering the transcripts from the perspective of the nodes, refining and recoding

the data ensuring that any duplicated were removed. This process resulted in a number of changes to the framework, which are discussed in Section 5.5.

5.4. What I learnt: Results & Discussion

Between October – December 2019 the five GCRF Pis were contacted. Four agreed to an interview and Pr1 declined to be involved in this study due to other commitments. The context of the research was explained in detail to each PI as well as what involvement in this study would entail and how it would influence the research. An information sheet and consent form were presented to the PI. All Pis signed the form either verbally on the interview recording or on paper prior to the start of the interview. This was in accordance with the ethics approval by the University of Nottingham Ethics Committee as outlined in Chapter Four, section 4.4.1. The results of the interview are presented following the structure of the theoretical framework; first the strategic planning element and second, the enabling environment matrix. This section provides the basis for methodological and structural changes based upon the data analysis and feedback from the Pis.

5.4.1. Strategic Planning Element

Through the following section I shall present the results and highlight a number of examples where the theoretical framework identified either positive or negative attributes.

Table 5.3 shows the results of the coding process for the strategic planning element. This represents the distribution of nodes and the frequency of discussion points.

Table 5.3: Co-Production Matrix for All Interviews

	I1	I2	I3	I4	I5	Total
Purpose		6	2	8	3	19
Assumptions		0	5	2	1	8
Expectations (Researcher + User)		6	3	4	5	18
Participation, Engagement		5	4	7	5	21
Reflection		7	7	5	8	27
Total	**0**	**24**	**21**	**26**	**22**	

5.4.1.1. Purpose

The first sub-factor is ***Purpose*****:** The discussions around purpose focused on a number of questions; What is the project trying to achieve? Where did the idea originate? Is the project driven by the researcher or the users? The core response from the four Pis was as follows:

> *So before we applied for any money we managed to get some pump priming to go to Vanuatu and start engaging with communities over there and trying to scope what the big challenges were facing them […] so that's why we are looking at water and water quality because that is what the communities wanted" (Pr2)*

> *"we were trying to develop an infield tool that can be used by small order farmers to determine the nutrient content of their soil and also of organic amendments" (Pr3)*

> *"So we have got the engineers modelling for landslides and earthquakes. And basically the idea is that we are heading up the social science element of it and it comes from the recognition that you can have technical expertise and models which all work but our view is unless you get down and talk to some people, all the models might be correct but none of them might work when you go to implement them in the field. We are currently working on a project called TERSE which is basically sustainable electrification in rural communities." (Pr4)*

> *"We basically want to understand, or that was the original idea of the project, what are the obstacles and opportunities for electrification in Africa" (Pr5)*

As can be seen in the quotes, the clarity of purpose differs between projects. The projects with greater clarity of purpose tended to have a more direct approach to meet their research aims. Pr2 & Pr5 co-produced their purpose with key stakeholders, wanting to engage users at an early stage in the research process. Pr3 has the opposite approach, applying a technology designed for the UK to Ghana and Kenya consulting

the users on suitability only. Pr4's approach lies somewhere in the middle as they were asked to complete the research by a national government but have co-produced policy recommendations as well as integrating social factors (derived from semi-structured interviews) into their electrification model. Thus, the key theme is how the level of co-production for the project purpose reflects the level of user ownership throughout the project stages.

5.4.1.2. Assumptions and Expectations

Assumptions covers a range of issues in the interviews. This node can be divided into the expectations of the researchers (or project managers) and the expectations of the end-user. The researcher expectations section includes questions about end-user needs, suitability or appropriateness of technology, social constructions, community resilience, willingness, and if a 'westernised' approach will work in a low-income context. The quote below from Pr3 illustrates a social assumption the PI had made about the tomatoes being stolen but had not fully considered the social aspects of this assumption.

> *"[we were doing] field trials with tomatoes and I was very concerned that at the end, because these are not in fields with barbed wire, people would vandalise, steal and take the tomatoes so that we wouldn't have any data. But that was really not the problem, I was completely misled, because nobody came anywhere near it because it was applied with FDF [Faecal derived fertiliser] […] we didn't find any pathogens, it very safe […] we were very keen to give some to the farmer for free as he has been helping me and he said no, I won't have any because my wife won't allow me, she won't have those vegetables in the house […] we have even been told there are evil spirits dwelling in this produce, it's not good for you"*
>
> *(Pr3)*

Assumptions made by the technology end-users based around the communicated outcomes of the projects form the the root cause of not moderating expectations effectively. Pr4 illustrates this with ineffective communication between the

government and working communities resulting in the community expecting free electricity for life and the government expecting the communities to pay a tariff.

Replicating the assumptions sub-factor, expectations are divided into the researcher's and end-users' expectations. Researcher expectations cover a range of issues around: the type of technologies needed, the accuracy and cost of technologies, financial factors, project life cycle and management. Pr2 summarises the expectation factor most effectively:

> *"We had a few ideas about the sort of technologies that we work on and what we think we could do but we wanted to be sure we were addressing a real need in Vanuatu" (Pr2)*

Pr2 continues with, "that's why we are looking at water and water quality because that is what the communities wanted" this has resulted in moderated expectations for both the researcher and the end-users. Both have communicated effectively and understand what the core purpose of the project is. Neither had an unrealistic or uninformed expectation, this resulted in the alignment of end-user and researcher priorities. As identified in Chapter Two this misalignment of priorities can result in the failure of energy technology for poverty-alleviation projects. Other user expectations include expectation management through open workshops around level of participation, and who owns the final technological solution (in Pr2 this is set out in Memorandum of Understanding (MoU)). However, the communication of these expectations must be available in a local, understandable language or communicated through pictorial format. Pr4 states that "instructions on [the solar panels] are in English which is interesting because lots of people didn't speak English and lots of people couldn't even read so again, there is a lack of foresight on the part of the government and the implementing partner". The breakdown in the communication of expectations leads to project failure, as stated in Pr4, "in the future it's going to be a risk between a political and social buy-in as communities are not getting what they think they've been promised, and the government can't actually provide what they promised." This managing of expectations and the failure to mitigate against different expectations is also explained in Pr5:

"[energy companies] are not aware of the community needs to a large extent. They don't explain their solution enough, so there is a big gap between the perception of the community of the solution and the perception the developer has. One example is a few sellers do a solar home system on a pay as you go basis so community members rent the solar home system and they pay per kWh or per day depending on the business model of the supplier and if they don't pay, then they get switched off and the community members often don't understand why this is the case so they get really mad or they are trying to hack the system to get more electricity out of it" (Pr5)

This is where capacity building or educational training is required to close the gap between expectations and reality. The engagement of the levels or societal groupings explored further in the EEM.

The difference between the assumptions and expectations of the GCRF PIs is not fully clear from this analysis. The question must then be asked if these two sub-factors can be combined into one. Expectations are traditionally based on our own life experience, "a belief that something will happen because it is likely" (Oxford University Press, 2019) whereas assumptions are based on "a belief or feeling that something is true or that something will happen, although there is no proof" (Oxford University Press, 2019). In this case, expectations based on the experience of the Pis, rather than the experience of the end-users, dominate the expectations section thus when the difference is "proof" or "life experience" these expectations are this similar to, if not the same as an assumption of end user-experience. This means that these two sub-factors can be combined into one that can interrogate the assumptions of all key stakeholder groups.

5.4.1.3. Participation and/or Engagement

Whilst Participation and/or Engagement is not included in the theoretical framework presented in Figure 4.4 (p.114), the PI interviews quickly identified this as a core element of the SPE. Additionally, the participation or engagement strategy was the linking element between the SPE and EEM. This sub-section outlines the methods of engagement identified in the interviews.

The method of engaging end-user determines the level of ownership, equality and the utilisation of local resources across the project cycle or value chain. A number of tools emerged from the interviews that help facilitate this engagement process. Pr2 facilitates a bricolage process (Gurca and Ravishankar, 2016), defined by Pr2 as:

> *"bricolage basically means DIY, rather than going in with a concept of what the structure should be like, be that a committee, we go into communities and allow them to design the structures themselves based on their knowledge of what does work and what doesn't work in communities. It's interesting how in every community, all in the same country and all very similar, comes up with a slightly different looking structure on how they will manage these technologies" (Pr2)*

The process was conducted through a series of multi-stakeholder workshops aimed at bringing together various key stakeholders - communities, NGOs and local/national government. Moreover, the workshop format captures and manages the expectations of the stakeholders. However, the presence of these stakeholders in the same physical space did not mean there was a willingness to collaborate. Engagement thus becomes a co-produced activity where engagement is required across all stakeholders for the process to be successful. The facilitation of workshops between key stakeholders is a common process for information gathering however, it only featured in one other project, Pr5.

Pr3 engaged farm extension workers and stressed the importance of empowering these stakeholders to manage the project.

> *"we felt that it's not for foreign scientists to come and tell them how good this [technology] is, because many foreign scientists do that. If you want to be really effective you have got to work with the people, especially through the extension workers" (Pr2)*

However, if the users are engaged too late in the project cycle, it might be found that their needs are different to the project aims; Pr3 had exactly this problem:

"Upon engaging the farmers, we said that we were only interested in nitrate, but they said they were interested in phosphate and potassium, but the paper strips we have found for potassium and phosphorous don't really lend themselves" (Pr3)

Pr2 negated this by co-producing the project outcomes at the beginning of the project cycle, creating a greater understanding what the communities really need. However, this level of engagement can lead to other problems such as, who owns the technology after the project is completed. The timing of engaging key stakeholders is critical in technology adoption. Pr4 reinforces this with another example of government engaging too late with communities which leads to a lack of buy-in and interest in using the implemented technology.

"I think there is a slight power issues obviously and perspective issue because of what's been delivered by the government, it doesn't actually meet the needs of the population for one and the energy is not enough, the amount they have been given […] I think also it's not just about the negotiating and the design it's also about ownership and making sure that there is ownership that builds legitimacy and long term connection with whatever it is that you are trying to do" (Pr4)

Pr4 had tried to better understand the needs of the users by engaging the communities, the government and local energy providers, however engagement was not successful. This approach of engaging three levels of society is also seen in Pr5, yet, the outcome differs as Pr5 is at an earlier stage in their project cycle;

"we performed around 50 interviews with policy makers, NGOs but we also included the business to get an understanding of their priorities with regards to energy in general, we wanted to find out if there were any conflicts between the institutions, we wanted to see if there were any gaps, so basically how can we achieve regulatory and policy framework that enables off-grid electrification and where are the gaps right now" (Pr5)

This was paired with over 1000 quantitative surveys resulting in a comprehensive data set for energy usage. Similar to Pr2, Pr5 facilitated conversations between the project levels, hopefully enabling future collaborations. The engagement factor is summarised well by Pr5:

> *"We all have this wonderful idea that we are constantly in touch and everything is wonderful in the community because you have long standing co-operation and communication but, in the end, how manageable is that. Especially if you scale your business" (Pr5)*

5.4.1.4. Reflection

A key learning from the interview process was the importance of reflecting, echoing what is seen in the Responsible Innovation Framework (Engineering and Physical Sciences Research Council, 2013). The role of reflection enables an iterative or cyclical relationship between the co-production sub-factors. This is illustrated through all the GCRF projects in, identifying limitations and barriers, modifying engagement strategies based on the specific socio-techno-economic context, redefining the research objectives (purpose) as well as identifying what was successful.

> *"We then went back to the communities and told them what we could achieve and what we couldn't achieve, again having the discussion thinking about those things that are critical and those things that are less critical" (Pr2)*

5.4.2. Enabling Environment Matrix

The EEM was designed to capture complex contextual issues, reflecting IBM-WASH (Dreibelbis et al., 2013), however these complex contextual factors are more accurately captured by the purpose sub-factor in the SPE with the contextual factors mapping a causal pathway between the four SPE sub-factors. Instead, the EEM captured the roles of each individual stakeholder group and how that role could influence behavioural change, with the added benefit of connecting these roles across the multiple stakeholder groups. For example, a change in government energy policy can be seen across the groupings as well as across the three core factors. Whilst this was unexpected during the interview process, in retrospect it was a significant step

forwards in the power of the theoretical framework. Now, not only can the framework identify need, understand how assumptions/expectation influence this, and create methods of engagement and reflect on progress, it has the ability to additionally identify the specific role of key stakeholders in facilitating behavioural change of end-users across the three core values to create actionable outcomes that transform barriers into enablers.

This transformation process is mapped across the SPE sub-factors as barriers are identified, assumptions interrogated, meaningful engagement strategies conducted which address the identified barrier, and finally, a reflection process which established if the barrier has been effectively transformed in to an enabler. If this transformative process hasn't occurred the cycle should repeat itself dependant on the exiting knowledge and thus more effectively respond to the barrier.

The modification of underlying strategy was applied before the interview analysis and the EEM was populated with this in mind. In the following section, instead of focusing on the individual project learnings, as the outputs of these interviews are to develop the framework rather than evaluate the project, I have identified the key themes emerging from all projects under the EEM factors. This means that the following analysis will consider the overarching data trends over the 116 data points.

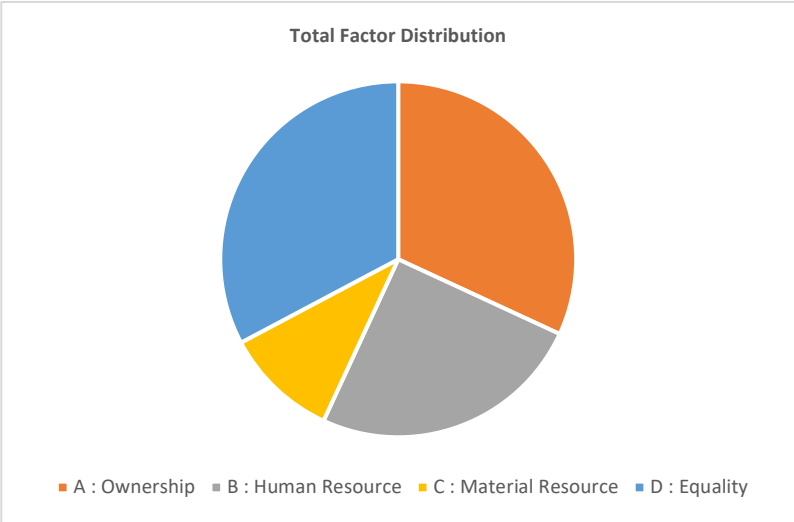


Figure 5.4: Ownership, Utilisation & Equality Factor Relationship

The core factors, Ownership, Utilisation and Equality, were identified in Chapter Four from a range of literature groups. Whilst these factors were seen as core to success in

implementing technologies into low-income environments, the relationship between, and interaction of these factors was not fully understood. Initial conclusions from the interviews show a balanced relationship between ownership, utilisation and equality representing 31.9%, 35.3% and 32.8% of the interview answers as shown in Figure 5.4. However, the balanced nature of the factors does not represent a balanced relationship within the individual projects. Projects that were more market orientated focussed on the ownership factor, whereas more traditional top-down charity focussed projects focussed on equality. The use of local resources depended on the appetite of the PI for long term change due to the difficulty of establishing local technology mechanisms rather than simply importing technologies from the UK.

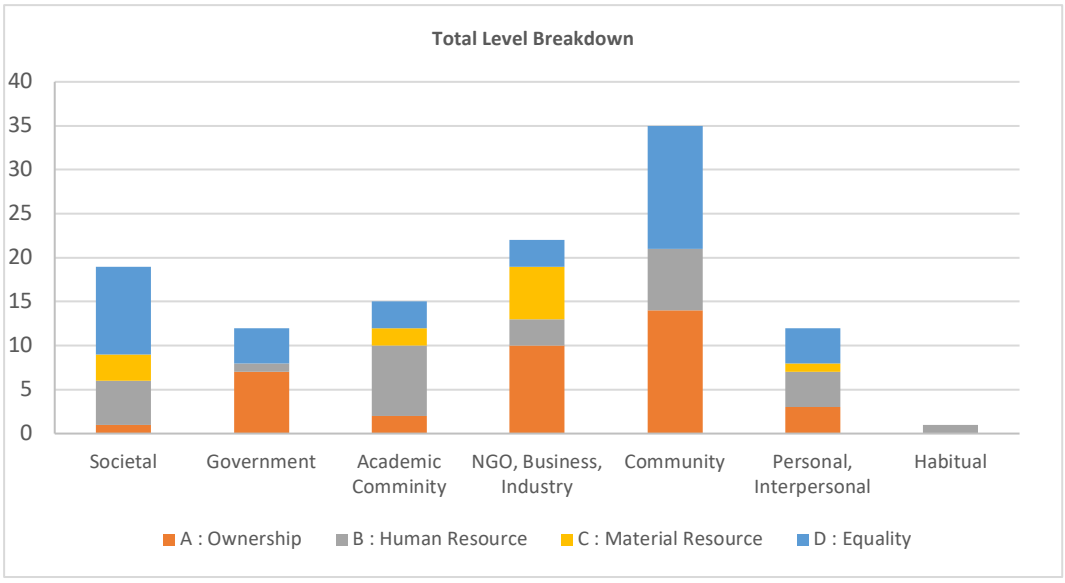


Figure 5.5: Total Level Breakdown

Table 5.4: Enabling Environment Matrix for All Interviews

	A: Ownership	B: Human Resource	C: Material Resource	D: Equality	**Level Total**	**Level Total/Sum of Matrix**
Societal	1	5	3	10	19	0.164
Government	7	1	0	4	12	0.103
Academic Community	2	8	2	3	15	0.129
NGO, Business, Industry	10	3	6	3	22	0.190
Community	14	7	0	14	35	0.302
Personal, Interpersonal	3	4	1	4	12	0.103
Habitual	0	1	0	0	1	0.009
Factor Total	37	29	12	38	116	
Factor Total/Sum of Matrix	0.319	0.250	0.103	0.328		

Figure 5.5 & Table 5.4 shows the distribution of the individual levels and how the three factors interact with the individual levels.

5.4.2.1. *Distribution of Levels*

As expected, the dominating level is community. This was predicted as all GCRF projects focus on solving global challenges in low-income areas in accordance with the GCRF goals; these low-income households are traditionally located in rural communities due to the limited work opportunities. This reinforced by the community level in Figure 5.6. Figure 5.6 depicts a world cloud analysis of the interview transcripts, the word communities (and its similar words) was used 1.53 times more than the next most frequent word. Additionally, given the beneficiary centred approach that the theoretical framework looks to employ, placing the community at the centre of this is an important methodological step independent of the implementation model used.

Second to community is the NGO, Business & Industry Level. This result is due to the co-produced technology implementation mechanisms with local in-country partners. These GCRF projects look, to varying degrees, to utilise existing systems, materials and local contextual knowledge to allow the researcher (or project manager) to use funding more effectively.

Figure 5.6: WordCloud Analysis of all Transcripts

Another observation is the lack of data on the personal or interpersonal level. The selection of GCRF projects were keen to engage communities as an entity but did not look to understand deeper personal or interpersonal connections between community members. The main challenge stated when engaging individuals is the

time required to complete individual interviews rather than focus groups. Focus groups provide a quick community group consensus, however, as discussed in the qualitative research background in Chapter Four, focus groups can misrepresent group opinion as the loudest individuals can dominate and the most marginalised members do not express their views. Individual interviews also require, in most cases, a number of face-to-face interactions to build an open and trusting relationship between interviewer and interviewee to negate the issues associated with outsider status, which can take time that is not available. However, this multi-interview approach and negation of outsider status is important when understanding the barriers to adoption and sustained use of a technology. Given that these barriers differ between the adoption and sustained use phases as well as with spatial and temporal changes, this could result in a lack of information about habitual use. This is captured by the lack of result in the habitual level of Figure 5.5. This does suggest that a structural change is required in the EEM where the habitual level is integrated into the personal level, especially as the EEM defines the roles of key stakeholders, I shall discuss this further in Section 5.5.2.

Whilst the prevalence of the academic level was expected (ranking 4/7), as the interviews were conducted with academic researchers, the impact of this was the decreased importance of the community level. When looking at the relationship between the community and academic levels, more academic community involvement in a project resulted in less community involvement. Initial results would suggest this was due to local partners being identified though academics using their networks to increase the efficiency, productivity or success of their projects, rather than an individual or community-based approach. For clarification, whilst the academic community level is prevalent in research situations, such as the GCRF projects, this role would be replaced by funding or implementation organisations for projects outside of academia.

The role of local and national Government throughout these GCRF projects was in creating a regulatory framework that encouraged innovation and, in some cases, provided subsidies for the technology itself. Whilst some projects interacted directly at a government policy level, others were just recipients of policy decisions. For

example, Pr4 was asked by the government to create a model for rural electrification but was not consulted in the decision-making process which resulted in a misalignment of government and end-user priorities. However, Pr4 did not feel they could inform the government of this mismatch in priorities as they were only an implementation partner and the payment for work depended on the completion of the outputs. This traditionally top-down model, where information travels unidirectionally from top to bottom resulting into no inter-level interactions, resulted, in this case, in the exclusion of end-user priorities. There is capacity for larger government involvement if the outcomes are co-produced with community representatives and this mismatch of proprieties is identified and modified accordingly. The theoretical framework identifies this mismatch in the EEM and allows the implementing partner to reflect and modify the strategy.

5.4.2.2. Factors/Level Interactions

The results also show how the factors interact with the levels. The distribution of the *Ownership* factor in Figure 5.5 (p.149) mirrors the overall trends with Community, NGO, Business & Industry and Government levels representing the majority of project focus.

A number of coded nodes were shared by the societal and government levels within the ownership factor as governments establish the policy and regulatory environment that influences societal values. These include not only intellectual property, social structures, entrepreneurship and law but also how the use of technologies and are communicated to wider society. Building on the shared values across the assumptions SPE sub-factor and EEM societal level, I will present a case for removing the societal level and integrating it into the co-production element of the framework in Section 5.5.

Utilisation is divided into two sub-factors, which shall be considered separately as stated in Chapter Four – the utilisation of human and material resource. The utilisation of human resources is based upon using existing networks, systems and processes to increase the efficiency of the project. For example, using a farm extension worker in Kenya to facilitate the relationship between the academic community and community levels as in Pr3 or utilising existing skills in a community to build the technology as

seen in the self-evaluation in section 5.4.3. As the nature of the GCRF projects are research based much of the utilisation of human resources is through the academic network created by the individual PI. The expectation was that the community level would dominate this sub-factor however the NGO, Business & Industry and government levels also show a number of interactions. The implication is that for larger project, such as these GCRF projects, it is important to engage key stakeholders who have the ability to operate across multiple levels. A point shared by the market map framework (Practical Action Consulting and EUEI PDF, 2015).

The outlying point contained within the human resource factor in the habitual level referenced the maintenance of the technology and how this could be integrated into community habit by engaging members of the community. As shown in the data, maintenance and the ongoing cost of technology use was not widely considered by the interviewees. This was possibly due to the structure of the research and the funding; it becomes difficult to convince a community to be part of a pilot if maintenance costs are required after the end of the pilot.

The utilisation of material resources shows the use of local materials. Perhaps, surprisingly, using the materials that were already at the GCRF project sites was not widely considered. This was either due to technologies, such as the paper strip (Pr3), not being readily available or the complexity of the technology being too great for local manufacturing capacity, such as the solar cells (Pr4/Pr5). This provides a major area of concern, as extensively identified in Chapter Two, where technologies are designed in a laboratory environment and expected to be successful in a low-income environment despite not considering local processes and systems. By utilising the SPE of the framework, a better understanding of what these local systems are can be obtained, whilst the actionable activities that need to be undertaken are contained in the EEM element.

The final factor to analyse is *Equality.* This factor is embedded in the underlying aims of all the literature groups considered in Chapter Two as well as the core outcomes of the UN SDGs. Equality refers to not only societal equality, through the fair treatment of political and cultural minorities, but the equitable design of technologies throughout the product lifecycle as seen in the Circular Economy (Eurpean Union,

2019). Equality also deals directly with the power structures in the project context. However, there is an understanding that it is not appropriate to actively disrupt local systems with traditionally westernised values, “Our position was not necessarily to disrupt [the local power structures] but we also didn’t shy away from them. By breaking [the participants] them into groups and bringing them back together in some way you are highlighting the differences in the community” (Pr2). Whilst considering who you are working with, equality also considers how you communicate with verbal and/or non-verbal communication methods. This connects to the qualitative research literature where there are many different methodologies concerned with appropriate inclusion (Creswell, 1997b, Mack et al., 2005, Kielmann et al., 2012), especially with regards to concepts such as Community Led Total Sanitation (CLTS) (Chambers, 2009). The data showed community and societal equality as having the most significance with the other groupings being similar in their proportions, except the habitual level which had no data.

5.4.3. The Theoretical Framework as a Self-Evaluation Tool

The GCRF PI interviews provided an opportunity to, externally and impartially, evaluate a series of large scale, high budget projects. Whilst this form of external evaluation is possible for large scale projects, smaller and lower budget projects do not have the opportunities to have external evaluators hence the need for the theoretical framework to be used as a self-evaluation tool, similar in ethos to the social enterprise (The SORI Network, 2015, Somers, 2005) and international development planning tools (Freer and Lemire, 2019, Valters, 2014). The detailed background for the GCRF TLUD Project can be found in Chapter One.

Given this framework builds upon experience I have gained in the field across the globe, as well as the literature background, the resulting bias should be acknowledged when I am using the framework as a self-evaluation tool. However, the self-evaluation, conducted in December 2019, still resulted in a number of data collection and project strategy modifications. Using the structured approach of the theoretical framework highlighted a shortcoming in the data collection process. This resulted in modifying the collection strategy from not only being about the lived experience of the technology end-users but also collecting data from non-users in the same or

neighbouring communities (through informal interviews); allowing the capture of information dissemination through a community as well as how the TLUD ICS was perceived by non-users. In one case, the 2020 data collection identified that the TLUD ICS was given ownership by the community to their religious leader and now it was called, “the lama’s [monks] cookstove”, a perception that had not been captured by previous monitoring and evaluation visits. This evaluation process also further refined the semi-structured interview guide around the four core factors (co-production, ownership, utilisation and equality) linking the interview questions to the technology implementation theory as well as providing a better understanding of what works in reality.

The self-evaluation identified two significant inadequacies in the TLUD ICS project; first, the project does not directly consider the equality factor in its implementation model. Whilst efforts were made to understand, and to some extent conform, to existing power structures the majority of interviews were conducted with men who were traditionally not involved in food cooking but the supervision of cooking events. More effort was required by persons conducting interviews to create a balanced view resulting in more equitable results. Second, the TLUD project did not map the needs, perceptions/expectations, actions and reflections as clearly as possible in the identification of end-user need. This was due to the process being conducted via the implementation partners who had utilised their networks from previous projects to identify need rather than using a robust strategic planning element.

5.4.3.1. Was the self-evaluation useful?

The framework helped develop the project strategy due to its pre-determined structure and links to the implementation literature as well as allowing comparison, due to its values-driven nature, between the other larger scale GCRF projects. This values-driven nature also forces focus on the end-user rather than other more quantitative statistics. The framework also captured perceptions of key stakeholders and the biases/pre-conceptions of each stakeholder, which may differ from the actual reality. As a self-evaluation tool, the framework forces a confrontation between perception and reality resulting in the modification of strategy to better capture project and end-user priorities. This process has also developed understanding of the

theoretical framework through the creation of a self-evaluation question guide derived from the semi-structured interview guide. However, the self-evaluation did not have the same depth as the GCRF PI interviews. The reason for this is the difficulty of remaining objective given the pre-existing project bias and expectations. For the theoretical framework to be used effectively as a self-evaluation tool a step by step guide, similar to the online interface for the HEED Tool (Humanitarian Engineering for Energy for Displacement, 2020), must maximise the objectivity of the self-evaluator as well as aid in practitioner accessibility. This is discussed further in the future work section of Chapter Seven.

5.5. Theoretical Framework Development

The GCRF PI interviews, supported by the self-evaluation, tested the initial version of the theoretical framework to better understand the intersection between theory and practice. Whilst the energy-technology implementation literature provides a basic understanding of the phenomena around the adoption and sustained use of energy technologies, the practical experiences of GCRF PIs adds nuances not captured by the literature. This resulted in a number of structural changes to the framework in both elements as well as a number of methodological changes.

5.5.1. Strategic Planning Element

Structural changes to the SPE aim to better capture the relationship between the four refined sub-factors: Purpose, Assumptions/Expectations, Engagement/Participation, Reflection. As seen in the Modified Theoretical Framework (MTF), Figure 5.7 (p.159), the four-factors exist around a central co-production element with purpose acting as the start point. Assumptions and/or expectations are established around the purpose. The engagement strategy then builds on the first two sub-factors, and the reflection aspect then establishes what worked, what didn't and if there needs to be a modification to the purpose (or any other co-production sub-factors). This results in the four sub-factors having a casual cyclical relationship, rather than the individual factors presented in Figure 4.4 (p.114).

Whilst initially I thought the barriers and enablers to adoption and sustained use (or behavioural determinants) would be captured in the enabling environment section due to the similarity in structure to the IBM-WASH framework (Dreibelbis et al., 2013),

however this was not the case. The EEM focussed more directly on the roles of the key stakeholders rather than the behavioural determinants. The behavioural determinants were captured more effectively across the four SPE sub-factors, specifically in the purpose sub-factor. The purpose sub-factor then captures end-user needs as well as aligning all stakeholder priorities through co-production. The behavioural determinants are then mapped across the other sub-factors. For example, if finance is identified in the purpose/need sub-factor, assumptions and expectations are then established, an engagement strategy such as a subsidy or loan is deployed, then this process is reflected upon and refined. The SPE can then identify barriers to technology implementation and translate these barriers into enablers when including the EEM. The knock-on effect of this is that the SPE must be completed before the EEM is populated. In effect, the SPE is the planning tool and the EEM determines the success of implementation through defining the roles of key stakeholders.

Lastly, the societal level is focused on understanding the contextual systems that impact how the three EEM factors can be implemented throughout the other key stakeholder groups or levels. Thus, the societal level shares characteristics with the assumptions/expectations sub-factor due to many assumptions and expectations being driven by complex contextual factors linked to specific societal environments. These factors shall be combined in the SPE to reduce the complexity of the MTF with the understanding that these societal aspects are not removed but placed into a different part of the theoretical framework.

5.5.2. Enabling Environment Matrix

The interview process reinforced that the end-user orientated approach of the theoretical framework was crucial in defining the key stakeholder roles that would influence the adoption and sustained use of poverty-alleviating technologies. The three EEM factors, Ownership, Utilisation and Equality, provided an alternate perspective on defining success. This values-driven approach prioritises end-users over traditionally qualitative measures of success, i.e. the number of cookstoves bought by end-users. Given the important role of each key stakeholder group, and the transition of behavioural determinants to the SPE, the habitual level was integrated into the personal/interpersonal key stakeholder group. This is the most significant

change to the EEM as seen when comparing Figure 4.4 (p. 114) and Figure 5.7. (p.159) Given this transition to key stakeholder groups rather than societal levels, as seen in Dreibelbis et al. (2013), each stakeholder group has their own perspective on the theoretical framework which may not align with reality due to pre-existing bias or even personal pride. If the results (or perceptions) of each key stakeholder group are individually mapped onto the EEM this will result in 5 EEM perspectives. By mapping these different perspectives, the misalignment of priorities and the understanding of role could be established and rectified. This not only highlights discrepancies in role but also shows how the key stakeholder groups interacted with one another through any overlap in the EEM perspectives. When combined with the visual mapping mechanisms shown in Figure 5.5 (p.149), this produces a powerful tool accessible to development practitioners and policymakers to quickly understand the conceptual landscape of their energy project.

5.5.3. Modified Theoretical Framework

The MTF, in Figure 5.7, captures the SPE and EEM modifications identified in the GCRF PI and self-evaluation interviews. The MTF also presents many more EEM sub-factors identified from the interview data analysis. The modified framework will form the underlying methodology for the Nepali fieldwork in partnership with Practical Action Nepal presented in next chapter.

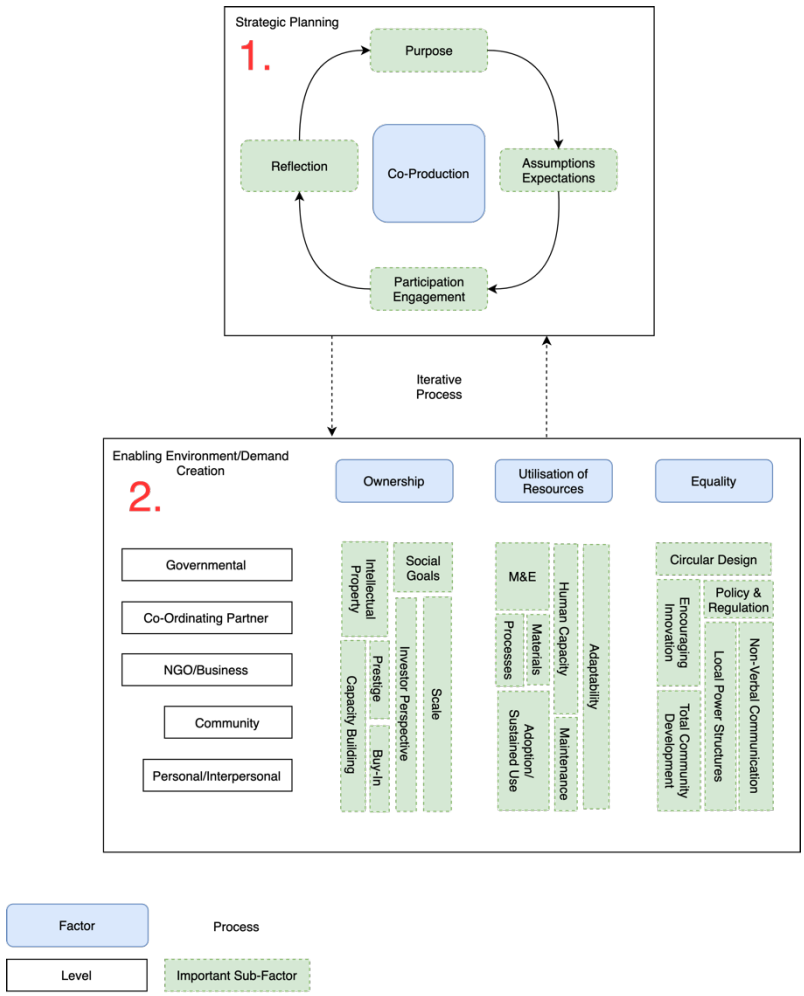


Figure 5.7: The Modified Theoretical Framework

5.6. Conclusion

To summarise, this chapter conducted a systematic review of 882 GCRF projects using the inclusion/exclusion criteria of zero award pounds, SDG7 alignment and technology AND/OR enterprise to identify five appropriate projects for interviews which would test the viability of the theoretical framework. Initially, this process identified 10 possible projects, which were then further reduced to 5 by removing duplicates and unsuitable technologies such as nuclear. The final project list is shown in Table 5.1 (p.137). In line with the International Development Planning Tools, such as the Logframe and Theory of Change, I conducted an inputs, activities, outputs, outcomes and impact analysis, the results displayed in Table 5.2 (p.138). The international development sector use IAOOI to simply map interventions with linear causality (p.51) (DFID, 2012). At this stage of analysis, the nuances of complex social structures could be overlooked as only a high-level understanding was needed. This process identified areas that would be of significant interest to the development of the theoretical

framework. Additionally, whilst the systematic review process was important in terms of this research, it also developed technical skills around the use and implementation of the systematic review methodology.

The theoretical framework methodology, outlined in detail in the previous chapter, includes a series of semi-structured interviews based around the two elements of the framework, the strategic planning element and the enabling environment matrix. PIs were asked about the purpose of their project and how they had identified need, factors which were important to the success of their project, the roles of key stakeholder, how their project related to the theoretical framework four core factors, and at the end were given the opportunity to share their thoughts on the proposed theoretical framework structure. The analysis of the interviews was conducted using Nvivo 12 (QSR International, 2019) and coded to produce a set of results for each project that where then combined to identify key themes across all projects. The focus of this process was to conduct an overarching evaluation of each GCRF project resulting in the development the theories and methods included in the theoretical framework.

The results showed a diverse range of interactions with the four core factors, co-production, ownership, utilisation and quality. The framework visually mapped projects, identifying themes and neglected/over-resourced areas (in both levels and factors). It also identified a relationship between the academic levels' involvement in project and the impact of that involvement on the community level. In addition to identifying themes in the GCRF projects, through internal and external evaluations, the semi-structured interviews and subsequent analysis provided clarification on the framework structure and methodology. This highlighted the value of the SPE in identifying behavioural determinants as well as the importance of the EEM mapping key stakeholder group perceptions and interactions. These structural changes included refining the relationship between the four SPE sub-factors, integrating the societal level into the expectation/assumptions sub-factor, combining the habitual and personal levels as well as defining the cyclical relationship between the SPE and EEM. The resulting Modified Theoretical Framework (MTF), shown in Figure 5.7, shall

be used as the basis for the next chapters methodology, where I shall evaluate the behavioural elements of Practical Action Nepal's Results Based Financing project.

Chapter Six – An Evaluation of Practical Action Nepal's Results Based Finance Program

6.1. Introduction

This chapter applies the Modified Theoretical Framework (MTF), Figure 5.7 (p.159), to the Nepali Biomass Sector through Practical Action Nepal's (PAN) Results Based Finance (RBF) project under research objective three – use the theoretical framework to evaluate a technology implementation project in the Nepali biomass energy sector, resulting in an understanding of both the barriers to sustained use & theoretical framework applicability. Further background on the Nepali biomass sector can be found in Chapter Three. The PAN RBF project looks to develop a market for ICS in Province 3 and Gandaki Province of rural Nepal which is situated 100km west of Kathmandu. The program involved offering increased customer choice by building the capacity of market chain actors, strengthening support services and facilitating an enabling environment for the purchase of ICS. The main modality of the project is results based financing (DFID, 2015a, GIZ, 2018) structured on a number of factors including stove performance (tier level), warranty and remoteness of the intervention area. Demand side incentives were provided to the private sector including, suppliers of stoves for last mile distribution and local financial institutions. Supply side elements included behavioural change campaigns and targeted assistance was provided to end-users to incentives ICS adoption. The RBF project was implemented in two parts, RBF1 focussed on a number of tier 2 (International Organization for Standardization, 2012) ICS and RBF2 (the follow on project which is still continuing) focussed on tier 3 ICS with a behavioural change element.

In this analysis I shall focus on elements of RBF1 and RBF2 with the aim of better understanding the key stakeholders' roles in creating the enabling environment for behavioural change around adoption and sustained use of tier 3 or above ICS. The four research objectives for this chapter are:

1. Understand what the behavioural determinants are and engagement strategies for adoption and sustained use of T2 and T3 ICS

2. Map the role of key Stakeholders in the RBF Project using the Modified Theoretical Framework (MTF) Methodology.
3. Understand the relationships between key stakeholders and how they influence the enabling environment for behavioural change.
4. Identify and rank areas for improvement with regards to influencing the behavioural change of end-users to promote adoption and sustained use of ICS.

The MTF provides a stakeholder orientated multi-level analysis of energy-based technology implementation in low-income environments, shown in Figure 5.7 (p.159). This framework identifies complex social, environmental and economic contextual factors that can often act as barriers to technology adoption and sustained use. In addition, the MTF translates these barriers into enablers. These issues are contextually specific; the MTF does not provide common issues but a methodology to discover and analyse the specific context, in this case the Nepali biomass ICS sector. In the context of PAN RBF, the MTF was used as an evaluation tool in an ongoing project to provide a number of recommendations. The MTF is divided into two elements, the Strategic Planning Element (SPE) and the Enabling Environment Matrix (EEM). The SPE aligns the project outcomes with the needs of the technology users through considering four co-produced sub-factors: Purpose, Assumptions and Expectations, Engagement and Reflection. The purpose factor identifies behavioural determinants or factors which influence behavioural change. These can range from willingness for users to pay for technologies or cultural traditions around open fire cooking. The assumptions and expectations sub-factor identify the misalignment of key stakeholder assumptions and end-user expectations. The engagement sub-factor identifies the programmatic engagement strategy, and the reflection sub-factor provides an opportunity for modifying the strategy based upon key stakeholder feedback.

The EEM defines the role of each key stakeholder group as well as visually mapping the interactions between these key stakeholder groups. These key stakeholder groups or levels are: Government, NGO/Business, Co-ordinating partner, Community and Individual. These groups are mapped across three core factors which influence the

adoption and sustained use of poverty-alleviating energy technologies: ownership, utilisation and equality.

Table 6.1 shows the milestones and timeline that was agreed with PAN to ensure that the results of this study are beneficial for both the RBF project and future projects. As seen in Table 6.1 the fieldwork was conducted between January – April 2020.

Table 6.1: Milestones agreed with PAN

Phase 1	Interviewing Key Stakeholders Based in Kathmandu (completed 7/02/20). Interviews in phase 1 include: national government representatives, financing institutions, coordinating NGO (Practical Action), partner businesses (manufacturers & distributers)
Phase 2	Interviewing Key Stakeholders based in the Field (completed 28/02/20) Interviews in phase 2 include: technology users (and non-users), community individuals, influential community groups, local government representative, local NGO representatives.
Phase 3	Transcription and Analysis of Data (completed 28/03/20)
Phase 4	Present Initial Findings to Practical Action (completed 04/04/20)
Phase 5	Write Report for RBF Project [Integrating learnings for future projects] (completed 15/05/20) – MODIFIED due to impact of COVID-19

The remainder of this chapter is divided into five sections. Section 2 outlines the MTF methodology including the interview structure, participant selection, data analysis and presentation. This section also highlights context specific modifications to the MTF methodology and concludes with a selection of limitations. Section 3 presents the SPE and EEM results and discusses their implications on the success of PAN RBF in the adoption and sustained use of ICS. Section 4 contains a number of recommendations to PAN which would result in a more effective behavioural change strategy. Section 5 presents a number of MTF modifications as well as proposing a final name for the framework. Section 6 summarises the findings and suggests a number of areas for future work.

6.2. Methods

As discussed in detail throughout the previous chapters the MTF utilises a qualitative data collection methodology divided into four sections, semi-structured interviews, focus groups, informal conversations and semi-structured observations. The semi-

structured interviews and focus groups used a semi-structured interview guide[17] from the MTF methodology which was developed for the GCRF interviews (Chapter Five) and modified for PAN RBF. Additional informal conversations helped to frame the semi-structured interviews as well as helping reduce the effect of outsider status, as discussed in section 6.2.4. The observations were used to clarify user claims, for example if the end-user stated they used the ICS every day yet there was no soot blackening or firewood stacked close to the ICS then the interview information and observations did not support each other.

The MTF methodology was based upon a phenomenological approach to qualitative research where the lived experience (Creswell, 1997b) of the end-users and the meaning behind why people make decisions is of key importance. Given the importance of accurately capturing the lived experience of all key stakeholders, study participants were selected based upon advice from Practical Action Nepal on who the key stakeholders were both in Kathmandu and in the field as well as through my previous experiences of field work in Nepal. All of the interview participants were closely involved with the RBF project in a range of roles which are summarised in Table 6.2. For all key stakeholders, I conducted (with the help of a translator), a combination of semi-structured interviews, focus groups and observational methods. In the field, I was particularly interested in interviewing and observing a representative socio-cultural cross-section of Nepali rural villages.

6.2.1. Data Collection

The interview structure differs from Chapter Five in a number of areas. For the SPE data analysis the interviews were divided into two phases (similar to the academic/end-user division in the SPE of Chapter Five): Phase 1 and 2. Phase 1 (P1) involved all Kathmandu based key stakeholders and Phase 2 (P2) involved all field based key stakeholders. Reflecting traditional centralised Nepali power structures, the top levels of the EEM (government, NGO/business & co-ordinating partner) are situated in Kathmandu valley, which is geographically, topographically, culturally and contextually different to the rural bottom levels (community & user). By separating

[17] The P1 & P2 semi-structured interview guides can be found in the additional information.

the interviews into two geographically different phases, P1 generated project perceptions whilst P2 identified the end-user reality highlighting any mismatches in the SPE in addition to the perception matrices produced by the EEM. Moreover, during the coding process the Utilisation sub-factors, Human Resource & Material Resource, were modified to People & Systems and Material Resources. People & Systems extends Human Resources to capture a wider range of existing local skills and capabilities. Material Resources still captures the use of locally available raw materials and technologies. Additionally, the personal/interpersonal level was renamed to (non-) user to capture both the ICS end-users and the non-users situated in proximity to the end-users.

The P1 interviews are an evolution from the GCRF semi-structured interview, which means that the P1 interview guide is divided into four sections reflecting the structure of the MTF. First, gathering contextual data such as background information, role, gender, age and details on the organisation they represent. Second, the interview explored the four strategic planning elements (Purpose, Assumptions/Expectations, Participation/Engagement, Reflection) through the lens of co-production. The third section focuses on the Key stakeholders (KS) included in the enabling environment matrix, looking to understand KS roles and how they interact. Finally, I looked to understand how the KS integrate the three factors of end-user behavioural change (ownership, utilisation, equality) across the five core levels. Given the complexities of conducting field visits in Nepal due to the remoteness of working communities and the need to inform the relevant field-based stakeholders, the P1 interviews were completed, transcribed and analysis started before the P2 interviews were conducted. It was also important for PAN to combine this data collection visit with other work to reduce the cost of a field visit.

This resulted in the semi-structured interview guide for P2 (the community, end-user, local government and local NGO interviews) being shaped by the initial results from P1. The P1 interviews provided information on the perceived barriers to cookstove intervention and the biggest end-user focused behavioural change challenges. P2 provided user/community perspectives on these barriers, either capturing a different set of barriers, reinforcing the same barriers or a combination of the two. P2 was also

designed to capture user-orientated ideas that will helped to shape the end-user orientated behavioural change strategies of relevant key stakeholders. All interviews (P1 & P2) finished with an opportunity for the participant to ask any questions or talk about any relevant areas that they felt were overlooked.

Completing the interviews in two phases provided a unique opportunity to, not only map the behavioural determinants and best strategies to overcome these from the perspective of the community/end-users, but also from the perspective of the KS based in Kathmandu. Again, this led to a divide between perceived and end-user stated determinants. The KS that I interviewed were as follows:

Table 6.2: RBF Key Stakeholders

Government	1 x National Government (AEPC) 2 x Local Government (Myagdi and Baglung)
NGO/Business	1 x Local NGO 3 x Improved Cookstove Manufacturers 1 x Micro Finance Organisation
Co-Ordinating Partner	1 x Co-ordinating NGO (Practical Action x2)
Community	1 x Health Worker 1 x Community Forestry Representative 1 x Local Financial Cooperative 3 x Local Distributors
(Non-)User (Personal/Interpersonal Level)	4 x Tier 3 ICS Users 3 x Tier 2 Users 4 x Non-ICS Users 2 x User Focus Groups (Tier 2, Improved Traditional Cookstove & Traditional Cookstove Users) 4 x Informal Interviews with T2 Users

In order to comply with the University of Nottingham's Ethical Research Guidelines, all participants were shown and asked to read the pre-interview information sheet and asked any questions they had before the interview was conducted to ensure that they were comfortable with the process. All interviewees signed a consent form that allowed their data to be used as part of this study.

6.2.2. Data Analysis

The data analysis was divided into a number of parts in accordance with the MTF. First, the SPE involved coding the data in line with the four sub-factors (purpose, assumption, engagement and reflection) effectively mapping the Behavioural Determinants (BD) and Engagement Strategies (ES) to overcome the barriers to sustained use in line with the chapter objectives. In addition, the reflection element supports chapter objective four as well as the observations made in the field visits in March 2020. Second, coding of data into the EEM through the three factors (ownership, utilisation and equality) and five levels (Government, NGO/Business, Co-Ordinating Partner, Community, Personal/Interpersonal) showing the perceived roles of each KS from the perspective of each KS in line with chapter objectives two and three.

Strategic Planning Element

As the volume of data was large all coding was conducted using Nvivo12 (QSR International, 2019) which allowed easy classification/identification of nodes and cases for the first stage of coding. No pre-existing coding framework was used as it was important that emerging themes were driven by the interviewees not the interviewer. This reflected the nature of the open-ended questions asked through an inductive approach (Mack et al., 2005, Creswell, 1997b, Denzin and Lincon, 2018). P1 & P2 were treated as separate collections of data, which meant that I did not apply the coding framework established in P1 onto P2 but started the inductive process from the beginning[18]. Again, this was to highlight any differences between P1 and P2 in the phrasing or language used by the two groups of interviewees. After the coding frameworks were established the second stage of coding was to run through the nodes and confirm that firstly, they were correct and secondly, the definition of each node was correct whilst removing any repeated nodes to increase the robustness of the results. Following this, the BD and ES identified in P1 & P2 were compiled into a matrix which ranked the BD & ES on number of KS mentions – a rough importance

[18] The frameworks are presented in Appendix D (p.234).

guide. The reflection and assumptions & expectation elements were also coded using an inductive method to build a case for RO4.

Enabling Environment Matrix

The second part of the analysis, understanding the role of KS, captures the unique perspectives of the KS in the PAN RBF project through the EEM. This part of the analysis was designed to determine what each stakeholder believes their role to be and how they interact with other KS. The remaining three factors – ownership, utilisation and equality – were used as the framework for coding. The data was coded into both levels and factors, for example if a KS was talking about the role of government policy influencing local manufactures it was coded [Government, Utilisation (people & systems)]. This coding system produced a matrix which was then plotted to show a graphical representation of results. The nature of this data distribution provided an indication of how the KS perceived the project when coupled with supporting quotes.

In addition to the analysis stated above, I also asked interviewees about electric induction cooking as it will make up part of the PANs second Results Based Financing project. As induction hobs have a number of different contextual barriers to ICS, this part of the interview was to gauge interest in another cooking technology rather than to understand the complex contextual landscape.

6.2.3. Limitations

As with any research method there were a number of limitations. The first limitation was the limited scope of the interviews as we only visited a small number of communities in two districts (Myagdi and Baglung). It must be recognised that this small cross-section may not represent the entire project as over 35,000 Tier 2 and above ICS were distributed in RBF1 and another 5,000 Tier 3 and above ICS in RBF2. However, the local NGO which I interviewed was responsible for 22,221 cookstoves in the areas where RBF operated. We have tried to mitigate this limitation by asking the co-ordinating partner, PAN, to place the interview team in communities that give a representative cross-section of the entire project. This means that the views stated in this report represent the communities that we visited but the themes should be represented throughout the project working areas. Second, the MTF Methodology

was unproven as it was a novel research method which might have resulted in miss-information or difficult data analysis. In practice, all the key stakeholders worked closely together to ensure that nothing was missed in the translation, transcription and analysis stages; especially given the complexities of translating Nepali. Interviewer and translator bias must also be acknowledged in this novel research method. We looked to mitigate this by having at least two people present during the interview stage and, during the transcription stage, utilising a translator who was not present during the interviews. However due to the sensitivity of the data, and in line with the University of Nottingham's Ethical Guidelines, only I had access to all of the transcriptions and personal data to ensure participant anonymity.

There is a risk in all qualitative research that the interviewee will state what they think the interviewer wants to hear. In an effort to reduce the effect of this, when introducing the interviewer and their intentions, open and honest answers were encouraged. However, it is impossible to mitigate against the impact that other International Development projects have had on the communities in terms of successful or failed initiatives which may have resulted in differential treatment of interviewers. The difference between perception and reality among the interviewees must also be recognised. The interviews conducted with KS showed the perception of the KS, however these perceptions may not have reflected reality as they may have been influenced by pre-existing biases. There was very little that could be done to mitigate this apart from collecting a number of perspectives and seeking a group consensus. Finally, a number of the KS fit into 2 KS groups. For example, government official and end-user so we mitigated this by defining clearly at the beginning of the interview which role we would like them to have during the interview.

6.2.4. The Role of Interviewer Bias, Positionality & Outsider Status

Given the qualitative nature of this paper we acknowledge the influence of bias, interviewer positionality and outsider status (Sovacool et al., 2018, Sovacool and Hess, 2017) on the results. The issues arising around outsider status were more prevalent in the rural setting due to the larger perceived disparity between socio-economic status. I tried to mitigate the impact of being an outsider by staying in local accommodation in the community and building trust over a longer period of time. In the Nepali context

it is unusual for development practitioners to stay in the village that is the focus of the project as normally day trips are conducted from district headquarters. Also, being accompanied by a Nepali research assistant, even though he was from a different district, allowed conversation to occur in both formal and informal settings. The informal conversations, which occurred whilst eating and socialising with community members, resulted in deconstructing some Nepali preconceptions of Europeans and my own preconceptions of Nepali people and culture.

I also recognise two other key issues during the data collection, for a number of interviews conducted in Baglung a representative of the local NGO partner was present. Whilst it is difficult to measure the effect this presence had on the answers of the interviewees, especially as occasionally the local NGO representative would finish the answer to a question in an honest attempt to fill in information rather that direct the interview, the effect of this must be acknowledged. The second issue was highlighted when one during an interview, a member of a financial co-operative told a user what to say and did not allow the user to give negative feedback. In this case the co-operative member was asked to leave and again, we stressed the importance of open, honest feedback to the interviewee.

During the data transcription and analysis, it was important to involve the research assistant who was independent of Practical Action. This research assistant was responsible for translation during interviews and translating/transcribing interview transcripts from the recordings. Unfortunately, due to the complexities of translating Nepali a second research assistant was needed to meet the project deadlines and a research assistant was supplied by PAN who had previous qualitative research experience. 56% of transcripts were completed by the first research assistant and 28% by the second while I completed the remaining interviews conducted in English. In order to check transcription quality, both research assistants were asked to complete a number of the same transcriptions. This process of including three people, two of whom were present during the interviews, helped to mitigate positionality issues during the transcription of data. However, I alone conducted the data analysis in accordance with the Ethical approval to protect interviewee data, so an element of positionality must be acknowledged.

6.3. Results & Discussion

The following section outlines the results of the 31 semi-structured interviews from Phase 1 & 2. It follows the structure of analysis presented in the previous section, in line with the MFT elements. First, I consider the SPE results and the implications of these on the RBF project followed by the results of the EEM and discussions around the impact of these findings. In addition to the presentation of results, any modifications made during the analysis process of the MTF which result in more robust findings or more accurate capture data were noted and presented in section 6.5.

6.3.1. Strategic Planning Element

The presentation of results echoes the four sub-factors contained within the strategic planning element - see Figure 6.1. In this section I discuss how the purpose aligns with end-user needs through the identification of barriers and enablers or behavioural determinants influencing ICS adoption and sustained use across the two data collection phases. Additionally, I identify what assumptions key stakeholders made and the impacts of these on user expectations. I then consider the engagement strategy when interacting with technology users and the impact of this engagement strategy on end-user behavioural change. This section concludes by stating the key stakeholder reflections resulting in the recommendations presented in section 6.4.

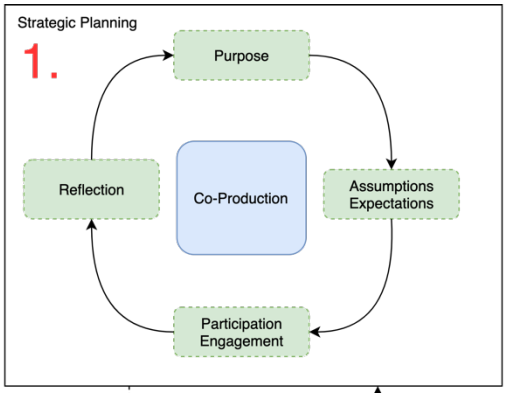


Figure 6.1: Strategic Planning Element

5.6.1.1. Purpose & Need

Table 6.3 presents the top 10 perceived barriers and enablers from P1 as well as the end-user generated barriers and enablers from P2. The table was created by ranking determinants based upon the total number of mentions in the key stakeholder interviews. As the question format was open, these ideas were generated by the

interviewees and not led by the interviewer. 65 barriers and enablers emerged from the coding and data analysis of 1486 data points. The top 10 from each phase are presented in Table 6.3 to condense the results into a manageable format. In contrast to Dreibelbis et al. (2013), who group barriers and enablers into contextual, psychosocial and technological factors, I have not used this method but ranked the 65 barriers and enablers by mention. However, a further development of the framework may find this grouping helpful for exploring the contextual issues in more detail. In this chapter, the analysis of individual determinants was not conducted as PAN were interested in extracting key learnings and overarching themes, thus key issues have been identified and are discussed further.

Table 6.3: Top 10 Barriers & Enablers for Kathmandu & Field based Key Stakeholders

Ranking	Phase 1 (Perceptions)	Phase 2 (Actual)
1	Awareness\Don't understand benefits	Convenience and Stacking
2	Finance\Willingness to Pay	CS Use\Heating
3	CS Use\User Experience	Finance\Can't afford ICS
4	Convenience and Stacking	Aspiration
5	Historical Use - living in traditional way	CS Use\Smoke and Health\Smoke affecting health
6	Aspiration	CS Use\Time Saving\Time saved cooking
7	Time Saving\Time (not) saved preparing fuel	Availability of other Tech.
8	CS Use\User Friendliness of Tech	CS Use\Firewood or Biomass Fuel\No shortage of firewood (collection from own land)
9	Social Status	Awareness\Understand benefits of ICS
10	Finance\Other financial priorities	CS Use\Taste of food better with wood
10=	Dependency	CS Use\Firewood or Biomass Fuel\ICS uses less firewood
10=	No Supply Chain\Pellets	-

It is important to reiterate that the results of P1 show the perceived barriers and enablers from the perspective of Kathmandu based key stakeholders, whereas P2 shows barriers and enablers as identified by end-users. The first difference in results between P1 and P2 is that the Kathmandu based key stakeholders have a different perspective of what is important to the end-user. Ranking 1st in P1 as the biggest barrier to adoption is that end-users do not understand the benefits of cooking with an improved cookstove:

"the awareness among the user is still not adequate. They are not understanding why this cook stove should be in their kitchen. That awareness still has not been created enough. Unless the user understands it, it is doom to fail" (NGO/Business)

However, it became clear that all 17 of our P2 user/non-user interview stakeholders (personal/interpersonal level) clearly understood the benefits of using an improved cookstove. Interviews with them indicated that the gap was not in awareness, but around basic training given to the ICS end-users:

"Many people have not used it because they did not know how to use it. There should be some monitoring teams who should come over, and if they see such situations they should teach us how to properly utilize it. But nothing like this happened. They just did it for sales" (Personal/Interpersonal)

The core findings from P2 centred on the convenience of each cooking technology which resulted in stacking technologies (the use of multiple cooking technologies concurrently to satisfy cooking needs (Masera et al., 2000)) and financial assistance, not for the interviewees, but for other potential users who may need it. Each interview in P2 stated that no cooking technology satisfied all their needs thus people used multiple technologies at once as illustrated in the following quote:

"We cook in an improved cook-stove [mud & brick]. After that, daal is made on gas [LPG] in the pressure cooker. And then I cook the vegetables outside in improved metallic cook-stove. After that in winter, water is boiled in "Bhushe" cook-stove [sawdust Tier 2} and we bathe from it.

When we cook for the goat we use the "Taulo" [Three Stone Fire]. If we have to cook flat-bread, I think now I should use this [Tier 3 Metallic Cookstove] to make dry flatbread." (Personal/Interpersonal)

Figure 6.2: Typical Rural Nepali Kitchen

Figure 6.2 shows the typical kitchen that was visited in the data collection phase. This user stated that there were seven different cooking technologies being used with three energy sources (LPG, kerosine, wood): LPG hob, an open fire, improved mud & brick stove, tier 2 metallic cookstove x2, tier 3 metallic cookstove and a kerosene stove.

The motivation for the use of each of these technologies emerge from the rest of the barriers and enablers, the three stone fire (TSF) and improved mud and brick cookstove provide heat during the winter as well as a larger scale cooking option such as cooking for cows. LPG stoves are quick, so are used for tea as well as for emergencies and when entertaining guests (to convey social prestige as well as reducing smoke in the home) but tend to be used sparingly as gas bottles cost no less than 1500npr (15USD) to refill.

The time saved whilst cooking on any technology was viewed as important for aspirational reasons linked to a desire to free up time for leisure:

"People now-a-days seek luxury. Not only people from cities but people from villages also yearn for luxury. Maybe it is also due to foreign employment. Now, in the villages all the agricultural lands are on the verge of being unproductive, as people do not want to work in the fields. Everybody use gas, electricity is being used for rice cooker even to boil water. So people are yearning for pleasure that is the reason. Previously, the hills rarely had dense woods but now as I said the lands are returning

to woods as people are not willing to work hard, so there is loads of wood. It is because people seek for luxury. People want pleasure." (Personal/Interpersonal)

P2 did show that users understood the impact of smoke on health, "*if we can get more advanced and better stove than this which will not emit smoke, which will also protect us from diseases"* (Personal/Interpersonal) however these long terms risks were 'backgrounded' (Jewitt et al., 2020) by priorities such as a need for space heating, preferences for the taste of food cooked on a TSF or improved mud ICS biomass, or a desire to utilise an abundance of free firewood rather than paying for LPG. This cost orientated perspective carried through into the financial behavioural determinants.

Finance appears at 2nd & 10th place in P1 and 3rd in P2. However, the "willingness to pay" seen in P1 does not correlate with the "can't afford ICS" in P2. P2 key stakeholders state that users do have the capacity to pay for a cookstove but are unwilling to redirect the small amount of income they earn to an improved cookstove, a P1 key stakeholder explains this process, *"they [end-users] think it is absurd to buy a stove for Rs 2-3000 when you can make it using some stones, bricks and mud for 100 or 200 rupees* […] *They are not health conscious but financially conscious" (NGO/Business).* However, one P2 stakeholder suggested this was not the case for the majority of people: *"It is not because people cannot spend money, there could be some like 2-4 people out of 100 who cannot afford it" (Community).* But all P2 interviewees were concerned about the price of the cookstove.

5.6.1.2. Assumptions & Expectations

Twenty-two different **Assumptions & Expectations** emerged from the analysis, the top 10 by mention can be seen in Table 6.4. Many of these assumptions and expectations are dealt with in the reflection sub-factor as they are interconnected. The underlying assumption of RBF1 & 2 is that users want cookstoves but cannot afford them. Whilst this does appear from the P1 interviews, end-user demand would suggest that the situation is more complex that it seems. The reflections section shows how these assumptions and expectations have impacted the project.

Table 6.4: Top 10 Assumption & Expectation for Kathmandu & Field based Key Stakeholders

Ranking	Phase 1	Phase 2
1	Project Mechanisms work as designed	High quality technology which works as is described[19]
2	Users want ICS	Users are price orientated
3	Users are price orientated	Users take loans for ICS
4	High quality technology which works as is described[20]	No education, results in no use
5	Value chain is re-usable	The new generation want new technology
6	Use depends on need	Price to decrease as more people use ICS
7	No education, results in no use	Project Mechanisms work as designed
8	The new generation want new technology	Warranty will be honoured
9	There is no duplication of work	Expectation of Quality Service
10	ICS market is unpredictable	Information dissemination process is slow
10=	BD are different in different geographies	-

5.6.1.3. Participation or Engagement

The **participation or engagement** sub-factor takes into account the previous two sub-factors and builds an engagement strategy that adequately satisfies the technology users' needs whilst also taking into account the assumptions and/or expectations. In the introduction I labelled these Engagement Strategies (ES), Table 6.5 outlines the top 10 (out of 33 ES and 716 data points) by mention. Unsurprisingly in a project about supply chain strengthening the top ranked ES in P1 was 'Supply Chain Strengthening'. This builds upon the assumption that 'Users want ICS' (ranked 2nd in P1 assumptions) and that there is not sufficient capacity on the supply side to meet the demand. However, this is contradicted by the P1 top ranked behavioural determinant that users do not understand the benefits of ICS – this would suggest that there is a low demand due to a lack of understanding on the demand side, not a lack of supply. There is an

[19] P2 community members stated that although many ICS had been marketed as 'smokeless' this was not the case in their experience.

understanding of this contradiction in RBF which has resulted in the local NGO, distributors and community groups completing awareness campaigns (Ranked 1st in P2) through a number of mechanisms that appear important in both P1 and P2. These include the use of 'Formal or Informal Peer to Peer marketing', 'social media marketing', promoting local products and fuels, and leveraging the impact of the Indian 2016 LPG blockade[20].

Table 6.5: Top 10 Engagement Strategies for Kathmandu & Field based Key Stakeholders

Ranking	Phase 1	Phase 2
1	Supply Chain Strengthening	Awareness Campaign\Communicating ICS Benefits
2	Awareness Campaign\Communicating ICS Benefits	Mobilize Financial Institutions
3	(Government) Policy & Subsidy\Incentive Scheme (Coupon System)	Formal or Informal P2P Marketing\Recommendation from friend or Community leader
4	Awareness Campaign\Cookstove Demonstration	Awareness Campaign\Cookstove Demonstration
5	(Government) Policy & Subsidy\Reduction in ICS Cost	(Government) Policy & Subsidy\Reduction in ICS Cost
6	Modifications of Tech. to Satisfy User Need	Formal or Informal P2P Marketing\Volunteer Distributor
7	Formal or Informal P2P Marketing\Recommendation from friend or Community leader	(Government) Policy & Subsidy\Providing documents
8	Mobilize Financial Institutions	Blockade
9	Habituate Technology	Social Media Marketing
10	Warranty and Maintenance	User buying from Local Market
10=	(Government) Policy & Subsidy\Local Manufacture Preference	Formal or Informal P2P Marketing\Through community groups

In terms of responding to the financial behavioural determinants there are a number of strategies that are being used across a number of societal levels. The first is the National Government led cookstove subsidy (Ministry of Population and Environment, 2016) which results in the reduction of the ICS price at the consumer level. However,

[20] Information on Indian Fuel Blockade - https://www.bbc.co.uk/news/world-asia-35041366 (Accessed 11.05.20)

a number of stakeholders suggested that due to the volume of paperwork associated with the subsidy system the price point for the user was not sufficiently reduced:

> *"it [the subsidy] also requires lots of paper works and what we have shown is it has not contributed to price reduction also because there is a big subsidy management cost, eventually for users there is nothing for users. They are getting subsidy just to compensate quality assurance, paper works, management, tax, actually if there was no subsidy they could get the stove in same price" (NGO/Business)*

This is discussed further in the reflection sub-factor. The second strategy is the mobilisation of financial institutions through incentives provided by PAN to the financial institution and by convincing the financial partner of the social impact of work. But there is an impact of financially incentivising local financial institutions which will also be seen in the reflections section.

There are two ES that appear in P1 but not in P2. These are 'modification of technology to satisfy user need' and 'habituate technology'. The P1 interviews focused on developing the technology to suit the need of users, as lab standards are different to user needs:

> *"So the one which is best suited for the lab purpose is not so suitable with the users because in lab they have many standards. But when implementing that standard, when you go to the user, the users are not satisfied with that […] both things need to be matched" (NGO/Business)*

However due to the widespread nature of stacking, users do not expect the technology to suit all their needs, as they have access to a number of solutions. Additionally, given the lack of bottom-up information transfer between users and manufacturers, there is no possibility from a user perspective of modifying the technology to suit their needs.

Finally, the habituation of technology or the integration of the technology into the user's daily routine was not considered by the users as, if it is convenient, it will be used and if it is not, it will not be used.

5.6.1.4. Reflection

The final sub-factor in the strategic planning element is **Reflection.** These reflections have been raised in the 32 KS interviews and are important to identify areas of improvement as well as giving the KS the power to influence and co-produce the project.

Table 6.6: Top 10 Reflections for Kathmandu & Field based Key Stakeholders

Ranking	Phase 1	Phase 2
1	Problems with subsidy system or incentive	User has no communication with local NGO (M&E)
2	Improvements, Feedback for ICS	Improvements, Feedback for ICS
3	RBF1 to RBF2 improvements	User not knowing how to claim warranty
4	There is duplication of programs	User Perspective\Feel cheated by distributor (financial co-operative etc)
5	Positive Impacts of RBF	User has no communication with local government
6	People with money buy, people without money do not	Positive Impacts of RBF
7	User has no communication with local NGO (M&E)	User not taught to use or build ICS effectively
8	User has no communication with local government	Problems with subsidy system or incentive
9	Focus on adoption rather than sustained use of ICS	Communication of Funding Systems to Users
10	Government doesn't understand ICS programs	User don't know anything about ICS program
10=	Manufacturer implemented suggested changes	-
10=	Other KS involved in improving ICS	-
10=	Manufacturers not involved in M&E	-

Not all reflections were based upon areas of improvement; many were complementing the positive aspects of RBF and reflection upon how RBF2 has built upon RBF1, such as:

"There is a big difference because previously the diseases inflicted by smoke like COPD (Chronic obstructive pulmonary disease), Lung diseases,

pneumonia in kids have dramatically declined after using the modern cook stoves" (Community)

"The cook stove that have been distributed from this organization has given us a sigh of relief because people are not littering ashes here and there and the consumption of woods has gone down and it is also a bit beneficial for environment and for health" (Personal/Interpersonal)

"What I like about this project is that you are not promoting certain type of stoves actually you are giving choices to the user. And based on their willingness, the model they would like they are buying the stoves […] User getting choices to choose the project is the unique thing about this project" (NGO/Business)

There are also a number of recurring themes through this element. The first is 'Improvements/Feedback for ICS'. Whilst this is important for a manufacturer, the RBF project gives the end-users a large selection of choice when purchasing a tier 2 or 3 ICS and PAN were more interested in developing methods of behaviour change rather the technical development of ICS. Hence, I will not consider the technical ICS improvements further in these results. However, in terms of supply chain strengthening, there was no supply chain for the fuel for the tier 3 stove (pellets) which results in the correct fuel not being used. This has led to poor performance and discarding of the technology in the RBF2 communities. Further, the ICS users, being in the bottom level, do not reflect about the project goals or systems, just reflections on the technology itself. These reflections are an extension of the barriers and enablers. For example, one of the barriers is convenience, some users reflected that the T3 cookstove was not convenient enough.

There were a number of reflections on the financial systems, this included the incentive to financial institutions and users and the national subsidy system (discussed in Chapter Three). The incentive to local financial institutions was given per cookstove that they were able to sell. The opinion of a number of users was that the institution forced its members to purchase the cookstove, *"if they are the member of it [the financial institution], it is mandatory for them to get it [the cookstove]"*

(NGO/Business) which resulted in a lack of support and training from the users, *"They just said that okay cook-stove has arrived, if you want to take it, come. The one who has the money, will take it, that's it. They didn't even talk about its benefits and negative effects"* (Personal/Interpersonal). This highlights an underlying communication issue which emerged in a number of areas.

The incentive to users was conducted through a voucher system, if the user attended a cookstove demonstration and was interested in purchasing the cookstove then a voucher would be given. However, in reality:

> *"We only have one tier 3 cook stove for sampling and it has Rs 3000 subsidy and we also have a token, remember the one we showed you yesterday […] If you are interested you can take the token and buy the cook stove […] We have said if you do not have money to buy the cook stove we will provide it" (Community)*

Next, it is difficult for the users to understand the system that reduces the cost of the cookstove, as at point of sale the end-users are presented with a price, not an explanation of how that price was achieved. Especially when projects are duplicated through different organisations in the same geographical area, users see the same technology for significantly different prices. This influences their choice to purchase new technologies as many of these projects give away technology for free. This issue of duplication should not happen as all energy projects are meant to be approved by AEPC and the local government, so the simple conclusion to draw is that this process does not stop duplication. The duplication of energy projects has another significant side-effect in relation to the distorted perception of value from the user perspective. In RBF2 the tier 3 cookstove costs around 9000Npr (according to manufactures), however it is being sold to the users at 2500npr. In RBF 1 the tier 2 cookstove was priced at 3000npr but was found in the local market by a number of users for 1200npr. This led users to ask *"when cost is 1200nr in the market why are they taking 3000npr?" (community member)* and resulted in users not adopting ICS, a core goal in the RBF project. The other P2 KSs feel the results of this as, due to the results-based nature of

the funding mechanism, there is a pressure for results rather than sustained use. One P2 KS summarised:

> *"Yes, if the results are not visible right now, it does not mean it is not a success […] But we want immediate results like we are given target of distributing 'x' amount of stoves in 2 years' time but people are coming even after the completion of the project. It is a positive thing and I think this is the social benefit. We want quick fixes. We are asked to meet our target and distribute 'x' amounts of stove and get the money to pay our staffs and management" (NGO/Business)*

This also affects the quality of monitoring and evaluation as there are no resources allocated to this:

> *"When it comes to the places we are intending to go for RBF 2, we have been doing it but when it comes to the areas in RBF 1, there was no monitoring because previously we had the program so we went there, but now we are not related with the program. But if the RBF 2 program will be conducted in our past working areas, the monitoring will be done automatically" (NGO/Business)*

Not only does this short-term view impact the local NGO, distributors and community groups, but it dictates the feedback mechanisms from the end-user perspective. There is not time for the users to communicate with the levels above them (ranked 1st, 5th 7th 9th in P2 and 7th, 8th 10th in P1). This also has an effect on 'users not knowing how to claim the warranty' (3rd) or 'adequate training around using the cookstove' (7th).

The final reflection is not contained within Table 6.6, but still remains important – *"What people want is the organization should provide it for free, and people are willing to use it if they get it for free"* (Personal/Interpersonal). This contradicts the core values of the market element of RBF. As users seem not to be using the cookstoves when they pay for them, it is not logical to assume that use will increase if they are provided for free.

6.3.2. Enabling Environment Matrix

The EEM (Figure 6.3) establishes what each KS believes their role to be and how they interact with other key stakeholders. As the coding process is done for each stakeholder group there is a large volume of data - 392 data points coded into the matrix across the full data set – only the key points will only be considered.

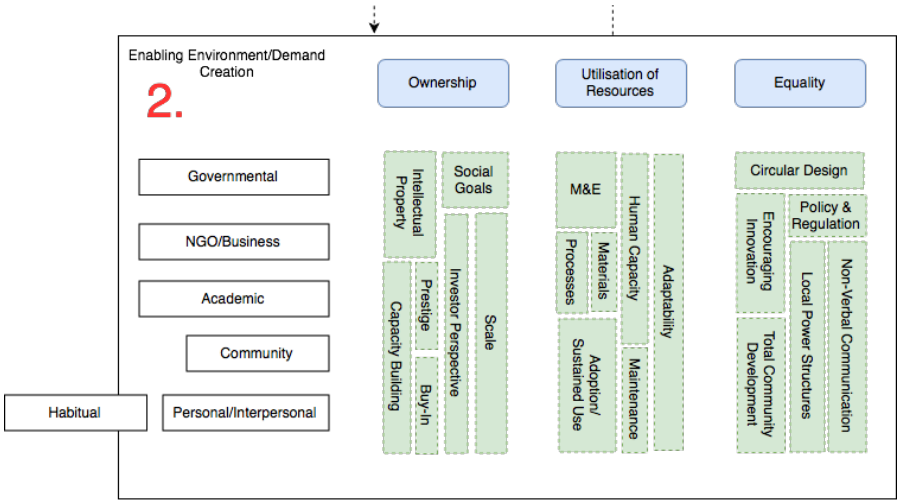


Figure 6.3: Enabling Environment Matrix

Figure 6.4 shows the relationship between the three main factors: Ownership, Utilisation [sub-divided into People & Systems[21] and Material Resources] and equality – from all KS perspectives. Typically, these three factors would represent 1/3 of the chart each, however in this case the utilisation factor accounts for 0.444 of the distribution.

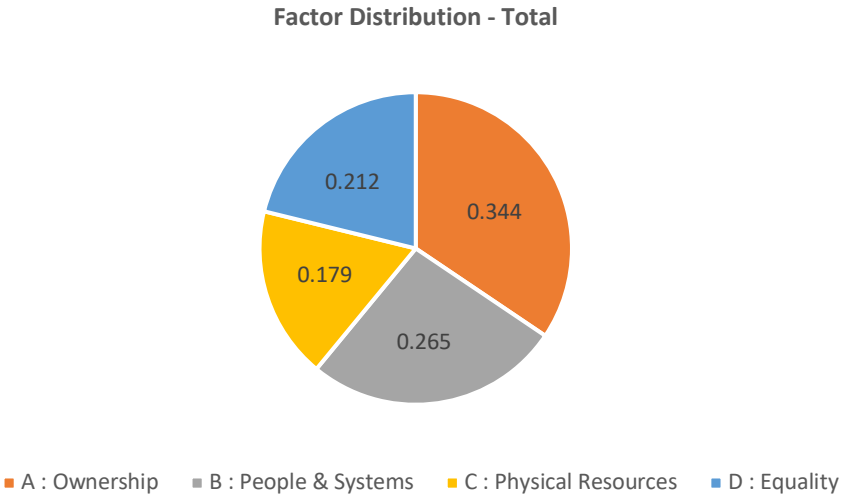


Figure 6.4: Ownership, Utilisation & Equality Factor Relationship

[21] An extension of Human Resources stated in the previous Chapter (p.162)

This is the result of KS having to utilise existing people & systems to carry out the required work, for example, using the RBF2 project to monitor the RBF1 project (as stated above) or utilising community events:

> *"We do not have the financial prowess to organize programs but what we are doing is, we reach out to people when they gather for instance co-operative meetings, fairs etc and try to spread the information about the benefits cook stove" (NGO/Business)*

The detailed breakdown of what was included in the three core factors can be seen in the KS role perspective table, Table 6.7, and Appendix E (p.244). Figure 6.5 shows how the core factors are distributed amongst the KS groups from all KS perspectives where the NGO, Business key stakeholder group has the perceived most important role in RBF. This is no surprise given the supply chain strengthening aspects of this project. What is surprising is the lack of a perceived role for the co-ordinating partner as there were zero mentions from the (non-)user perspective about the co-ordinating partner and only a few from the other KS groups. Given that the co-ordinating partner manages all the KS groups, there was a distinct lack of visibility.

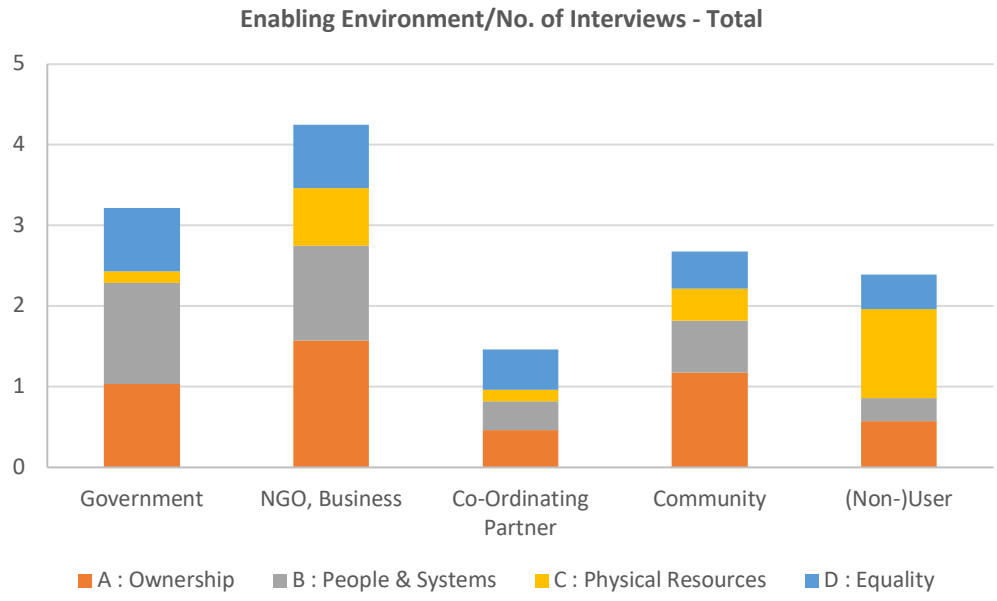


Figure 6.5: Total Factor/Level Breakdown

Whilst Figure 6.5 shows the distribution of data across the key stakeholder groups and core factors, highlighting the importance by mention of key stakeholders and core factors, Table 6.7 shows the specific perceived roles of each key stakeholder group

from, in this case, the perspective of the personal/interpersonal or user and non-user KS group. By mapping the roles of each key stakeholder group from each key stakeholder group's perspective the perceived role of each stakeholder is established and the misalignment between expectation and reality identified by comparing multiple perspectives. For example, in Table 6.7 as mentioned above, there is no perceived role for the co-ordinating partner from the perspective of the (non-)users prompting a change in communication method. In addition, roles ordinarily carried out by the co-ordinating partner such as awareness campaigns and assessing needs are completed by the community from the perspective of the (non-)users which also required a modification of communication strategy. Whilst the EEM enables the practitioner to dive deeply into the perceptions of each key stakeholder group, in this section I shall consider a number of overall trends of themes. For specific role perceptions of KS groups refer to the tables in the Appendix E (p.244).

Table 6.7: (non-)Users Perspective (Personal/Interpersonal Level)

	Ownership	**Utilisation**		**Equality**
		Human & Systems	**Material**	
Govt.	Local Govt. Programs (energy, farming, infrastructure etc.)	Assessing Need (or not)		
NGO/Business	Cookstove Promotion Social Media Marketing Subsidy Dissemination	Communication with User (Or Not) M&E	Warranty	Preferential treatment to friends not needy Success of other projects
Co-ordinating Partner				
Community	ICS Distribution/Awareness	Assessing Needs before starting project	Warranty through local distributor Community Forestry Group	Co-Operative Loans Reputational Risk due to lack of communication
User	Quality of Product & Service Recommended from Friend Providing Citizenship Card Seeking Luxury Investment in ICS	Lack of Communication on Subsidy System Willingness to pay Reliance on others for Technology	Technology Stacking Who will repair if it breaks? Firewood Collection Building ICS Themselves Dependency on import of LPG	Confusion over dissemination Migration Decreasing Birth Rate

The analysis showed a number of trends throughout all the KS groups. The first, a recurring theme throughout the analysis, is communication between KS groups. This

includes information transfer between KS, as information is often disseminated by the co-ordinating partner in a top-down model with limited opportunity for feedback through bottom-up methods. For example, all of the non-user and user interviews indicated a lack of opportunity to give feedback to either the local NGO or local distributors. The root of this issue is a confusion over responsibilities resulting in an 'economy of no-knowledge' – a passing down of responsibilities to the KS that interact with the users, whether that is the community groups, local NGO or local distributors. The first effect of this is that due to these undefined roles all other stakeholders think that the others should be doing more to help. The second effect is the reputational risk associated with disseminating cookstoves. There were three stakeholders who interact directly with the community who were concerned about this due to the inconsistent pricing of cookstoves, communication regarding funding systems that reduce prices, and support systems post payment.

This is most apparent when it comes to the government's role in RBF[22]. All KS groups stated that the government should take a more active role in understanding the energy needs of the rural populations. Again, all non-users and users did not have an opportunity to talk to local government about their energy needs. One user stated, *"We are people from educational sector, when they [government] do not have time to ask about the school, there is no chance of asking about cooking" (Community).* Yet, when interviewing local government officials, the response was the same, *"they [the co-ordinating NGO] can bring different programs not only this kind"* (Government) with the responsibility on the co-ordinating partner to help the community, shifting the responsibility away from government. However, the government officials did offer to provide lists of marginalised people if they were approached, which they have not been.

The final trend was around monitoring & evaluation and where the responsibility of the KS ends in terms of cookstove dissemination. Monitoring is conducted, often over phone, by the NGO (through the local distributors due to budget constrictions) to check the ICS have been received but not to check if the ICS are being used.

[22] even though RBF1&2 do not interact with the government subsidy scheme.

6.4. Recommendations Presented to PAN

This section provides a short overview of the recommendations that were presented to PAN in Kathmandu. These recommendations were divided into five groups: Communication, the impact of incentives, understanding why end-user purchase ICS, the reusability of market chains and adoption vs. sustained use.

More effective communication methods are needed for both bottom-up and top-down information sharing to define who takes responsibility for each role as well as what is assigned to the role. The lack of communication between key stakeholder groups was highlighted by beneficiaries of PAN RBF not having heard of PAN or the role they fulfil in the project. In addition, there was no end-user understanding of how the incentive system worked and how it affected the cost of the cookstove, resulting in a reputational risk for the local suppliers. Moreover, the researchers were the first representatives from the project to be in contact with the users resulting in a perception of no support. The lack of communication around subsidy also resulted in the tier 2 ICS being priced at 3000npr and the tier 3 at 2500npr (when the manufactures quoted price was 9000npr) – a technologically superior product for less.

This line of investigation prompted the question, does an incentive have a positive impact? And positive from whose perspective? From the perspective of the end-users the incentives drive down the cost of ICS, possibly increasing the likelihood of purchase. However, given the high number of international organisations promoting ICS in the same villages/districts many potential users will just wait until they are given the cookstove for free. The incentives also distort the cost of technologies, as explained above, resulting in a distorted value for money proposition where users expect more than possible. The impact of multiple incentives of different amounts on the community distributors and local NGOs is reputational risk. By associating with one program and not effectively communicating the incentive, local organisations are seen as money making or trying to profit off the end users. In the context of a local women's financial cooperative this has discredited their financial schemes outside of RBF. However, RBF carries weight in international development funding circles currently despite many of these drawbacks.

Next, a better understanding why people purchase ICS and what users' value is needed as highlighted by the differing results from P1 and P2 of the SPE. P1 KS stated simply that people don't understand the value of ICS and users need to be more aware. Yet, P2 showed definitely people understand value as there have been cookstove programs here for 15+ years. Community members want better service and support as it's not about a lack of finance for the majority but how conveniently the ICS fits into their existing cooking stacks. However, many P2 users also stated that purchasing an ICS does not mean they will use it.

RBF1 focuses on tier 2 ICS, RBF2 on tier 3 with plans to expand to electric induction hobs. All of these project phases have been directed at the same or geographically close communities prompting the question - is the market chain sustainable for reuse? Many community members asked the question, why wouldn't they just wait as there will be another better one after and why did they not start with the best ICS (T3). Given the limited disposable income end-users, and only one subsidy per household, end-user would prefer to invest once in the better technology, not continue to buy ICS year after year.

The end-user behavioural change elements of RBF2 suggest a transition from producing impact to changing behaviours when building on RBF1 however, in reality only 5% of households were monitored for use which is not enough to establish sustained use. In one case, a local cooperative believed over 80% of tier 2 ICS were still in use whilst my observations directly contradicted this. More emphasis is needed on supporting the sustained use of ICS by end-users, rather than the limited support given currently in the form of, at best, a cooking demonstration.

6.5. Further Theoretical Framework Development

Echoing the strategy of Chapter Five, this chapter looks to develop the Modified Theoretical Framework based upon the practical experience of implementing the MTF. Given the significant framework development jump in the previous chapter the changes proposed here are suggestions for possible methodological changes rather than core structural or methodological modifications. In addition to this, I will also assign the MTF its final name that will appear in any publications that include the framework.

When identifying the barriers and enablers of energy technology implementation contained within the purpose SPE sub-factor, as discussed earlier, further grouping of barriers and enablers, in line with the WASH behavioural change model, would simplify the data presentation and possibly allow further detailed analysis. However, the usefulness of further groupings would be dictated by how the MTF is applied to the specific project context. In this case of this chapter, further grouping would not have enhanced the evaluative nature of the research objectives. In addition, mapping individual barriers or enablers through the four sub-factors (need, assumptions, resulting engagement strategies, reflections) would result in strategies designed for specific contexts. For example, if finance in rural Nepal is identified as a barrier, the assumptions around finance are identified, a financial engagement strategy designed and after implementation the strategy is reflected upon, a more comprehensive understanding of what influences end-user behavioural change will emerge. This results in the transformation of barriers to enablers.

A minor structural change modifies the relationship between the SPE and EEM. In the MTF the SPE and EEM existed outside one another, separated in a cyclical or iterative relationship. However, as the purpose of each element is further defined throughout this chapter, the EEM element has focused on defining role and relationships of key stakeholders – the core part of defining the most efficient engagement strategy. This has resulted in the EEM matrix linking directly to the engagement sub-factor as seen in Figure 6.6. The minor structural change promoted a new line of thinking for future developments of the MTF. In the same way the EEM expands upon the engagement sub-factor, the IBM-WASH matrix expands upon the purpose and need sub-factor. Future work may include further exploration of the SPE sub-factors to gain great clarity on project process and methodologies.

In addition, renaming the ‘Academic’ Level to ‘co-ordinating partner’ provides a level of flexibility in the role of this level to reflect the diverse nature of energy implementation models. This renaming of the level also prompts a rearrangement of the co-ordinating partner and NGO/business levels as in RBF, PAN was not the connection between the community or individuals and the NGO/business level. PAN was a facilitating partner who dealt with each KS individually but not as a connecting

partner. The NGO/business level interacts directly with the community/personal levels as well as, in some cases, the governmental level.

There is scope for future work in developing the sub-factor relationship in the SPE, modifying the presentation of the EEM results and the creation of a user guide to help practitioners and policymakers conduct this process. I shall discuss these developments further in the concluding chapter.

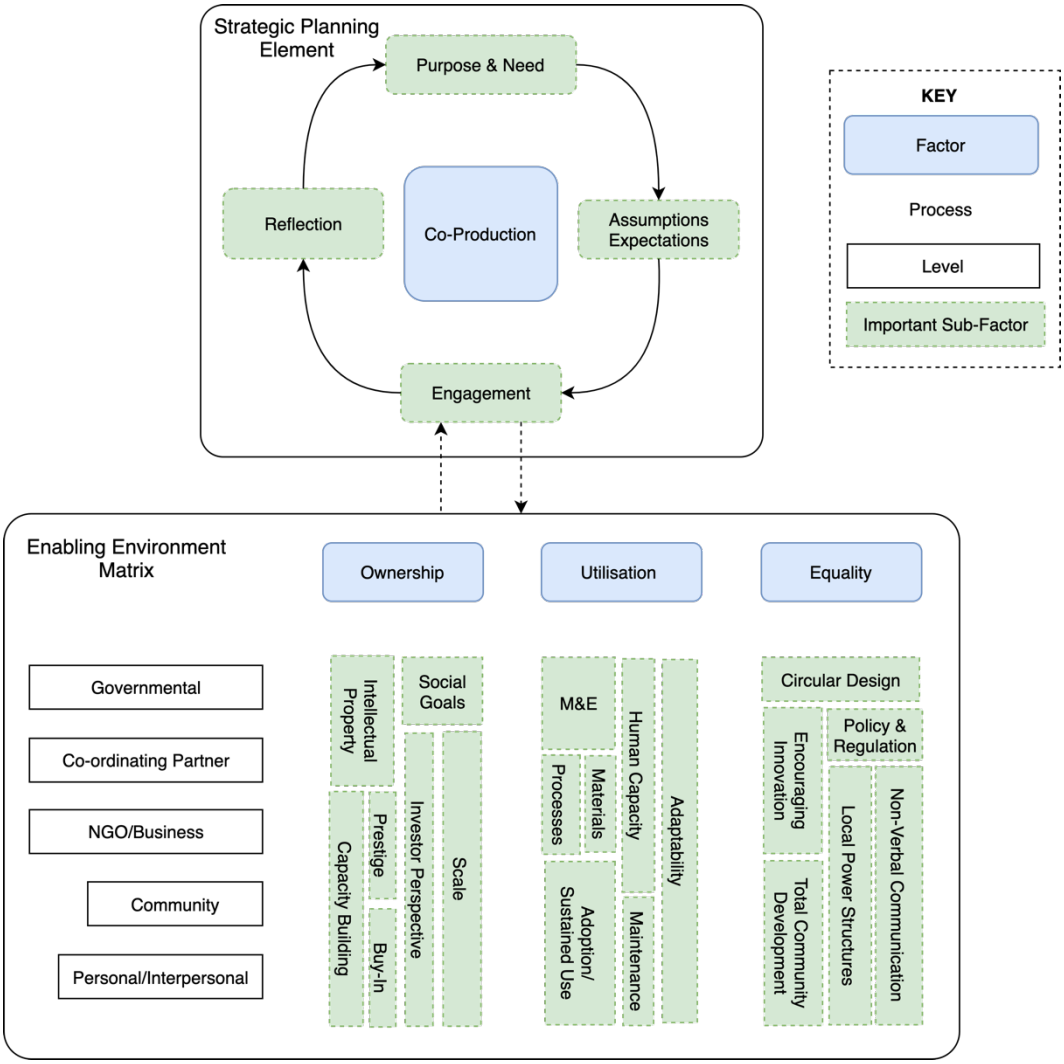


Figure 6.6: Technology Implementation Model for Energy

Considering these changes, the final theoretical framework, which I have called the Technology Implementation Model for Energy (TIME) can be seen in Figure 6.6.

6.6. Conclusion

The aim of this chapter was to better understand the key stakeholders' roles in creating the enabling environment for end-user behavioural change around open fire cooking, resulting in the users adopting tier 2 or above improved cookstoves through

an RBF model. The methodological approach was shaped by the MTF presented in Figure 5.7 (p.159). I set out to achieve four chapter-based objectives which fall into research objective three: Using the theoretical framework to evaluate a technology implementation project in the Nepali biomass energy sector, resulting in an understanding of both the barriers to sustained use & theoretical framework applicability.

In concluding I consider to what extent this chapter satisfies these four chapter-based research objectives and identify a number of MTF modifications. Chapter objective one looks to understand the barriers, enablers and engagement strategies for adoption and sustained use of T2 and T3 ICS. This objective was satisfied through the SPE of the MTF, specifically the purpose and engagement sub-factors. 65 behavioural determinants emerged from the analysis of 32 key stakeholder interviews with the top 10 by mention presented in Table 6.3 (p.173). These share similarities with Shrestha (2002) such as end-users' needs not being met and a transition from top-down orientated models to bottom-up demand driven models. Throughout the SPE data collection and analysis, the key stakeholders were divided into two phases, P1, the Kathmandu based key stakeholder and, P2, the field-based stakeholders. This highlighted the difference between the perceived barriers and enablers in P1 and the end-user identified determinants in P2. The multi-phase approach to the SPE also highlighted different perceptions of ES where P1 was focussed on Supply Chain Strengthening and Awareness Campaign\Communicating ICS Benefits, whereas P2 highlighted, Awareness Campaign\Communicating ICS Benefits, Mobilizing Financial Institutions and Policy & Subsidy\Reduction in ICS Cost.

The EEM was designed to capture key stakeholder roles and define their relation to the three factors that enable technology implementation, this relates to chapter objectives two and three. Table 6.7 (p.186) shows the (non-)user perspective which includes the perceived roles of each key stakeholder group. When compared with the other key stakeholder perception tables (shown in the Appendix E (p.244)) the relationship between the different key stakeholder groups can be established. This process highlighted the lack of effective communication between key stakeholders, for example, none of the (non-)users had heard of PAN.

The final chapter objective identifies areas for improvement with regards to influencing the behavioural change of end-users to promote adoption and sustained use of ICS. The recommendations given to PAN were as follows; More effective communication methods needed for both bottom-up and top-down information sharing, better understanding why people purchase ICS and what users' value, rethinking the role of financial incentives and the reputation risk to local distributors of financial institutions. These recommendations raise questions about whether the existing market chain is reusable for future iterations of ICS dissemination. Lastly, the RBF model promotes adoption over sustained use due to its focus on results. The focus must be redefined to sustained use as the behavioural change of end-users is key to the transition away from traditional cooking technologies such as the TSF. This chapter also highlighted a number of issues around bias, interviewer positionality and outsider status during the data collection and analysis. Issues arising around outsider status were more prevalent in the rural setting due to the larger perceived disparity between socio-economic status, influencing bias was seen through P2 stakeholders influencing interviewees, and my own positionality must be acknowledged during the data analysis.

The application of the MTF to the PAN RBF project resulted in a number of MTF modifications to better capture both, the understanding of barriers to energy technology implementation and the key stakeholder group roles. These modifications included further groupings of barriers and enablers depending on application of MTF and mapping of barriers to enablers through the purpose -> assumptions -> engagement -> reflection framework. I also renamed utilisation sub-factors to more accurately capture roles and interactions of key stakeholder groups which resulted in swapping the co-ordinating partner and NGO/business levels. I also identified areas of future work, further development of the SPE sub-factors, improvement to the presentation of EEM results and the creation of an MTF user guide. Finally, I renamed the MTF to the Technology Implementation Model for Energy (TIME).

Chapter Seven – Conclusion

7.1. Introduction

A long history of ICS interventions across the globe has resulted in numerous examples of low adoption rates and limited sustained use. Despite the path set out by the UN SDGs (United Nations, 2016) 3 billion people still use biomass as their primary source of energy which results in 4 million deaths due to indoor-air pollution (The World Bank, 2018). In the Nepali context, 64.8% of rural households use firewood as their primary fuel source (National Planning Commission, 2018) with an estimated 24,000 deaths[23] due to Indoor Air Pollution (The World Bank, 2018). Initiatives such as Practical Action Nepal's Results Based Finance project promote supply and demand side programmes to transition Nepali rural households from traditional to improved cooking technologies. Yet, as seen throughout Chapter Six, there are still many rural households that are left behind in this process.

The overarching aim of this research was to develop an approach to energy technology implementation for Nepal's practitioners and policymakers to better understand the contextual barriers faced by the key biomass energy stakeholders. This aim translated into four research objectives across the seven chapters of this thesis, these objectives were:

1. Establish the knowledge gaps in the existing technology implementation literature to develop a novel theoretical framework that can analyse the socio-cultural, environmental & financial barriers to the sustained use of poverty alleviating technology.
2. Evaluate the theoretical framework against existing projects which fit the poverty-alleviating technology criteria.
3. Use the theoretical framework to evaluate a poverty-alleviating technology project in the Nepali biomass energy sector, resulting in an understanding of both the barriers to sustained use & theoretical framework applicability.
4. Outline the potential suitability of the theoretical framework for other country markets and sectors.

[23] 113 in 100,000 People

The structure of research revolved around two concurrent work streams, the identification of barriers and enablers to the adoption and sustained use of energy technologies in Nepal as well as the development of a theoretical framework to accurately capture these complex contextual factors. The theoretical framework was derived from four core literature groups: appropriate technology, social enterprise, Health and WASH behavioural change models, and International development planning tools. These literature groups brought together qualitative, quantitative, traditional charity and market-based demand and supply side strengthening approaches, methods of identifying and influencing end-user behavioural change as well as engineering design methodologies based around the use of local materials and resources. This resulted in the development of the Technology Implementation Model for Energy (TIME). TIME identifies complex contextual barriers to energy technology adoption and sustained use, defines the roles and interactions of key stakeholder groups as well as redefining how impact is measured. TIME closes the research gaps by; focusing on sustained use rather than the adoption of technology, integrating end-user and other Key stakeholder group perspectives into the project design, implementation and evaluation, providing a coordinated values-based strategy for ICS dissemination, and integrating previously overlooked elements such as maintenance.

Through an extensive literature review of previous ICS interventions across the globe and in Nepal, I identified common barriers to adoption and sustained use of ICS as well as a number of methods of categorisation. The implementation of the Market Map in Chapter Three identified more specific barriers for the Nepali ICS biomass sector. TIME expanded upon these Nepali barriers, adding a number of deeper insights into phenomena such as stacking, the role of existing community structures, and cultures on ICS adoption and sustained use.

This final chapter summarises the core findings from this research by presenting the development of a novel theoretical framework and a number of barriers identified in the literature, through the Market Map and TIME. It also outlines the impact of COVID-19 on this research as well as research recommendations, limitations and possible areas for future work.

7.2. Development of a Theoretical Framework to Understand Complex Contextual Barriers to Energy Technology Implementation

In this research, I chose to focus on three technology implementation perspectives (the institutional, international practitioner and social scientist) which resulted in the identification of relevant theories of implementation. In Chapter Two I presented and analysed in detail, the Responsible Research and Innovation Framework, Appropriate Technology, Logframes, Theory of Change, Results Based Financing, end-user Behavioural Change Models used in both ICS and WASH sectors based on more broad health theories, the Market Map, Social Enterprise and the Circular Economy as well as a number of smaller market-based tools and theories. The literature review process identified two significant research gaps: firstly, whilst there is significant research surrounding the identification of the barriers and enablers to successful implementation, there is limited research on how to translate these barriers into enablers and how key stakeholders' roles influence this process. Secondly, there is no overarching energy technology implementation model that focuses on the behavioural change elements of technology adoption and sustained use.

7.2.1. Identification of Technology Implementation Themes

From the existing literature, I identified a number of relevant themes that were linked to the successful implementation of energy technologies. This included methodological steps, such as the identification of behavioural determinants from WASH BCMs (specifically the matrix structures and levels from IBM-WASH) as well as more general themes of ownership and equality from social enterprise, reflection and engagement from RRI, assumptions and expectations from Logframes, and mapping change processes from ToC.

Additionally, the value of the Market Map was explored through an application to the Nepali Biomass sub-sector in Chapter Three. The key learnings from this chapter are that market maps can be a useful tool for highlighting key barriers to the uptake of biomass-fuelled and other ICS especially in terms of identifying bottlenecks and complexities within the policy and regulatory framework. However, the market map has limited scope for the exploration of the social, cultural and financial factors as well as how these factors interact with the different key stakeholders in the value chain. I

also addressed the lack of a monitoring and evaluation element. The process of implementing an existing energy technology implementation framework created a practical knowledge base that was carried across to the development of a novel implementation model, which simultaneously satisfied the research gaps as well as addressing the shortcomings of the Market Map framework.

7.2.2. Development & Evaluation of Technology Implementation Model for Energy

Building on the themes and structures identified in Chapter Four, I developed an initial theoretical framework (Figure 4.4 p.114) that sought to address the research gaps. This initial theoretical framework was tested through five semi-structured interviews with a number of GCRF primary investigators. These interviews led to a number of structural and methodological changes, which included: refining the relationship between the four Strategic Planning Element (SPE) sub-factors, integrating the societal level into the expectation/assumptions sub-factor, combining the habitual and personal levels as well as defining the cyclical relationship between the SPE and the Enabling Environment Matrix (EEM).

These changes resulted in the Modified Theoretical Framework (Figure 5.7 p.159) which was taken forward into Practical Action Nepal's Results Based Finance project as a tool for evaluating the behavioural elements of supply and demand side interventions to promote the purchase of tier 2 & 3 ICS. The full methodological approach for this evaluation, in line with research objective two, can be seen in Chapter Six. This process of semi-structured interviews, focus groups, observations and informal conversations further refined the framework. These additional changes included: further groupings of behavioural determinants depending on application of MTF, renaming utilisation sub-factors to more accurately capture roles and interactions of key stakeholder groups, linking the EEM to the SPE through the engagement sub-factor, and mapping of barriers to enablers through the purpose -> assumptions -> engagement -> reflection elements. This transformative process from identification of barrier to the creation of an engagement strategy to that overcomes the barrier (turning it into an enabler) is especially key in successful energy programming. Figure 6.6 (p.191) shows the final version of the theoretical framework, termed the Technology Implementation Model for Energy (TIME) which was

presented at the end of Chapter Six. TIME satisfied the research objectives in developing a novel theoretical framework that can analyse the socio-cultural, environmental & financial barriers to the sustained use of poverty alleviating technology and translate these barriers into enablers through the SPE. A full explanation of the elements, factors and sub-factors can be found in Chapter Four Section 4.3.1.

TIME builds upon concepts from other models to explore the mechanisms of behavioural change around energy technology adoption and sustained use. For example, the SPE expands on the focus element of SaniFOAM and the EEM builds upon the enabling environment elements of the Market Map. The novelty of TIME is in its ability to identify complex contextual factors and map these factors across the four SPE sub-factors as well as defining key stakeholder roles and interactions that influence behavioural change. TIME also introduces novel core values that influence end-user behavioural change (ownership, utilisation and equality) which have not been explored in this contextual or sectoral setting previously. Additionally, the hybrid structure of the framework includes both multi-level and causal approaches that reflect and build upon the knowledge of the practitioner as the complex contextual factors evolve in space and time.

7.2.3. Comparison of Market Map & Technology Implementation Model for Energy Results as a Practitioner Tool

The application of two frameworks to the Nepali biomass ICS sector allows a direct comparison of the two methodologies and quality of results. In Chapter Three I used the Market Map tool (Practical Action Consulting and EUEI PDF, 2015) to evaluate the Nepali biomass ICS sector through reviewing government policy documents and semi-structured interviews with key stakeholders in the ICS value chain. I further refined and strengthened these results by presenting at the ICIMOD Air Pollution Conference in Kathmandu to a range of national and international energy experts. In Chapter Six I used the MTF to evaluate PANs RBF project through a series of semi-structured interviews, focus groups, observations and informal conversations with ICS key stakeholders. Whilst the MTF represents a technology user orientated approach and

the market map a high-level overview, both frameworks added value to the understanding of the Nepali biomass ICS sector.

The Market Map tool was developed to map or evaluate a specific sector or sub-sector, providing an overview across the three levels (Market Chain, Inputs, Services and Finance, Enabling Environment). However, as discussed across this research, the market map treats the technology users as a part of the value chain with limited influence on other key stakeholders rather than a central voice to influence strategic decisions that have an impact on the adoption and sustained use of technology. Conversely, TIME is focused on the voice of technology end-users and other key stakeholders through the co-production factor of the SPE element. This is achieved by building upon the market map strategy with a more in-depth qualitative data collection and analysis methodology. This unique combination of development planning tool, behavioural change model and market mapping elements allow practitioners and policy makers to gain deep insights into the relevant energy sector and how it is influenced by wider contextual issues. Additionally, the reflection sub-factor creates a model that can adapt to changing contextual need with time (Willoughby, 1990, Carr, 1985) and space (Jewitt, 2011).

7.3. Barriers to Adoption & Sustained use of Poverty Alleviating Energy Technologies in Nepal

In addition to developing a novel energy implementation model for practitioners and policymakers, this research looked to identify barriers to the adoption and sustained use of poverty alleviation technologies both globally, through the literature review, and in Nepal through the Market Map and MTF implementation. It was important to establish general barriers in the literature to gain a greater understanding of what the theoretical framework had to capture. The following section summarises the barriers identified in the literature review, the market map and TIME.

7.3.1. Barriers Identified in Literature

Barriers identified in the literature range from financial barriers, such as willingness to pay, affordability of technologies and access to financial institutions, to, socio-cultural barriers, such as stacking of technologies, the historical role of cooking and type of food cooked, and environmental barriers, such as the availability of firewood and

impacts of deforestation. Figure 2.2 (p. 32) summarises common barriers identified in a systematic review of the literature by Rehfuess et al. (2014) and divides these factors into seven categories (fuel and technology characteristics, household setting and characteristics, knowledge and perception, financial, tax and subsidy aspects, market development, regulation, regulation and standards, programmes and policy mechanisms) of which the most important factors for ICS adoption are fuel savings, impacts on time, smoke, health and safety, stove costs and subsidies, demand creation.

Whilst Rehfuess et al. (2014) give a broad overview of the common barriers, the literature review also identified a number of specific barriers which I categorised under the Financial, Environmental and Socio-Cultural groupings. A summary of all identified barriers can be found in Table 2.1 (p.39). Additionally, I reviewed WASH literature as suggested by Sesan et al. (2018) to determine any cross-sector learnings. This resulted in a number of alternate strategies of grouping behavioural determinants as they are referred to in some of the wider end-user orientated behavioural change literature. These included the psychosocial, technical and contextual grouping of IBM-WASH, Focus, Opportunity, Ability, Motivation of SaniFOAM and Reach, Efficacy, Adoption, Implementation and Maintenance of RE-AIM. Finally, the literature review highlighted the importance of understanding the barriers and/or enablers for each specific context, in this case the rural Nepali biomass ICS sector.

7.3.2. Assessments of Nepali Biomass Sector

7.3.2.1. Nepali Barriers Identified in Market Map

The Market Map successfully identified a number of high-level barriers that should be acknowledged by policymakers as well as more general barriers and enablers for household and institutional ICS users. These high-level policy barriers included the restrictive nature of the Renewable Energy Subsidy Policy (Ministry of Population and Environment, 2016) due to its 'one stove per kitchen' rule and the complexity of implementing the subsidy program. In cases cited by the ICS manufacturers and distributors, this complexity has led to the subsidy only covering the extra costs of paperwork rather than reducing the cost for the end-user. Additionally, Nepal's subsidy program does not differentiate between nationally and internationally

manufactured biomass ICS and end-users make no distinction between local or imported biomass ICS as for them affordability is central to acceptability. Unfortunately as shown by the Government list of approved ICS (Renewable Energy Test Station, 2019), international manufacturers often prioritise combustion efficiency over end-user preferences resulting in high costs and low adoption or sustained use rates. The market map also highlighted an underdeveloped institutional ICS market due limited funding for institutional solutions. However, Nepal's subsidy policies have been largely successful in both creating and sustaining a market which fosters alternative energy projects and the dissemination of household scale biomass ICS. When comparing the Nepali biomass sector to East Africa through the Market Map (Stevens et al., 2019), it highlights a lack of a local artisan stove market which could be critical in effectively reacting to regional/local demand for improved solutions.

Stacking, or the use of multiple cooking technologies to satisfy end-user needs, was the most common barrier identified in the market map semi-structured interviews. The use of multiple cooking solutions was primarily driven by cost and convenience as LPG hobs were often used for guests, metallic ICS were used in summer when they could be moved outside, traditional mud stoves were used for specific food groups and TSF were used for larger meals or preparing feed for livestock. However, social status and the availability of fuel also play a key role in determining which cooking solution was used. The complexity of these cooking stacks and unrecognised nature of stacking in the Government of Nepal's Household survey and renewable energy subsidy program causes major issues when biomass ICS become broken or discarded and, as the beneficiary does not qualify for another ICS, there is a tendency for them to 'backslide' to unimproved stoves, as seen in Jewitt et al. (2020).

7.3.2.2. Nepali Barriers Identified by TIME

A number of barriers identified in Chapter Six by TIME are similar to the barriers identified in Chapter Four with the market map. However, whilst there are a number of similarities especially around the stacking phenomenon, TIME provided more detailed insights into the barriers to adoption and sustained use, as well as the roles of key stakeholder groups and how the interaction between these groups influences the behavioural change of end-users. This additional detail was produced through the

detailed TIME semi-structured interview guide and resulting data analysis methodology as the number of semi-structured interviews was similar to the MM research. In addition, the SPE element divides the barriers between perceived (from Kathmandu-based key stakeholders), labelled P1, and actual (from field-based key stakeholders) end-users, labelled P2, priorities to highlight any differences between the project assumptions and expectations.

The top five barriers by mention from the Kathmandu based key stakeholders were: Awareness\Don't understand benefits, Finance\Willingness to Pay, CS Use\User Experience, Convenience and Stacking and Historical Use - living in traditional way. These barriers were based on Kathmandu key stakeholder's own perceptions of barriers, built on their own life experience, rather than conducting the more time demanding process of understanding actual end-user lived experience. In contrast, the top five barriers by mention from the field-based key stakeholders were: Convenience and Stacking, CS Use\Heating, Finance\Can't afford ICS, Aspiration and ICS Use\Smoke and Health\Smoke affecting health. The difference between these barriers highlights a failure of the wider international development energy sector, argued throughout this thesis, in focusing on promoting perceptions of need rather than identified and reacting to actual end-user needs. The ability of TIME to map perspectives highlights this significant discrepancy between these two groups of stakeholders. In the process of translating these barriers into enablers TIME allows the user of the framework to understand and explore these mismatched barriers through the assumptions and expectations sub-factor.

The ability of TIME to interrogate assumptions to distinguish between subtleties in for example, financial barriers where the difference between "willingness to pay" and "being able to afford an ICS" would determine the resulting demand-side strengthening strategy, is critical to project success. TIME also highlighted a number of differences between the perceptions and reality of the demand and supply side strengthening activities that resulted in project inefficiencies.

7.4. COVID-19 Impact

On March 23rd 2020, Nepal entered into a national lockdown due to the global COVID-19 pandemic, which has had a significant impact on PANs programs as well as the

ability to implement the recommendations of Chapter Six. Ideally, chapter Six would conclude with the effects of the recommendations on the adoption and sustained use of tier 2 & 3 ICS, however this is not currently possible. Practical Action continue to act in accordance with Government Guidelines meaning that work in the near future may be possible.

The impact of COVID-19 on this research goes beyond the disruption to PANs programming. COVID-19 also compromised my ability to complete research objective four - Outline the potential suitability of the theoretical framework for other country markets and sectors. The shutdown of international travel, changing UK Government advice on safe travel destinations and an updated University of Nottingham Travel policy made a field trip to collect data from another sector and/or country impossible. In addition, the qualitative nature of this research and the importance of understanding the lived experience of technology end users could not be captured over Microsoft Teams as many subconscious behavioural determinants would be missed. I do not feel the quality of this thesis had been compromised by not completing research objective four, however, this does provide an opportunity for future work outside of my work as a PhD student.

In addition to the research implications of COVID-19, I must also acknowledge the personal impact that the restrictive nature of life over the 3rd year of my PhD has had on my ability to efficienctly and effectively work. The unbalancing between work and home environments has resulted in difficulties that I had not envisioned at the beginning of this process.

7.5. Research Recommendations

7.5.1. A Co-Produced Approach to Energy Technology Implementation

A long history of energy technology implementation in low-income environments has resulted in varied and diverse strategies to increase the end-user demand and create value sustainable chains through incentivising suppliers. These strategies have revolved around environmental, educational, safety and health goals yet the complex contextual barriers often seem to be the determining factor in success. This paper proposes a new system wide approach, similar to IBM-WASH “transcending the individual level” (Dreibelbis et al., 2013), where the technology end-users not only

partake in the development of the implementation strategy but are seen as equitable co-producers central to sustainable change. Traditionally implementation models are either top-down or bottom-up driven, with the decision-making process either at the top or bottom, with the implementing partner or the end-user. This system devalues the contribution of one or more key stakeholder groups, TIME proposes a system where all key stakeholder groups co-produce the implementation strategy. For example, in the Nepali context, this meant that from the Government perspective, policy must take into account complex contextual factors developed by end-users and focus on developing project goals around key stakeholder group strengths. However, this co-produced strategy is reliant on a fair and open communication methodology where no key stakeholder groups have decision making power over another which, can be challenging as traditionally one partner holds the financial power.

7.5.2. Perception Vs. Reality

The multi-phase strategy of the SPE highlights differences between the key stakeholder group perceptions and the reality of technology end-users. As shown by Practical Action's RBF project, these differences between perceptions and reality can have a significant impact on the project outcomes. In this case, PAN inadvertently negatively impacted the reputation of local distributors, manufacturers and NGO representatives through an assumption of need rather than actual identification through end-users. This problem of misaligning assumptions is not exclusive to Energy Technologies; this element of TIME has application across many International Development programs that are traditionally top-down led. Whilst distinguishing between perceptions and reality has additional time requirements, this research recommends that all energy technology-based poverty alleviation projects conduct this process to easily highlight shortcomings and possible areas of failure.

Understanding the different between perceptions of technology developers and the reality of technology users is critical for euro-centric engineers to develop energy technologies that react to the actual needs and aspirations of low-income communities. Current best sector practice does not look to interrogate these differences which, as has been argued throughout this research, is a central reason for the failure of many improved cookstoves, and wider energy, projects. Moreover, by

TIME developing a methodology for this process engineers across the International Development sector (outside of energy) can utilise and adapt TIME to their own sectors.

7.5.3. Defining Impact

Throughout this research defining impact or the way in which success has been measured has fallen into two categories, either quantitatively or qualitatively. For example, the number of ICS bought or adopted is often thought of as a quick and easy method of understanding the success of a stove program. However, as I have explored extensively in the literature review and results chapters, this categorisation of "success" does not capture any end-user behavioural decisions associated with the sustained use of ICS. This leads to a misrepresentation of success to funders and implementation partners, in PA's RBF project this led to many ICS being purchased but not used due to a lack of monitoring, training on use and support post purchase. TIME presents an alternative strategy to measure impact through the four core factors: co-production, ownership, use and equality. Whilst it is more difficult to quantify results through this method, modifying the definition of impact from adoption to sustained use, ensures a more significant impact on the behavioural change of end-users. However, this change in impact definition also requires the funding and implementing partners to understand complex contextual factors, such as stacking, and the role that each specific energy technology has in the behavioural change process. In the case of biomass ICS, this is as a 'steppingstone' technology to initiate behavioural change around open fire cooking resulting in the transition of the entire energy stack to a series of cooking technologies higher up the energy ladder.

7.6. Limitations and Future Research

Despite the strengths of the research presented in this thesis, there are a number of limitations and areas for future work. In addition to the qualitative limitations stated in Chapters Five & Six, the following section details a number of TIME limitations. The impact of COVID-19 highlights the human centred nature of this research, the ability to travel to the contextual setting that is being evaluated is key in effectively mapping the sector or sub-sector of focus. Without the ability to experience the contextual factors, many insights are lost. This either required a change in the focus of TIME or

more detailed training of field-based practitioners to conduct this research. However, given the heavy theoretical background, without training, TIME could be difficult to effectively implement for practitioners. Additionally, given the detailed methodological steps required to adequately understand the complex contextual factors as well as the roles and interactions of KS groups, practitioners and policymakers would be required to invest project funds (or time) to implement TIME. As stated in the research recommendations, the process would increase the chances of programmatic success, however, given the inflexibility of the International Development sector around adopting new methodological processes, this investment requirement may be a significant limitation for TIME.

Future research involves further development of TIME in three specific areas. First, an additional level of analysis when coding the interview data for the EEM. Currently the first level identifies themes, and second level removes duplicated nodes. When coding in these two levels, the barriers and enablers of technology implementation are given equal weighting. However, it would be interesting to add an additional weighting level to see the impact of a different weighting on the graphical representation of the EEM. Second, whilst the graphical presentation of EEM results communicates general themes across the core factors and key stakeholder groupings. Further development of this presentation method is needed to highlight the difference in role perceptions. Third, this research has provided a step forwards in the energy technology implementation literature, however, the exploration of the interactions between TIME and other frameworks such as IBM-WASH may provide deeper insights into the behavioural decisions of technology end-users. For example, the SPE Purpose & Need sub-factor may benefit from the structured approach of the IBM-WASH framework in grouping behavioural determinants, echoing the EEM element acting as an expansion for the SPE engagement sub-factor.

In addition to these structural and methodological improvements, there is also future work developing an online tool to help with practitioner and policymaker accessibility building on the user guide described in Chapter Six. This online tool would contain the semi-structured interview templates, a step-by-step methodological guide to data collection and standardised analysis format. This could allow practitioners and

policymakers to identify common issues in other energy technology implementation projects, thus increasing the efficiency of implementation across the value chain. This element of future work should also look to satisfy RO4 as the end-user focused co-produced implementation strategy presented in this research may have significant importance to other sectors that implement poverty alleviating technologies where traditional market-based mechanism fail to overcome complex contextual barriers. The framework should be applicable to other sectors as proved by the GCRF interviews as well as the frameworks roots in literature outside of the energy sector.

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9. Appendices

Appendix A: Ethical Approval

Ethics Committee Reviewer Decision

This form must be completed by each reviewer. Each application will be reviewed by two members of the ethics committee. Reviews may be completed electronically and sent to the Faculty ethics administrator (Jo Deeley) from a University of Nottingham email address, or may be completed in paper form and delivered to the Faculty of Engineering Research Office.

Applicant full name Benjamin L Robinson

Reviewed by:

Name DE13

Signature (paper based only)

……

Date ……8 January 2019……

■ Approval awarded - no changes required

☐ Approval awarded - subject to required changes (see comments below)

☐ Approval pending - further information & resubmission required (see comments)

☐ Approval declined – reasons given below

Comments:

I am happy for this to proceed.

Please note:

1. The approval only covers the participants and trials specified on the form and further approval must be requested for any repetition or extension to the investigation.
2. The approval covers the ethical requirements for the techniques and procedures described in the protocol but does not replace a safety or risk assessment.
3. Approval is not intended to convey any judgement on the quality of the research, experimental design or techniques.
4. Normally, all queries raised by reviewers should be addressed. In the case of conflicting or incomplete views, the ethics committee chair will review the comments and relay these to the applicant via email. All email correspondence related to the application must be copied to the Faculty research ethics administrator.

Any problems which arise during the course of the investigation must be reported to the Faculty Research Ethics Committee

Appendix B: GCRF Semi-Structured Interview Guide, Consent Form, Information Sheet

GCRF Participant Semi-Structured Interview Guide

The following guide will be used to prompt discussion around topics associated with factors that influence successful project design, implementation and evaluation for energy-based initiatives. There are no set questions as these discussions will be led based on participant responses. This means that depending on the flow of the interview and the types of energy initiative, certain topics may or may not be covered during each interview. Furthermore, depending on responses, the topics may run in a different order than presented in this guide.

Introduction

- Participants will be introduced to the researcher.
- The participant information sheet and consent form to be read aloud in English or the local dialect.
- Opportunity for participant to ask questions about the forms and the study.

Tape recording and photography

- Ask interviewee for permission to tape record the interview. Explain that it is important to capture their words and ideas; using a tape recorder will allow the researcher to do this.
- If interviewee does not permit tape recording ask if it is ok to take written notes.
- Re-inform the interviewees they will remain anonymous and the notes and recordings will be kept strictly confidential. Tape recordings, written notes and equipment will be kept in a locked safe and transferred to a password protected computer as soon as possible.
- Ask the interviewee for permission to take photographs during the interview and observational process. Explain that; Photos are useful to provide an accurate record situational context. Photographs may include yourself or other members of your Institution as long as you are happy to be in the pictures. You do not have to be in the photograph. Photographs taken may be used for any lawful purpose including publications, reports and conference posters. Photos will **not** be printed with participant names.
- For more information about the use of the photographs, please refer participant to the information sheet.
- If interviewees do not permit the use of photography no-photography equipment will be used.

Consent

Before signing the consent form ensure that;

- The participant has been given time to ask questions about the tape recorder and/or photography.
- Participants are re-informed that they may withdraw all or parts of their data. There would be no consequence of withdrawing information and no reason is required.

- Participants are provided with the information sheet and copy of consent form in either English or Nepali.
- Identify contact details of researcher should participants wish to make contact following their interview.
- Ensure participant is happy to continue with the study and to sign or print on the consent form.
- Researcher to co-sign the consent form.

Beginning the interview

Before starting any further questioning explain to participants that:

- There are no wrong answers.
- Where possible it may help to give examples of their experiences.

Turn on the tape recorder and test it together

Date of interview	
Institutional code	

Questions & Prompts to be covered in the Semi Structured Interview

1. Background	
Questions	**Prompts**
Theoretical Framwork	• Explain the PhD research (ensuring the research is rooted in reality)
GCRF Project	• Can you tell me about your GCRF Project (and your role in it)? • This is my understanding of your project from the GCRF brief, has the project changed over its implementation? • Was any kind of Project Design Framework used to help create this project? (Is this affected by scale?)

2. Project Design (Levels and Factors)	
Questions	**Prompts**

GCRF Levels	• Can you tell me about the levels on which your is aimed at and what impact this has on other levels of society? • The most important in this list.
GCRF Themes or Factors	• Can you tell me about the factors or themes that will determine the success of your project? • Barriers to sustained use & biggest challenges • The most important in this list. • Top-down or bottom-up process
Process	• How themes or factors have been integrated into the project process (Contextual factors). • What happens next/the future. • Biggest Project Challenges?

3. The Theoretical Framework	
Questions	**Prompts**
Theoretical Framework Factors	• How to **Beneficiary/Local Ownership, Utilisation, Equality & Co-Production** integrate into your GCRF Project? • Is there a key theme or factor missing?

4. Any other questions for the interviewer?	
Questions	**Prompts**

Ending the interview

At the end of the interview participants will be thanked for their time and let know that we will be in touch if any additional information is needed.

GCRF Participant Consent Form

Name of Principal Investigators

Benjamin Robinson (PhD Researcher), Dr Mike Clifford (Associate Professor), Dr. Sarah Jewitt (Associate Professor) - University of Nottingham UK

Purpose of the Research

The purpose of this study is create a novel enterprise model to increase uptake of energy-based interventions in low-income countries. This interview will determine factors that influence successful project design, implementation and evaluation across energy based interventions.

Participation in this Research

Participation in this research will consist of:

- A semi-informal interview with a researcher (and translator). If you consent to take part in an interview it will be arranged around your time and can take place either over the phone, on skype, at your office or a pre-agreed location. Discussions will be based around your (or your organisations) project(s). Interviews may last 30-60mins depending on the time you have available and the information you wish to share. Participation may involve the audio recording of the interview and note taking. All personal information will be removed from your interview data to ensure your accounts remains completely confidential and anonymous.

Audio recording and note taking will be only be used at the discretion of the participant. Any information provided in the interviews will be completely confidential and anonymous.

What will happen to the Data

Information collected from your interview will be used to develop a tool to help implement energy interventions on a community level. It is anticipated that this information will be disseminated by the collaborating organisations through academic publication, organisational resources or conference presentations. Your name will not be included within these reports but your organisations name will be unless you do not wish for the organisation to be identified. Inform the researcher directly and tick the box below.

I **do not** grant the researcher permission to disclose the organisation I am associated with (please tick if applicable)	

Please read or listen to the following information in this form;

To confirm each box has been read and understood please tick the box following each statement below

I voluntarily agree to take part in this study	
I confirm that I have been given a full explanation by the above named investigator or research assistant and that I have had the chance to read or listen to the information provided in the participant information sheet.	
I have been given the opportunity to ask questions and discuss the study with the investigator or research assistant on all aspects of the study and have understood the advice and information given as a result.	
I authorise the investigator to disclose the results of my participation in the study but not my name.	
I understand that information about me recorded during the study will be kept in a secure database. Data will be kept for 7 years after the results of this study have been published.	
I understand that I can ask for further instructions or explanations at any time during the investigation.	
I understand that I am free to withdraw from the study at any time without penalty.	
I understand there will be no payments for the participation in this research.	
I understand that if information is disclosed during the interview that indicates intentional abuse or harm of a minor, the investigator has an obligation to breach confidentiality and pass this information to the relevant authorities.	

Participant Name.....
.....

Participant signature or thumb print .....
Date.....

I, Benjamin L Robinson, the researcher, confirm that I have fully explained the purpose of the study and what is involved.

Researchers signature
.....Date.....
.....

The signed copy of this form is retained by the researcher, and at the end of the project passed on to the principal investigator. A Participant Information Sheet will be given to the participant for their own records.

GCRF Participant Information Sheet

Dear Participant,

I am a postgraduate researcher from the University of Nottingham UK, my research looks at creating a novel enterprise model to increase the uptake of energy based interventions in low-income countries by drawing on the appropriate technology and social enterprise movements. The creation of this model will provide the structure for an energy based intervention in Nepal, evaluating its effectiveness. If you would like to hear more about this research, please find our contact details on the final page of this document.

Before you decide if you would like to take part in our investigation, it is important for you to understand why this research is being done and what it may involve. Please take the time to read or listen to the following information carefully, you may also take the time to discuss this with friends or relatives before deciding if you so wish. If anything is not clear or if you would like more information than is provided here, please ask. If you decide to take part, you may keep this leaflet for your reference.

What is the purpose of this Interview?

The purpose of this interview is to determine the factors that influence successful project design, implementation and evaluation across energy based interventions.

Why have you been chosen?

You have been recruited for one or more of the following reasons;

- You are a member of a University or NGO working in energy-based development programs.
- You are a member of a small or medium enterprise that has social and/or environmental outcomes.
- You are a member of a technology based social enterprise.

Do you have to take part?

No, participation is voluntary. It is up to you to decide whether to take part. If you do decide to take part, you will be given this information sheet to keep and be asked to sign a consent form. If you do decide to take part you are still free to withdraw at any time without giving a reason. You may request that all or some of your data be destroyed and will not be used in the study. There are no consequences to deciding that you no longer wish to participate in the study.

What will taking part involve?

Participation in this research will consist of:

- A semi-informal interview with a researcher (and translator). If you consent to take part in an interview they will be arranged around your time and can take place either over the phone, on skype, at your office or a pre-agreed location. Discussions will be based around your (or your organisations) project(s). Interviews may last 30-60mins depending on the time you have available and the information you wish to share.

Participation may involve the tape recording of the interview and note taking. All personal information will be removed from your interview data to ensure your accounts remains completely confidential and anonymous.

Are there any hazards, inconveniences and risks associated with this study?

No, this study is purely informational. You will not be asked to do anything to put yourself at risk during this study.

What are the possible benefits of taking part?

Taking part in this study will help us to achieve a greater understanding of the energy based interventions in low-income countries, contributing to the creation of a novel enterprise model. There are no financial payments attached to taking part in this research.

What if something goes wrong?

Participation is voluntary. If you change your mind about taking part in the study, you can withdraw at any point without explanation. If you decide to withdraw, you can decide whether to withdraw some or all of your data. If you decide to withdraw your data this will be destroyed and will not be used as part of the study.

Will my taking part be kept confidential?

All information collected about you and your institution during the course of the research will be kept confidential. Your data will be given a participant code that will be unidentifiable to you. Your consent form will not be used to identify you and will be filed separately from all other information. Field notebooks will be locked in a secure location at the researcher's base. All transcribed or recorded interview data will be kept on a password protected computer.

What will happen to the results of the research study?

The information collected from your interview will be used to determine factors that affect successful energy-based interventions in low-income countries. It is anticipated a final report will be completed and form part of future academic publications, organisational resources or conference presentations. The information will not be used in any way that will allow you or your family to be identified individually.

Who is organising the research?

This study forms part of a PhD funded by the University of Nottingham, field visits are coordinated by Ben Robinson (the PhD researcher) and supervised by Dr Mike Clifford and Dr Sarah Jewitt – all contact details below.

Who has reviewed this study?

The study has been reviewed and approved by the Faculty of Engineering Ethics Committee (University of Nottingham, UK)

Who can I complain to?

In the case you have a complaint about the researcher, the research assistant or any aspect of the study you can initially approach the primary supervising researcher (Dr. Mike Clifford).

If this does not achieve a satisfactory outcome, and you wish to make a formal complaint about the conduct of the research then please contact The University of Nottingham Engineering Faculty Research Ethics Officer - Dr Gary Burnett, Room 51 Coates, University Park, Nottingham, NG7 2RD, (+44) 0115 95 15030, gary.burnett@nottingham.ac.uk

Contact for Further Information

PhD Researcher - Ben Robinson
Email – Benjamin.robinson@nottingham.ac.uk
Phone (UK) - +447942789093

Or

Supervising Researcher Dr Mike Clifford
Email - mike.clifford@nottingham.ac.uk

Phone (UK) – (+44) 0115 846 6134

Or

Supervising Researcher Dr Sarah Jewitt
Email - sarah.jewitt@nottingham.ac.uk

Appendix C: Practical Action Nepal Results Based Financing Phase 1 & 2 Semi-Structured Interview Guide, Consent Form, Information Sheet, Observation Guide

RBF Phase 1 Semi-Structured Interview Guide

The following guide will be used to prompt discussion around topics associated with factors that influence successful Behavioural Change (BC) campaigns as well as defining the roles of the key stakeholders. There are no set questions as these discussions will be led based on participant responses. This means that depending on the flow of the interview and the types of initiative, certain topics may or may not be covered during each interview. Furthermore, depending on responses, the topics may run in a different order than presented in this guide.

Introduction

- Participants will be introduced to the researcher.
- The participant information sheet and consent form to be read aloud in English or the local dialect.
- Opportunity for participant to ask questions about the forms and the study.

Tape recording and photography

- Ask interviewee for permission to tape record the interview. Explain that it is important to capture their words and ideas; using a tape recorder will allow the researcher to do this.
- If interviewee does not permit tape recording ask if it is ok to take written notes.
- Re-inform the interviewees they will remain anonymous and the notes and recordings will be kept strictly confidential. Tape recordings, written notes and equipment will be kept in a locked safe and transferred to a password protected computer as soon as possible.
- Ask the interviewee for permission to take photographs during the interview and observational process. Explain that; Photos are useful to provide an accurate record situational context. Photographs may include yourself or other members of your Institution as long as you are happy to be in the pictures. You do not have to be in the photograph. Photographs taken may be used for any lawful purpose including publications, reports and conference posters. Photos will **not** be printed with participant names.
- For more information about the use of the photographs, please refer participant to the information sheet.
- If interviewees do not permit the use of photography no-photography equipment will be used.

Consent

Before signing the consent form ensure that;

- The participant has been given time to ask questions about the tape recorder and/or photography.
- Participants are re-informed that they may withdraw all or parts of their data. There would be no consequence of withdrawing information and no reason is required.

- Participants are provided with the information sheet and copy of consent form in either English or Nepali.
- Identify contact details of researcher should participants wish to make contact following their interview.
- Ensure participant is happy to continue with the study and to sign or print on the consent form.
- Researcher to co-sign the consent form.

Beginning the interview

Before starting any further questioning explain to participants that:

- There are no wrong answers.
- Where possible it may help to give examples of their experiences.

Turn on the tape recorder and test it together

Date of interview	
Institutional code	

Questions & Prompts to be covered in the Semi Structured Interview

1. Organisational Background
State the name of your organisation and the position that you hold.
First can you please briefly explain what your organisation does?
Can you also talk about the role that you have in this RBF project? (policy, design, implementation, evaluation, finance etc.)

2. Strategic Planning/Co-Production	
Questions	**Prompts**
Purpose	• Explain what they think the purpose of this project is. Or the purpose/importance of their role in the project.
Assumptions/Expectations	• Are these societal, community or individually based. • Are these based on past experiences of what has worked. Or personal assumptions of what will work
Participation/Engagement	• What is the strategy from their perspective and how could they improve it?

	• Are they engaged in the process? And in what way are they engaged?
Reflection	• How are they reflecting on their role, including a community voice? Or assuming success. Are there any improvements to be made?

3. Enabling Environment (Levels/Key Stakeholders) Govt. NGO/Business. Co-Or P. Comm. Personal.	
Questions	**Prompts**
Key Stakeholders	• Who are the key stakeholders in this project for you? • How do you interact/communicate or work with them? • Are some key stakeholders more important than others?
Introducing Levels/Key Stakeholders that were not mentioned?	• E.g. what do you think the government's role is in making this project more successful?

4. Enabling Environment (Factors)	
Questions	**Prompts**
Factors for Behavioural Change	• What do you think are the most important factors for BC around cooking? • Explain some of the barriers to sustained use & biggest challenges to BC? And the most important in this list. • Different between strategies for adoptions and strategies for sustained use. • What happens next/the future.
Introducing Factors that were not mentioned	• How to **Beneficiary/Local Ownership, Utilisation, Equality & Co-Production** integrate into the RBF project. • How is the key stakeholder promoting these factors?

5. Any other questions for the interviewer?	
Questions	**Prompts**
Is there anything we haven't mentioned that you feel is important?	

Ending the interview

At the end of the interview participants will be thanked for their time and let know that we will be in touch if any additional information is needed.

RBF Phase 2 Semi-Structured Interview Guide

The following guide will be used to prompt discussion around topics associated with factors that influence successful Behavioural Change (BC) campaigns as well as defining the roles of the key stakeholders. There are no set questions as these discussions will be led based on participant responses. This means that depending on the flow of the interview and the types of initiative, certain topics may or may not be covered during each interview. Furthermore, depending on responses, the topics may run in a different order than presented in this guide.

Introduction

- Participants will be introduced to the researcher.
- The participant information sheet and consent form to be read aloud in English or the local dialect.
- Opportunity for participant to ask questions about the forms and the study.

Tape recording and photography

- Ask interviewee for permission to tape record the interview. Explain that it is important to capture their words and ideas; using a tape recorder will allow the researcher to do this.
- If interviewee does not permit tape recording ask if it is ok to take written notes.
- Re-inform the interviewees they will remain anonymous and the notes and recordings will be kept strictly confidential. Tape recordings, written notes and equipment will be kept in a locked safe and transferred to a password protected computer as soon as possible.
- Ask the interviewee for permission to take photographs during the interview and observational process. Explain that; Photos are useful to provide an accurate record situational context. Photographs may include yourself or other members of your Institution as long as you are happy to be in the pictures. You do not have to be in the photograph. Photographs taken may be used for any lawful purpose including publications, reports and conference posters. Photos will **not** be printed with participant names.
- For more information about the use of the photographs, please refer participant to the information sheet.
- If interviewees do not permit the use of photography no-photography equipment will be used.

Consent

Before signing the consent form ensure that;

- The participant has been given time to ask questions about the tape recorder and/or photography.
- Participants are re-informed that they may withdraw all or parts of their data. There would be no consequence of withdrawing information and no reason is required.
- Participants are provided with the information sheet and copy of consent form in either English or Nepali.

- Identify contact details of researcher should participants wish to make contact following their interview.
- Ensure participant is happy to continue with the study and to sign or print on the consent form.
- Researcher to co-sign the consent form.

Beginning the interview

Before starting any further questioning explain to participants that:

- There are no wrong answers.
- Where possible it may help to give examples of their experiences.

Turn on the tape recorder and test it together

Date of interview	
Institutional code	

Questions & Prompts to be covered in the Semi Structured Interview (state code on recording)

STRESS: there are no wrong answers, we are interested in your honest opinion, thoughts and feelings.

6. Strategic Planning/Co-Production	
Questions	**Prompts**
Purpose	• Have you heard about the practical action project?
Assumptions/Expectations	• What have you heard? • What is your expectation?
Participation/Engagement	• Are you engaged in the process? And in what way are you engaged?
Reflection	• Are there any improvements to be made?

7. Enabling Environment (Factors)	
Questions	**Prompts**
Typical Day	• Tell me about a typical day for you when it comes to cooking (including firewood collection, food purchase, food preparation, cooking, cleaning) • Is this day different in winter and summer (seasonal)?

	• What else do you use your traditional cookstove for? • What do you value most about your cooking technology?
Awareness of other Technologies	• Do you know about the benefits of using a cookstove? • If so, why do you use it or why not? • What is your experience of ICS? • And what do you use each technology for? (if cookstove stacking)
Factors for Behavioural Change	• What factors are most important to you when it comes to cooking/the technology? • Why would you not buy a cookstove? (explain reason behind points) • How does the availability of LPG influence your cooking? • What happens next/the future. • Would you use a ICS if your neighbour or community leader did? • Electricity connection

8. Enabling Environment (Levels/Key Stakeholders) Govt. NGO/Business. Co-Or P. Comm. Personal.	
Questions	**Prompts**
Key Stakeholders	• Who are the key stakeholders within the community for you? • How do you interact/communicate or work with them? • Are some key stakeholders more important than others?
Introducing Levels/Key Stakeholders that were not mentioned?	•

9. Any other questions for the interviewer?	
Questions	**Prompts**
Is there anything we haven't mentioned that you feel is important?	

Ending the interview

At the end of the interview participants will be thanked for their time and let know that we will be in touch if any additional information is needed.

RBF Observation Guide – Field Visit 11/02/20

Buy using this method as supplementary to the semi-structured interviews, we are looking to capture the unspoken behavioural indicators. Behaviours that the user does not even realise they are doing. Observation is also used to reinforce what is being stated in the interviews, if someone says they use the cookstove but it does not look like it has been used, this should indicate to the interviewer to rephrase the path of questioning.

Objective notes are key – meaning can not be attributed to anything.

What we are interested in observing:

- Context of household (where it is, what is it like, is there a tv, are there animals?)
- Family health (does anyone have a cough, do they have medications lying about, how many in the family, who is there when looking around, does anyone have any burns)
- Kitchen Set up (multiple cookstoves, soot on the walls, cooking inside or outside, stove quality)
- Gender rolls around cooking
- Fuel (collected, made, by who?)
- How do people there interact with each other?
- Is the house connected to electricity?
-

Note all locations with interview codes

Results Based Finance: Consent Form

Name of Principal Investigators
Dr Mike Clifford, Associate Professor, University of Nottingham UK
Ben Robinson, Post-Graduate Researcher, University of Nottingham UK
Pratik Bhandari, Research Assistant

Purpose of the Research
The purpose of this study is to evaluate the behavioural change elements of the Practical Action Results Based Finance (RBF) project. Resulting in a series of recommendations to improve the effectiveness of the behavioural change elements.

Participation in this Research
Participation in this research will consist of one or both of the following components;

1. A semi-informal interview with a researcher and translator. If you consent to take part in an interview they will be arranged around your time and can take place in your home, business or in a community area. Discussions will be based around your involvement with the RBF project. Interviews may last 30-60mins depending on the time you have available and the information you wish to share. Participation may involve the tape recording of the interview, note taking and photography. The use of photography is at your discretion. All personal information will be removed from your interview data to ensure your accounts remains completely confidential and anonymous.

2. Informal observation - the researchers may ask you to show them around so as to observe your business, NGO or community. This observation will be informal and you should feel free to share your thoughts and opinions. In this time the researcher may make a record using photography.

Audio-recording, note taking and photography will be only be used at the discretion of the participant. Any information provided in the interviews will be completely confidential and anonymous.

What will happen to the Data
Information collected from your interview will be used to provide recommendations to Practical Action. It is anticipated that this information will be disseminated by the collaborating organisations through academic publication, organisational resources or conference presentations. Your name will not be included within these reports.

Please read or listen to the following information in this form;

To confirm each box has been read and understood please tick the box following each statement below	
I voluntarily agree to take part in this study	

I confirm that I have been given a full explanation by the above-named investigator or research and that I have had the chance to listen to the information provided.	

I have been given the opportunity to ask questions and discuss the study with the investigator or research assistant on all aspects of the study and have understood the advice and information given as a result.	
I authorise the investigator to disclose the results of my participation in the study but not my name.	
I understand that information about me recorded during the study will be kept in a secure database. If data is transferred to other it will be made anonymous. Data will be kept for 7 years after the results of this study have been published.	
I understand that I can ask for further instructions or explanations at any time during the investigation.	
I understand that I am free to withdraw from the study at any time without penalty.	
I have been informed there will be no payments for the participation in this research.	
I understand that if information is disclosed during the interview that indicates intentional abuse or harm of a minor, the investigator has an obligation to breach confidentiality and pass this information to the relevant authorities.	
I grant the researcher named above the right to take photos. These photographs may include me and/or my organisation or community in connection with the above study. I agree that they may use these photographs without my name for any lawful purpose this will include reports, publications and conference presentations.	

Participant signature or thumb print …… Date……

I, Benjamin Robinson, the researcher, confirm that I have fully explained the purpose of the study and what is involved.

Researchers signature ……Date…….

The signed copy of this form is retained by the researcher, and at the end of the project passed on to the principal investigator.

Appendix D: Practical Action Nepal Results Based Financing Coding Framework

RBF_Interviews_V1_28.01.20 Coding Matrix

Strategic Planning Element

Name	Description
Co-Production (Mapping BD & Strategies)	
1. Behavioural Determinants Matrix	
Aspiration	Aspiration of user
Availability of other Tech.	The abundance of other technologies apart from the TSF and the role that has on user decision making.
Due to Topography	
Rural Urban Divide	
Awareness	
Don’t know about RBF	
Don't understand benefits	
Understand benefits of ICS	
Backsliding	
Convenience and Stacking	How does stacking and thus convenience affect cookstove use?
CS Use	The BD based around the technology (all cookstoves)
Ability to Borrow the ICS	
Ash in Food	
Ashes as Fertilizer	
Boiling Water	
Cleaning Pots	
Cooking for Cows	
Dry Hands	
Durability	
Family Size	
Firewood or Biomass Fuel	Using less and chopping into smaller pieces.
Buying firewood	
Collection from Jungle	
Difficult collecting firewood	
ICS uses less firewood	
No shortage of firewood (collection from own land)	
Using firewood for big occasions	
Using less wood due to LPG	
Utilising waste	
Heating	People and keeping food warm

	Mental Health	The impact of cooking with an open fire on mental health
	Multiple Burners	The role of the ICS having more than one place to cook
	Portability of ICS	
	Quality	The quality of the product
	Safety	Burns, cut, scrapes etc
	Smoke and Health	
	Cooking with firewood is healthier	
	Should be no smoke	
	Smoke affecting health	
	Smoke going outside	
	traditional stove has too much smoke	
	Taste of food better with wood	
	Time Saving	
	Time (not) saved preparing fuel	Improved cookstoves take more time as the user has to prepare firewood.
	Time saved cleaning	Cleaning soot off pots, pans, walls and ceilings
	Time saved cooking	
	User Experience	Previous negative experiences have impacted the decisions that users make in adopting new technologies
	User Friendliness of Tech	Lab/Field Divide. Ease of Use, Chopping Wood into Smaller Pieces
Dependency		The role that previous interventions have had on users, eg. NGO giving cookstoves for free
Finance		
	Cant afford ICS	
	Not willing to invest	
	Other financial priorities	Such as education, phones, motorbikes, building houses
	Spend on cheapest technology	TSF costs much less than an improved cookstove
	Waiting for ICS to be cheaper or free	Through mass production or waiting for another organisation to distribute it for free
	Want to Invest	Have said they will pay for an improved cookstove but have not done so yet
	No willingness to Pay	No willingness to pay as the traditional stove costs nothing (not factoring in user time in the collection of firewood)
Government Mistrust		The government has not supported them in other projects so why should the users trust them in this.

Historical Use - living in traditional way	Too hard to break the habits of a lifetime so users don't.
Hygiene	Cooking with open fire makes the house dirty and users want a more hygienic house.
Literacy	Users can not read or write so think they cannot understand how to use cookstove (leaflet that was distributed)
Migration	Younger generation moving from rural to urban or abroad
No Supply Chain	No infrastructure or limited supply
Electricity	
ICS	
LPG	
Pellets	
Not Fashionable	Cooking is not fashionable
Poverty	The users have other priorities due to their position in society.
Reputational Risk	Reputation risk of users promoting technology to their friends if it does not live up to the expectation.
Social Status	Buying ICS to increase user's social status
User make ICS themselves	Users want training to make t.he ICS themselves
2. Assumptions & Expectations	
Assuming researchers where there to give stove for free	
BD are different in different geographies	
Energy is not Government Priority	
Expectation of Quality Service	Pre and post buying of technology
High quality technology which works as it is told	Smokeless doesn't always mean smokeless
ICS market is unpredictable	No real demand for cookstoves
Information dissemination process is slow	
No education, results in no use	
No expectations, just bough as was curious	Linked to social status, user wants the latest technology.
Price to decrease as more people use ICS	
Project Mechanisms work as designed	
The new generation want new technology	Seeking Luxury
The T3 ICS will cost more electricity	

There is no duplication of work	
Time saving leads to negative activities	Such as gambling or consuming alcohol
Use depends on need	
Users are price orientated	Make it cheaper and they will buy and use
Users scared of NGOs and Manufactures	Don't want them to come into their community
Users take loans for ICS	
Users want ICS	
Value chain is re-usable	Tier 3 stoves can be promoted through the Tier 2 value chain, Induction hobs through the T3 etc.
Warranty will be honoured	
3. BD Strategies Matrix	
(Government) Policy & Subsidy	National/Local systems and mechanisms which increase the availability of ICS to users. As well as previous projects such as the mud-cookstove training.
Connecting KS to Users	
Incentive Scheme (Coupon System)	
Local Manufacture Preference	
Providing documents	
Reduction in ICS Cost	
Support in modifying policy	
Training to make cookstove	
Awareness Campaign	Spreading awareness about the technology and benefits
Communicating ICS Benefits	Through marketing campaigns, communication with users, pamphlets, radio shows etc.
Cookstove Demonstration	
Finance Available	Make users aware that there is finance available for ICS
House visit Program	
Through other Programs	
Blockade	Influence on LPG blockade in 2016 and how a similar mechanism could be used to get users interested in ICS.
Formal or Informal P2P Marketing	
Between Castes	
Competition between users	
Distributors only helping friends	

Giving away cookstove to test	
Inter-Generational	
Public Pressure	Communities forcing people to adopt technologies
Recommendation from friend or Community leader	
Social Pressure	
Through community groups	
Volunteer Distributor	
Habituate Technology	Integrate technology into everyday habit (also referred to as to domesticate)
Mobilize Financial Institutions	Incentivise financial institutions to help with the financial barriers to implementation as well as providing loans to users for ICS. This includes financial co-operatives and MFIs.
Modifications of Tech. to Satisfy User Need	Multi-use to better satisfy needs
Nationalistic Pride	Better to use firewood from Nepal than LPG from India
Remittance	the results from families having more income due to remittance and how can this be leveraged for ICS
Social Media Marketing	Use of social media to target groups and also target areas that are not accessible to KS
Supply Chain Strengthening	Investment in Local Infrastructure, creation of market mechanisms for dissection of ICS
Targeting Marginalised Communities	Targeted marketing for marginalised groups as the perception is that these people need more help in terms of awareness and finance.
User buying from Local Market	Connecting ICS to other equipment (farming) as well as users going to find ICS outside of the programs
Warranty and Maintenance	Users making decisions based upon the support that they will get post payment
4. Reflections	
Budget constrictions for KS	
Focus on adoption rather than sustained use of ICS	
Government doesn't understand ICS programs	
Improvements, Feedback for ICS	
Manufacturer implemented suggested changes	
Manufacturers not involved in MandE	

Other KS involved in improving ICS	
Positive Impacts of RBF	
Problems with subsidy system or incentive	
RBF1 to RBF2 improvements	
There is duplication of programs	
User Perspective	
Communication of Funding Systems to Users	Users to not understand the subsidy systems etc,
Comparison with other technologies	
Feel cheated by distributor (financial co-operative etc)	
Havent used ICS after buying	
Local NGOs other projects have made life easier for users	
Need to be identified before ICS bought by distributor	
People with money buy, people without money do not	
People with money migrate	
Researchers asking questions gave users a voice	
User don't know anything about ICS program	
User has no communication with local government	
User has no communication with local NGO (MandE)	
User not knowing how to claim warranty	
User not taught to use or build ICS effectively	
What users actually paid for the cookstove	

Enabling Environment Element

Enabling Environment Matrix (Role of KS)	
KSs	Key Stakeholders

1. (Non-)User	
2. Community Groups	Forestry & Health
2. Financial Co-Operative	
2. Local Distributor	
3. Coordinating Partner	
4. (Micro-)Finance	
4. INGOs & NGOs	Anyone Non-Governmental Organisation who isn't the Co-Ordinating Partner (Practical Action)
4. Manufacturers	
5. Local Government	
5. National Government	
5. Provincial Government	

Framework Factors	
Equality	
Ownership	
Utilization	
People & Systems	
Material Resources	The Technology, Raw Materials, Electrical Connection

Induction Hob

Induction Hob (Electric Cooking)	**EXTRA – as PA was wanting to run a Induction Hob project using the T2/3 value chain.**

Appendix E: Practical Action Nepal Results Based Financing Key Stakeholder Perception Tables

RBF Key Stakeholder Perception Tables

Table 9.1: Government Perspective

	Ownership	Utilisation		Equality
		Human & Systems	Material	
Govt.	Subsidy System Local Govt. Promotion Distribution	Aligning Projects with Policy Plan Data Duplication Communication (Previous Successes & failures, and what the subsidy is) Local Govt. Networks (with Nat government and other KS)		Nat. Govt. Understanding Programs not working No Funding at Local Govt. Level Energy not a priority area Stopping Migration Data on Marginalised Groups
NGO/Business	Demonstration/Distribution	Responsible for Instillation Utilising Local Govt. For Promotion	Promotion of other more convenient technologies Knowledge of Technology	Target Marginalised Groups International business taking over national market
Co-ordinating Partner				Stopping Data Duplication
Community	Promotion through Community Groups			
User	Users need to inform themselves & buy technologies		Cost-Comparisons Be. Tech Utilizing Available Fuels (Sawdust etc.)	Luxury-Seeking Dependency on Financial Help Financial Migration
OTHER				

Table 9.2: NGO/Business Perspective

	Ownership	Utilisation		Equality
		Human & Systems	Material	
Govt.	Subsidy System Policy Priority (Induction?) Energy Baseline Survey Smokeless Kitchen Regulation Barrier Awareness Campaigns	Centralisation to Federalised Govt. System Govt. Tenders & Grants Local Govt. Good Practice Guidelines	LPG Import Electrical Infrastructure	Subsidy System (Targeting lower castes) Local Govt. Funding for Energy Projects Policy Priority Lack of co-ordinated response Corruption
NGO/Business	Cookstove Demonstration/Information dissemination Awareness Campaigns (Radio, leaflets, gatherings) Marketing: Wood = NEPAL, LPG = INDIA Behavioural Change Data	M&E (KS feedback) Employing (training) Local People for Manufacture and Maintenance Market Competitiveness Existing Value Chain (/project network) Communication between KS Using existing programs or technologies to help promote cookstove (lack of funding) Govt. Consultation on Strategy	Importing Products Using Local Materials Quality of Products Building ICS Pellet Supply Chain Lab/Field Differences in Performance Correct MRP Modification of Technology	Operational/Reputational Risk Equal Access to Products – MFI Programs Manufactures not able to go direct to customers (more cost to user) Ineffective Communication International business taking over national market
Co-ordinating Partner	Awareness Campaigns Pressure on Results rather than impact Effective Facilitation	M&E Managing other KS Facilitation between KS	Want to see Technology Development from PA	Incentive Distorting Market Conflicting Projects
Community	Cookstove Demonstration Influence Buying Behaviour Forestry Group	Value Chain	Local Maintenance Hubs Building/Assembly ICS	Equal Access to Products – Co-Ops Programs Distributors cost orientated
User	Communication between users (P2P marketing) Habituate (/domesticate) Technology	No user and Manufacturer link – not feedback on willingness to pay	Use of Wood as primary or secondary fuel source Access to Electricity Processing of Fuelwood	Financial Incentives from Co-Ordinating Partner Rural/Urban Divide in energy access

	User readiness Buying ICS		ICS Design Feedback Technology Stacking	Dependency through Subsidy User Choice Inter-community divide Different needs of men/women
OTHER				

Table 9.3: Co-Ordinating Partner

	Ownership	Utilisation		Equality
		Human & Systems	Material	
Govt.	Working Groups (Green & Inclusive Energy Program) Delivering Policy (Basic Needs)	Relationship bet Local & Nat Govt. Impact of Federalisation		Govt. not aware of Energy Needs Duplication of Projects
NGO/Business	Manufactures focus on price NGO focus on health House to house visit program	Managing Local Financial Institutions M&E		MFIs
Co-ordinating Partner	Providing Incentives to Users, Co-Ops etc. Radio Program, Leaflet, Posters and Banners Needs to provide for free	Managing, Guiding, Providing Technical Support all the KS	Identifying ICS for Program	Quality, Timely Delivery Fraud/Corruption Sustainable Exit Strategy
Community	Local Distributor/co-op marketing & demonstration Marketing Agent Incentive	Mobilize Health Groups Forestry group Co-operatives		Giving access to Finance
User		Social Pressure to Buy		
OTHER				

Co-ordinating partner – this KS had the only mention of the funding partner (EnDev) in all the interviews.

Table 9.4: Community Perspective

	Ownership	Utilisation		Equality
		Human & Systems	Material	
Govt.	Local Govt. ICS Distribution National subsidy policy	Collaborating with Local Distributors		National Govt. not hearing energy needs Disaster Relief & Response
NGO/Business	Local NGO organising events for demonstration Social media marketing	NGO Managing local Stakeholders Utilising Community and Govt. Networks	Product Improvement though feedback	Effective communication with Community
Co-ordinating Partner	Demonstration Awareness by Social Media Increasing Subsidy Providing Inventive to Co-Op			Providing Subsidy Conflicting Programs & Distorting Markets
Community	Distribution of ICS Connecting Customers with Product Spreading Awareness Innovative Market Mechanisms Social Media Marketing Training on Correct Use Local Distributors reaching remote markets Co-Operative returning cookstoves	Utilising Community and Govt. Networks Collaboration with Financial Co-Operative M&E Paperwork Mistakes	Warranty Implementation	Giving ICS to Marginalised People (Post-Payment) Reputational Risk Providing Finance to Marginalised Groups
User	Using the ICS and tell peers of their experience P2P Marketing Seeing Luxury	3K npr Investment from 1000 co-op members for funds for program	Feedback to Manufactures	Male/Female Divide the importance of ICS

OTHER				