Assessment of Household Energy Access: The Progress out of Energy Poverty Index (PEPI) Toolkit for the Microfinance Sector

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Abstract

Sustainable energy for all is one of the explicit goals of the United Nation's post-2015 development agenda, aiming to overcome the unaffordability, unavailability and unsustainability of energy supply. It refers to the one third of the world's population that still relies on intermittent or non-existent electricity supply, and on fossil fuels for cooking and heating; and which is mostly located in rural areas where there is little or no possibility of obtaining cleaner fuels, grid connection or decentralized energy systems. Microfinance services, among other mechanisms, offer a vehicle to improve energy supply of these underserved population. The number of microfinance institutions (MFIs) providing *green lending* programs, i.e., offering consumer finance solutions for the acquisition of modern energy technologies, has steadily increased. However, the success of the scaling- up process of green lending is still debatable. Thus, by facilitating tools, the microfinance sector can estimate its potential in committing to meeting the proposed global goals and strengthen its role in enabling energy access. So far, a series of indicators exist to measure the environmental performance of MFIs but none to measure the energy situation of clients. Such indicators would allow MFIs to support decision-making processes, monitor clients' achievements in energy access or even supply input to assess other basic needs. Hence, this research addresses the challenges of measuring energy access at household level, defining the role of the microfinance sector in achieving and improving energy access and the misleading potential of poverty assessment metrics to predict the quality of energy supply. During field research in south-west of Colombia at the MFI Contactar, a thorough energy needs assessment following the ESMAP multi-tier framework (MTF) [Bhatia and Angelou, 2015] has been conducted on a representative sample size (384 households-clients) in rural, peri-urban and urban areas. The results, capturing much broader dimensions of electricity access and cooking facilities, unveil the real quality of energy at the households, which the majority are currently connected to the grid. Based on the results collected from the field, adopting the underlying structure of the ESMAP MTF and refining suggestions from [Groh et al., 2016, Bensch, 2013, Stevens et al., 2015], the Progress out of Energy Poverty Index (PEPI) toolkit has been designed to measure and monitor access to electricity services and supply and cooking solutions at household level. It also aims to bring energy services to the core of the metric, facilitating the implementation and understanding of the multi-tier approach for the microfinance and energy sector, and provides a meaningful tool for monitoring and assessing progress.

Keywords:

Green microfinance, energy access metrics, multi-tier approach, rural financial inclusion, rural energy inclusion, two-hand model,

Abstract

Nachhaltige Energie für Alle ist eines der expliziten Ziele der Entwicklungsagenda 2015 der Vereinten Nationen, um Erschwinglichkeit, Verfügbarkeit und die Nachhaltigkeit der Energieversorgung zu sichern. Es bezieht sich auf das eine Drittel der Weltbevölkerung, welches immer noch auf intermittierende oder nicht vorhandene Stromversorgung und auf fossile Brennstoffen für Kochen und Heizen angewiesen ist; Und welches sich überwiegend in ländlichen Gebieten befindet, wo es wenig oder gar keine Möglichkeit gibt, saubere Kraftstoffe, Netzanschlüsse oder dezentrale Energiesysteme zu erhalten. Mikrofinanzierungsdienste, neben anderen Mechanismen, bieten ein Werkzeug zur Verbesserung der Energieversorgung dieser unterversorgten Bevölkerung. Die Zahl der Mikrofinanzinstitute (MFIs), die Programme zur Verfügung stellen, d.h., die Verbraucherfinanzierungslösungen für den Erwerb moderner Energietechnologien anbieten, hat stetig zugenommen. Allerdings ist der Erfolg des Skalierungsprozesses der Green Lending noch umstritten. Folglich kann der Mikrofinanzsektor sein Potenzial abschätzen, um die vorgeschlagenen globalen Ziele zu erreichen und seine Rolle bei der Ermöglichung des Energiezugangs zu stärken. Bisher gibt es eine Reihe von Indikatoren, um die Umweltleistung von MFIs zu messen, aber keine, um die Energiesituation der Kunden zu messen. Solche Indikatoren würden es MFIs ermöglichen, Entscheidungsprozesse zu unterstützen, die Fortschritte der Kunden im Energiezugang zu verfolgen oder sogar einen Beitrag zur Bewertung anderer Grundbedürfnisse zu liefern. Daher befasst sich diese Forschung mit den Herausforderungen, den Energiezugang auf Haushaltsebene zu messen und die Rolle des Mikrofinanzsektors bei der Erreichung und Verbesserung des Energiezugangs und des irreführenden Potenzials von Armutsbewertungsmetriken, zur Vorhersage der Qualität der Energieversorgung, zu definieren. Während der Feldforschung im Südwesten von Kolumbien am MFI Contactar wurde eine gründliche Energiebedarfsbewertung nach dem ESMAP-Multi-Tier-Framework (MTF) [Bhatia and Angelou, 2015], auf einer repräsentativen Stichprobengröße (384 Haushalte - Kunden), in ländlichen, peri-städtischen und städtischen Gebieten durchgeführt. Die Ergebnisse, die viel breitere Dimensionen von Elektrizitätszugang und Kochgelegenheit erfassen, enthüllen die reale Energiequalität in den Haushalten, mit welcher die Mehrheit derzeit mit dem Netz verbunden ist. Das "Index zur Bewertung der Energie-Armuts-Entwicklung (Progress out of Energy Poverty Index - PEPI)" Toolkit, wurde auf der Grundlage der aus dem Feld gesammelten Ergebnisse, der Annahme der zugrunde liegenden Struktur des ESMAP MTF und der Verfeinerung von Anregungen von [Groh et al., 2016, Bensch, 2013, Stevens et al., 2015] entwickelt, um den Zugang zu Elektrizitäts- und Versorgungs- und Kochlösungen auf Haushaltsebene zu messen und zu überwachen. Es zielt auch darauf ab, Energiedienstleistungen messbar zu machen, die Umsetzung und das Verständnis des mehrstufigen Ansatzes für den Mikrofinanz- und Energiesektor zu erleichtern und ein sinnvolles Instrument zur überwachung und Bewertung des Fortschritts zu bieten.

Keywords:

Green microfinance, Energiezugang Messgrößen, Multi-Tier-Ansatz, ländliche Energie-Integration, Zweihand-Modell,

Summary

Energy access has been recognized as an imperative development factor at economic, social and human levels. More than two billion people worldwide lack access to modern energy, including electricity access and modern cooking solutions. Upon the launching of the Sustainable Development Goals (SDGs), the definition and measurement of energy access has taken on significant importance for governments, development agencies, private and non-governmental organizations and financial institutions, among others. By aiming to achieve affordable and reliable universal access to modern energy services by 2030, the SDG 7, out of the 17 global goals, calls for a standardized monitoring of progress towards this goal.

The objective of this research is two-fold. The first aim is to present a detailed analysis of the energy access of microfinance clients in southwestern Colombia, focusing on the population involved in micro-lending. In collaboration with the Colombian MFI Contactar, the study is based on the multidimensional *(multi-tiered)* energy access framework (MTF), recently launched by the World Bank's Energy Sector Management Assistance Program (ESMAP), which considers several attributes associated with the concept of energy access. Results revealed the poor quality of electricity supply, compared to the above-average national rate on the country's energy access figures and an energy stacking behavior in terms of the variety of cooking fuels and devices for cooking according to household affordability and availability. By revealing the real quality of the population's current energy access, the analysis calls for interventions in reliability, quality and affordability, providing on the one hand, valuable information for service improvements to regional electrical utilities to bridge those gaps and, on the other hand, a detailed overview of energy needs for cooking. In order to revise the accuracy of metrics at the MFI level, the research also evaluates the potential of existent poverty metrics such as the Progress out of Poverty Index (PPI) [Schreiner, 2004] currently used by the MFI to predict quality of energy access (PPI Scorecard for Colombia). The assessment results showed that the Colombian PPI fails to properly describe both the level of energy access and the availability and affordability for cooking solutions. However, significant correlations between consumption and the likelihood to fall under the poverty level show an inversely proportional correlation.

Driven by the motivation of aligning sectorial strategies to reach SDGs and further promote the multi-tier approach, the second focus of this study consisted of the development of a toolkit for project implementers, aimed at tracking specific attribute progress at the household level. In particular, based on the ESMAP MTF tool [Bhatia and Angelou, 2015] and the results of the related survey, the research proposes the Progress out of Energy Poverty Index (PEPI) as a toolkit directed, as an initial step, to MFIs willing to identify and to satisfy the energy needs of their clientele and track their progress. Considering the close, long-term relationship and MFIs' infrastructure, and their steady increasing interest in satisfying client energy needs and increasing their market, the toolkit can be adopted by MFIs engaging in *green lending*. Nonetheless, additional orga-

nizations supplying energy access to the base of the pyramid can also use the tool to monitor the effects of their products, services or programs. The PEPI supports organizations in (i) identifying the energy needs of their current and potential clientele in order to efficiently tailor green lending or energy access programs; (ii) measuring and tracking program impact on household energy access; and (iii) assessing and comparing the effects of modern energy technology on improving the quality of modern energy services and the level of provision over time for household electricity services and supply and cooking solutions.

The toolkit is based on the adapted multi-tier frameworks [Bhatia and Angelou, 2015], to assess electricity supply and cooking facilities, and it entails (i) a set of expanded frameworks in attribute detail and differentiations, (ii) a ready-to-use survey tool filtered according to electricity power source and cooking solution and (iii) an index to assess the progress towards energy access for all based on panel data.

The modified set of metrics for energy access aims at aligning the global goal SDG 7 targets with the redefinition of energy access according to the multi-tier framework, grouping the energy access attributes into three global attributes and assessing progress through the variation of their deltas over time. Hence, the composite index provides deeper information on the quantity and quality of energy access obtained from the global attributes associated with energy access, avoiding misinterpretations of a condensed individual index. The developed surveys are software-based tools for data collection and analysis, in which access is exclusively assessed based on the services available to the household. The survey tool contains the electricity supply and services and cooking facilities frameworks, whose energy metrics can be adjusted to country specific realities. No electricity consumption is assessed through an individual tier-framework. Finally, through the repeated implementation of the toolkit, the PEPI index to measure the progress out of energy poverty across the different dimensions of energy access is delivered, based on a weighted average of the progress in the global attributes.

Upon rolling out this approach and highlighting the priority of achieving universal energy access, the proposed PEPI toolkit enables organizations engaged in energy access activities to identify the energy needs of their clients (or regions of work), track improvements in the energy ladder and the associated attributes of energy access. Hence, providing tools for the microfinance industry will help stakeholders to design and negotiate the inter-sectorial development of energy programs, defining the role of the microfinance sector on the achievement of the SDGs.

Kurzfassung

Zugang zu Energie wurde als einer der entscheidenden Faktoren für die wirtschaftliche soziale und menschliche Entwicklung erkannt. Weltweit haben über zwei Milliarden Menschen keinen Zugang zu moderner Energie, weder zu elektrischer Energie noch zu sauberen Kochmöglichkeiten. Durch die Veröffentlichung der Sustainable Development Goals (SDGs), bekamen die Definition und das Erfassen von Daten über den Zugang zu Energie hohe Relevanz, u.a. für Regierungen, Entwicklungsagenturen, Private- und Nichtregierungsorganisationen sowie Finanzinstitute. Um das vorgegebene Ziel, bezahlbaren und verlässlichen universellen Zugang zu modernen Energiequellen bis 2030 umzusetzen, verlangt das SDG 7 nach einem standardisierten Monitoring des erreichten Fortschritts.

Diese Untersuchung zielt auf zwei Ergebnisse ab. Das erste Ziel ist es eine detaillierte Analyse des Energiezugangs von Mikrofinanzkunden im Südwesten von Kolumbien zu präsentieren. Dabei liegt der Fokus auf dem Teil der Bevölkerung der Mikrodarlehen besitzt oder schon aufgenommen hat. In Zusammenarbeit mit dem kolumbianischen Mikrofinanzinstitut (MFI) Contactar, wird die Studie mit Hilfe des *(multi-tiered)* Multi-Tier Energy Access Framework (MTF), welches kürzlich von der World Bank, Energy Sector Management Assistance Program (ESMAP) veröffentlicht wurde [Bhatia and Angelou, 2015], durchgeführt. Dieser Ansatz ermittelt mithilfe technischer, ökonomischer und sozialer Attribute die Qualität und Quantität des Energiezugangs. Die Ergebnisse zeigen die schlechte Qualität der Energieversorgung, verglichen mit den überdurchschnittlich hohen nationalen Zahlen zum landesweiten Energiezugang und ein Energie *stacking* Verhalten bei den unterschiedlichen Arten von Brennmaterial zum Kochen, nach Bezahlbarkeit und Verfügbarkeit durch die Haushalte ermittelt. Durch das Aufzeigen der tatsächlichen Qualität des Energiezugangs, deckt die Analyse Handlungsbedarf bei der Verlässlichkeit, Qualität und Bezahlbarkeit auf. Außerdem werden Informationen über die regionale Energieversorgung bereitgestellt, um die erkannten Engpässe besser versorgen zu können und es wird eine detaillierte übersicht über den Energiebedarf zum Kochen erstellt.

Um den Nutzen des verwendeten Ansatzes auch für MFIs zu validieren, werden ebenfalls die Möglichkeiten von etablierten Methoden, wie dem Progress out of Poverty Index (PPI) [Schreiner, 2004], untersucht, den das MFI aktuell verwendet um die Qualität des Energiezugangs vorher zu sagen (PPI Scorecard für Kolumbien). Die Ergebnisse der Untersuchung zeigen, dass der Kolumbianische PPI weder den aktuellen Grad des Energiezugangs noch die Verfügbarkeit und Bezahlbarkeit der verwendeten Kochmittel korrekt darstellt. Jedoch weist eine deutliche Verbindung zwischen dem Konsum und der Wahrscheinlichkeit unter das Armutslevel zu fallen, eine umgekehrt proportionale Korrelation auf.

Damit die Strategien zur Umsetzung der SDGs in allen Regionen vereinheitlicht werden und der Multi-Tier Ansatz weiter verbreitet wird, befasst sich der zweite Teil der Studie mit der Entwicklung eines Toolkit zur Umsetzung von Projekten, die dazu dienen den Fortschritt von ausgewählten Attributen bei Haushalten zu erfassen. Auf Grundlage des ESMAP Tool [Bhatia and Angelou, 2015] und den Umfrage Ergebnissen, wird MFIs empfohlen als ersten Schritt den *Progress out*

of Energy Poverty Index (PEPI) (Index zur Bewertung der Energie-Armuts-Entwicklung) zu verwenden, um die Nachfrage ihrer Kunden nach Elektrizität und Kochmittel zu identifizieren und zu bedienen sowie deren Fortschritt zu erfassen. Wird die nahe, langfristige Beziehung, die Infrastruktur der MFI, das ständige aufnehmende Interesse die Nachfrage der Kunden zu bedienen und der wachsende Markt berücksichtigt, kann das Tool angepasst werden, so dass es den MFIs ermöglicht in den Markt für green lending einzusteigen. Außerdem können weitere Organisationen die Energiezugang für den *Base of the Pyramid* (BoP) bereitstellen das Tool nutzen um die Auswirkungen ihrer Produkte, Services oder Programme zu erfassen. Der PEPI unterstützt Organisationen bei (i) der Ermittlung des Energiebedarfs ihrer aktuellen und potentiellen Kunden, um effektive Programme für green lending oder Energiezugang zu designen; (ii) der Messung und Erfassung der Veränderungen durch die Programme beim Energiezugang von Haushalten; und (iii) der Untersuchung der Auswirkungen moderner Technologien bei der Verbesserung der Qualität des Energiezugangs und der Höhe der Aufwendungen über die Zeit des Haushalts für Elektrizität und moderne Kochmöglichkeiten.

Das Toolkit basiert auf dem angepassten Multi-Tier Framework, um Elektrizität und Kochmittel bereitzustellen und es bringt (i) eine Auswahl an erweiterten frameworks mit größerer Auswahl an unterschiedlich ausgeprägten Merkmalen; (ii) ein einsatzbereiter Fragebogen für Energiequellen und Kochkonzepte; und (iii) ein Index um den Fortschritt beim Energiezugang. Die Modifizierten Parameter zur Definition des Energiezugang bringen die globalen SDG 7 Ziele mit der Neudefinition des Sustainable Energy for All (SE4All) Global Tracking Framework zusammen. Die Merkmale des Energiezugangs werden in globale Attribute gruppiert und der Fortschritt durch die Variation der Deltas über der Zeit untersucht. Damit liefert der Verbund-Index tiefergehende Informationen über die Quantität und Qualität des Energiezugangs, welche durch die globalen Merkmale für Energiezugang erhalten werden und vermeidet dabei die Fehlinterpretationen die ein einzelner Index verursachen könnte. Die entwickelten Umfragen sind softwarebasierte Tools zur Datensammlung und Analyse, in welchen der Zugang ausschließlich anhand von Diensten untersucht wird, welche in den Haushalten verfügbar sind. Das Umfrage-Tool enthält Energieparameter zu Elektrizität und Kochmitteln, die auf die untersuchten Länder angepasst werden können. Kein Verbrauch von Elektrizität wird durch das Tier-Framework untersucht. Durch den wiederholten Einsatz des Toolkits, ergibt sich der PEPI, um den Fortschritt aus der Energiearmut über die verschiedenen Dimensionen des Energiezugangs, auf Basis des durchschnittlichen Fortschritts der globalen Attribute, zu messen. Durch diesen Ansatz und das hervorheben der Notwendigkeit eines universellen Energiezugangs, erlaubt das PEPI Toolkit Organisationen, welche an einem verbesserten Zugang zu Energie arbeiten, den Energiebedarf ihrer Kunden (oder Regionen) zu ermitteln, Verbesserung auf der Energieleiter oder ähnlichen Merkmalen zum Energiezugang zu erfassen. Die Bereitstellung von Tools für die Mikrofinanzindustrie erlaubt den Akteuren die inter-disziplinäre Entwicklung von Energieprogrammen, mit der Rolle des Mikrofinanzsektors definiert anhand der Errungenschaften der SDGs.

Contents

Abbreviations and Acronyms

AI Access Index
BD Biogas Digesters
BoP Base of the Pyramid
CESPI Correlation Energy Services Proxy Index
CFL Compact Fluorescent Lamp
CL Confidence Level
COP Colombian Peso
COSA Committee on Sustainable Assessment
CSPI Correlation Services Proxy Index
DANE Departamento Administrativo Nacional de Estadstica
DESCO Distributed Energy Service Company
EDI Energy Development Index
e-MFP European Microfinance Platform
EPP Energy Poverty Penalty
ESI Energy Supply Index
ESMAP Energy Sector Management Assistant Program
EU European Union
FI Financial Institution
FPL Fuel Poverty Line
GDSA Gestión de Desempeño Social y Ambiental
GF Grameen Foundation
GIF Green Inclusive Finance
GPA Green Performance Agenda
GTF Global Tracking Framework
HDI Human Development Index
ICT Information and Communication Technology
IEA International Energy Agency
IHS Integrated Household Survey
ICS Improved Cooking Stoves
IFC International Finance Corporation
ISIC International Standard Industrial Classification of all Economic Activities
ISO International Organization for Standardization
IWA International Workshop Agreement
LED Light-emitting Diode
LPG Liquified Petroleum Gas
ME Margin of Error

MDG Millennium Development Goal
MECS Multisector Energy Investment Projects
MEPI Multidimensional Energy Poverty Index
MFEPI Microfinance Environmental Performance Index
MES Microenergy System
MEA Microenergy Appliance
MFI Microfinance Institution
MIX The MIX Market Platform
MSME Micro-, Small- and Medium-Enterprises
MTF Multi-tier Framework
NGO Non-Governmental Organization
PAYG Pay-As-You-Go
PCIA Partnership for Clean Indoor Air
PEPI Progress out of Energy Poverty Index
PIFIL Plan de Investigación para el Fortalecimiento Integral de las Comunidades
PPI Progress out of Poverty Index
PV Photovoltaic
R&D Research and Development
RE Renewable Energy
SCD Solar Crop Driers
SDG Sustainable Development Goal
SE4ALL Sustainable Energy for All
SHS Solar Home System
SME Small and Medium Enterprises
SPI Social Performance Indicators
SPI4 Social Performance Index Tool
SPM Social Performance Management
TEA Total Energy Standard
UN United Nations
UNDP United Nations Development Programme
UNIDO United Nations Industrial Development Organization
USA United States of America
USD United States Dollar
USSP Universal Standards of Social Performance
WB World Bank
WEO World Energy Outlook
Wh Watt hour

WHO World Health Organization

Wp Watt peak

WF Water Filters

WT Water Tanks

1. Introduction

The establishment of the *Global Goals* of the United Nations (UN) [UNDP, 2016] represents a huge challenge on various scales for both governments and public authorities. Setting up a development agenda always aims to synchronize initiatives, funds and tools to operationalize programs, which in turn help meet the targets. At the same time, when exploiting stakeholders' ability to push ambitious programs forward, it is imperative to develop functional tools to track the programs' progress in achieving the established targets, in order to correctly guide policies, funding and project follow-ups. Thus, defining a common language and disseminating best practices among stakeholders are key issues in achieving the specific goals.

This thesis focuses on the challenges of defining indicators to measure progress in household-level energy access – e.g., the improvement of electricity and cooking supply – fostered by programs linking microfinance mechanisms with the provision of modern energy services. To date, a variety of methods to measure microfinance institutions' (MFIs) activities focusing on an environmental agenda fail to assess the energy access quality of microfinance customers. The primary goal of this dissertation is to propose a measurement and tracking tool in order to assist the microfinance sector in taking concrete action to achieve energy access for all.

The Sustainable Development Goals After the UN established the Millennium Development Goals (MDGs) in 2000, which included eight anti-poverty targets to be met by 2015, there was widespread disappointment that the goals did not address the challenge of enabling energy access for all. As a result, the scientific community set about emphasizing the key role of modern clean energy[1] for the achievement of the MDGs (see e.g., [AGECC, 2010, Legros et al., 2009, Ilskog, 2008, MacLean and Siegel, 2007, Modi, 2004, DFID, 2002]). More specifically, it has been argued that a sustainable, accessible and affordable energy supply – such as modern electricity for household and community usage, productive use and cooking solutions – is crucial to enabling development and

[1] Clean energy refers to renewable energy sources (e.g., solar, biomass, wind, hydropower and geothermal), liquefied petroleum gas (LPG) as fossil fuels that emit little greenhouse gas, and traditional fossil and biomass fuels that use technologically advanced processing, practices and/or products such as energy-efficient cookers [UNCDF, 2012]. Throughout this thesis, the concepts of modern clean energy and modern energy services will be used interchangeably, referring to the use of clean energy as defined above.

well-being [AGECC, 2010, MacLean and Siegel, 2007, Modi et al., 2006]. Hence, access to energy services is essential for sustainable development in developing countries, since these are critical enablers and contributors to a virtuous cycle of human, economic and social improvements [OECD, 2007].

In 2012, the launch of the *Sustainable Energy for All* (SE4ALL) program[2] – a joint initiative of the Secretary General of the UN and the World Bank (WB) striving to achieve universal access to modern energy by 2030 – formally established the need to alleviate *energy poverty* or *energy deprivation*, defined as a broader concept rather than just a lack of energy access. According to [Barnes et al., 2011], the definition of energy poverty is the point at which people use the bare minimum of energy, derived from any source, needed to sustain life. Above this point, energy contributes to welfare and increases economic well-being, while below this point people lack enough energy to sustain normal lives.

Figure 1.1.: The Sustainable Development Goals (SDGs)

The SE4ALL program paved the way for channeling mandates to achieve these objectives and for placing energy access on the list of global priorities. In September 2015, the UN Member States adopted the Sustainable Development Goals (SDGs)[3] (Figure 1.1), including *energy access for all* (SDG 7) and the impact of climate changes (SDG 13) as parts of the sustainable development agenda. However, replacing the MDGs with the SDGs, and thus adding energy access to the list of Global Goals[4], is just the beginning of a greater challenge: lowering energy deprivation by fostering universal energy inclusion, which, as opposed to mere energy access, aims to improve the energy service quality for vulnerable and low-income groups at affordable cost [Groh, 2014].

[2] See http://www.se4all.org/

[3] See https://sustainabledevelopment.un.org/post2015.Throughout this thesis, the terms Energy SDG and SDGs will be used interchangeably in referencing to one (SDG 7) or several of the 17 Global Goals of the 2030 Agenda for Sustainable Development.

[4] See http://www.undp.org/content/undp/en/home/sdgoverview/post-2015-development-agenda/goal-7.html

Energy Supply for the Base of the Pyramid According to [IFC and WRI, 2007], four billion people constitutes the base of the economic pyramid – BoP, i.e., people with low annual income population (below $3,000 in local purchasing power) and living in relative poverty. The BoP represents a considerable share of the world's population, and includes over 70% of the population in Africa, Asia, Eastern Europe, and Latin America and the Caribbean. Since most people who do not have access to electricity and rely on biomass for cooking live in the poor parts of emerging and developing countries, i.e., slums and rural areas, next to food and housing, satisfying the energy needs often represents the biggest expense [Gradl and Knobloch, 2011]. Indeed, approximately 35% of rural areas worldwide lack of reliable access to either electricity or clean cooking facilities [IEA, 2011]. These deficiencies hinder the development of basic infrastructure, education and health, as well as the productivity and local value creation. Women and school-aged children from rural areas are affected in particular, as they have to collect fuelwood, a time-intensive activity that keeps them away from more beneficial activities [Barnes and Toman, 2006,Saghir, 2005].

Modern energy technologies – referred to in this thesis as microenergy systems (MES), i.e., decentralized energy systems based on small and locally usable energy conversion units using clean energy that enable spatial interconnection between energy demand and energy supply (microenergy appliances, MEA) [Philipp and Schäfer, 2009] – enable increasing profitability and productivity of micro, small and medium enterprises (MSMEs), small industries, and agriculture. Hence, affordable access to MES improves people's quality of life and contributes to poverty reduction. Following the SDGs' agenda, one single principle should guide macro and micro interventions targeting energy access: enabling access does not mean solely focusing on the source of energy itself, but also on guaranteeing affordable, reliable and safe energy services that are essential to the users' daily well-being. However, to date, there are very few dissemination methods that reach the population segment that has limited access to electricity and improved energy technologies, mainly because of the high initial capital costs needed for energy poverty alleviation [IEA, 2011, Beck and Martinot, 2004].

The role of Microfinance in Energy Access Microfinance is generally known as the provision of financial services for low-income populations, i.e., people living in poverty who are not considered bankable [Rao and Rao, 2010, Armendáriz de Aghion and Morduch, 2005]. Particularly, microfinance mechanisms are based on the idea that a lack of collaterals, stable employment and verifiable credit history (making commercial banking inaccessible) can be overcome via alternative lending techniques (e.g., group lending and loan guarantors), local information flows and consecutive loans [Ahlin and Neville, 2008]. Hence, the possibility of splitting up high investment costs into affordable monthly installments makes sustainable financing via microfinance a viable approach, among others, to overcome the affordability barriers for energy integration. Moreover, since MFIs have tight local networks and close relationships with their customers [Kebir, 2009], they also represent a vehicle for the dissemination of MES striving for sustainability.

The microfinance industry's increasing engagement in environmental issues has established the field of *green microfinance*, combining microfinance services and products pinpointing environmental responsibility (e.g., [Allet, 2012, Realpe Carrillo, 2014, GreenMicrofinance, 2007]). Programs exploiting MFIs' capabilities for enhancing energy supply have gained increasing prominence in recent decades - see Figure 1.2. In several contexts, MFIs have partnered with energy service suppliers[5] to disseminate clean energy technologies (see, e.g., [Srinivasan, 2007, Morris et al., 2007]). MFIs diversify their portfolio by introducing a financial product to finance MES and, through these partnership, agree to share responsibilities with the energy service supplier delivering the technology to the microfinance client.

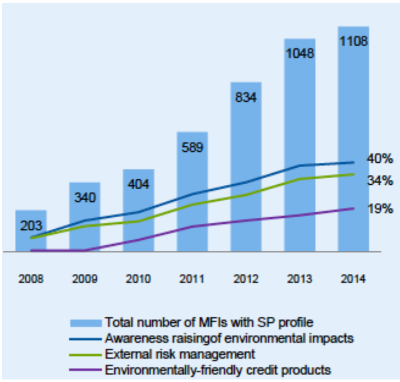

Figure 1.2.: Measuring the commitment of the microfinance industry to sustainable development. Number of MFIs reporting to the MixMarket platform (www.mixmarket.org) on their performance within a set of established *Green Performance Indicators*. Source: [Pierantozzi et al., 2015]

In particular, microcredits designed to help low-income populations meet energy demands using locally based sources through MES aim at alleviating energy poverty by enabling affordable and sustainable access. Moreover, partnering MFIs with the energy sector may open up new financial and energy markets, attract new clients for financial services, alert existing clients to new energy services, and contribute to poverty alleviation [Morris et al., 2007]. The rationale is that microfinance and consumer lending make it possible for companies to sell high-quality (i.e., more expensive) products to customers with low purchasing power by being paid for them in small installments. As such, it is a tool for overcoming the price barrier in economically poor areas [Van Elteren, 2007, Hall et al., 2008, Rippey, 2009].

[5] Energy service suppliers refers to established companies that offer MES, usually small and medium enterprises (SMEs). In particular, these include regional, national or local distributors and/or service providers, and, depending on the technology, it can also include manufacturers partnering directly with the MFI.

Hence, establishing concrete goals and providing sectoral support, microfinance's potential could be exploited to achieve *energy access for all*. To this end, the microfinance sector's role must be systematically framed, and proper tools must be designed to support its operationalization and measure its achievements over time. However, the implementation of MES in rural regions with weak infrastructure requires careful design and planning that take economic, social and environmental dimensions into account [Philipp and Schäfer, 2009]. Moreover, the individual initiatives should be planned in view of the development goals, and their outcome should be aligned using common metrics.

MFIs Decision-Making Process and Energy Access Monitoring The intersectoral partnerships are at the base of *green lending* (or green loans) [Realpe Carrillo et al., 2015, Allet and Hudon, 2013, Levaï et al., 2011, Allderdice et al., 2007], which enable MFIs to disseminate MES, and thereby offer an alternative to improving energy access and providing viable distribution channels.

At the same time, in order to guarantee a relevant impact of microcredits tailored to meet energy demands, MFIs need to accurately select potential MES to include in their portfolio, following a "bottom-up" approach, i.e., starting with an analysis of their clientele. By first identifying their clientele's energy needs, uses and the costs involved, MFIs can better configure financial services that address product sustainability. However, MES choices are often the result of a demand analysis and top-down approaches (e.g., from funders, donors, development cooperations, etc.) [Levaï et al., 2011]. Thus, the possibility of assessing energy access achievements of selected MES and predicting their relation to quality improvement is instrumental to the decision-making processes of the partnership between an MFI and an energy service supplier.

The microfinance sector still has no systematic way of measuring the progress of MES implemented in regions with unreliable energy infrastructure. This fact is mainly due to the newness of green lending in the microfinance sector and to the fact that global metrics for all topics concerning environment management are primarily established at the organizational level. Furthermore, in the last decades, there has been no consensus in the energy sector on a conceptual definition of energy poverty or the appropriate techniques to measure it. This led to the common use of the traditional methods for energy access assessment: connected or not connected to the grid, cooking with biomass or not.

Academics and practitioners had made several attempts to come up with a system for measuring energy progress. In 2013, the SE4All Global Tracking Framework (GTF) first published a concrete set of indicators using a *multi-tier approach* [Global Tracking Framework (GTF), 2013] that assesses the multidimensionality of energy. However, the ability of this approach to efficiently tackle the main attributes of energy access and assess changes over time undermine its potential for delivering in-depth assessments of MES potential to tackle affordable, reliable and safety energy access. Consequently, statistics on long-term trends are currently not available for MES that have been financed and implemented in rural areas, particularly in goods-producing sectors like agriculture or micro-business. Without standardized tools, organizations face challenges in monitoring the impact of MES in households and micro-businesses, a crucial aspect for policy designers and private implementers.

1.1. Objectives

This research is driven by the desire to support MFIs and stakeholders in the energy sector throughout their decision-making process and in the interpretation of their results, and to achieve a better understanding of MES' potential to increase energy access in regions with poor infrastructure. Specifically, this paper is based on the rationale that financing decisions should be based on a comprehensive analysis, taking into account the MFI clients, the effects of MES on clients' energy access level, and the trackability of the level of energy access achieved by diversifying an MFI's portfolio. Until now, there has been no tool supporting organizations in these kind of assessments.

First, this dissertation aims to identify scientific methodologies for defining the potential of energy access quality obtained through MES at the household level. As a next step, the findings will be translated into a decision-making and monitoring tool for assessing the impact of MES. This tool aims eventually at supporting the portfolio diversification of MFIs and assisting any other organization involved in improving electricity supply or cooking facilities for low-income populations.

The methodology has been developed based on the results of field research that was conducted in southwest Colombia in collaboration with the Colombian MFI *Contactar*, with the objective of characterizing the energy access level of the microfinance clients. The analysis of this case study serves, on the one hand, to fine-tune the assessment methodology and to further clarify the role of energy in households and, on the other, to provide a basis for the developed tool to assess energy access at the micro level.

In detail, the goals of the thesis can be summarized as follows:

I To analyze the household-level energy usage of a selected sample of microfinance clients using the multi-tier approach

II To assess the attributes describing energy access for electricity supply, services and consumption and cooking facilities at the household level

III To assess the correlation between poverty metrics and energy poverty data

IV To develop a systematic and flexible tool – adaptable in different geographical regions – that financial institutions and energy stakeholders can use to assess energy access and to identify their clientele's energy needs, usages, costs, and expenses

V To develop a methodology to measure progress out of energy poverty based on the multi-tier approach

VI To validate the developed tool with the collected data

1.1.1. Measuring the Progress out of Energy Poverty

Despite the existence of different indices developed to evaluate the performance of green microfinance (see [Pierantozzi et al., 2015]), the impact of these programs on the energy access of the microfinance clientele, e.g., in terms of the alleviation of energy poverty, has not been measured yet. There is also no index specific to the microfinance industry that measures and tracks the deprivation of access to modern energy services. Motivated by these needs, this thesis is based on the application of a multidimensional energy access framework to a set of microfinance clients in order to develop a *Progress out of Energy Poverty Index* (PEPI), which is meant to be a tool for microfinance sector stakeholders and organizations implementing energy access projects. This index aims at establishing an effective way of measuring the impact of green lending programs in order to support MFIs and energy service suppliers in quantifying their ability to satisfy the different dimensions of energy access of their clientele.

		Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
1. Capacity	Power capacity ratings (in W or daily Wh)		Min 3 W	Min 50 W	Min 200 W	Min 800 W	Min 2 kW
			Min 12 Wh	Min 200 Wh	Min 1.0 kWh	Min 3.4 kWh	Min 8.2 kWh
	OR Services		Lighting of 1,000 lmhr/day	Electrical lighting, air circulation, television, and phone charging are possible			
2. Availability (Duration)	Hours per day		Min 4 hrs	Min 4 hrs	Min 8 hrs	Min 16 hrs	Min 23 hrs
	Hours per evening		Min 1 hr	Min 2 hrs	Min 3 hrs	Min 4 hrs	Min 4 hrs
3. Reliability						Max 14 disruptions per week	Max 3 disruptions per week of total duration <2 hrs
4. Quality						Voltage problems do not affect the use of desired appliances	
5. Affordability					Cost of a standard consumption package of 365 kWh/year < 5% of household income		
6. Legality						Bill is paid to the utility, prepaid card seller, or authorized representative	
7. Health & Safety						Absence of past accidents and perception of high risk in the future	

Figure 1.3.: Multi-tier Framework for Electricity Supply

Specifically, this study follows the multi-tier approach fully described and published by the global and multi-donor technical assistance trust fund, the Energy Sector Management Assistance Program (ESMAP) of the World Bank (WB) [Bhatia and Angelou, 2015]. In this approach, diverse aspects of energy access (such as energy supply, electricity services, energy consumption and cooking) are analyzed in different *frameworks*, defining for each of them a set of attributes (e.g., duration, reliability, quality, etc.) in order to represent the multidimensionality of energy access. In practice, following empirically predefined criteria for each attribute, each household is then ranked in a specific *tier* (from 0 to 5) [Bhatia and Angelou, 2015] to detail the deficiencies in energy supply performance and to better frame possible interventions (Figure 1.3).

For each framework, the results are condensed into a set of composite indices that take into account the proportion of the sample households in each tier and thus describe the energy access of the population. Figure 1.4 depicts an example of index calculation.

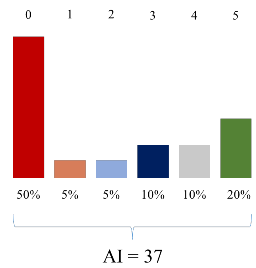

Figure 1.4.: An example of an access index (AI) computation according to [Bhatia and Angelou, 2015], based on the proportion of households ranked in tiers 0 to 5

Following the idea of underlying the multi-tier framework (MTF) from the ESMAP, the PEPI aims to simplify and expand this multidimensional approach by focusing primarily on household-level electricity access (e.g., supply and services) and cooking solutions.

For the purposes of this study, the ESMAP MTF for analyzing energy access has been implemented considering a set of microfinance clients, in collaboration with the Colombian MFI *Corporación Empresa Nariño Contactar*. Contactar is a medium-sized MFI (more than 70,000 clients in 2014) operating mainly in southern Colombia (see Figure 1.5, left). It has a vast track record in the triple bottom line approach and remarkably prioritizes its environmental impact in addition to its financial and social objectives.

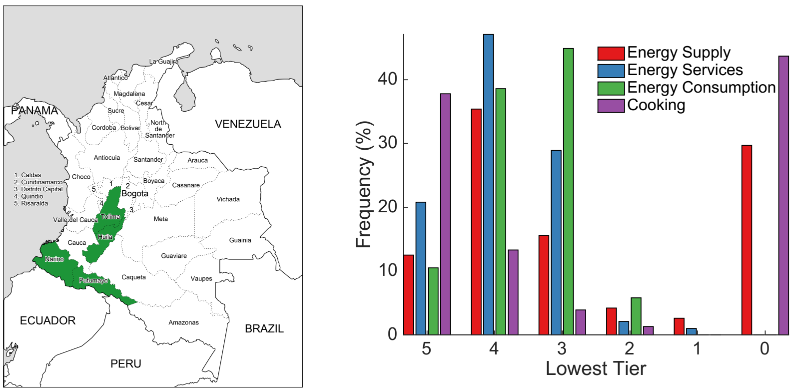

Figure 1.5.: Left: Regions of Colombia where the case study was carried out (original map downloaded from: www.your-vector-maps.com) Right: Summary of the results of the case study in southern Colombia, in terms of tier ranking of households in the four considered frameworks (energy supply, energy services, energy consumption, cooking solutions)

By collecting data from the different regions covered by Contactar, the energy access of its clients has been characterized in detail (in terms of energy supply, electricity services, electricity consumption and cooking facilities, highlighting the differences between urban and rural areas (see Figure 1.5, right). The case study has also identified the ways in which energy access lacks most, according to the multi-tier analysis proposed in [Bhatia and Angelou, 2015] and further studied and discussed in [Groh et al., 2016].

As a next step, based on the outcome of the survey and the ESMAP MTF, a multidimensional measure of energy poverty was defined in terms of three *global* attributes for electricity supply – *reliability*, *affordability* and *safety* – and three attributes for cooking facilities – *affordability*, *availability* and *safety* – aggregating the associated attributes included in the ESMAP MTF approach. The established framework builds upon the ESMAP conventions [Bhatia and Angelou, 2015], including a set of modifications echoing the suggestions from [Groh et al., 2016] and [Bensch, 2014] to fine-tune the deeper ranges of energy poverty.

Moreover, a hybrid index that takes all attributes into account is proposed in order to measure the progress out of energy poverty achieved by a household during a certain period of time. The index has the properties of aligning the attributes specified in the SDG 7, with the same multidimensional features of the ESMAP multi-tier metric, and allowing aggregated and disaggregated data analysis.

1.1.2. The PEPI Toolkit

The PEPI toolkit developed in this thesis comprises specific questionnaires for measuring access to energy supply and cooking facilities. The toolkit uses the multidimensional energy access tool and its corresponding tier-ranking matrices as well as an automated data-processing and analysis tool. Based on easy-to-use survey sheets, the toolkit (see Figure 1.6) requires only basic training for its application by an institution in the field.

The toolkit allows energy usage (electricity supply and services and cooking solutions) to be assessed with a focus on the quality of the services and the costs of access. By adapting the ESMAP MTF, each household is ranked in three pillars of global attributes associated with energy access. The energy access indicators are then normalized and combined, creating a single hybrid index. Hence, tracking the energy access performance of households in a geographical area as part of a specific program, the PEPI enables stakeholders to measure the progress out of energy poverty, assess performance of the intervention and monitor target achievements.

The ultimate goal of the PEPI is to help MFIs and energy service suppliers reach the energy poor by providing tools to facilitate products and programs monitoring in infrastructure-poor areas and assess whether clients' energy needs are met or not. Through an extensive and systematic implementation of the PEPI, MFIs can track multidimensional energy access and progress at the single household level. Thus, MFIs will be able to make their green lending products better suited to real customer needs, monitor the performance of their financial services and products, and track clients' progress out of energy poverty over

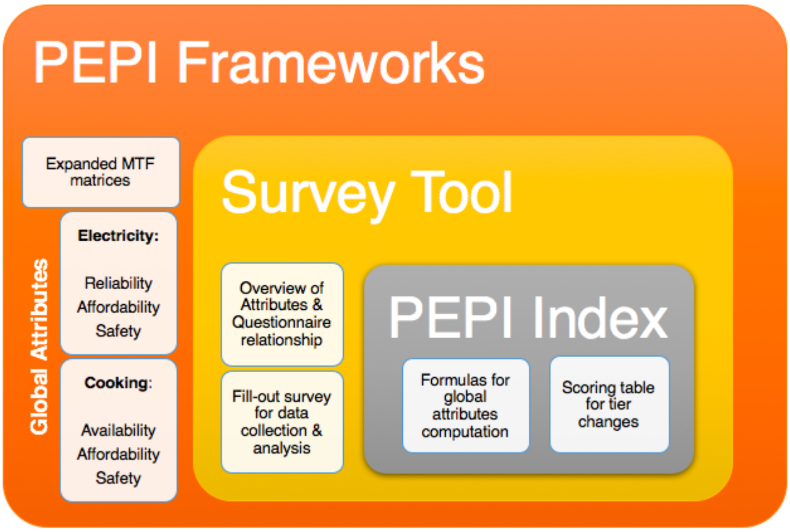

Figure 1.6.: PEPI toolkit components

time. At the same time, donors will have a quantitative assessment tool to better allocate their funds, while trends of the indices may provide useful insights into required interventions and specific axes of action.

1.2. Research Design

1.2.1. Hypothesis and Research Questions

Hypothesis 1. Energy access at the household level can be measured by tools based on multidimensional and multi-tier assessments. Access to electricity and improved energy services are evaluated based on the capacity of available appliances.

Research Questions

1.(i) How can the level of energy access in remote rural areas be concretely and constructively assessed?

1.(ii) How are the different dimensions of energy access related? Does the relevance of the energy access attributes depend on the local context?

Hypothesis 2. The potential of green microfinance and MES to improve the quality of energy access can be assessed through the multi-tier approach aligned with the Energy SDG targets.

Research Questions

2.(i) To what extent do MES contribute to the improvement of energy access quality in energy deprived areas ?

2.(ii) How can the performance of MES be evaluated and included in a holistic energy access assessment of electricity supply and cooking facilities?

Which attributes' characteristics are relevant to assess energy access? Which global attributes are needed to provide a detailed picture of energy supply performance in a target area?

2.(iii) How can the energy services enabled by MES be measured and compared at the household level?

2.(iv) How can the achievements of green lending be measured with regard to the Energy SDG?

Hypothesis 3. The development of a new assessment methodology will allow financial institutions and energy service suppliers to systematically evaluate the progress of energy access provided through MES in a specific geographical area.

Research Questions

3.(i) Which parameters and attributes should be taken into account when assessing the performance of MES?

3.(ii) Which frameworks have to be considered in the evaluation of electricity access and cooking facilities?

3.(iii) Considering a long-term assessment approach, how should an index be designed in order to effectively quantify the progress (or the variation, in general) of the tier-ranking of energy access within the same household?

1.2.2. Methodology

In order to track energy access improvements via green lending programs, the research methodology is based on a data analysis of a microfinance population sample.

To this aim, part of the research consists of a case study involving an empirical investigation with evidence from different data sources. The research database contains the results of the implementation of the ESMAP multi-tier tool [Bhatia and Angelou, 2015], juxtaposed with the poverty metric system – the Progress out of Poverty index (PPI) [Schreiner, 2004] – in order to infer the ability of poverty assessment metrics to predict energy access performance.

Based on the energy access results of the sample from the MFI Contactar, conclusions on the measurement algorithms have been drawn. Following these considerations, a proposal of an improved assessment tool based on an adapted multi-tier framework has been introduced and described. The tool aims to enable financial institutions and other implementers to identify energy needs, and carry out continuous tracking and monitoring. Through longitudinal research design, the progress analysis is designed to use panel data, which provides in-depth information about the processes being studied over time.

By achieving new insights into the impact of microfinance on energy access in a particular context, this dissertation has also an exploratory nature aiming to assess current energy access measurement systems. The analysis, as well as the development of a toolkit for the microfinance and energy sector, is based on the results of the case study and on a review of recently proposed methodologies.

This dissertation pursues the overall goal of using data collection and analysis for decision-making, tracking and monitoring purposes, and is thus based on a theoretical appraisal and critical assessment, formulating a path for useful and practically adequate measurement methods. The designed metric and toolkit rely on their potential to best assess the global attributes, and their corresponding categories associated with energy access.

This doctoral thesis consisted of four main phases. First, a literature review has been conducted in order to portray the state of the art in the research linking energy deprivation, energy demand, energy affordability, microfinance, green lending, and the corresponding measurement and evaluation methodologies. As a next step, a characterization of the clients of the MFI Contactar was carried out using the data collected from via the ESMAP MTF survey application and the institutional available data (disbursed loans, client application forms, questionnaires, client feedback). The outcome helped define the relevant indicators for assessing energy access at the household level. Building on the results of the second stage, the third stage aimed to develop a systematic decision-making tool to help MFIs identify their customers' energy needs and expenses, characterize the energy access quality with regard to electricity supply and cooking facilities, and analyze energy gaps that could be bridged by market mechanisms. The fourth phase consisted in testing the developed tool in the existing dataset and comparing those results with the ones obtained using the ESMAP MTF tool.

1.2.3. The First Steps in Developing the Toolkit

1. Screening of Household-level Energy Access in Selected Regions This step aimed first to obtain a portrait of the energy access of the microfinance clientele with regard to the electricity supply, services and consumption patterns. Moreover, an analysis of the cooking facilities is performed. Parallel to the energy access analysis, the analysis of the PPI of the sample is conducted. Subsequently, attributes related to the energy supply and services are depicted, differentiating regional location, and rural and urban results. Simultaneously, pitfalls of attributes results are identified through the data analysis. The featured energy supply attributes are clustered for electricity supply, electricity services, electricity consumption and cooking facilities and tier-index is calculated for each specific framework.

2. Poverty Data vs. Energy Data Assessment This stage assessed the capacity of poverty metrics (PPI) to describe the quality of household-level energy access. To this end, an analysis of the PPI indicators and scoring card used at the institutional level is conducted. Based on the poverty indicators, electricity supply, electricity services, electricity consumption and cooking facilities are analyzed. In another stage, an energy access questionnaire with the specific metric frameworks is developed. The assessment considers three different frameworks (electricity supply, consumption and cooking facilities). Data collected from existing clients are analyzed against panel data of poverty indicators, following a profile characterization. The energy access is characterized analyzing the compiled data and its correlation with the poverty likelihood (PPI).

3. Definition and Development of the Measurement Tool Indicators, attributes and parameters to be considered within each input data category are defined. The adaptations of the multi-tier approach are discussed and described in detail. Specific adapted frameworks for electricity supply and services and for cooking facilities are developed. Results obtained in the energy access assessment conducted in the first phase will be analyzed and compared to the previous index derived from the multi-tier approach [Bhatia and Angelou, 2015]. Completing the index toolkit, a scoring mechanism is introduced for measuring the progress out of energy poverty. Specifically, tier-ranking changes over time are differentiated and evaluated, referring to the kind of change the household experienced.

The PEPI survey focuses exclusively on energy access data. Socio-demographical data are not part of the survey, as it is assumed that the energy access data can be combined with institutional data available at each of the MFIs. For the longitudinal analysis of a triple bottom line assessment, panel data of the socio-demographical data previously collected from the MFI, together with multiple (min. twice) data collected from the developed toolkit in a specific time period, are required. At the level of the microfinance clientele, the survey – replicable in any MFI or energy service supplier (i.e., implementer) – will serve to estimate current energy usages, related costs and energy access tier-ranking. Particularly, the characterization entails information on the energy attributes associated with the energy supply.

1.3. Overview of the Thesis

The rest of the thesis is organized as follows: Chapter 2 focuses on energy access in rural areas, describing the potential of MES, the available measurements of energy poverty and the ESMAP MTF. In order to complete the research background, Chapter 3 is dedicated to green microfinance, to the financial models related to it, and to the available indicators to measure the impact of green microfinance programs. Chapter 4 focuses on the context of the research, describing the MFI Contactar, partner of the field research study, describing the development of its green microfinance initiative and the related geopolitical and economical contexts. The case study is detailed in Chapter 5, describing the methodology for the selection of the clients sample and the results of the ESMAP MTF tool, in terms of electricity supply, consumption and services and access to cooking solutions. Lastly, the obtained multi-tier ranking is analyzed with respect to the clients' PPI data available from Contactar. Chapter 6 is dedicated to the development of the PEPI toolkit. The chapter describes the adaptation of the ESMAP framework considering the results of the case study and enhancing the focuses of the considered attributes in view of the SDGs. Finally, the conclusions of the research are drawn in Chapter 7, discussing further work to foster the introduction of the toolkit at the inter-sectoral level.

2. Energy Poverty in Rural Areas

Energy poverty has been defined as the lack of access to modern energy services. This primarily affects low-income people; constraining their energy consumption, leading to the use of polluting fuels, or resulting in a level of energy consumption that is insufficient to support social and economic development [Bhatia and Angelou, 2015]. Following the definition from [Pachauri et al., 2012b], *modern energy access* includes access to three forms of energy: (i) less polluting household energy fuels for cooking and heating, which can range from cooking with improved cooking stoves with traditional fuels, or cooking with non-solid fuels such as liquid, gaseous, electric or solar-thermal; (ii) electricity for powering appliances and for lighting; and (iii) mechanical power from electricity that improves productivity.

The concept of *access* has also been widely discussed, defining it either from the perspective of the target beneficiaries or the mode of energy supply. Diverse attributes of access discussed in literature include affordability, reliability, quality and adequacy. In particular, access to clean energy has been claimed to strongly depend on availability and affordability, considering not only the possibility to acquire energy services, but also the capability of households to choose between efficient and modern energy services [Brew-Hammond, 2010]. Particularly, the analysis in [AGECC, 2010] suggested to characterize energy access depending on a given geographic area, i.e., including the availability of resources, the institutional and technical capacity of the involved stakeholders, the regulatory and policy environment and the relative cost of technologies. Hence, by acknowledging the role of these factors, energy access can be fostered by an optimal combination of different interventions.

Affordable and reliable provision of modern energy services remains a challenge, impeding economic development, especially in rural areas. Indeed, the lack of access of modern energy services prevents the development of basic infrastructure and improvement of basic living standards [Rao et al., 2009, MacLean and Siegel, 2007], resulting in a so-called *vicious cycle of poverty.* In this context, [Groh, 2014] empirically developed the concept of the *energy poverty penalty* (EPP) as a trap that delays rural development at household level. The penalty describes how energy expenses vary depending on the level of access to energy services, with significant differences for those experiencing a certain level of deprivation. The proven causality between energy and development has driven public policy to establish ambitious goals and call for action to governments, donors and practitioners in the field.

In 2013, 1.2 billion people lacked access to electricity and more than 2.7 billion people were estimated to rely on biomass for cooking, typically using inefficient stoves in poorly ventilated spaces [IEA, 2013]. By 2015, the number of people without the access to electricity had declined to 1.1 billion. However, far less progress was achieved on access to clean cooking, as 2.9 billion people still declared to use biomass fuels for cooking and heating [IEA and WB, 2015]. The rural areas were the most affected, with 260 millions of rural households without access to electricity (87% of the 300 millions of households worldwide), and, according to [The World Bank, 2008a, AGECC, 2010], it is estimated that another billion of people only have access to unstable and intermittent electricity networks. In this context, proper definitions of energy poverty metrics and assessment methodologies are necessary, in order to support the implementation of efficient and timely development strategies.

The first part describes different aspects of the relationship between energy access and development, focusing on the relevance of access to clean energy technologies, outlining the barriers for technology dissemination (in Section 2.1) and describing the so-called energy transition path (in Section 2.2). The second part is dedicated to the role of microenergy appliances (MEAs) and microenergy systems (MES) in tackling energy poverty (Section 2.3), discussing the relevance of electricity access in rural areas and in productive activities (Section 2.4). Finally, the third part reviews selected approaches currently used to measure the lack of energy access. In particular, a set of energy poverty indicators is described in Section 2.5, while Section 2.6 focuses on the innovative multi-tier framework approach (MTF), first introduced in 2013 [Global Tracking Framework (GTF), 2013] and further discussed in [Bhatia and Angelou, 2015].

2.1. Universal Energy Access for Sustainable Development

Access to modern energy services, intended as the physical availability of modern energy carriers and improved end-use devices at affordable prices for all [Pachauri et al., 2012b], is considered to be crucial for economic growth [Rao et al., 2009], as well as a starting point for sustainable development [UNDP and WHO, 2009]. In fact, with the increasing importance of renewable energy and energy efficiency combined with the failure of national governments to make significant progress on universal access, the need for alternative solutions has gained a prominent role in the Post-2015 development agenda.

At the macro level, the correlation between economic development and energy access has been broadly empirically researched. In particular, [OECD and IEA, 2010] demonstrated the correlation between the Energy Development Index (EDI) and the Human Development Index (HDI), arguing that the positive effects of access to modern energy services in development paths include the impacts on the HDI, on the level of education and on the growth of GDP. However, the precise cause-effect relationship between energy access and human welfare remains partially unresolved [Pachauri and Spreng, 2004, Zerriffi, 2007].

In fact, while the literature agrees that energy access has a positive impact on the economic growth, this is not always the case for least-developed countries [Stern and Cleveland, 2004], due to the low rate at which energy access increases. Among others, [Goldemberg, 2004] observed a strong positive correlation between energy access and economic growth in early development stages, but, at the same time, a reversal of this trend after a certain level has been reached.

Nevertheless, it has been shown that economic progress in the developing world has yielded an enhancement of energy access for many communities in the last decades. This has been the case, for instance, of East Asia and Latin America, where the electricity networks has been extended [Kaygusuz, 2011]. Regions such as South Asia and Sub-Saharan Africa, where about the half of the population without access to electricity lives, continue to lag far behind the rest of the respective continents, especially concerning rural electrification [The World Bank, 2008a].

More specifically, while the urban electrification rate reaches the 90% in developing countries, the rate of rural electrification reaches only 48.4% in South Asia and 11.9% in Sub-Saharan Africa, against the yet low average rural electrification rate of 58.4% considering all developing countries. In addition, more than 80% of the rural population in developing countries worldwide rely on biomass for cooking [Barnett, 1990], and are hence exposed to the risk of respiratory and lung diseases[1]. Despite this, more efficient and safer fuel solutions for cooking (such as LPG – liquid petroleum gas) are often unavailable or unaffordable in rural areas. Hence, the major challenges to be tackled comprise the inefficient use and production of traditional energy sources, involving relevant economic, environmental and health hazards, as well as the uneven distribution of electricity access, petroleum, and natural or liquified gas among populations [Barnes and Floor, 1996].

In fact, the asymmetries in living and in equity conditions, derived from the lack of energy access (especially electricity), affect income generation and communities development, tending to accentuate already existing social differences. Hence, the increased poverty, the lack of opportunity for development, and the uneven distribution of access to energy sources eventually yield considerable migratory flows to large cities and an increasing disbelief regarding its own future [Kaygusuz, 2011].

2.2. Energy Transition Paths

The concepts of *energy ladder* and energy transition refer to the process that a household undertake in the transition from traditional to modern energy, depending on the choice of energy sources and energy technologies. The rationale behind the energy transition is that the potential to acquire better quality

[1] According to the World Health Organisation (WHO), the indoor smoke inhalation due to burning biomass causes over 1.6 million premature yearly deaths, whereas half of them are of children younger than 5 years old [Legros et al., 2009].

and more sustainable sources depends monotonically on the household income. According to this criteria, the level of development of the household can be associated with a higher energy consumption and with changes in the energy mix toward higher percentages of modern energy and better service quality. As previously discussed, rural households in least developing countries, who are particularly affected by energy poverty, lie on the lowest rung of the energy ladder, and the concept of energy transition claims that through a more efficient use of resources, modern energy will allow these populations to enter a sustainable technological path of development.

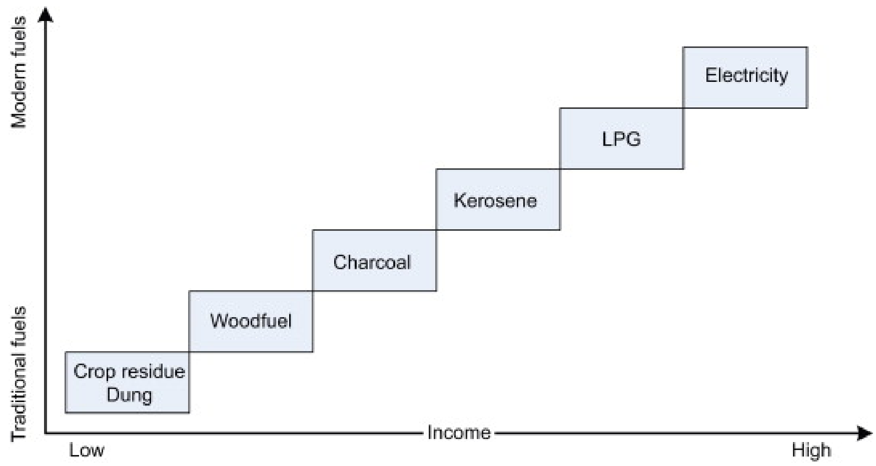

Figure 2.1.: Energy ladder according to fuel [Kowsari and Zerriffi, 2011]

As an example, Figure 2.1 depicts a metaphorical ladder describing how a household ascends from using traditional biomass and primitive technologies towards modern energy sources and more efficient cooking equipments [Kowsari and Zerriffi, 2011]. In this case, the attributes appraised through the energy choice increase entail the efficiency, the cleanliness and the ease of use. In order to move upwards along the ladder, the ability of acquiring improved technologies and better fuels is highly related to (increase in) income, as well as to the availability and to the accessibility of sources and technologies, as observed by [Barnes and Floor, 1996, Masera et al., 2000, Elias and Victor, 2005] and also confirmed by econometric evidence [Hosier, 2004].

However, the energy ladder model has been questioned in regards to its over-simplification on the use and selection of fuel and to its limited view of reality in which these processes take place [Kowsari and Zerriffi, 2011]. Specifically, [Kowsari and Zerriffi, 2011, van der Kroon et al., 2013] stress the inefficiency of the model as it relies on a universal hierarchy of fuels as well as household's income as the major determinant of fuel choice, failing at identifying further factors of energy access choice.

For instance, parallel technology usage is also observed in rural contexts. Due to availability, affordability and practicability, households opt for broader options of energy sources and technologies. This situation is referred as *fuel/energy stacking*, i.e., when multiple energy sources (fuels/devices) are simultaneously used to satisfy household's energy needs. The main reasons for the fuel stacking lie in the need of backup fuel options to cope with intermittent energy supply, to shield from unstable fuel markets and to keep up cultural practices and preferences, while benefiting from available modern energy sources and technologies [Pachauri and Spreng, 2004, Elias and Victor, 2005, van der Kroon et al., 2013] Particularly, the findings from [Masera et al., 2000] describe how stacking instead of switching to clean fuels is rather the norm in most households. Moreover, although [Masera et al., 2000] observed that an increase in income might yield a partial or full shift of the energy stacking towards cleaner and more efficient energy carriers, their empirical research demonstrates that the benefits from clean fuels or technology adoption are usually smaller with stacking than those expected from pure switching.

2.3. Microenergy Systems

Among the different sources of energy, electricity is considered to be one of most important within the path toward economic sustainability, as electricity is generally the preferred choice for lighting and running appliances [Pachauri et al., 2013]. Moreover, electricity is often considered representative of the rural development itself [Kaygusuz, 2011]. However, despite the increasing amount of global investment in the power sector within the last 15 years, electricity generators and distribution networks in rural areas still struggle to achieve the required capacity in order to satisfy the constantly growing power demand.

Moreover, in several regions, traditional and centralized grid-based approaches are neither physically feasible nor economically affordable for the majority of unserved households, making the unavailability of electricity one of the most visible signs of rural-urban differentiation and rural underdevelopment. Indeed, electrification focusing on connecting rural areas to national or nearby grids are mostly not considered to be the least-cost option [Saghir, 2005]. According to [Zerriffi, 2007] the challenge of these initiatives is threefold: first, the high dispersion and low consumption needs of rural populations result in a lower return of the initial high costs to supply the energy utility; second, rural households have a limited ability to pay; third, the lack of required infrastructure and of constant maintenance often lead to a low quality and reliability of delivered electricity services.

To face these challenges, [Smith, 2000, Schäfer et al., 2011] proposed the concepts of *micro-energy appliances* (MEAs) and *micro-energy systems* (MES). The formers are defined as small and locally usable energy conversion units that allow a spatial interconnection between energy demand and energy supply as an energy-converting appliance in the energy sector [Philipp and Schäfer, 2009], while MES consist of groups of MEAs and their framing system.

Electric Energy	
MES	**Usage**
Mini-grid (solar, hydro, wind)	Residential, Micro-business
Solar Home System	Residential, Micro-Business
Solar Pico PV Lamp	Residential, Micro-Business
Solar Water Pump	Livestock, Agricultural Recreational, Residential
Thermic Energy	
MES	**Usage**
Solar Water Heater	Residential, Micro-business Livestock (Diary-factory)
Improved Cooking Stove (Manufactured Solid Fuel Stove)	Residential, Micro-business
Improved Baking Oven	Residential, Micro-business
Biodigestor	Residential, Micro-business
Solar Stove	Residential
Solar Crop Dryer	Agricultural

Table 2.1.: Examples of Microenergy Systems

Being decentralized energy systems, MES represent a way forward to target particular energy needs, making use of locally available energy resources and transforming it to direct use at the end-user location [van der Straeten et al., 2014] (see examples 2.1). Through the increase of the competitiveness of MES in comparison to conventional energy sources (in terms of costs and quality services), its marketability gains particular attention [Barnes and Floor, 1996, Saghir, 2005]. In fact, the findings from [Zerriffi, 2007] describe how energy delivery models building on MES have an advantage on sustainability and replicability, compared to centralized electrification projects. This is due to the adaptability to the specific needs of the MES customers shifting decision-making and implementation at the local level. Furthermore, MES can provide a technically viable alternative to conventional energy, especially for the tasks related to agricultural production and processing (such as land preparation, planting, fertilization, irrigation, harvesting, transport, processing and storage). Moreover, MES can reduce the labour associated with physical drudgery and animal power, thus helping to increase the productivity of several agricultural tasks.

However, the dissemination of MES requires the creation of favorable frameworks [Groh, 2015]. In particular, it is necessary to overcome the prohibitive initial upfront costs for end-users, the difficulty of defining cost-covered financial scheme, the need of customized mechanisms for MES distribution, and the high costs of cleaner energy– due to the subsidies for fossil fuels and nonrenewables [IEA and Photovoltaic Power Systems Program, 2002, Beck and Martinot, 2004]. In recent years, practitioners and academia have extensively researched preconditions and means for the successful implementation and dissemination of MES, as well as the economic and ecological impacts at different levels [van der Straeten et al., 2014].

On the one hand, due to the limited ability to pay for energy services in economically deprived regions, finding a suitable and sustainable financing mechanism for capital intensive MES is a major issue. In this context, flexible financing, i.e., adapted to the end-user, might play an important role in actively fostering energy access at the BoP. On the other hand, in order to be cost-effective, the selection of sustainable MES should not be biased towards renewable energy sources, although it should take into account a proper assessment of the efficiency and operational costs of traditional energy sources. When determining the most suitable choices for MES in a specific local context, the selection should be based on local energy needs, source availability and institutional factors. Consequently, the involvement of local actors in energy access initiatives is decisive to understand the prevailing local conditions and needs [Agbemabiese, 2009, Zerriffi, 2007].

2.4. Productive Uses of Energy

Besides the importance of energy access at the household level, modern energy is associated with improvements of living also due to its potential of enhancing income generation and business opportunities, by creating new economic activities or by increasing the production outputs of existing ones through a more efficient use of energy and other resources [Etcheverry, 2003]. In other words, the link between energy access and economic development is strongly connected to the increase in productivity, defined as the ratio of value creation to energy consumption and to the relevance of the considered energy services for productive uses.

In order to integrate this concept in the context of MES, the work of [Saari, 2006], who defines the concept of business productivity in an operational way, is of particular relevance. Namely, [Saari, 2006] describes productivity as a part of economic activity with the main purpose of satisfying human needs. Met by means of tools, the degree of need satisfaction depends to the success of the tool in its purpose of use.

From a formal point of view, the definition of productive use of energy (PUE) has been deeply debated and it has been recently framed under different umbrellas. Particularly, PUE has been traditionally conceived as any use of energy that directly helps generate income [Kittelson, 1998]. This view has been later extended to other productive activities that are able to enhance income and welfare, taking into account the impact that energy services can have on education, health and gender equality [Cabraal et al., 2005, Etcheverry, 2003]. In this case, the considered productive activities include work for income-generation and wealth creation, comprising both market production with an exchange value, and subsistence/home production with actual use value and potential exchange value clancy-kooijman-2006. Moreover, [Meadows et al., 2003] identified expenses, collection, production and utilization time, as well as the level of dependence the business processes on energy inputs as the main factors determining the value of modern energy for micro and small enterprises.

Focusing on rural areas, the major emerging productive uses for renewable energy include agriculture, powering small industry and commercial services, and production of electricity for social services such as drinking water, education and health care facilities [Martinot et al., 2002]. Table 2.2 illustrates how, by addressing the energy components of agriculture and off-farm activities, the potential for income generation of rural households and enterprises can be increased, detailing the energy services involved in different productive processes and the current available options in terms of renewable energy sources.

Energy services	Income generating value to rural HH and SMEs	Renewable energy options
Irrigation	Better yields, higher value crops, greater reliability, growing during periods when market prices are higher	Wind, photovoltaic (PV), Biomass
Illumination	Reading, many types of manual production during evening hours	Wind, PV, Biomass, Micro-Hydro, Geothermal
Grinding, milling, husking	Create value-added product from raw agricultural commodity	Wind, PV, Biomass, Micro-Hydro
Drying, smoking (preserving with process heat)	Create-value added product. Preserve produce to enable selling to higher-value markets	Biomass, Solar Heat, Geothermal
Refrigeration, ice-making (preserving with electricity)	Preserve products to enable selling to higher-value markets	Wind, PV, Biomass, Micro-Hydro, Geothermal
Expelling	Produce refined oils from seeds	Biomass, Solar Heat
Transport	Reaching markets	Biomass (e.g., biodiesel)
TV, radio, computer, internet, telephone	Education, access to market news, entertainment, co-ordination with suppliers and distributors, weather information	Wind, PV, Biomass, Micro-Hydro, Geothermal
Battery charging	Wide range of services for enduser	Wind, PV, Biomass, Micro-Hydro, Geothermal

Table 2.2.: Energy services for productive activities, added-value and renewable energy options

Several studies have portrayed the role of productive use of energy for development of micro- small- and medium-sized enterprises (MSMEs) as a key factor for community development. In fact, the effects of energy access on productive activities have been claimed to be dependent on the nature of the local community, on development programs, the business owner's skills, market access and demand factors as well as on the access to credit [Barnes, 2007, Peters et al., 2009].

However, in order to determine to which extent modern energy fosters microenterprise development, [Meadows et al., 2003] emphasize the importance of analyzing the heterogeneity of the micro-enterprise sector as it entails a broad spectrum of income-generating activities with varying needs. For instance, in previous research on the role of energy in productivity, [Morris et al., 2007] indicate how productive activities such as irrigating arable land, generating salable crops, selling cool drinks, charging mobile batteries, or refrigerating fish have direct advantages from improved energy access. Indeed, businesses are differently dependent on energy; their energy-intensity and effects of obtaining access vary accordingly. However, [Rogerson, 1997] stresses that access to energy might indeed foster the modernization of already established micro-activities, not necessarily encouraging the growth of new enterprises.

2.5. Measuring Energy Poverty

Energy poverty at the household level, seen as the lack of energy access, has been traditionally measured by *binary* metrics, such as having or not having an electricity connection and cooking with non-solid fuels [2]. This characterization masks major differences in the condition of the delivered energy services, calling for a modernization of methods for quantifying the energy access.

In fact, the metrics focusing on the availability of grid connections are not able to capture broader deficiencies in the relevant attributes, such as affordability, reliability and quality of service [Global Tracking Framework (GTF), 2015]. Hence, binary metrics are an insufficient measure of energy poverty [AGECC, 2010, Practical Action, 2013, IEA and WB, 2014] when aiming at tracking the progresses towards the SDGs. Similarly, metrics based on the usage of solid biomass results in the same lack of information concerning available cooking solutions, as the households might make use of multiple cooking fuels or cook with improved cooking stoves to efficiently use fuel, reducing indoor air pollution and preventing health hazards. Therefore, both academia and practitioners in the field of energy and development widely accepted that quantifying energy access goes beyond binary assessments and it needs to entail different attributes, in order to better capture the quality and quantity of delivered energy [Bazilian et al., 2010, Pachauri et al., 2012a, Bensch, 2013].

Subsequently, although the definition of "access to modern energy services" has been largely under discussion (see, e.g., [Pachauri, 2011, Khandker et al.,

[2] The denomination of non-solid fuels entails liquid fuels (e.g., kerosene, ethanol, other biofuels, etc.), gaseous fuels (natural gas, LPG, and biogas), and electricity or solid fuels, such as traditional biomass (firewood, charcoal, agricultural residues, and dung), processed biomass (pellets, briquettes, etc.) and other solid fuels (e.g., coal, lignite, etc.)

2012, Bazilian et al., 2010, Bensch, 2013]), targets for 2030 point to the achievement of “universal access to modern energy services” as dictated by the SE4ALL decade (2014-2024) of the UN. In order to build upon the results achieved in the development of metrics, [Groh et al., 2016] point out the need of defining universal energy access and common assessment tools in order to enable stakeholders to track endeavors and achievements.

Although a collective consensus on an energy poverty metric has not been achieved yet, several proposals to measure energy deprivation have been published. In contrast to poverty, which is commonly measured based on a relative poverty measure (*poverty line*), energy poverty is related to the multidimensional nature of energy access. Hence, the concept faces the challenges of the absence of a universal definition of energy access and the complexity involved in achieving accuracy in its measurement [Bhatia and Angelou, 2014].

Over the last decades, several indicators have been developed in order to capture the different uses of energy, either mirroring other indicators designed for measuring poverty indices or as an evolution of existing unidimensional energy access indicators. These measures range from indicators to assess energy access to indices quantifying the degree of development related to energy or the deprivation of access to modern energy services. In particular, the investigations of [Bensch, 2013] categorize existing energy metrics in two groups, unidimensional and multidimensional indicators, comparing in detail their advantages and their drawbacks. Similarly, [Nussbaumer et al., 2011] groups the metrics developed to measure energy poverty and sustainable development in three broad categories, distinguishing between single indicators, dashboard (a set of individual indicators) and composite indices. Single indicators are easier to work with, but they fail in picturing the multidimensional issues, such as development or poverty. A dashboard, being based on multiple indicators, improve the comprehensiveness of the aspects to be monitored, although the quantity of indicators may increase the complexity of analyzing changes over time, sometimes requiring an aggregation model. Finally, composite indices are based on a set of sub-indicators, aiming at capturing diverse dimensions of an issue to be depicted in one indicator. On the one hand, composite indices maintain the simplicity of single indicators, while still depending on multiple attributes. On the other hand, the definition of a composite index requires a reduction process and the final result is then depending on the efficiency of the aggregation method and to the assumptions of assigned weights (due to the arbitrariness involved).

The rest of this Section is dedicated to four relevant composite energy metrics proposed in the last decade, which quantitatively assess energy poverty and address the multidimensional nature of energy access: the Energy Development Index (EDI) [IEA, 2004], the Energy Poverty Index (EPI) [Mirza and Szirmai, 2010], the Multidimensional Energy Poverty Index (MEPI) [Nussbaumer et al., 2011], and the Total Energy Assessment (TEA) [Practical Action, 2012]. These metrics are also summarized in Table 2.3, in terms of their definition of energy poverty and of the considered attributes. The need of describing energy access from a multidimensional perspective has been translated into the proposal of a set of attributes to characterize the overall quality of energy services in developing countries, setting the basis of an innovative multi-tier framework [Bensch, 2013, Bhatia and Angelou, 2015], which will be described in detail in Section 2.6.

Energy Development Index (EDI) The EDI [IEA, 2004], mirroring the Human Development Index (HDI) from United Nations Development Programme (UNDP) [Bensch, 2013], is based on six energy services prescribing a minimum level of service. It also combines qualitative with quantitative indicators to analyze household access to fuels, electricity and mechanical power, analyzing their progression in the use of modern energy services.

Energy Poverty Index (EPI) The EPI, developed by [Mirza and Szirmai, 2010] is a composite index to measure the degree of energy poverty among rural households (originally tailored for the case of rural Pakistan). In particular, The EPI measures the inconvenience for the household associated with the use of the different sources of energy, taking into account its energy shortfall and the household size.

Multidimensional Energy Poverty Index (MEPI) The MEPI [Nussbaumer et al., 2011] has been introduced as a modification of the Multidimensional Poverty Index (MPI). It is composed by a measure of the incidence of energy poverty and by a quantification of its intensity, focusing on energy services. Based on micro-data from household surveys, the MEPI enables the estimation of country values from available datasets. However, the arbitrary poverty cut-off is one of its main deficiencies.

Total Energy Assessment (TEA) The TEA methodology [Castán Broto et al., 2015, Practical Action, 2012] assesses key energy services against minimum standards, focusing on energy services, on the use of biomass, on electricity access and on mechanical power. It consists in a survey for energy access at household level and in three indicators comprising the Energy Supply Index (ESI).

Additionally, as identified by [Bensch, 2013], a further metric can be constructed out of the Correlation Services Proxy Index (CSPI) [Rippin, 2011] to create an energy poverty metric, the Correlation Energy Services Proxy Index (CESPI). In contrast to the MEPI, the CESPI is more restrictive as deprivation of any sub-dimension results in classification as energy poor. On the other hand, the CESPI is more sensitive, as it is able to capture the correlation between energy poverty indicators. Among other proposals, the approach of [Foster et al., 2000] quantifies energy poverty by establishing a Fuel Poverty Line (FPL), defined as the inability by households to meet their energy needs. This metric considers then energy consumption, energy efficiency and a method to estimate a country fuel poverty line, providing information on energy consumption and the related costs to such access.

Index	Dimensions	Energy poverty definition
EDI	• Per-capita commercial energy consumption • Share of commercial energy in total final energy use • Share of population with access to electricity	Adequate access if has access to both, modern fuels and appliances
EPI	Qualitative and quantitative indicators of • the "energy inconvenience excess" associated with the energy mix used • insufficient energy to meet basic household needs (energy shortfalls)	30% above the average value of total energy inconvenience
MEPI	• Modern cooking fuel and stove usage • Electricity access • Radio or TV ownership • Phone ownership • Fridge ownership	Dual cut-off: Dimensional cut-offs for each sub-dimension & weights
TEA	• Modern cooking fuel and stove usage • Electricity access and usage • Radio or TV ownership • Phone ownership • Fridge ownership • Energy for enterprises • Energy for community services	Energy poor if any dimension is deprived

Table 2.3.: Multidimensional energy poverty metrics

2.6. The Multi-tier Framework Approach

Recently, a new multidimensional definition of energy access, has been proposed under the Global Tracking Framework (GTF) initiative, one of the four initiatives of the SE4ALL Global Knowledge Hub, hosted by the Energy Sector Management Assistance Program (ESMAP) of the World Bank.

In this approach, energy access is characterized using a *multi-tier framework* (MTF), i.e., ranking the different attributes describing energy access in different tiers, in order to better capture the quantity and quality of electricity supply, as well as the efficiency, safety and convenience of cooking facilities [Global Tracking Framework (GTF), 2013]. The concept of a multidimensional measurement of energy supply was first proposed by AGECC, EnDev and Practical Action [AGECC, 2010], while the multi-tier ranking according to specific thresholds was finally brought into light in 2013 as the ESMAP, in consultation with a diverse group of agencies and programs[3], elaborated a new definition of energy access based not only on energy usage, but taking into account its performance along a set of specific attributes [Bhatia and Angelou, 2015].

In particular, this innovative methodology, referred as a new "milestone" for the monitoring of global progress [Bensch, 2013], measures energy access based on desirable attributes such as: adequateness, availability (when needed), reliability, quality, affordability, legality, convenience, healthy, and safety [Bhatia and Angelou, 2014]. In each of these dimensions, the energy access performance is ranked from 0 (the lowest tier) to 5 (the highest tier), depending on specific thresholds, that must be defined for each attribute. The tier levels reflect a balance between the diverse spectrum of energy access, attempting to provide meaningful differentiation between energy access attributes, in order to obtain a technology-neutral index, which is a key for energy access measurement [Bazilian et al., 2010].

Moreover, the different areas of energy use are considered, referred as *locales* of energy access:

- Energy access at the *households level*, described by the multi-tier frameworks for electricity supply, electricity services, electricity consumption, energy for cooking solutions and energy for space heating.
- Energy for *productive use*
- Energy for *community uses*, described by health facilities, educational facilities, street lighting, government buildings, and public buildings.

For each component of these locales, a separate tier-ranking is calculated, in order to characterize all the required qualities for energy services. After having defined the ranking for each attribute of a particular framework, the final ranking is obtained using a *lower-based* rule, i.e., assigning to each individual

[3] The collaborative effort included organizations such as EnDev, Lighting Africa, Practical Action, The Global Alliance for Clean Cookstoves, UNDP, UNIDO, World Bank and WHO, with previous experiences in energy poverty indexes development (such as Practical Action, The Global Alliance for Clean Cookstoves), or which rigorously track their impact through internal metrics (such as EnDev, Lighting Africa).

(household or enterprise) the lowest tier among all attributes.

Considering a population sample, the multitier ranking allows to compute different *access indices*, based on a weighted average of the overall performance. At this stage, the different frameworks can be combined in composite indices.

The household locale (which will be considered for the case study described in Chapter 5) and the locale for productive use (which is the most relevant in the context of microbusiness development) will be shortly described in Sections 2.6.1 and Section 2.6.2, while Section 2.6.3 details the approach proposed in [Bhatia and Angelou, 2015] for the composite index calculation.

2.6.1. Energy Access at the Household Level

Electricity supply In order to overcome the limits of binary measurements of electricity access, the multi-tier framework for electricity supply considers the key attributes that constrain its usefulness (such as limited quality, affordability, the presence of illegal connection and the risk of accidents). In detail, household electricity is described through the follow attributes: (i) capacity, (ii) duration (including daily supply and evening supply), (iii) reliability, (iv) quality, (v) affordability, (vi) legality, and (vii) health and safety (see Table 2.4).

Electricity Services and Electricity Consumption Besides electricity supply, a separate multi-tier framework can be defined for access to electricity services, in order to track how an improvement in electricity supply reflects in increased and improved access to services. In particular, the matrix measuring access to household electricity is based on the type of appliances used in the household (see Table 2.5, right). Hence, different tier ratings across access to electricity supply and access to electricity services aim at reflecting the case when appliances are available, but supply is poor, or the case when appliances (or high consumption) are unaffordable, despite adequate supply.

A further multi-tier framework is defined for electricity consumption, closely aligned with the one for electricity services (see Table 2.5, left). In this case, the tier thresholds are based on annual and daily consumption levels, without focusing on the diversity of appliances actually used by the household. Moreover, the potential use of energy efficiency appliances not necessarily reflected in the estimated thresholds [Bhatia and Angelou, 2015].

Electricity Supply

	Capacity *(Power, Daily capacity Service)* *gradual*	**Duration** *(Hours)* *gradual*	**Reliability** *(No. of disruptions)* *gradual*	**Quality** *binary*	**Affordability** *binary*	**Legality** *binary*	**Health/Safety** *binary*
Tier 5	Min 3000 kWh and 8219 Wh or very high power appliances	Min 22 hours/day, min 4 hours/night	Max 3 disruptions per week, max 2h long	Good quality of energy supply	Cost of consumed 365kWh less than 5% of income	Legal energy supply	No accident or risk
Tier 4	Min 1250 kWh and 3425 Wh or high power appliances	16-22 hours/day, min 4 hours/night	Max 14 disruptions per week				
Tier 3	Min 365 kWh and 1000 Wh or medium power appliances	8-16 hours/day	More than 14 disruptions per week	Poor quality, damaged appliances		Illegal energy supply	Accidents or risk feeling
Tier 2	Min 73 kWh and 200 Wh or low power appliances *Electric lighting, air circulation (if needed), TV & phone charging*	4h-8h/day, min 2h/night			Cost of consumed 365kWh more than 5% of income		
Tier 1	Min 4.5 kWh and 12 Wh or very low power appliances *Lighting 1000 lmhrs/ day & phone charging (Min 12 Wh)*	Less than 4 hours/day, min 1h/night					
Tier 0	No electricity	Less than 4 hours/day, less than 1h/night					

Table 2.4.: Multi-tier Matrix: Thresholds of attributes and tier ranking standards for the electricity supply framework

	Electricity Consumption	Electricity Services
Tier 5	More than 3000 kWh / Year	Very high-power services (air conditioning, electric water heater)
Tier 4	More than 1250 kWh / Year	High-power services (microwave, hair dryer, toaster, iron)
Tier 3	More than 365 kWh / Year	Medium-power services (fridge, freezer, washing machine, mixer, rice cooker, water pump)
Tier 2	More than 73 kWh / Year	Low-power services (TV, PC, printer, ventilator)
Tier 1	More than 4.5 kWh / Year	Very-low power services (light bulbs, phone charger, radio)
Tier 0	Less than 4.5 kWh / Year	None of the above

Table 2.5.: Thresholds of attributes and tier ranking standards for Electricity Consumption and Electricity Services Frameworks

Energy for Cooking Solutions In order to measure the access to energy for cooking, the multitier framework considers the following attributes: (i) health (based on indoor air pollution), (ii) convenience (based on fuel collection time and stove preparation time), (iii) safety, (iv) affordability (based on costs on cookstove and fuel), (v) efficiency, (vi) quality, and (vii) fuel availability.

This framework has been defined consistently with a rating system proposed by the International Workshop Agreement on Cookstoves (IWA)[4] for measuring cookstove performance [Bhatia and Angelou, 2015]. The framework matrix is detailed in Table 2.6. Note that three of the seven attributes composing this framework (health, safety and efficiency) require measurement by a competent agency in order to correctly evaluate the energy access of the household.

Energy for Space Heating At the household level , energy for space heating (where needed) can be availed through a range of solutions, including electric heating, fuel-based centralized district heating, fuel-based standalone heating, and direct solar heating. In this case, the multitier framework is based on (i) capacity, (ii) duration, (iii) quality, (iv) convenience (fuel collection time), (v) affordability, (vi) reliability, (vii) health (air quality) and (viii) safety.

[4] The IWA was organized in 2012 by the The Partnership for Clean Indoor Air (PCIA) and the International Organization for Standardization (ISO) organized the IWA in February 2012. The rating system agreed by the participants proposed to evaluate cookstove models in tiers of performance in different areas: fuel usage, emissions, indoor emissions and safety.

Cooking Facilities

	To be measured by a local competent agency						
	Health	**Safety**	**Efficiency**	**Convenience**	**Availability of primary fuel**	**Affordability**	**Quality**
		IWA Safety Tiers, accidents or perceived risks		*Stove preparation (SP) time & fuel acquisition and preparation (FAP) time* gradual	*gradual*	*binary*	*binary*
Tier 5	PM2.5<10 mg/m3, CO<7 mg/m3	IWA Tier 4, no accidents or perceived risks	Tier 4	SP time <0.5 min/meal, FAP time <2 min/meal	Primary fuel is readily available all year	Stove and fuel cost < 5% of HH income	No major effect of primary fuel quality
Tier 4	PM2.5<35 mg/m3, CO<7 mg/m3			SP time <1.5 min/meal, FAP time < 5 min/meal	Primary fuel is readily available for at least 9 months/year (80%)		
Tier 3	PM2.5<100 mg/m3, CO<20 mg/m3	IWA Tier 3	Tier 3	SP time <3 min/meal, FAP time < 10 min/meal	Available less than 9 months/year	Stove and fuel cost > 5% of HH income	Heat rate variates
Tier 2	PM2.5<250 mg/m3, CO<50 mg/m3	IWA Tier 2, accidents or perceived risks	Tier 2	SP time <7 min/meal, FAP time < 15 min/meal			
Tier 1	PM2.5<250 mg/m3, CO<50 mg/m3	IWA Tier 1	Tier 1				
Tier 0	higher emissions	IWA Tier 0	Tier 0				

Table 2.6.: Multi-tier Matrix: Thresholds of attributes and tier ranking standards for cooking solutions framework

2.6.2. Energy Access Framework for Productive Engagements

The complexity of defining a common metric for energy access for productive use is due to the wide diversity of productive activities, to their varying scales of operations and degrees of mechanization.

In this case, the multi-tier methodology is built upon the concepts that productive uses of energy refer to those that allow to increase income or productivity, i.e., value-adding activities, and that these uses involve diverse sources of energy. Therefore, in order to measure the level of access of energy, the different applications are grouped into broader categories as lighting, information and communication, motive power, space heating, product heating and water heating [Bhatia and Angelou, 2015]. For each of these categories, the multi-tier framework (detailed in Tables 2.7 and 2.8), is built on nine attributes that determine the usefulness of the supply for each application needed for the productive activity.

In the course of a household energy survey, the assessment consists in the following steps:

- Identification of earning members
- Identification of relevant energy appliances used based on their significant impact on productivity, sales, cost or quality
- Identification of primary energy source for each application
- Assessment for the key attributes of energy supply and lower-based overall tier ranking

Attribute	**Tier 0**	**Tier 1**	**Tier 2**	**Tier 3**	**Tier 4**	**Tier 5**
Capacity						
Electricity (Power)		Min 3W	Min 50 W	Min 200 W	Min 800 W	Min 2kW
Electricity (Daily supply)		Min 12 Wh	Min 200 Wh	Min 1.0 kWh	Min 3.4 kWh	Min 8.2 kWh
Electricity (Typical source)		Solar lanterns	Solar Home Systems	Generator or mini-grid	Generator or grid	Grid
Non-electric				Available non-electric energy partially meets requirements	Available non-electric energy largely meets requirements	Available non-electric energy fully meets all requirements
Both				No application is absent solely due to energy supply constraints		
Duration of daily supply						
Electricity		Min 2 hrs	Min 4 hrs	Min 50% of working hours	Most of working hours (Min 75%)	Almost all of working hours (Min 95%)
Non-electric				Available non-electric energy partially meets requirements	Available non-electric energy largely meets requirements	Available non-electric energy fully meets all requirements
Both				No application is absent solely due to energy supply constraints		
Reliability					No reliability issues that have severe impact	No reliability issues or little impact
Quality				No quality issues that have severe impact	No quality issues or little impact	

Table 2.7.: Thresholds of attributes and tier ranking standards for Productive Uses of Energy Frameworks - Part 1 (Note: W: watts; Wh: watt-hours)

Attribute	**Tier 0**	**Tier 1**	**Tier 2**	**Tier 3**	**Tier 4**	**Tier 5**
Affordability					Variable cost of energy is less than two times the grid tariff	Variable cost of energy is less than grid tariff
Legality					Energy bill is paid to authorized body	
Convenience					Time and effort in securing and preparing energy does not cause severe impact	No convenience issues or little impact
Health *(indoor air quality from use of fuels)*						
PM2.5 (mg/m3) — CO (mg/m3)		[To be specified by competent agency (WHO)]			<35(WHO, IT-1) — <7(WHO Guideline)	<10 (WHO Guideline) — <7(WHO Guideline)
OR Use of fuels (BLEENS)		non-BLEENS for heating (open/with smoke extraction)			Use of BLEENS or equivalent (if any)	
Safety					Energy supply solutions have not caused any accident over the past year that required professional medical assistance	Energy supply have not caused any accident over the past year

Table 2.8.: Thresholds of attributes and tier ranking standards for Productive Uses of Energy Frameworks - Part 2 (Note: BLEENS consists of: biogas, LPG, ethanol, electricity, natural gas and solar; CO-carbon monoxide; kW: kilowatts; kWh: kilowatt-hours; LPG: liquid petroleum gas; PM: particulate matter)

2.6.3. The Energy Access Index

The approach described in [Bhatia and Angelou, 2015] also introduces a composite Access Index (AI), with the aim of measuring the energy access level of an entire population (i.e., a region or a country). According to [Bhatia and Angelou, 2015], the index is computed as an arithmetic mean via

$$\mathrm{AI} = \sum_{k=0}^{5} V_k P_k, \tag{2.1}$$

where k is the tier number, P_k is the proportion of households in tier k and V_k is a measure of the degree of access of the people in tier k. In particular, the choice $V_k = 20k$ is used in [Bhatia and Angelou, 2015], which yields an Access Index ranging from 0 to 100. In this case, the AI can be interpreted as the overall access percentage in a particular sector for the considered population. Figure 2.2 sketches two particular example of the AI computation, in which two different multi-tier rankings produce the same AI.

As observed in [Bhatia and Angelou, 2015], there is no particular reason for taking $V_k = 20k$. As well, different approaches for computing the AI (such as a geometric mean instead of an arithmetic mean) could be more appropriate in different circumstances.

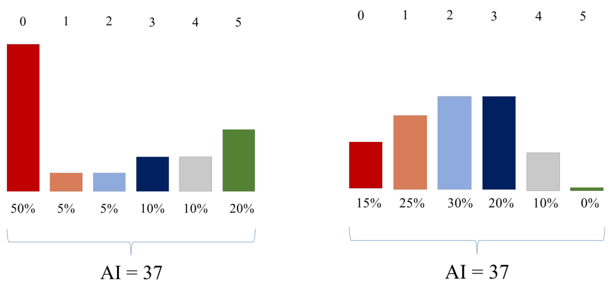

Figure 2.2.: Two examples of AI computation according to (2.1), producing the same composite index. In the first situation, the population is mostly concentrated in tier 0, while, in the second example, the sample is more distributed among tiers

One of the motivations behind the introduction of the AI is the possibility of measuring the improvement in energy access of a population over time, by multiple and consecutive implementations of the energy survey. On the one hand, by reducing the multi-tier rankings (one for each framework) to a set of composite indices allows the consideration of different samples of the population for each evaluation, as only the average performance is taken into account. On the other hand, the tiers depend on predefined thresholds, while several attributes are binary (i.e., consisting only of tier 0 or 5). Hence, it is difficult to estimate to which extent the composite index, which is solely defined by the lowest tier among all attributes, might be biased by these thresholds.

3. Tackling Affordability and Access to MES: Green Microfinance

The lack of energy access in rural areas can be attributed to a variety of factors, including economic meltdowns, market performance and legal and regulatory arenas [Beck and Martinot, 2004, The World Bank, 2008a]. Among these, the financial barriers, which result in both a limited ability to pay and in the unavailability of high up-front investments, have a considerable impact. As discussed in Chapter 2, decentralized energy solutions, such as MES, might provide more affordable options due to their adaptability to the particular context (e.g., solar home systems, biogas digesters, solar water heaters, grain-mills, or improved cooking stoves) [Barnes and Floor, 1996, Smith, 2000] and by enabling a gradual increase in the size of investments. However, the initial costs still remain a major issue in several cases.

The issue of affordability of energy services, as observed by [Winkler et al., 2011], does not affect only the energy access, but also the energy use. Particularly, in the case of electricity, [Lucas et al., 2003] maintain that the populations deprived of energy access, besides needing to overcome the initial connection costs (or the costs for the acquisitions of power source equipments), often lack the means to acquire efficient and appropriate MES. Hence, financial barriers are considered to be a cause of the so-called *vicious cycle of poverty*, a concept that describes the correlation between micro-enterprising activities (income-generating activities which sustain livelihoods) and access to modern energy services. According to [Lucas et al., 2003], such a cycle is broken only by efficiently tackling efficiently the energy poverty, i.e., by combining improved energy services with additional income generation.

Microfinance is an approach to deliver financial services to a segment of the populations otherwise excluded from commercial banking. It is based on the principle that the BoP, with access to improved financial services, has the capacity to generate higher income by increasing the output of economic activities. In order to overcome the informational and institutional barriers usually associated with commercial banking [Armendáriz de Aghion and Morduch, 2005, Banerjee et al., 2010], microfinance makes use of social pressure and characteristic lending techniques (small amounts, consecutive group lending, community engagement as loan guarantors and social default penalties, among others).

In recent years, microfinance has been seen as a viable strategy for tackling financial barriers to energy access, such as initial investment costs. In fact, by supplying financial services to the *non-bankable* (by commercial banking), microfinance can overcome the liquidity constraints of households and micro-entrepreneurs, enabling the financing and affordability of MES over time[1].

Several financial institutions worldwide have developed strategies devoted to improving energy access for underserved populations via microfinance mechanisms. These approaches often consist of establishing partnerships with energy product service suppliers and adapting existing financial services with new credit products, so-called *green loans*, which finance the purchase of renewable energy or energy efficient technologies [Wenner, 2002, Hall et al., 2008, Allet, 2012]. These intersectoral partnerships demonstrate the fact that by enabling the acquisition of modern technologies and designing tailored microloans, MFIs can help to reduce poverty [Srinivasan, 2007, Rao et al., 2009], attract new customers, and improve access to MES for existing customers, thus enlarging the market of energy product service suppliers [Morris and Kirubi, 2009].

However, despite these developments, the microfinance movement to address energy access has advanced at a slow pace, and the successful scaling-up of projects combining energy access and microfinance schemes is still the subject of open discussions (see e.g., [Groh and Taylor, 2015]). In fact, while energy service suppliers are often unwilling to operate in remote rural areas without a guarantee that financing is available for their customers, MFIs are unwilling to issue loans for MES without a guaranteed partnership with an energy service supplier with high-quality products [Morris and Kirubi, 2009]. On the other hand, the scale at which MFIs operate is insufficient to alleviate energy poverty on a larger scale [OECD and IEA, 2010], as, without additional subsidies, microfinance mechanisms encounter difficulties adjusting loan instalments to prior expenditures for kerosene, candles, diesel or battery charge [Martinot et al., 2001, Morris and Kirubi, 2009]. In this respect, through scenarios simulations, [Pachauri et al., 2012b] analyzed the best strategies in order to achieve universal energy access by 2030. The results showed that supporting policies that provide a combination of subsidies and microfinance, thus increasing affordability of running costs, are likely to be most successful and cost-effective in achieving the final targets.

This chapter focuses on the linkage between financial inclusion and energy access, on the debated role of microfinance in scaling up access to MES and on available metrics to measure the environmental performance of microfinance. Firstly, Section 3.1 introduces the role of microfinance in overcoming financial

[1] This research focuses on the role and the potential of microfinance mechanisms for the financing of MES, in order to explore green microfinance's role in assisting those MFIs involved in green lending programs. It must also be mentioned that the use of mobile banking and mobile cash services in retail and wholesale shops have enabled new opportunities for credit access and increased the affordability of MES. In fact, by eliminating the need for in-person transactions, mobile payments have helped to reduce barriers to trade (see, e.g., the case of M-Pesa in Kenia and bKash in Banglasdesh, both as mobile banking and cash transfer services used for selling products and buying from their distributors) and such technical and financial innovations on end-user financing have enabled distributed energy services companies (DESCOs) to rapidly expand their market, under schemes such as *Pay-As-You-Go* (PAYG).

barriers for energy access, as well as the mechanisms used to facilitate energy access, distribution and delivery or installation. Next, Section 3.2 describes the financial models behind the green lending programs, while Section 3.3 explores approaches that can lead to inter-sectoral collaborations that serve as models of partnerships or ventures, in order to enhance energy access in a specific geographical region. The last part of the chapter is dedicated to relevant indicators used in the field of microfinance: Section 3.4 discusses the assessment of the impact of green microfinance, while Section 3.5 focuses on the Progress out of Poverty Index (PPI), which is used by MFIs to estimate the level of poverty of their clients.

3.1. Green Microfinance and Green Lending

Microfinance delivers financial services to low-income populations who otherwise lacking access to commercial banking services, by exploiting peer pressure and innovative lending techniques. In particular, in order to be successful, the business model of MFIs relies on a solid distribution network and on constantly maintaining a close relationship with clients. In the last decade, since the launch of the International Year of Microcredit 2005 by the United Nations (UN) and the honouring of the Grameen Bank and its founder Muhammad Yunus (awarded the Peace Nobel Prize in 2006), the expectations regarding the impact of microfinance in development processes have steadily increased.

The popularity of microfinance, together with microfinance success stories worldwide, lead to an explosion of interest in the microfinance sector in developing countries, for both non- and for-profit institutions [Ghosh, 2013]. However, the impact of microfinance has been severely questioned as there remains a lack of empirical evidence to demonstrate the benefits. One of the main criticisms claims is that microfinance intensifies mechanisms that ensures the short-term profitability of MFIs while increasing the vulnerability of the poorest and only benefiting the better-off [Banerjee et al., 2010, Coleman, 2006]. Other authors have argued that microfinance resulted in a growing bubble of expectation despite of the institutional and sectoral meltdowns, disappointing those who hoped it would alleviate poverty [Hulme, 2000, Maren et al., 2011, Ghosh, 2013].

According to [Groh, 2014], in order to positively affect the quality of life of low-income clients, one must take into account the symbiotic relationship between financial and energy inclusion, which is based on their mutual benefits and on a bidirectionally causality. Access to finance can lead to energy inclusion in terms of affordability and better financial means, i.e., people who have access to financial services are able to finance their basic energy needs and either pay for grid-supplied electricity or purchase a distributed energy generation system. On the other hand, by financing the purchase of a distributed energy generation system through small monthly installments to retailers or intermediaries, those at the BoP can then use the energy generated to increase their productive capacities and repay over the course of two to three years [MicroEnergy International, 2014].

Due to their infrastructure (i.e., multiple offices, established communication channels, local loan officers networks) and to their customer relationship management, MFIs have been acknowledged as vehicles which help enable energy access, by allowing access to MES via their microlending mechanisms [Devine et al., 2010, UNDP, 2000, Mohiuddin, 2006, Srinivasan, 2007, Rao et al., 2009]. The label *green microfinance* refers to the ensemble of microfinance services addressing the triple bottom line, i.e., fostering an impact at the economic, social and environmental levels. More specifically, green microfinance entails a variety of internal or external activities that MFIs undertake with the common goal of fostering green businesses and contributing to environmental preservation [Realpe Carrillo, 2014]. [Hall et al., 2008] listed the following as main motivations to "go green": scale risk management, regulation procedures, competition pressure, ethical considerations and access to funding [Van Elteren, 2007], as the main key drivers, while [Allet, 2011] also indicated risk mitigation interests, ethical responsibilities, donor pressure or business opportunities, directed by both ethical and instrumental arguments.

Among the activities comprised in the green microfinance spectrum, *green lending* aims at facilitating access to clean energy technologies- renewable energy or energy efficient appliances- by designing customized credit products for the target population in order to finance energy systems[2] [Realpe Carrillo, 2014, Pierantozzi et al., 2015].

If the loans for clean energy technologies are appropriately designed to closely match installments with existing expenditures on fuels or income flows [Morris et al., 2007], energy access lending programs can result in attractive self-repaying credit schemes, as a consequence of automatically generated savings [Levaï et al., 2011]. Interested MFIs in diversifying their portfolio design loans for MES [Levaï et al., 2011], facilitating necessary after-sale services and expanding their coverage by developing new business models [Allderdice et al., 2007, Kebir et al., 2013]. However, as green loans are built upon the linkage between the microfinance and energy sectors, MFIs must possess the willingness and the capabilities to channel capital into loans for MES, as well as a high capacity to assume the largest risk [Rao et al., 2009].

Hence, pursuing these opportunities requires not only strategic decisions from the MFIs' management followed by identification of adequate products and careful program design, piloting, and roll-out [Levaï et al., 2011], but also extensive and unconditional support from the energy product service suppliers [Morris et al., 2007]. These considerations are in line with the results of [d'Almeida and Roberts, 2014]. Based on an analysis of 17 Latin American countries, the authors studied the hypothesis that high demand for MES and low barriers to market entry promote entry into the green microfinance market. Among others,

[2] [Shuite and Forcella, 2015] framed green lending within Green Inclusive Finance (GIF), which refers to financial services that support economic growth in a clean, resilient and sustainable manner, and focus on the BoP including micro, small, and medium-sized enterprises in low-income countries or such subsets of population within other developing countries [IFC, 2013]. As such, green lending can be seen as one of many instruments that address climate change, under the umbrella of GIF comprising the multidimensional purpose of economic development, social inclusion and environmental sustainability.

they show a low correlation between the fact that an MFI decided to offer green loans and the high demand of MES from the population due to low electrification rates or high costs of substitutes (e.g., high electricity prices, high diesel prices, etc.). Their findings specifically revealed that government interventions are not necessarily required in order to encourage firms to diversify their portfolio with green loans, provided that there is a strong business environment for microfinance with low barriers to enter.

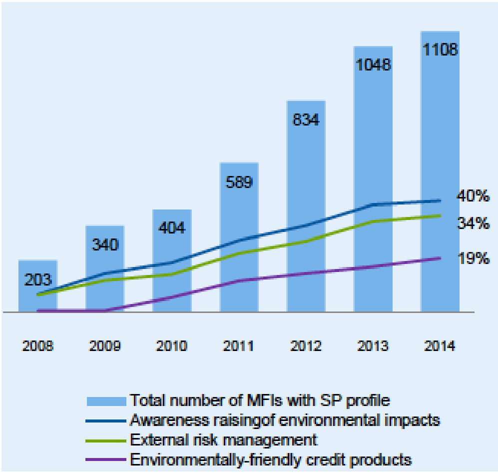

Figure 3.1.: Number of MFIs reporting on Green Performance Indicators (see [Pierantozzi et al., 2015])

The portfolio diversification of MFIs, in order to integrate green lending products, can be seen as an opportunity to extend their market and to better reach vulnerable communities. However, whether driven by environmental consciousness or business opportunities, green initiatives still appear to lack long-term sustainability. Moreover, the scaling-up of green lending programs still remains a challenge, and profitable business models have not been validated on a large scale yet [Realpe Carrillo, 2014]. Indeed, the fact that the number of MFIs offering green lending -despite increase- is still relatively small invites a reflection (see Figure 3.1).

The analysis from [Shuite and Forcella, 2015] claims that the main arguments restraining financial institutions to integrate green loans into their portfolio includes high investment costs, the low environmental awareness, and the overcoming of the issues related to the establishment of complex partnerships. Accordingly, despite of the fact that green microfinance contributes to overcome the barriers of access to credit, green loans and microcredits, especially individual loans, seldom target the poorest of the poor, to whom MES are still not affordable [Groh and Taylor, 2015]. For instance, [Beck and Martinot, 2004] stress that notwithstanding the availability of microfinance services aiming at improving MES access, loan conditions and duration are still significant barriers for this segment of the population. Moreover, it has been claimed that loans are not always sufficient to overcome the barrier of the initial cost of MES in remote areas. The studies presented by [Beck and Martinot, 2004, The World Bank, 2008b], among others, argue that, in order to guarantee fair competition between renewable and conventional energy sources, proper legal and regulatory framework are needed, such as limiting subsidies for fossil fuels and introducing additional grants for supporting clean energies.

3.2. Clean Energy Technologies Finance Models

Initiating a green lending program requires strategic decisions from the MFIs' management and operational capacities. As a next step, MFIs and energy product service suppliers negotiate their role (responsibilities and ownership) based on different delivery models, that vary worldwide with respect to engagement strategies, product offerings, service delivery, and specific business models. In this context, [Parkerson, 2005] differentiates three different credit sale forms

- the lease purchase model,
- the dealer credit model (one-hand model), and
- the end-user credit model (two-hand model).

While in the first two approaches only one organization is responsible for the production, delivery, financing and after-sales services of the energy systems, in the two-hand model (see also Figure 3.2) the financial institution establishes a cross-sectoral partnership with energy product service suppliers, so that the responsibilities between the two parts are clearly shared, and the business relationship stresses on utilizing each actor's expertise concerning the end-users. Specifically, financial institutions provide financing and technology suppliers install the system, train and offer after sale maintenance[3].

A further benefit of two-hand models is that MFIs are rather attracted to partner with energy companies [Morris and Kirubi, 2009], instead of incurring heavy organizational changes or assuming the entire supply chain of the technologies by themselves [MEI and PF, 2010, Kebir and Heipertz, 2010]. However, crucial prerequisites for an appropriate supply chain design are both reliable energy product service suppliers and a high level of commitment of the MFIs' management and of their operational forces [Morris et al., 2007]. Indeed, diversifying an MFIs' portfolio by introducing green loans represents an opportunity for both partners to extend their markets jointly, thereby reaching vulnerable communities in need of both access to finance and/or energy [Groh, 2014]. Specifically, the assumption behind the two-hand model is that, through a systematic approach, MFIs are able to build up commercial relationships with energy product service suppliers and thus to (i) diversify the MFI's portfolio, (ii) foster local

[3] An exemplary one-hand model approach takes place in Bangladesh at Grameen Shakti. Founded in 1996, Grameen Shakti is a worldwide leader in energy lending that disseminates solar home systems (SHS) to energy deprived populations. The organization has been able to convert the challenges of energy supply into business cases along the supply chain. Besides SHS, Grameen Shakti also offers financing for improved cooking stoves and biogas digesters. As of September 2016, the organization has financed 1,692,194 SHS, 949,984 ICS (since 2006) and 32,668 biogas gasifiers (since 2005), leading the MF green sector in MES financing. For further information see www.gshakti.org.

industries by increasing the market outreach and facilitating know-how and technology transfer and (iii) satisfy the energy needs of the underserved clients.

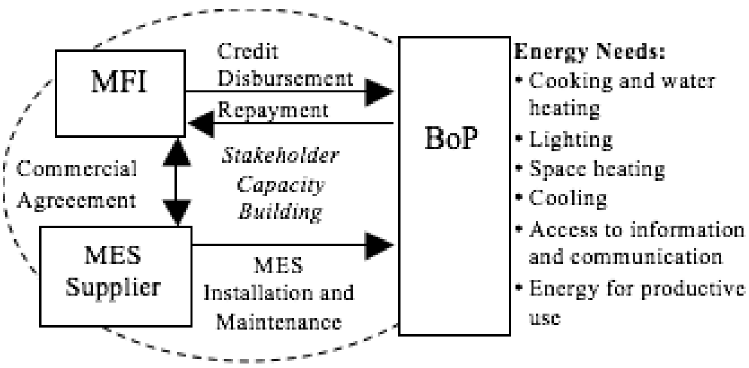

Figure 3.2.: Two-Hand Model Scheme [Realpe Carrillo et al., 2015]

Among the green microfinance initiatives, green lending still appears to lack long-term sustainability, and therefore the scaling up of a two-hand model approach remains a challenge for both parties. The major obstacles are the access to better technical assistance, the development of efficient supply chains on a large scale, and the lack of profitable business models [Realpe Carrillo, 2014].

More in detail, the high investment costs in the learning process and the limited access to knowledge and to technical expertise are two main obstacles for the MFIs as they pursue large-scale commercialization. Concerning local energy companies (mostly SMEs) involved in two-hand green lending models, the main challenges reside in the design of the supply chain and in the adaptation of their products and services in order to be able to expand their market together with the partner MFIs. Furthermore, efficiently reaching remote clients becomes a challenge for both MFIs and energy product service suppliers.

3.3. Cross-sectoral Cooperation to Tackle Energy Poverty

The joint effort of the microfinance and energy sector towards improving the access to energy services may contribute substantially to the achievement of the SDGs. However, in order to achieve results on a significant scale with the implemented electrification projects, serious investments are required from multilateral and bilateral donor community, as budgetary resources of MFIs and energy product service suppliers are constrained.

Regarding this issue, two approaches building on cross-sector cooperation have been proposed by [De Gouvello and Durix, 2008]. They describe the experience of a multi-sector committee in Senegal which, given earlier attempts from the energy sector to contribute to poverty reduction, made key policy decisions in order to support a renewable energy program joining the financial and the energy sectors. In view of this study, [De Gouvello and Durix, 2008] describe two operational methodologies to foster cooperation between sectors with complementary steps from a *systematic* and a *pragmatic* perspective. Their motivation consisted in proposing an approach to rural electrification that ensures a positive impact on communities, targeting the direct impact on livelihoods and revenue generation beyond the provision of connections and kilowatt hours. Rather than waiting for spontaneous positive effects of electrification projects to trickle-down in rural areas, the alternative proposed by [De Gouvello and Durix, 2008] focuses on productive uses of electricity. They specifically identified the necessity of working across sectors and the importance of a political will for implementation. By reaching out to other sectors to help generate their output, the authors call from political will to implementation.

The *systematic approach* (Figure 3.3, left) defines the necessary steps prior to cross-sectors energy program, such as the financing of modern technologies through microcredit, based on the impact of the selected energy technologies on the community. In particular, it consists in the identification of the productive activities and of the energy usage of the target population, followed by a categorization of productive activities carried out in a specific rural area. Next, an analysis of the contribution of electricity to the productivity of the considered economic activities shall be conducted, followed by an identification of the required technologies or equipment and hence an assessment of basic economic viability.

The *pragmatic approach* (Figure 3.3, right) entails primarily the identification and promotion of productive uses of electricity. It consists of an analysis of rural development priorities, the identification of sector programs and areas of cooperation, and the analysis and implementation of the technical design and costing. The main aim of this approach is to establish an effective stakeholder cooperation within renewable energies concessions. Within this approach, [De Gouvello and Durix, 2008] introduce the multi-sector energy investment projects (MECs), as an opportunistic and practical method to speed up the delivery of positive impact of renewable energy.

Figure 3.3.: The systematic (left) and the pragmatic approach (right) for cross-sectoral cooperation according to [De Gouvello and Durix, 2008]

3.4. Indicators on Green Microfinance

Stakeholders involved in implementing green microfinance have been interested in the development of analytical tools for MFIs aimed at fostering the integration of environmental objectives within their strategic plans. Consequently, categories and terminology have been harmonized and green practitioners have coordinated their effort to agree on metrics and standards definitions of the concept of “green”. Specifically, several indexes in the area of environment and microfinance have fostered the potential and ability of MFIs to commit to environmental goals. This section briefly describes the Microfinance Environmental Performance Index, proposed by [Allet, 2011], the Green Performance Agenda, developed by the companies Enclude and Hivos, the MIX set of environmental indicators [Pierantozzi et al., 2015], and the Green Index, developed by the European Microfinance Platform (e-MFP) Action Group Microfinance & Environment [Allet, 2014]. The main characteristics of these methodologies are also summarized in Table 3.1.

Microfinance Environmental Performance Index (MFEPI) The MFEPI[4] aims at measuring the environmental performance of MFIs, hence assessing the engagement of MFIs in preserving the environment. The MFEPI has been a pioneer tool in investigating the impact of microfinance on the triple bottom line, i.e., tackling social, economic and environmental goals. Given the increasing interest of MFIs in implementing environmental management programs, the tool developed by [Allet, 2011] aimed at facilitating the microfinance sector to measure environmental performance, focusing in actions and processes rather than in outputs. The tool is based on management performance indicators, assessing the following five dimensions: environmental policy, ecological footprint, environmental risk assessment, green microcredit, and environmental non-financial services. The indicators within each axis are depicted in Table 3.2.

[4] In the original publication [Allet, 2011], the Microfinance Environmental Performance Index has been shortened using the acronym MEPI. However, for the sake of clarity, in this section this index is abbreviated as MFEPI, in order to distinguish it from the MEPI introduced in Section 2.5.

Index	Outputs	Axis of actions
MFEPI	Assessment of MFI's environmental performance	I Environmental policy II Ecological footprint III Environmental risk assessment; IV Green microcredit V Environmental non-financial services
GPA	Self-assessment of MFI today's and tomorrow's performance	List of activities and tools
MIX Env. Indicators	Binary metrics (MFI performs or not specific environmental activities)	I Environmental policy II Environmental risk assessment III Environmental risk outstanding loans assessment IV Green loans V Environmental micro-insurance
Green Index	Assessment of MFI's environmental performance	I Environmental strategy II Environmental risk management III Green opportunities

Table 3.1.: Green Microfinance Indicators

Environmental Policy	
Mission	Environmental protection mentioned in the official vision, mission, or values (1 pt.)
Environmental Policy	Formal policy on environmental responsibility (1 pt.)
Manager	A person appointed to manage environmental issues (1 pt.)
Incentives	Incentive system to encourage employees to take into account specific environmental objectives (1 pt.)
Ecological Footprint	
Carbon Audit	Previous realization of a carbon audit (1 pt.)
Footprint Objectives	Specific objectives to reduce ecological footprint (e.g., reduction in energy consumption, carbon emissions, waste, etc.) (1 pt.)
Staff Awareness	Toolkits to raise employees' awareness of good practices in paper, water, and energy consumption, transportation, waste management, etc. (1 pt.)
Reporting	Inclusion of environmental performance indicators in annual report (paper, water, and energy consumption, etc.) (1 pt.)
Environmental Risks Assessment	
Exclusion List	Use of an environmental exclusion list (1 pt.)
Screening Tools	Use of specific toolkits to evaluate the environmental risks of clients' activities (1 pt.)
Staff Training	Training module to teach loan officers how to evaluate the environmental risks of their clients' activities (1 pt.)
Monitoring Information System (MIS)	Inclusion of indicators into MIS to track the environmental performance of clients (1 pt.)
Green Microcredit	
RE&EE Loans	Provision of credits to promote access to renewable energy or energy efficient technologies (RE&EE) (2 pts.)
Green EEN IGAs Loans	Provision of loans with reduced interest rates to promote the development of environmentally-friendly activities (2 pts.)
Environmental Non-Financial Services	
Client Chart	Environmental chart to be signed by clients (1 pt.)
Client Awareness	Programs to raise clients' awareness on environmental risks (1 pt.)
Promotion Action	Organization of actions to promote environmentally-friendly microenterprises (1 pt.)
Client Training	Training and other services to support clients who want to develop environmentally-friendly activities (1 pt.)

Table 3.2.: Microfinance Environmental Performance Index (MFEPI) [Allet, 2011]. The score of each evaluation axis (right column) is indicated in brackets.

Green Performance Agenda (GPA) With the purpose of supporting MFIs with a practical guide that addresses their environmental agenda, Enclude and Hivos designed the GPA, consisting of a self-assessment tool which appraises the MFI's perspective of their environmental performance 'today' and 'tomorrow'[5]. The application of the GPA provides a list of tools to plan and improve their performance suggesting the desirable impact of conducting such activities without quantifying in detail the effects.

MIX Indicators The largest available set of green indicators (and, more broadly, of social performance indicators) are the one proposed within the microfinance platform MIX Market[6] [Pierantozzi et al., 2015], where data have been collected since 2009. The qualitative indicators on environmental performance, available to the public, are solely based on binary metrics, reflecting whether the MFI does or does not conduct a particular "green" activity. Within the set of the MIX indicators linked to environmentally friendly products and/or practices (see Table 3.3), only two describe whether an institution offers green loans entailing the financing of clean energy technologies e.g., (i) Products related to renewable energy (e.g., solar panels, biogas digesters) and (ii) Products related to energy efficiency (e.g., insulation, improved cooking stoves, etc.).

(1) The institution includes clauses in loan contracts that require clients to improve environmental practices/mitigate environmental risks.
(2) The institution offers specific loans linked to environmentally friendly products and/or practices. The environmentally friendly credit product offering are environmentally friendly practices or products related to environmentally friendly practices (e.g., organic farming, recycling, waste management, agroforestry or silvopasture, clean water, etc.).
(3) The institution offers specific loans linked to environmentally friendly products and/or practices: - Products related to renewable energy (e.g., solar panels, biogas digesters, etc,) - Products related to energy efficiency (e.g., insulation, improved cook stoves, etc.) - None of the above

Table 3.3.: MIX Environmental Indicators: Environmental Policies and Initiatives.

An analysis of these indicators [Shuite and Forcella, 2015, Pierantozzi et al., 2015] showed that the number of MFIs offering products related to renewable energy and to energy efficiency is increasing (see Figure 3.4). However, a drawback of this classification is that environmentally friendly credit products not strictly included in the renewable energy or energy efficiency categories or practices are

[5]See www.gpa4mf.blogspot.com
[6]See http://reports.mixmarket.org/crossmarket

classified as “none of the above”.

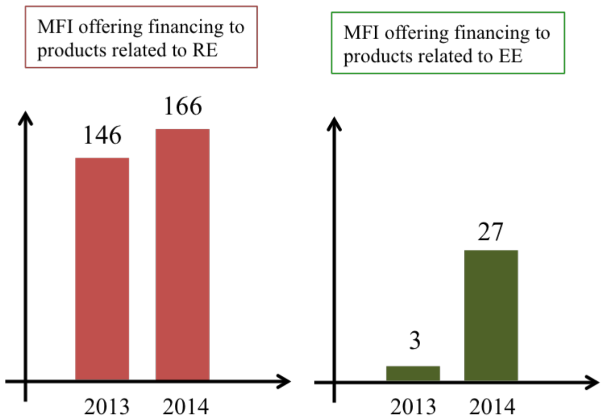

Figure 3.4.: Number of MFIs offering financing to products related to renewable energy (RE) and to energy efficiency (EE) according to yearly MIX reports in 2013 (N:1335) and 2014 (N:1466)

Green Index Presented to the microfinance sector by the Microfinance and Environment Action Group from the European Microfinance Platform (e-MFP), the Green Index provides a full picture of the environmental engagement of an MFI, depending on (i) its formal environmental strategy, (ii) its environmental risk management, and (iii) the offer of green opportunities, including in the latter, among others, the provision of financial services to purchase environmentally friendly technologies (see Table 3.4).

The Green Index (Table 3.4) includes the 6 dimensions of the Universal Standards and offers it as an optional module[7]. Without aiming at measuring impact, the index intends to measure processes providing an overview of the means of the MFI to reach its environmental objectives [Allet, 2014].

The research of [Pierantozzi et al., 2015] provides a picture of available qualitative and quantitative indicators. It also provides an analysis of the easiness and usefulness of tracking environmental indicators, describing the perceptions of MFIs involved in green activities. Results show that MFIs consider tracking of green loans easier and more useful method than tracking other green activities. However, authors recommend to differentiate between the types of green loan disbursed. Categories include renewable energy, energy efficiency, agroforestry, waste management, clean water, sanitation and ecotourism. Yet, indicators do not differentiate between financed technologies or basic need (e.g., energy, water, sanitation, etc.).

Since 2014, the Green Index has been included in the Social Performance Indicators (SPI) of CERISE[8], a French association focused on disseminating knowl-

[7]As of November 2015, 31 MFIs completed the Green Index. 24 institutions within accompanied self-assessments, while 7 of them as a self-assessments [e-MFP, 2015].

[8]See www.cerise-microfinance.org

Numeration	Green Indicator
Green a	**The institution addresses environmental issues through a formalized strategy.**
Green a11	The institution defines its environmental strategy.
Green a12	The institution implements its environmental strategy.
Green b	**The institution manages its environmental risks.**
Green b11	The institution implements actions to reduce its internal ecological footprint.
Green b12	The institution monitors its internal environmental risks.
Green b21	The institution evaluates the level of environmental risk of its clients.
Green b22	The institution includes the level of environmental risk as a factor in the loan approval.
Green b23	The institution monitors the external environmental risks.
Green b24	The institution raises clients' awareness on environmental risks.
Green c	**The institution fosters green opportunities.**
Green c11	The institution provides specific green loan products.
Green c12	The institution provides other green financial products.
Green c13	The institution provides green non-financial services.

Table 3.4.: Green Index - Set of Indicators (summarized)

edge and tools for ethical finance, and in the Social Rating of the company MicroFinanza Rating[9], demonstrating further efforts of stakeholders to systematically assess the environmental performance of MFIs.

In particular, CERISE, founded by five French organizations specialized in microfinance, involves MFIs, networks, technical assistance providers, investors, and donors worldwide. Its working areas include impact finance and social performance, governance, rural and agricultural finance. So far, by November 2015, the results have showed CERISE that many MFIs do not see the relevance of the index and that practices are lagging. While beginners recognized the tool has contributed to their understanding of the concept of *green*, more experienced MFIs (in any of the green MFI axis) showed to be more structured and more mature in managing their environmental performance.

On the other hand, MicroFinanza Rating integrated the Green Index early 2015 and it has back-tested the environmental performance results according to the Green Index structure. Results of the implementation confirmed the limited number of financial institutions involved in green activities, and that only a share of the double bottom line financial institutions have a triple bottom line impact [e-MFP, 2015]. Specifically, in regards to green lending, MicroFinanza Rating found that the demand among the target population and the increasing availability of technical providers in a country constitute a high potential for the financial institution to offer green financial products. Further findings from those MFIs which completed the Green Index, demonstrated that MFIs are

[9]See http://www.microfinanzarating.com

considering the feasibility of introducing and scaling-up loan products for eco-housing, SHS and water purification [e-MFP, 2015].

3.5. Microfinance Metrics to Assess Poverty: The Progress out of Poverty Index (PPI)

For the institutions serving the BoP, the capability of measuring the level of poverty of their clients is of fundamental relevance, in order to quantify the effectivity of their programs or projects in targeting the poor.

To this aim, the Progress out of Poverty Index (PPI) [Schreiner, 2004] is a worldwide used statistical based tool which assesses the poverty level. In particular, the PPI consists of 10 questions with specific scoring systems, which can be adjusted to each country. As a result, the PPI score is associated with the likelihood of a household being below the poverty line (based on a daily income threshold which depends on the country). In order to provide a complete benchmark for reporting the contextual reality of the households, especially in relation to overall poverty levels in the country, the PPI manages to portray the most relevant indicators directly associated with poverty levels, instead of using monetary indicators (total income, net income from crops, total household assets, etc.). Using the net income as a proxy for poverty may provide an incomplete, although valuable, understanding of the socioeconomic status of the beneficiaries [COSA, 2015]. The hypothesis of the tool methodology is that other non-crop factors (or monetary income) affect their poverty, therefore, a broader tool is particularly useful. Measuring the PPI over time allows to efficiently track the households progress out of poverty along the organizations' activities in a geographical area. A test conducted by the Committee on Sustainable Assessment (COSA) debates the accuracy of the PPI. Specifically, since the tool is created using national consumption data, the likelihood that the tool efficiently describes the level of poverty of different populations within a country may fail. For instance, considering populations that are by their nature agricultural producers may not be, in general, nationally representative.

Within the microfinance sector, the Grameen Foundation (GF) has promoted the use of the PPI for more than a decade. As an example, the PPI scorecard developed for Colombia (and currently used by the MFI Contactar, see Chapter 4) is shown in Figure 3.5. The survey is based on the 2009 Integrated Household Survey (IHS) conducted by DANE (the Colombian National Administrative Department of Statistics, for its acronym in Spanish), updated in December 2012, accommodating the new poverty lines created by the Colombian government, which are still currently used [Grameen-Foundation, 2012].

Entity	Name	ID		Date (DD/MM/YY)
Member:			Joined:	
Field agent:			Today:	
Service point:			Household size:	

Indicator	Value	Points	Score
1. How many household members are 18-years-old or younger?	A. Four or more	0	
	B. Three	5	
	C. Two	11	
	D. One	17	
	E. None	23	
2. What is the highest educational level reached by the female head/spouse?	A. None, or pre-school	0	
	B. Primary or middle school	3	
	C. High school	6	
	D. No female head/spouse	8	
	E. Post-secondary or college (1 to 4 years)	9	
	F. Post-secondary or college (5 years or more)	17	
3. How many household members spent most of the past week working?	A. None	0	
	B. One	9	
	C. Two or more	14	
4. In their main line of work, how many household members work as wage or salary employees for a private firm or the government?	A. None	0	
	B. One	4	
	C. Two or more	11	
5. What is the residence's rate class for electricity?	A. No class or zero (no connection, pirated connection, or generator), one, or two	0	
	B. Three	4	
	C. Four, five, or six	9	
6. What fuel or energy source does the household usually cook with?	A. Firewood, wood, charcoal, coal, electricity, gasoline, petroleum, kerosene, alcohol, or waste material	0	
	B. LPG from a cylinder or tank	2	
	C. Natural gas from a public network	3	
	D. Does not cook	6	
7. Does the household have a working clothes washing machine?	A. No	0	
	B. Yes	4	
8. Does the household have a working refrigerator or freezer?	A. No	0	
	B. Yes	3	
9. Does the household have a working DVD?	A. No	0	
	B. Yes	4	
10. Does the household have a motorcycle and/or a car for its own use?	A. None	0	
	B. Motorcycle only	3	
	C. Car (regardless of motorcycle)	9	

Figure 3.5.: PPI Scorecard for Colombia, originally developed in November 2012 by Mark Schreiner of Microfinance Risk Management, L.L.C.. Source: http://www.progressoutofpoverty.org/country/colombia.

4. The MFI Contactar

The field research presented in this thesis (see Chapter 5) has been carried out in collaboration with the *Corporación Empresa Nariño Contactar*[1], a Colombian medium-sized MFI covering four departments in south-western Colombia (in order of outreach size: Nariño, Huila, Putumayo and Tolima, see Figure 4.1 for details), established in 1995 as an NGO.

Figure 4.1.: Regions of Colombia covered by Contactar (original map downloaded from: www.your-vector-maps.com)

By offering a variety of products adapted to the needs to their clients, Contactar addresses the triple bottom line. In particular, the institution offers inclusive financing, based on individual and group credits for basic financial needs, as well as customized financial products for agriculture and micro-insurances, targeting

[1] www.contactar-pasto.org

primarily the rural population dedicated to agriculture and cattle. Moreover, as an institution with a vast track record in diversifying its portfolio, Contactar also offers specialized non-financial products, seeking to develop the private business initiatives and entrepreneurial skills of their clients. In particular, since 2011 the MFI has acquired valuable experience in green lending, developing financial products for the acquisition of clean energy technologies.

In 2014, the German consulting company MicroEnergy International GmbH (MEI)[2] was hired by the Citi Foundation to support Contactar in developing its *green strategy*. This assignment established a strong partnership between Contactar and MEI. In this context, given the interest of the MFI in identifying the energy needs of the clients, as well as in establishing a systematic methodology for the energy access assessment, the proposal to conduct field research parallel to the consulting services provided by MEI was very welcomed within the institution. Moreover, Contactar has a department dedicated to all activities related to the environment, called the the Social and Environmental Performance Management Department (GDSA)[3]. The goal of the GDSA is to transform Contactar's social and environmental mission and vision into reality[4]. This department, also in charge of all research activities, has a strong interest in the systematic collection of client data, thus the proposed research aligned with their current strategy. At the same time, the fact that the MFI serves clients living in very diverse climatic and economic conditions, and the possibility of accessing the demographic information from the MFI database, made Contactar an ideal partner for implementing and analyzing the detailed multi-tier assessment survey [SE4ALL and WB, 2014].

The objective of this chapter is to introduce the partner MFI and the local context in which the field research was framed. In particular, Section 4.1 presents the regional Colombian context, in terms of the microfinance market, energy access and green microfinance, while in Section 4.2 the profile of Contactar will be briefly described, portraying its clients and its regions of work. Finally, Section 4.3 is dedicated to the green lending program implemented at Contactar, describing the energy technologies offered and the methodology used by the institution to select them.

4.1. Geopolitical and Economic Contexts

Colombia is a country rich in natural resources, with a high biodiversity and an ample ecosystem in need of preservation. In this context, clean energy and sustainable development play an important role in keeping up the pace of economic growth. With 1'446,000 inhabitants without access to electricity and modern fuels (in 2015) [The World Bank, 2016], there is a huge potential for the

[2] www.microenergy-international.com

[3] For its acronym in Spanish: *Gestión de Desempeño Social y Ambiental*

[4] By raising financial and environmental awareness among clients and internal staff, the GDSA team provides the MFI with a competitive advantage and enhances the institution's commitment to improve the living standards of its clientele. The GDSA is also in charge of managing communication with suppliers and customer satisfaction follow up.

dissemination of clean energy technologies and of related financial products.

Concerning the macro picture of the microfinance sector, Colombia is the third largest country in Latin America per number of microfinance clients [Serrano, 2009]. With more than 2,8 million clients and 43 MFIs (reporting to the MIX Market platform in 2016), the sector has been steadily increasing in the last decade with the support of the governmental program *Banca de las Oportunidades*[5]. Since 2011, two national financial networks (*Asomicrofinanzas* and *Asobancaria*) have contributed to the collection, exchange and management of information within the sector at a national level. This initiative led to the introduction of the topic "green microfinance" in the country. In particular, the awareness-raising campaign undertaken by these organizations has encouraged MFIs to commit to environmental protection by integrating an environmental axis within their market strategies.

Green Microfinance As an emerging market with, as of recently, very little (anecdotical) practice[6], the green microfinance sector has a strong potential for growth and replication. Particularly, 2012 marked the signing of the Green Protocol [CNG and Asobancaria, 2012], an official commitment from Colombian financial institutions in conjunction with the Ministry of Environment and Sustainable Development to emphasize the importance of green microfinance products and to incorporate them into their portfolio[7].

However, the expansion of the green microfinance market still faces challenges which can only be tackled over a longer time, by building experience, raising awareness among the key stakeholders and sharing the positive results of implementing innovative strategies. As observed by [Gutiérrez and Reddy, 2015], the most important barriers towards access to finance for rural populations include:

- the limited participation of private financial institutions lending in rural areas;
- the existence of public support programs for rural agricultural credit with perverse incentives;
- the limited range of assets used as collateral;
- the limited credit history and financial education of the rural population; and
- the lack of agricultural insurance to support risk management and facilitate access to credit.

A further aspect, in the specific context of Colombia, is that most of the small and medium enterprises (SMEs) are rural and their profiles are considered to be risky, making the access to microcredits through the usual financial system more difficult. Moreover, the legal framework for green microfinance in the

[5] See www.microfinancegateway.org/es/pais/colombia and www.bancadelasoportunidades.gov.co

[6] According to Climatescope 2012, only 3 financial institutions were offering green products: the MFIs *Activos y Finanzas SA*, *Fundesmag* (i.e., 2 out of 29 MFIs) and the national development bank *Bancóldex*. Clean energy credit providers included: *Bancolombia*, BBVA Colombia and *Banco de Bogotá* [MIF and Bloomberg, 2012]

[7] See the Green Protocol (official document) [CNG and Asobancaria, 2012]

country is still in its incipient phase, leading to a lack of clarity on legal aspects of terms and conditions. Lastly, due to the high variability of geographical and socio-economic characteristics of the different Colombian regions, there is a lack of standardization on product development, which increases the complexity of scaling up pioneer green microfinance initiatives.

Energy Access Colombia ranks seventh in the national electrification rate within Latin America, with 97% coverage [IEA, 2015] (99,7% urban and 87,9% rural electrification rate in 2012), slightly above the average of 95% of the neighboring countries[8]. However, the 2% of population uncovered by the grid, still represents about 1.2 million people, the seventh largest population in Latin America. In particular, according to the latest national census from 2005, Contactar focus regions (e.g., Nariño, Huila, Putumayo and Tolima) suffer from limited access to infrastructure as shown in Table 4.1 and Figure 4.2.

	Households	Off-grid	Off-grid, without water supply nor sanitation	Without natural gas
Huila	232,621	18,547 (8%)	11,629 (5%)	129,815 (56%)
Nariño	321,112	43,383 (14%)	37,880 (11.8%)	321,112 (100%)
Tolima	328,280	24,632 (8%)	17,849 (5%)	209,934 (64%)
Put.	61,032	20,346 (33%)	18,972 (31%)	60,531 (99%)
Total	943,045	106,908 (11%)	86,330 (9%)	721,392 (76%)
Colombia	9'742,928	623,141 (6%)	510,794 (5%)	5'797,241 (59%)

Table 4.1.: Access to infrastructure in the working regions of Contactar. Regions with the lowest access performance (in percentage) are marked in red

Hence, regardless of the positive trend of coverage shown in national statistics [IEA, 2015], Colombia still faces several challenges in the energy sector. Specifically, the Council of the Americas Energy Action Group [Viscidi, 2010] listed:

- the erratic pace of infrastructure development in comparison to investments in renewables energy and the strong dependence on oil and gas production;
- the expansion of drilling into new areas with environmental and social consequences;
- the lack of security, which puts at risk economic, political and social stability.

[8] Electricity access in 2013 - regional aggregates in Latin America: 22 million people without access to electricity; with 98% urban and 84% rural electrification rates

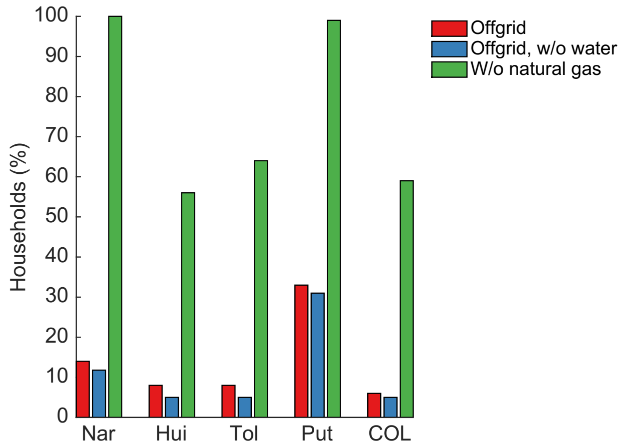

Figure 4.2.: Infrastructure access in working regions of Contactar

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4.2. Portrait of the Microfinance Institution

Contactar was founded in 1995 in Pasto (Department of Nariño, Colombia). Registered as a non-governmental organization (NGO), Contactar is currently the 10th largest MFI in Colombia (out of 43 MFIs currently reporting to the MIX Market platform)[9] with 81,068 clients (67,498 rural and 13,570 urban).

Contactar offices cover four Colombian departments in the southwest region of the country: in order of outreach, Nariño, Huila, Putumayo and Tolima (see also Figure 4.1 and Appendix C for more details). Table 4.2 and Figure 4.3 depict the distribution of clients in the different departments, together with the total department population. The table 4.2 includes also, for each department, the total population and the year when Contactar opened the first office on the regional territory.

	Clients	Active since	Population
Nariño	41,022 (50.6%)	1995	1'744,000
Huila	18,428 (25.4%)	2009	1'174,000
Tolima	8,931 (11.0%)	2015	1'410,000
Put.	10,504 (13.0%)	2010	345,000

Table 4.2.: Distributions of Contactar clients across the served regions

[9]Source: www.mix-market.org (data recovered on July 30th, 2016).

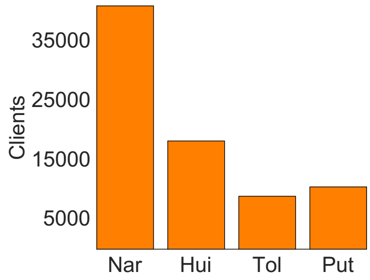

Figure 4.3.: Distributions of Contactar clients across the served regions

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In order to provide a more detailed picture of the MFI, Figure 4.4 describes the statistics of the clientele. Most of the customers belong to the age group 30 to 50 years (60%), with only primary education (60%) and only about 5% have completed a university degree. Moreover, the vast majority (about 95%) declare themselves to be self-employed, i.e., without a formal work contract.

As shown in Figure 4.5, the microcredits offered by Contactar are mostly individual (95%, compared to 5% for group loans), and more than 60% of loans are disbursed for business purposes, while about 20% are related to personal use or dedicated to improve housing conditions.

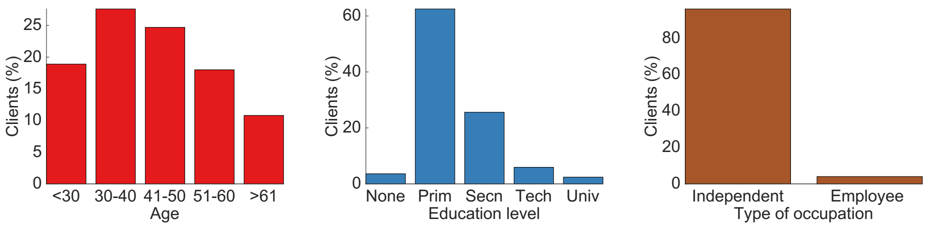


Figure 4.4.: Brief portrait of Contactar clients according to age (left), education(center) and type of occupation (right)

In order to evaluate the impact of its programs, Contactar utilizes the Universal Standards of Social Performance[10] into practice, monitoring the level of poverty of its clients over time through the Progress out of Poverty Index (PPI) developed by [Schreiner, 2004] (see Section 3.5).

The international organization Grameen Foundation (GF)[11], with the support

[10]The Universal Standards of Social Performance consist in a comprehensive manual of best practices created for microfinance stakeholders as a resource to help financial service providers achieve their social goals. For more information: http://sptf.info/universal-standards-for-spm/start-here

[11]The Grameen Foundation, pioneer developer of the PPI, seeks to continuously enhance its tool by providing support to the organizations applying the tool and disseminating the best practices for its implementation.

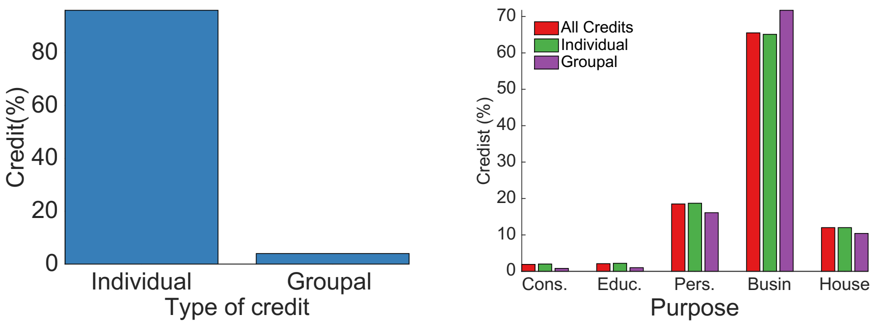


Figure 4.5.: Brief portrait of Contactar credits. Left: Type of Credit. Right: Purposes (Consume, Education, Personal Use, Business, Housing)

of the Cisco Foundation, introduced and implemented the PPI at Contactar. To this end, in 2012 Contactar loan officers and employees were trained on the PPI and on the interpretation of the results for strategic and operational decision-making processes within the organization. Since then, the MFI has consistently applied the tool to its clients. A portrait of the PPI scores of Contactar clients is provided in Figure 4.6.

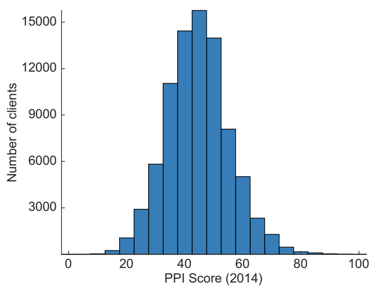


Figure 4.6.: Histogram of the PPI results among Contactar clients (data collected in 2014)

According to the analysis conducted by the Cisco Foundation in 2014 [Cisco Foundation, 2014], Contactar has a rather diverse spectrum of clients. The results showed that about 10% of the clients live in extreme poverty (i.e., PPI score less than 30), while 58% are vulnerable to falling below the poverty line (PPI score below 45) or are living in impoverished conditions. On the contrary, only 32% of the clients have a reduced likelihood of falling into poverty[12]. Particularly, the Cisco Foundation suggested that the wide range of categories might require a correct combination of social and economic strategies to effectively target the clients[13].

[12]Further details on the interpretation of PPI scores are provided in Appendix B.
[13]Note that Contactar does not register the PPI information nor due diligence data of rejected

4.3. The Diversification of Contactar in Green Microfinance: ConSuPlaneta

Since its establishment, Contactar has developed a range of products and training programs according to the needs of its clientele, innovated approaches and services, and prioritized its environmental impact, in addition to its financial and social objectives. Some examples of the financial products developed for tackling specific basic needs include *ConSuVivienda* (dedicated to housing), *ConSuEducación* (education), *ConSuTransporte* (transport). In 2011, Contactar identified cooking and drying crops as a major energy related issue for its rural clients, developing a Green Finance Program with its own means and initiative.

The portfolio diversification of Contactar started the same year, with a launching of a small pilot project that fosters access to clean energy technologies in the department of Nariño. Through a strategic association with a local energy service supplier, the pilot began with a donation of fixed improved cooking stoves (ICS) for 35 rural families. In 2012, combining microcredits with donations for ICS and biogas digesters (BD), the pilot project reached 81 rural families. One year later, through partnerships with small local suppliers in the region, and following a *two-hand model* approach, Contactar created its first green financial product *ConSuPlaneta* (see also Section 4.3.1) and started offering financing of locally distributed clean energy technologies, formally launching its Green Finance Program. In 2013, the program was based solely on credit. By then, the financed technologies included, besides ICS and BD, also solar crop dryers (SCD), water tanks (WT) and water filters (WF). A more detailed description of these MES and of the selection criteria is provided in Section 4.3. As of April 2015, the MFI has disbursed more than 800 green loans of the diverse set of technologies, targeting mostly the rural population, and satisfying specific energy needs for cooking, drying crops and water supply.

Currently (July 2016), the average loan period for Contactar's financial products is 17 months and the average monthly interest rate is 3.2051% (max. 3.5042% min. 2.0831%). For the *ConSuPlaneta* credits, a commission fee is charged in order to cover marketing costs, and the collateral was established at its minimum. The credit conditions of the financial product do not differentiate among technologies (see Table 4.3) except for the water filters, which are sold directly over the counter given the reduced price.

Since the launch of the green microcredit *ConSuPlaneta*, Contactar has demonstrated wide management capacities in designing customized microcredits to finance MES [Matas et al., 2015]. Specifically, the MFI has explored the different market segments in association with potential energy partners, in order to determine the best energy solutions for its customers, an essential requirement for the success of lending programs designed for financing MES [Levaï et al.,

loan applications. Furthermore, there is no consecutive data collection or systematized procedures for one-time clients, i.e., those who did not apply for a consecutive loan. Hence, an analysis of causalities or relationships between poverty measures and loan effects is not yet possible.

	Water Tank	Solar Crop Dryer	Improved Cooking Stove	Biogas Digester	Water Filter
Loan size (USD)	750	675	415	325	35
Period (Max.)	12	12	12	12	Cash
Interest rate	27%	27%	27%	27%	–
Commission Fee	4.5%	4.5%	4.5%	4.5%	–
Collateral	0.7%	0.7%	0.7%	0.7%	–

Table 4.3.: Portfolio of energy technologies offered by Contactar through the program *ConSuPlaneta*

2011]. By scaling up its Green Finance Program, Contactar seeks to reach the economically challenged population of Nariño, Huila, and Putumayo[14], as well as at creating the socio-economic and environmental impact needed to attract other Colombian financial institutions towards developing their green strategies [Matas et al., 2015].

4.3.1. A Two-Hand Model Approach

In the case of Contactar, the delivery methodologies, i.e., the set of systems and procedures that an institution develops in order to deliver its services [Waterfield, 2001], were based on a two-hand model. Namely, the MFI collaborated with MES suppliers following a *bottom-up* approach, whose steps are described in Figure 4.7.

In the case of Contactar, the delivery methodologies, i.e., the set of systems and procedures that an institution develops in order to deliver its services [Waterfield, 2001], were based on a two-hand model. Namely, the MFI collaborated with MES suppliers following a *bottom-up* approach, whose steps are described in Figure 4.7.

According to the bottom-up approach [Realpe Carrillo et al., 2015], the financial product *ConSuPlaneta* targets clients with specific energy needs: (i) decrease consumption of firewood for cooking by replacing firewood with gas or improving stove efficiency; (ii) improve the quality of agricultural crop drying processes; and (iii) improve the quality of the water supply. As observed in [Waterfield, 2001] the proper design of financial products and their delivery methodologies is fundamental in order to ensure their efficiency and sustainability. Hence, [Waterfield, 2001] advocates that credit institutions need to incorporate financial products and delivery methodologies which are both *appropriate* and *sustainable*, i.e., appropriate for the needs of the target group and sustainable in order to guarantee the continuity and long-term sustainability of the provided services.

[14] The green loan is not yet offered in Tolima, as the MFI expanded the supply of financial services to this department only in late 2015

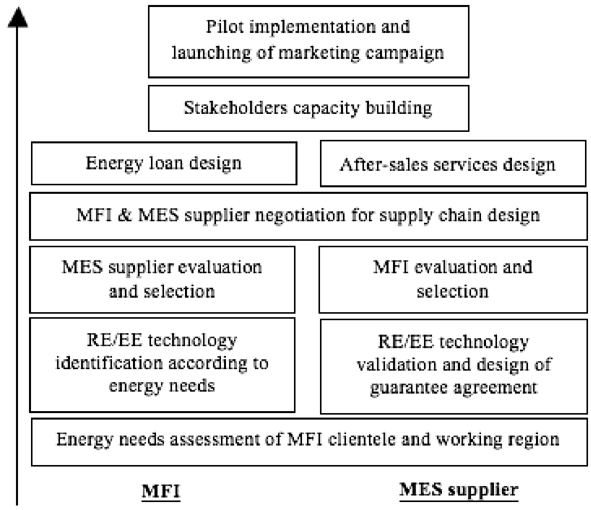


Figure 4.7.: Bottom-up approach of a two-hand model according to initiator [Realpe Carrillo et al., 2015]

The proper systematic approach described by [Realpe Carrillo et al., 2015] suggests the implementation of this scheme in order to guarantee a balanced partnership and a controlled supply chain design. In fact, in a two-hand model, both parties commit to work jointly and to select the technology based on the energy needs of the MFI clients and on their institutional profiles.

4.3.2. Selected Microenergy Systems

The clean energy technologies to be offered within *ConSuPlaneta* corresponded to those with the highest potential of increasing the income and/or the saving generation of domestic and economic activities [MicroEnergy International, 2014]. These MES were selected following a *systematic approach* [De Gouvello and Durix, 2008] (see Section 4.3.3). Particularly, in order to select the most suitable technologies, the main opportunities have been identified in the increase of labor productivity, in the improvement of product yield and quality (especially for coffee dryers), as well as in the development of new economic activities for the rural population (current and potential clients) [Matas et al., 2015]. Within the green strategy developed by MEI for Contactar, a market analysis was conducted in order to assess the market viability of the existing and potential MES to integrate in *ConSuPlaneta* portfolio. This study consisted in desk research, a client database analysis, and a survey carried out among the loan officers.

The technologies offered by Contactar since 2012 are briefly described below (see also Figures 4.8 and 4.9).

Figure 4.8.: Left: Solar Crop Dryer (for coffee beans). Right: Biogas Digester (for farmers with at least 10 pigs)

Figure 4.9.: Left:Water Tank. Right: Residential Water Filter

Solar Crop Dryer (SCD) A SCD consists in a structure made out of *guadua* also known as American Bamboo, an organic material available in the area that is commonly used for housing. The system has a size of 5 meters (length) by 4 meters (width). The exterior of the product is made of plastic and the installation lasts normally 3 working days. [SantaMaría, 2011] has validated the technology in Peru in a region geographically similar to Nariño. The comparison between the traditional drying methods and the ones used with the Solar Crop Dryer underlines the advantage of the increase in productivity (working-time spent in drying) and in quality (see also Table 4.16).

Biogas Digester (BD) A BD is a system measuring 1 meter (width) by 5 to 10 meters (length). The system converts animal residues into a mixture of gases. The biogas is composed of 60% methane gas (CH_4) and 40% carbon dioxide (CO_2), and this enables the mixture to be used for cooking[15], among other uses.

Thus, the BD offers cooking with methane gas and bio-fertilizer. The requirements for a functional biogas digester consist of daily animal waste and water (1 kg dung requires 3 water buckets). The installation lasts about 3 days.

Improved Cooking Stove (ICS) The fixed ICS consists of a grill for cooking, a boiler, an oven, a chimney and the respective gates for the firewood, ventilation and disposal of ashes. Its dimensions are 105 cm (length) by 73 cm (width); its installation lasts 4 hours. For the mobile ICS, measuring 110 cm by 85 cm by 68 cm (height), the installation lasts about a day. Both ICS models reduce firewood consumption, enable 4 spaces for cooking, an oven for baking and channel smoke out of the kitchen through the chimney.

Water Tank Seeking to cope with the adversities of climate change, the water tank enables rural families to reserve water for dry seasons. The water tank has a height of 2,20 m and a diameter of 3,30 m. Water is preserved from rainwater, close brooks or community tanks. The water tank capacity is conceived for an estimated consumption of 180 liters per day (5,400 liters per month) per household. In order to feed the water tank, the household roof must cover an area of at least 7 square meters.

Water Filters The *Eco-Filtro* functions as water-maker for households. It can filter up to 2 liters per hour and has a storage capacity of 35 liters. Its dimensions are: 39 cm diameter and 59 cm height and it weighs 8 kg without water. The water filters are sold for cash and they are relatively affordable compared to the average loan amount of 2'172,277 COP[16].

[15]Gas combustion is possible only if the concentration of methane gas is above 50%.

[16]Approximately 650 €, based on the exchange rate of October 15th, 2016.

4.3.3. The Systematic Approach

The implementation of the Green Finance Program and of the green microcredit *ConSuPlaneta* resulted from a set of steps, which can be framed under the the so-called *systematic approach* introduced by [De Gouvello and Durix, 2008]:

1 identification and categorization of productive activities of the targeted rural areas;

2 identification of areas of improvement in productive processes;

3 contribution of energy access through identified equipment;

4 economical assessment of new production process;

5 promotional campaigns for consumer targets.

Besides the application of the systematic approach, the following factors were also decisive in designing the business model of the Green Finance Program within the MFI:

- solid skills to develop an effective business model: in particular, the ability to demonstrate the positive impact on economic efficiency, on energy and monetary savings, and on improved education and quality of life;
- well-defined supply chain's involvement of all actors on the supply chain, whilst improving the operational efficiency of each one;
- standardization of product development: a well-structured supplier and commercialization base, avoiding the concentration of suppliers and/or clients;
- clear-cut credit characteristics: transparent and clear tenors, dates, amounts, operational processes, payments and grace periods.

The following sections describe in detail the steps undertaken within the systematic approach. Notice that, in this context, the approach is not restricted to electricity usage, as the authors initially aimed sought, but it also concerns mechanical and thermal energy usage, as the selected MES enable further uses of energy.

1. Identification and Categorization of Productive Activities of the Targeted Rural Areas Following the steps proposed by [De Gouvello and Durix, 2008], Contactar has first identified the type of productive activities taking place in its working area. Complying with the principles of classification by industry designed by the International Standard Industrial Classification of all Economic Activities (ISIC) of the United Nations, Contactar's internal codification applies the ISIC Colombian codification provided by the Colombian National Administrative Statistics Department (DANE, for its acronym in Spanish). Table 4.4 shows the ISIC codification used for the energy needs assessment, while Tables 4.5 and 4.6 show the sector-system matrix of clients by June 2014 [Matas et al., 2015].

ISIC Code	Productive activity
A	Agriculture, hunting, forestry and fishing
B	Mining and quarrying
C	Manufacturing
D	Electricity, gas, steam and air conditioning
E	Water distribution; disposal and treatment of wastewater, waste management and environmental remediation activities
F	Construction
G	Wholesale and retail trade; repair of motor vehicles and motorcycles
H	Transportation and storage
I	Accommodation and food services
J	Information and communication
K	Financial and insurance activities
L	Real estate activities
M	Professional, scientific and technical activities
N	Administrative activities and support services
O	Public administration and defense; compulsory social security schemes
P	Education
Q	Activities of human health care and social assistance
R	Arts, entertainment and recreation
S	Other service activities
T	Activities of individual households as employers; undifferentiated activities of individual households as producers of goods and services for its own usage
U	Activities of extraterritorial bodies and organizations

Table 4.4.: DANE Codification of productive activities used in Contactar database for loan disbursements

ISIC Code	Productive Activity	Number of clients
–	Others	2,629
A	Agriculture, hunting, forestry and fishing	43,755
A011	Transitory agricultural crops	8,436
A012	Permanent agricultural crops	20,877
A013	Plant propagation (nurseries activities, except forest nurseries)	
A014	Livestock	14,049
A015	Mixed farming (crop and livestock)	39
A016	Support activities to agriculture and livestock, and post harvest activities	
A017	Ordinary hunting and trapping and activities of related services	
A021	Silviculture and other forestry activities	14
A022	Wood removal	
A023	Collection of forest products other than timber	
A024	Support services to forestry	
A031	Pesca	5
A032	Aquaculture	335
B	Mining and quarrying	40
C	Manufacturing	3,623
C10	Manufacture of food products	676
C11	Manufacture of beverages	19
C12	Manufacture of snuff	0
C13	Manufacture of textiles	494
C14	Manufacture of clothing	471
C15	Tanning and re-tanning of leather; shoemaking; manufacture of suitcases, handbags and similar articles and manufacturing of saddlery and harness; dressing and dying of fur	449
C16	Wood processing and manufacture of products of wood and cork, except furniture; manufacture of articles of straw and plaiting	178
C17	Manufacture of paper, cardboard and paper products and cardboard	7
C18	Activities and production of printing copies from originals	41
C19	Coking, manufacture of oil refining and fuels blending activities	1
C20	Manufacture of chemicals and chemical products	28
C21	Manufacture of pharmaceuticals, medicinal chemicals and botanical products pharmaceutical use	
C22	Manufacture of rubber and plastic	14
C23	Manufacture of other non-metallic mineral products	51
C24	Manufacture of basic metal products	23

Table 4.5.: Productive activities (ISIC coditification A to C24) among Contactar clients – June 2014

ISIC Code	Productive Activity	Number of clients
C25	Manufacture of fabricated metal products, except machinery and equipment	146
C26	Manufacture of computer, electronic and optical products	1
C27	Manufacture of appliances and electrical equipment	
C28	Manufacture of machinery and equipment n.c.p.	11
C29	Manufacture of motor vehicles, trailers and semitrailers	13
C30	Manufacture of other transport equipment	0
C31	Manufacture of furniture, mattresses and box springs	361
C32	Other manufacturing	475
C33	Installation, maintenance and repair of specialized machinery and equipment	164
D	Electricity, gas, steam and air conditioning	
E	Water distribution; disposal and treatment of wastewater, waste management and environmental remediation activities	74
F	Construction	1,467
G	Wholesale and retail; repair of motor vehicles and motorcycles	11,151
H	Transportation and storage	1,708
I	Accommodation and food services	2,235
J	Information and communication	274
K	Financial and insurance activities	
M	Professional, scientific and technical activities	95
L	Real estate activities	814
N	Administrative activities and support services	228
O	Public administration and defense; compulsory social security schemes	
P	Education	22
Q	Activities of human health care and social assistance	62
R	Arts, entertainment and recreation	295
S	Other service activities	
S94	Activities of memberships	47
S95	Maintenance and repair of computers and personal and household goods	42
S96	Other activities of personal services	1,563
T	Activities of individual households as employers; undifferentiated activities of individual households as producers of goods and services for its own usage	24
U	Activities of extraterritorial bodies and organizations	
	Total	70,159

Table 4.6.: Productive activities (ISIC coditification C25 to U) among Contactar clients – June 2014

2. Identification of Areas of Improvement in Productive Processes From Table 4.5–4.6, it can be observed that, out of the 71,059 clients of Contactar, the vast majority are engaged in:

- permanent and transitory agricultural crops (27.8% and 11.2% respectively);
- livestock (18.7%) and wholesale and retail;
- repair of motor vehicles and motorcycles (14.9%).

The agriculture in all four regions of work (Nariño, Huila, Putumayo and Tolima) is mostly dominated by permanent agricultural crops rather than transitory ones. The livestock industry is characterized by its concentration in raising cattle throughout the four departments, especially in Huila. A more detailed client division within the agricultural categories is presented in the sector-system matrices per region in Tables 4.7 and 4.8, while Table 4.9 details the livestock activities.

		Nariño	Huila	Put.	Tolima
A011 - Transitory agriculture crops		14,388	6,906	12	13,800
A0111 Cereals (except rice), pulses, oilseeds	27 Barley	20	0	0	0
	48 Beans	978	1,725	0	2,824
	59 Corn	5,540	2,088	7	4,054
	77-78 Quinoa	18	0	0	0
	89 Wheat	395	0	0	0
	5030 Cocoa	29	477	0	1,044
A0112 Rice		48	435	1	709
A0113 Vegetables, roots and tubers	71 Potato	3,559	42	0	440
	91 Yuca	602	1,365	4	2,307
A0115 Fibre	5080 Fique	302	1	0	1

Table 4.7.: Transitory agriculture activities in Contactar working regions according to the 2005 National Census

For the main economic activities (transitory and permanent agriculture, livestock), the production processes are mostly dependent on fossil fuels (diesel and firewood) or on manual (mechanical) technologies. Table 4.10 depicts the production processes involved and the current machinery used depending on the different economic activities.

3. Contribution of Energy Access Through Identified Equipment By greening the financial services and scaling up the access offered to its clients, Contactar enables both low income households and micro-, small- and medium-sized businesses (MSMEs) an increase in welfare, productivity and competitiveness.

		Nariño	Huila	Put.	Tolima
A012 - Permanent agriculture crops		6,278	14,998	16	18,264
A0122 5159 Banana		962	1,416	11	2,877
A0123 5031 Coffee		3,214	9,320	0	9,384
A0124 Sugar	5035-5037 Cane	431	1,103	1	1,452
A0125 Cut flower	2-4 Achira	179	30	0	0
A0128 Aromatic and medicinal spices and plants	38-39 Coriander	58	13	0	28
	73 Parsley	4	0	0	0
	119 Thyme	1	7	0	0
	124 Peppermint	3	0	0	1
	125 Mint	1	0	0	1
	127-129 Lemongrass	42	54	0	150
	131 Chamomile	1	0	0	0
	132 Oregano	3	0	0	0
	5000 Achiote	2	1	0	2
	5006 Chili	7	3	0	
	5015-5016 Anise	7	0	0	
	5061 Coca	2	2	0	0
	5165 Romero	1	0	0	0
	5167-5168 Ruda	3	0	0	0

Table 4.8.: Permanent agriculture activities in Contactar working regions according to the 2005 National Census

Livestock		Nariño	Huila	Put.	Tolima
A0141	Cattle and buffalo	45,800	171,755	1,071	310,637
A0142	Horses, other equines	7,785	25,198	101	36,090
A0143	Sheep and goats	2,632	6,926	27	17,348
A0144	Pig	29,408	146	38,476	60,513
A0145	Breeding poultry	792,397	1'063,416	535	1'195,590
A0149	Other animals n.c.p.	344,483	39,019	-	35,776
	TOTAL	1'222,505	1'328,205	1,880	1'633,917

Table 4.9.: Livestock inventory according to 2005 National Census

Moreover, this creates new jobs within the institution and among the providers, and it disseminates affordable access to a sustainable energy supply and green products and services, thus ultimately improving the quality of life for vulner-

Activity	Production process	Machinery used
Transitory and permanent agriculture	Security, Safety, Irrigation, Crop drying, Tools cleaning	Lighting, Electric systems for, Water pump, Crop Dryers, Water heating
Livestock	Security, Safety, Tools cleaning, Irrigation	Fridges, Lighting Systems, Electric systems for water heating, Water pumps

Table 4.10.: Production processes and machinery in Contactar's working regions

able smallholders.

Considering the goal of satisfying energy needs in the regions of work, Contactar identified a range of modern technologies that is particularly effective for both household and productive uses [Matas et al., 2015]. The outcome is summarized in Tables 4.11 and 4.12. These shows, for each identified energy need, the different affected technologies (both for household and productive use). Moreover, Table 4.13 shows the market potential identified among Contactar's client pool, according to the energy needs based on the economic activities with which the clients are engaged.

Energy Need	Technology	Usage: Household (HH), Productive Use (PU)
Lighting	LED Lighting	HH & PU
	Fluorescent lamps	HH, PU
	Magnetic induction lighting	PU
	Automatic photovoltaic lamps	HH, PU
Refrigeration	Efficient industrial refrigerator	PU
	Cold rooms for storage and freezing	PU
	Efficient household refrigerator	HH, PU
Thermal insulation	Waterproofing roofs	HH, PU
	Thermal insulation doors	HH, PU
	Solar control films, window tinting	HH, PU
	Conditioning floors	HH
Energy Efficient Cooking	Efficient stoves	HH, PU
	Improved cooking ovens	HH, PU
Gas production	Biogas digester for gas generation	HH, PU
Agricultural products drying	Solar crop dryer for fruits or agricultural products	PU

Table 4.11.: Potential technologies for specific energy usages I - adapted from [Matas et al., 2015]

Energy Usage	Technology	Type of usage: Household (HH), Productive Use (PU)
Cooking	Electrical stove	HH, PU
	Solar stove	HH, PU
	Improved cooking stove	HH, PU
	Biodigester	HH, PU
Electrical Systems	PV (Peak and Mini)	HH, PU
	DC Photovoltaic system (Pico-PV and Mini Systems)	
Energy efficiency in industrial processes	AC voltage controller - Residential / Industrial	HH, PU
	Demand control (Servo Controls)	PU
	High efficiency electric motors	PU
	Automation and Remote Monitoring	PU
	Variable speed drives	PU
	Electronic ballasts	PU
	Movement sensors	PU
	Centrifugal pumps	PU
	Solar Water Pumps	PU
	Pump-Pressurized and constant pressure supply kit	PU
	Air compressors	PU
	Brick-making oven	PU
Washing and drying clothes	Washing machines	HH
	Clothes dryers	HH
Water treatment	UV water purifier	HH, PU
	Water purifier reverse osmosis equipment	HH, PU
	Commercial water softeners	PU
	Greensand filters	HH, PU
Water reservation	Water treatment system (septic tanks)	HH, PU
Water heating	Thermo-syphon solar water heaters	HH, PU
	Water heater for pools (polyethylene absorbers)	
	Water heater high-performance direct fire	
Water pumping	Solar water pumps	PU

Table 4.12.: Potential technologies for specific energy usages II - adapted from [Matas et al., 2015]

For the market research of potential technologies, the authors built upon the assumptions that each group of clients could benefit from the identified relevant technologies for its respective productive activity. According to the database of productive activities, the authors added the number of clients for which the considered technologies could be of relevance. The results are depicted in Table 4.13. Considering the offer of energy service suppliers within regions of interest and the relevance of the technologies within the existing market, Contactar opted in early 2011 to initiate the Green Finance Program offering BD and, a year later, including ICS, in order to first tackle the efficiency of cooking solutions.

Energy Usage	Activity	Market Potential
Lighting	Residential and Productive activity	120,247
Refrigeration	Commercial agriculture and for subsistence, Cattle, Retail trade	92,272
Thermal insulation	Residential and Productive activity	1,793
Energy efficiency for food preparation	Restaurants, Food selling	24,285
Washing and drying clothes	Residential	18,905
Water treatment	Residential	25,351
Water reservation	Residential	58,266
Electrical Systems	Commercial agriculture and for subsistence, Cattle, Wholesale business	107,857
Water heating	Cattle	29,804
Biogas digestor	Cattle	14,049
Product drying	Commercial agriculture and for subsistence	4,299
Water pumping	Commercial agriculture and for subsistence, Cattle	43,736
Energy efficiency in industrial processes	Industrial manufacturing	12,361

Table 4.13.: Market potential of energy technologies among the clientele of Contactar (first column) and corresponding energy usages (second column)

It shall be noticed that lighting, refrigeration and electrical systems have a relatively high market potential. In fact, by estimating a multiple use of appliances per household and MSME, the market potential is even higher than the number of Contactar's clients. However, despite this predicted market size, the systematic approach also identified the presence of obstacles concerning the maturity of the offer in the selected regions, and thus focused instead on more viable technologies (e.g., biogas digesters, improved cooking stoves and solar crop dryers).

4. Economical Assessment of New Production Processes The economic viability of the production processes involved a different assessment procedure for each technology. Furthermore, a necessary condition for the implementation of the assessment included the design of a supply chain in coordination with each technology supplier.

The following table illustrates the added value of the selected technologies. Specifically, Table 4.14 depicts the contribution of energy access to the commodity value chain, due to the improvement in cooking practices, lighting fuels and drying techniques, while Table 4.15 summarizes the cost reductions obtained by using BD, ICS and SCD in productive activities.

MES	Process supported	Contribution to the commodity value chain
ICS	Firewood burning	Fuel saving (energy efficiency)
BD	Digestion of waste to refine biogas for cooking and production of bio-fertilizer	Improvement of energy efficiency
SCD	Crop, fruit drying	Decrease of time spent in same process; increase of quality of dried product; decrease of waste product

Table 4.14.: Illustration of an example of the contribution of energy access to the commodity value chain

MES	Activity	Former associated cost	Costs reduction
BD	Daily firewood consumption and LPG consumption	Firewood cost: free (deforestation practices)	Time consumption: dung collection; water mixing; daily-weekly maintenance
ICS	Daily firewood consumption / LPG consumption	Firewood cost: free (deforestation practices)	Time consumption: firewood collection time, preparation time, cooking time
SCD	Time spent in drying processes	Daily expenses of farmers to spent in drying process	Reduction of days dedicated to drying
	Product lost after quality check-up	% Lost coffee production due to moist, garbage and contaminated beans	Full usage of amount dried

Table 4.15.: Cost reductions obtained from the use of MES in productive activities

Table 4.16 shows a comparison in further detail of crop drying time with and without a SCD, while Tables 4.17 shows the results of a water boiling test with ICS. In both tables the advantages of the proposed technologies over the traditional methods (for drying and cooking, respectively) can be easily appreciated. Finally, Table 4.18 summarizes the main characteristics of a BD.

	Without SCD	With SCD
Productivity		
Duration (time spent for crop drying)	Up to 12 days	Less than 7 days
Time spent per day for human activities involved in drying process	3 working days	1 working day
Quality		
Humidity	Humidity absorbed	None reabsorption
Waste	10%	0
Exportable quality	70%	75%

Table 4.16.: Comparison of traditional drying processes (without SCD) and with a SCD, for a crop quantity of 90 Quintals (9000 kgs) of coffee beans

	3-stone fire (traditional)	ICS (mobile)	ICS (fixed)
Boiling time - Cold start	21	38	43
Boiling time - Hot start (min)	49	29	21
Fuel consumption - Cold start (g/L)	382	129	225
Fuel consumption - Hot start (g/L)	513	124	113
Energy consumption - Cold start (kJ/L)	6722	3511	4047
Energy consumption - Hot start (kJ/L)	9841	2168	2043
Combustion speed - Cold start (g/min)	61	43	24
Combustion speed - Hot start (g/min)	35	43	27
Thermal efficiency - Cold start (%)	6	11.2	11
Thermal efficiency - Hot start (%)	5	17	20.2

Table 4.17.: Comparison of water boiling test results with different cooking stoves

	Small BD	Medium BD	Large BD
Size (Plastic calibre 8, diameter 1,25 m)	5m	7m	10m
Production capacity (biogas liters)	600l	900l	1300l
Required materials (TB: Tubular Plastic; CP: Ceiling Plastic)	TP 14m - CP 8m	TP 18m - CP 10m	TP 24m - CP 13m
Animals required (Average weather / Temperature conditions 18°C to 23°C)	10	14	25
Total dung per day (proportion 1:3) (40kg/day)	1000	1400	2000
Water consumption	3000 (120l/day)	4400 (180l/day)	6400 (255kg/day)
Materials price	380,000 COP	460,000 COP	580,000 COP
Installation price	300,000 COP	760,000 COP	980,000 COP
Guaranty time	5 - 7 years for materials		

Table 4.18.: Characteristics of biogas digesters according to size

5. Promotional Campaigns for Consumer Targets Contactar directly coordinated the design and implementation of promotional campaigns for the Green Finance Program that were tailored to each type of end-user. The materials developed for this objective include flyers, training manuals for loan officers, posters, in-house trainings, and supplier trainings at installation processes as well as radio spots. In particular, the promotional campaigns involved the following stakeholders:

- Contactar: communication and marketing strategy development for Green Program promotion;
- Radio stations: promotion and communication of Green Program at regional levels (Ipiales, Cumbal, Sandoná, Gualmatán, Túquerres, La Unión);
- Technology suppliers: promotion of Green Program at local levels and trainings for loan officers on technologies;
- MicroEnergy International: support for Contactar and promotion of Green Program at an international level;
- Citi Foundation: promotion and dissemination of Green Program through network events.

As of October 2016, Contactar has managed to establish its program in the departments of Nariño, Huila and Putumayo and it continuously coordinates with suppliers to further shape the respective supply chains of clean energy technologies.

5. Energy Usage in Rural Areas: Case Study in Southern Colombia[1]

Part of this research is framed under Contactar's motivation and willingness to better identify energy needs among its clients and to track the improvements in energy access through the financed technologies. To this aim, specific metrics that are able to assess the level of provision of energy, as well as to quantify the achievements of MES in supplying quality energy services, should be considered. In fact, the currently available national statistics concerning energy supply fail to describe specific quality attributes of the electrification or cooking fuels in specific regions. Hence, a detailed analysis of such access might provide Contactar valuable information for their Green Finance Program. Motivated by this need, the research included a case study dedicated to the assessment of energy access in the regions where Contactar operates. The study consisted in applying the MTF assessment tool [Bhatia and Angelou, 2014, Bhatia and Angelou, 2015] to a sample of the MFI's clients, comparing also the results of the panel PPI data available from the institution.

The energy access assessment study considered two aspects of energy access at the household level: electricity (supply, services and consumption) and cooking solutions. The main motivation to conduct this twofold assessment lied in the interest of the MFI to investigate energy uses at household level. Specifically, for Contactar it was important to describe relevant aspects of energy assess in the context of the MES currently offered in its Green Finance Program (Section 4.3), which include improved cooking stoves and biogas digesters. Moreover, an additional motivation to include the assessment of cooking solutions was to explore the possibility of testing their viability leaving out the attributes requiring laboratory tests (safety, efficiency and convenience).

This chapter summarizes the results of this case study, which was conducted from April to June 2015, based on the version of the multi-tier questionnaire available by March 2015. Firstly, in Section 5.1 the criteria for the selection of the sample clientele are described in detail, while, Sections 5.2 and 5.3 present the detailed multi-tier ranking results, focusing on electricity supply (and services) and cooking solutions, respectively. Finally, in Section 5.4 the multi-tier energy access results have been analyzed relating them with the PPI scores.

[1]Part of this chapter is currently prepared for submission to the Elsevier journal *Energy for Sustainable Development*.

5.1. Sample Selection

Sample Size The selection of the sample size is a crucial aspect of a survey study. Increasing the sample size often yields a more *statistically significant* results (in the sense of a lower probability of errors and an improved ability to detect less probable events).

In practice, the size of the sample is related to the precision of the estimate in terms of *margin of error* and *confidence level*. The margin of error describes the amount of sampling error in the results, expressing the likelihood that the survey result, conducted among the sample subjects, is representative of the description of the whole population. The confidence level is related to the level of significance of the results and it describes the probability that the estimated population parameters fall within a certain range of values (for instance, within the prescribed margin of error).

Formally, margin of error (ME) and confidence level (CL) can be related to the sample size n based on on the probability distribution assumed for the target population. Assuming a normal distribution yields

$$\text{ME} = z(\text{CL})\sqrt{\frac{\sigma^2}{n}}, \tag{5.1}$$

where σ^2 stands for the variance of the distribution and where the value $z(\text{CL})$, also called z-value, refers to the distance from the population mean μ, so that the interval $[\mu - z(\text{CL}), \mu + z(\text{CL})]$ covers a ratio of the population equal to CL (e.g., $z = 1.96$ for a 95% confidence level, see also Figure 5.1 – in this case, 95% of the area under the normal distribution lies within 1.96 standard deviations of the mean–.)

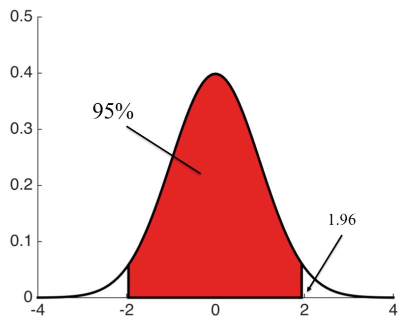


Figure 5.1.: Sketch of the meaning of z-value for a normal distribution

For dichotomies (questions allowing only two answers, e.g., positive and negative) it holds $\sigma^2 = p(1-p)$, where p refers to the probability of positive (or negative) answers. Hence, the above formula reduces to

$$\text{ME} = z(\text{CL})\sqrt{\frac{p(1-p)}{n}}. \tag{5.2}$$

If no a priori information is available, $p = 0.5$ is usually taken, giving equal probability to both events. This choice leads to

$$\mathrm{ME} = z(\mathrm{CL})\sqrt{\frac{0.25}{n}} \Rightarrow n = 0.25\frac{z(\mathrm{CL})^2}{\mathrm{ME}^2}. \tag{5.3}$$

In order to implement the Energy Survey (Household Questionnaire) [SE4ALL and WB, 2014], the size of the sample was selected based on a 95% confidence level (i.e., $z(0.95) = 1.96$) and a margin of error of 5% ($\mathrm{ME} = 0.05$) for dichotomies, resulting in a sample size

$$n = 0.25\frac{z(0.95)^2}{0.05^2} = 384. \tag{5.4}$$

Notice that the size of the sample for a given confidence level and margin of error depends, in general, also on the total size of the target population. Particularly, for small populations the required confidence can be achieved also with a smaller sample. In the case of dichotomies, the sample size for a finite population N, and prescribed confidence level and margin of error, can be estimated by

$$n(N) = 0.25\frac{z(\mathrm{CL})^2}{\mathrm{ME}^2}\left(1 + \frac{0.25z(\mathrm{CL})^2}{\mathrm{ME}^2 N}\right)^{-1}. \tag{5.5}$$

The sample size n_N given by (5.5) is always smaller than the size n provided by (5.3). For relatively large N (larger than about 150,000 individuals), n_N eventually coincides with n. Specifically, in the case of Contactar, considering a client pool of 77,150[2], the required sample size (confidence level 95%, margin of error 5%) would be, according to Equation 5.5, of 382 households.

Selection of Clients Based on Geographical Areas Considering the four regions in southern Colombia where Contactar operates (Nariño, Huila, Putumayo and Tolima (see 4)), the first selection criteria was based on covering both rural and urban clientele[3] reflecting the proportion of clients in each of the regions (see Table 5.1). To this aim, different climate zones were identified, which determined substantial cultural differences in terms of economic activities, diet and socially accepted living standards. Therefore, the routes to be followed by the interviewers were selected by considering diverse areas within each department, covering the diverse topography and climatic conditions. Particularly, the highest altitude registered was 3,486 m (a.s.l.), while the minimum was 321 m (a.s.l.), with characteristic mean temperatures varying between 11°C and 38 °C (see Table 5.2 and Figure 5.2 for details – (maps gen-

[2]MixMarket profile database for 2015.
Source: https://www.themix.org/mixmarket/profiles/contactar

[3]According to the DANE – National Administrative Department of Statistics – urban area is characterized by several blocks, delimited by roads or avenues, and it is provided with basic services such as aqueduct, sewage, electricity grid, hospitals or schools. On the contrary, rural municipalities are characterized by disperse distribution of households, without official street names, and mainly without access to public services or facilities. See also www.dane.com

erated with the free application GpsPrune [GpsPrune, 2015])–). However, due to security issues and given the current national conflict in Colombia, several villages where Contactar is present were excluded from the research.

	Total sample	Nariño	Huila	Put.	Tolima
Urban	69.5 %	43.8 %	84.2 %	100 %	58.2 %
Rural	30.5 %	56.2 %	15.8 %	0 %	41.8 %

Table 5.1.: Summary of the number of selected clients in urban and rural areas

	Subjects	Mean Altitude (min–max)	Mean Temperature (min–max)
Nariño	50 %	2383 m (1276 – 3486)	21.6 °C (21 – 36)
Huila	29.7 %	1347 m (450 – 1929)	24.7 °C (18 – 38)
Putumayo	16.9 %	1852 m (321 – 2933)	24.2 °C (13 – 38)
Tolima	3.4 %	321 m	31.6 °C (27 – 35)
Total	100 %	2032 m (321 – 3486)	23.3 °C (11 – 38)

Table 5.2.: Summary of the number of selected clients in the four considered regions

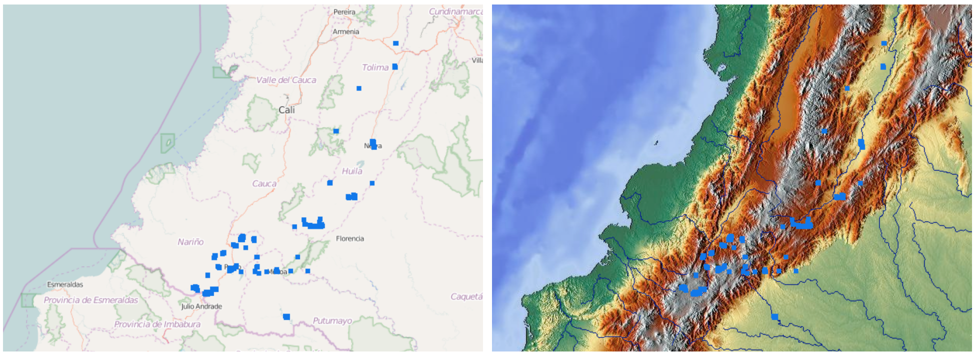


Figure 5.2.: GPS coordinates of the interviewed clients. Left: political map; right: physical map.

Selection of Clients Based on Availability of PPI Data The second selection criteria reflected the historical relation of the clients with the MFI, selecting the clients who had filled the PPI questionnaire applied in 2012 and in 2014 (38,449 and 82,758 loans applications respectively). This means that selected clients had a longer track record with the institution. However, in terms of energy access, a picture of their energy situation should not differ from the one of the clients who had filled out the PPI questionnaire only once (one-time client) or who have applied only recently for a financial service at the institution for the first time. Notice that the clients involved in the green lending program *ConSuPlaneta* were not selected for this study. This was due to the fact that their energy supply situation had been already affected by the acquired energy technologies and to the unavailability of data concerning their conditions prior to the financing.

As introduced in Section 3.5, Contactar collects the PPI data of all clients applying for any financial service at the institution since 2011. As for December 2015, almost a third of the clients filled out the PPI questionnaire twice (32,567 entries), i.e., they had applied and successfully received more than one loan at the institution. Note, however, that since Contactar extended its branches in Tolima only since 2013, PPI data were not available for the clients in this department (3.12% of the total sample). The average scores of the considered sample are shown in Table 5.3, according to the region and area of the clients. Specifically, this characterization shows that the PPI score is mostly uniform for the different regions despite of the diverse climatic conditions and cultures, while it tends to be higher (47.9 versus 39.7, on average) for urban clients compared to the rural ones.

	Total sample		Nariño		Huila		Putumayo	
	2012	2014	2012	2014	2012	2014	2012	2014
Urban	47.9	50.1	47.0	48.0	47.7	48.8	49.5	54.6
Rural	39.7	40.9	40.9	42.2	37.0	37.8	–	–

Table 5.3.: Summary of mean PPI scores (2012 and 2014) of the selected clients, according to their area (urban, peri-urban and rural) and region

Based on the above described criteria, the selection was randomized using the free software Research Randomizer [Urbaniak and Plous, 2013] for each branch cluster. Prior to the full survey implementation, a test-survey was conducted among 12 individuals in the Pasto peri-urban areas, where the headquarters of Contactar are located. The test served to adjust the terminology of the questionnaire, to clarify skipping patterns and to include other existing income sources.

Survey Implementation The survey was based on the multi-tier framework questionnaire relative to the household locale[4]. The questionnaire has been translated into Spanish by the Author[5] (see also Figures 5.3-5.4). The survey included 1276 variables entries with an average of 30 questions per module. The modules considered in this dissertation and their respective amount of questions and variables are described in Table 5.4, not including the questions for the identification of household, the data registering interview details (such as location or time) and the Household Roster first module.

[4]English Version 5 from 13th of December of 2014. At the time of survey implementation (March 2015), the tool included only 11 modules (A-K) [SE4ALL and WB, 2014].

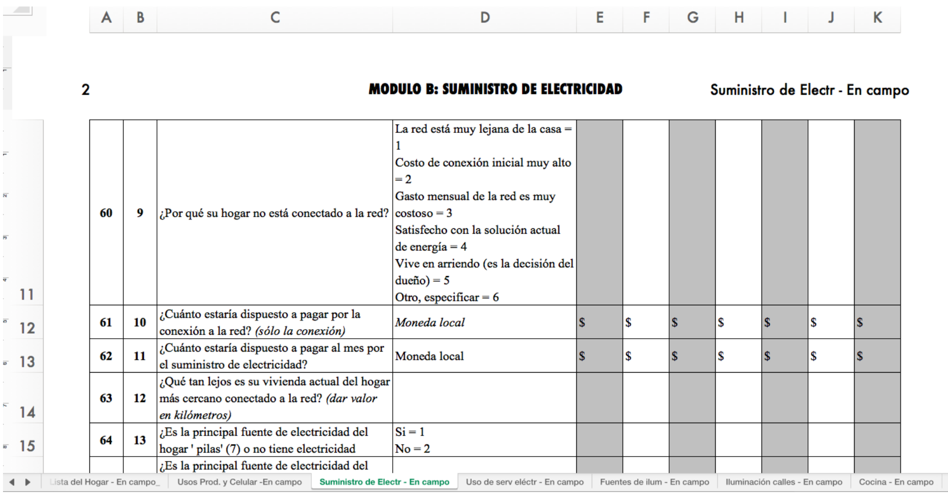
[5]The Spanish version is available on nataliarealpecarrillo.weebly.com. This translation was not created by The World Bank or the International Energy Agency and should not be considered an official translation of either organization. Neither the World Bank nor the International Energy Agency shall be liable for any content or error in this translation.

For its application, the original survey [SE4ALL and WB, 2014] layout was transformed into practical sheets so that the interviewers were able to conduct it using their notebooks. Therefore, data was directly uploaded into the data sheets ready for data analysis For each household, the survey took between 80 and 120 minutes, depending on the household size, i.e., on the number of family members living in the house.

With the collaboration and coordination of the general managers of Contactar in each office, the interviewers coordinated visits with the clients upon arrival (via mobile phone)[6].

Modules	No. of Questions
B: Supply of Electricity	34
C: Use of Electricity Services	6
D: Sources of Lighting Used within Household	5
G: Use of Cooking Stoves	42
K: Income	6

Table 5.4.: Modules, questions and variables considered in the implemented survey, following [SE4ALL and WB, 2014]



2 MODULO B: SUMINISTRO DE ELECTRICIDAD Suministro de Electr - En campo

	A	B	C	D	E	F	G	H	I	J	K
11	60	9	¿Por qué su hogar no está conectado a la red?	La red está muy lejana de la casa = 1 Costo de conexión inicial muy alto = 2 Gasto mensual de la red es muy costoso = 3 Satisfecho con la solución actual de energía = 4 Vive en arriendo (es la decisión del dueño) = 5 Otro, especificar = 6							
12	61	10	¿Cuánto estaría dispuesto a pagar por la conexión a la red? *(sólo la conexión)*	*Moneda local*	$	$	$	$	$	$	$
13	62	11	¿Cuánto estaría dispuesto a pagar al mes por el suministro de electricidad?	Moneda local	$	$	$	$	$	$	$
14	63	12	¿Qué tan lejos es su vivienda actual del hogar más cercano conectado a la red? *(dar valor en kilómetros)*								
15	64	13	¿Es la principal fuente de electricidad del hogar ' pilas' (7) o no tiene electricidad	Si = 1 No = 2							
			¿Es la principal fuente de electricidad del								

Lista del Hogar - En campo_ | Usos Prod. y Celular -En campo | Suministro de Electr - En campo | Uso de serv eléctr - En campo | Fuentes de ilum - En campo | Iluminación calles - En campo | Cocina - En campo

Figure 5.3.: Excerpt of the translated survey tool (electricity supply module) used for the field study

[6] In some of the villages, prior to the research, the national government had distributed flyers suggesting not to answer any type of survey or interview conducted by strangers, due to recent extortion cases. Hence, in a number of cases a coordination with the local office, prior to the interview, was needed to ensure trust from clientele.

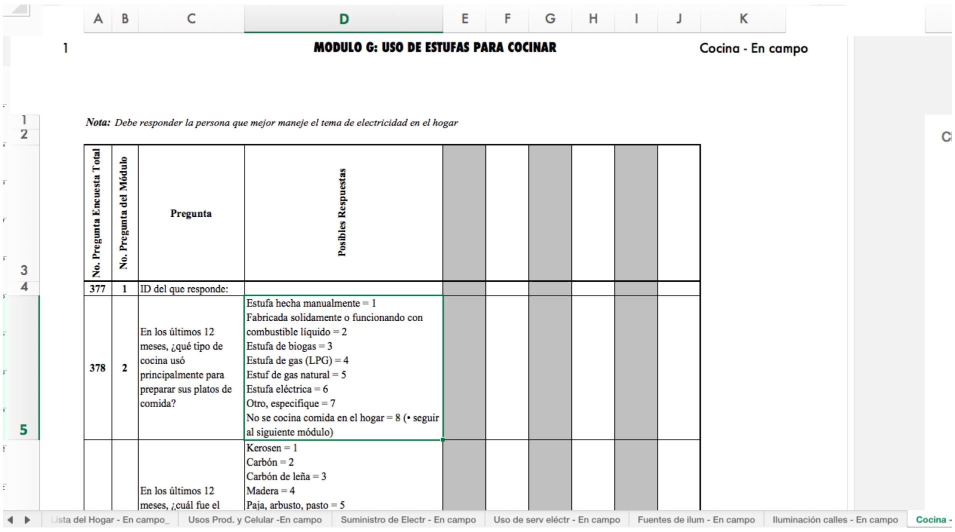


Figure 5.4.: Excerpt of the translated survey tool (cooking module) used for the field study

5.2. Analysis of Electricity Supply, Services and Consumption

5.2.1. PPI for Assessment of Electricity Services

As mentioned in Section 5.1, the pool of clients from which the sample was chosen had as requisite to have received a PPI score twice. In order to further motivate the need of specific indicators and of better measurement methodology for energy access, this section presents a summary of the conclusions drawn from the PPI questions related to electricity services.

The data reported in Table 5.5 shows that at least 91.7% of the interviewed clients (in 2014) have access to electricity (i.e., they own at least a washing machine, a fridge or a DVD player) in terms of enabled electricity services. The analysis revealed also a notable difference between urban and rural areas (97.2 % vs. 84.2 %), as well as a general improvement between 2012 and 2014 (+2% and +2.5% for the urban and rural area, respectively). However, no information was provided on the electricity supply capacity (power system), nor on the electricity consumption nor on the quality of the available electricity. These observations demonstrate how the PPI metric fails in correctly depicting the evolution of energy access, as the indicators on appliances ownership show an increase in all three categories (washing machine, fridge and DVD). Hence, based on the information provided by the PPI, conclusions may only be extracted in regards to the increasing level of power at the household (e.g., washing machines ownership increased). The ownership of fridges, on the other hand, is not a reliable indicator as some areas covered by the MFI are above 3,000 m.a.s.l., where populations exclude fridge acquisition from their basic needs.

Furthermore, due to the formulation of the PPI questionnaire, off-grid households are classified in the same category (i.e., they receive the same scoring) as the households classified in the lower 'rate-class' (0, 1 and 2). For instance, according to the PPI questionnaire, in 2012, 95.6% of the population lacked of access to electricity, or had an illegal connection or pertained to socio economical class of 0, 1 or 2; in 2014, the size of this group increased by 1.6%. However, no distinction can be made on the proportion of off-grid households. Moreover, considering that the rural households are considered to belong to first or second rate class, thus the indicator is not able to assess grid access in these areas.

	Total		Urban		Rural	
	2012	2014	2012	2014	2012	2014
Q.5 No connection, classes 1–2	95.6 %	97.2 %	93.3 %	95.2 %	99.3 %	100 %
Q.7 WM	38.1 %	43.8 %	54.3 %	61.1 %	15.8 %	19.7 %
Q.8 Fridge	77.3 %	82.9 %	88.6 %	93.4 %	61.8 %	68.4 %
Q.9 DVD	69.6 %	74.9 %	73.3 %	79.6 %	64.5 %	68.4 %
At least one appliance	89.5 %	91.7 %	95.2 %	97.2 %	81.6 %	84.2 %

Table 5.5.: Information on electricity services (ownership of washing machine, fridge/freezer and DVD) extracted from the PPI tool

The questions of the PPI survey related to cooking solutions (Table 5.6) revealed that 95% of clients in the urban area (2014) cook with gas (either from a tank or connected to a network), while only 50% in the rural area (2014) have access to these facilities. Since the categories given to the cooking solution question combined a variety of fuels, it is not possible to distinguish the usage of modern fuels (gas or electricity) nor the efficient use of biomass (through improved cooking stoves). Moreover, solid fuels such as firewood, wood, charcoal, mineral charcoal, kerosene, alcohol or waste are combined with non-solid fuels such as electricity and gas. Therefore, the results impede a more detailed analysis of the quality of access to cooking fuels. Furthermore, considering the usage of multiple fuels at household level, the indicator is constrained to the information of the primary stove; it does not reveal the variety of fuels used at the household neither the proportion of households that use more than one stove.

5.2.2. Multi-tier Analysis

This section is dedicated to the evaluation of electricity supply, electricity consumption and access to electricity services of the sample, according to the ESMAP MTF ranking approach with the tier thresholds established by [Bhatia and Angelou, 2015] (see also Tables 2.4 and Table 2.5).

Aiming at capturing the largest dataset to provide detailed insights and at identifying the most relevant indicators for the tier-ranking, the *comprehensive*

	Total		Urban		Rural	
	2012	2014	2012	2014	2012	2014
Gas (network)	14.4 %	18.5 %	24.3 %	30.1 %	0.7 %	2.0 %
LPG (tank)	54.7 %	58.4 %	65.7 %	65.4 %	39.5 %	48.7 %
Other	30.4 %	23.1 %	9.0 %	4.3 %	59.9 %	49.3 %
Do not cook	0.6 %	0 %	1.0%	0 %	0 %	0 %

Table 5.6.: Information on cooking facilities extracted from the PPI tool "Other" include: firewood, wood, charcoal, mineral charcoal, electricity, gas, kerosene, alcohol or waste

framework was implemented among the three levels proposed by [Bhatia and Angelou, 2015, pag 17][7].

After the data collection, the sample was ranked according to the tier-ranking proposed in [Bhatia and Angelou, 2015]. In what follows, the results for each attribute are described in detail, while the whole multi-tier matrix is summarized in Table 5.8 (percentage of households in each tier), Table 5.9 (number of households in each tier) and Figure 5.7. Moreover, the resulting access indices are reported in Table 5.10 and Figure 5.22.

Electricity Supply

Capacity The results of the survey show that the totality of the sample is connected to the grid, however, no information concerning the capacity of the connection was available[8]. Hence, the household peak capacity has been estimated considering the appliances used in the household, according to the values reported in Table 5.7.

As shown in Table 5.8 and Figure 5.5, peak capacities are concentrated between Tier 4 and Tier 5 (above 1,250 kWh and 3,425 Wh of daily supply, respectively) in the urban area (53% and 29%, respectively), while the vast majority of rural households fall in Tier 3 and Tier 4 (between 365 kW and 2,999 kW power, or between 1,000 Wh and 8,218 Wh of daily supply) (36% and 54%).

[7]Given the amount of data required for the described approach, three levels of the framework were proposed addressing the complexity of the MTF: a comprehensive, a simplified and a minimalistic framework, varying in the level of data aimed to be collected under each framework.

[8]The electricity utility only provided electricity consumption prices. Capacity was manually estimated following average usages of owned appliances.

Appliance	Power (W)
Light Bulb	100
CFL	30
FL	28
LED	10
TV	150
PC	150
Electric Stove	1000
Fridge	400
Freezer	400
Ventilator	100
Washing Machine	500
Microwave	600
Air Conditioning	1000

Table 5.7.: Appliance power used to estimate the household capacity. Sources: Daftlogic and ABS Alaskan.

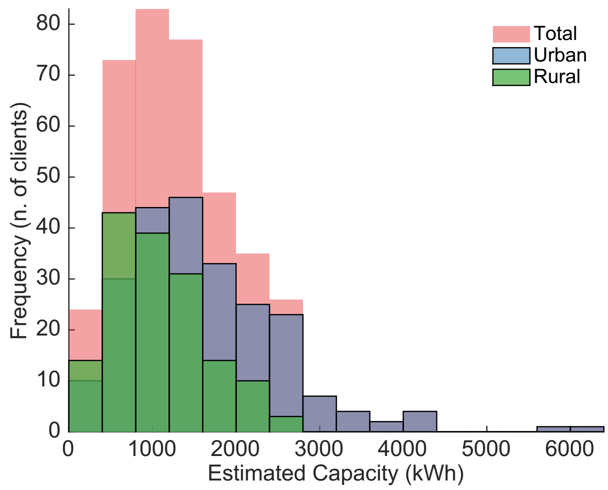


Figure 5.5.: Histogram of capacity data (considering total sample, urban and rural areas)

Duration The best performing duration of electricity supply was found in Huila with almost 95% of the sample assigned to Tier 4 and Tier 5, compared to the lowest, Nariño with only 70% in the same tiers, and 15% with less than four hours a day of electricity supply. Specifically, 10% of the sample had less than four hours of electricity during the day due to several unpredictable outages, which last more than one day in rural areas. In Putumayo, no information on longer interruptions than two hours is found, ranking its electricity supply as the most stable from the sample.

As for the seasons, the months of May and June are considered the ones in which the largest amount of electricity supply interruptions occur. In average, the sample suffers of 1.99 outages per week lasting around 17.5 hrs. Particularly, the duration of outages last from five minutes up to two days in the worst cases. Indeed, 18.5% of the interviewed complain that unpredictable interruptions are the most relevant issue concerning their electricity supply, and the 20% rank it as the second barrier.

Reliability In both urban and rural areas, the connection is reported to be unstable and affected by unpredictable interruptions. Specifically, Nariño and Tolima appear to be the most affected regions. Note that urban households dispose of a more deficient connection, with more than 84.3% suffering of more than two outages per day against more than 67.5% of the rural households.

Quality Concerning the quality of the supplied energy, rural households are the most affected (27.3% of the rural clients, against 14% of the urban clients, reported damaged appliances due to outages). Particularly, the department of Nariño is the one with the highest amount of cases of affected households. Moreover, from those affected by voltage fluctuations, 57.4% confirm that the presence of voltage fluctuation is not related to a a specific time of the year. The remaining households affirm that fluctuations would mostly happen during the first semester. Similar to the reliability of electricity supply, 19.5% of the sample identifies the low voltage and fluctuations problem to be the main barrier the households faced in regards to their electricity supply. Only 3% ranks it as a second barrier.

Affordability Analyzing electricity expenses related to an annual consumption of 365 kWh, in relation to the clients income, it is observed that, according to the metrics proposed by [Bhatia and Angelou, 2015], a very small proportion of households in urban and rural areas has excessive expenditures (more than 5% of income) in electricity (4.8% and 8.7% respectively).

In order to provide a more detailed view of the affordability results, Figure 5.6 shows the percentage of clients (on the y-axis) whose energy expenses stays below a given thresholds (x-axis) between 0% and 15% of the monthly income. From these curves, one can see that the rural population declare in general to have higher expenses (with respect to the monthly income). However, by considering only the 5% threshold, it masks these differences, as for both regions more than 90% of the sample is assigned in the highest tier.

Likewise, without considering the constraint on electricity consumption package, 22.9% and 21.7% of urban and rural households spend more than 5% of their income in electricity supply. Moreover, in Huila only 9.4% of households spend more than 5% of their income in electricity, while in Nariño less than 7% of the clients have high energy expenses. Note, however, that this department appears also to be the region characterized by the worse quality and reliability. Notably, despite the fact that the majority of the sample was ranked in the

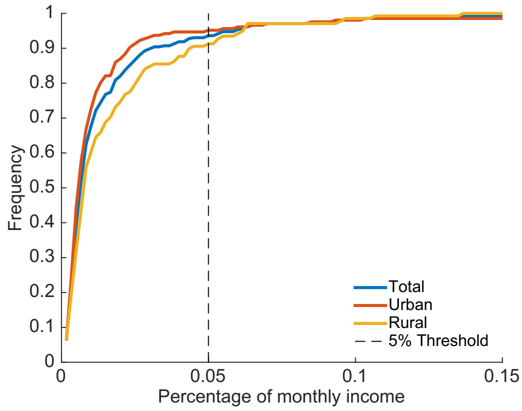


Figure 5.6.: Proportion of clients (y-axis) whose energy expenses does not exceed a certain percentage of the monthly income (x-axis)

highest tiers, one of the most relevant concerns of the interviewed population was the high cost of the electricity supply. Specifically, the 67.5% of the clients claimed it to be one of the two major issues the household faces, indicating that the 5% threshold might not necessarily reflects the perception and the priorities of the population regarding the distribution of their income and respective expenses.

Legality Except for two cases (rural households in Huila), all clients declared to be legally connected to the grid. However, the two subjects without legal connections pay significant amounts to neighbouring households for their connection and are satisfied with their current situation.

Health and Safety None of the sample have had any accident in the past year, though a minimal proportion (2.6% of households in Huila) feels a safety risk (e.g., due to the outages) for the need of using complementary energy sources. In fact, 80.7% use candles or fuel-run lamps as substitute energy source for illumination during the outages, leading to a perceptible increase of health-hazard in case of any unfortunate accident.

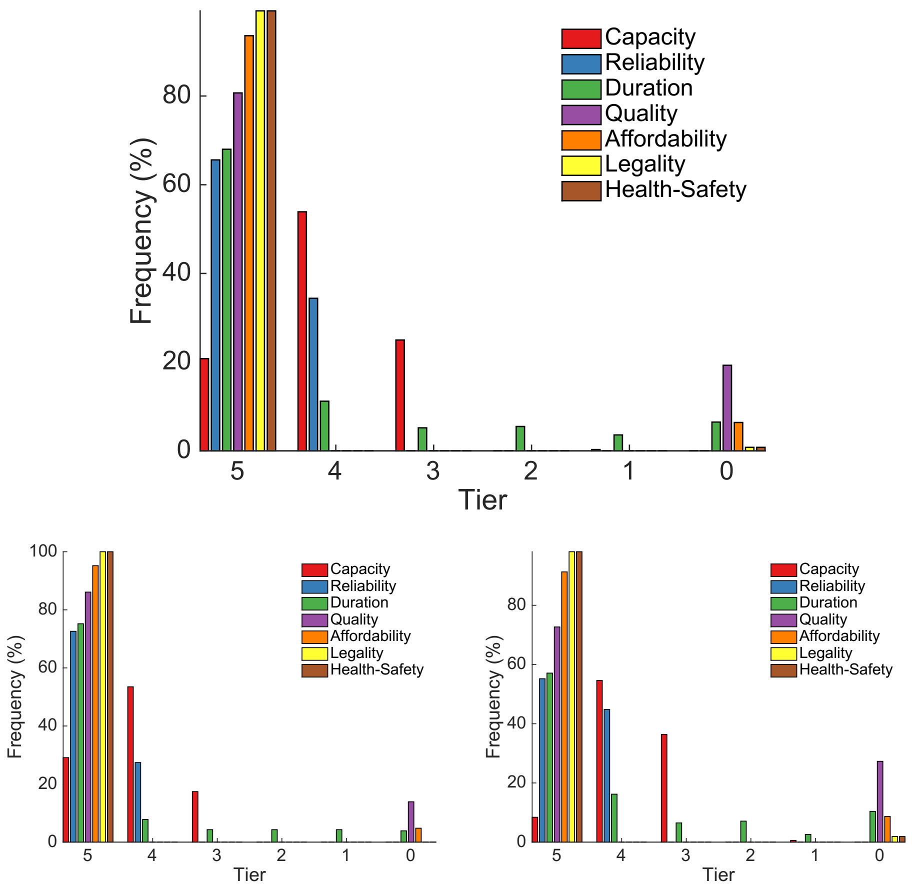


Figure 5.7.: Tier ranking for the different attributes (electricity supply), considering the total sample (top), the urban area (bottom-left) and the rural area (bottom-right)

		Area		Departments			
	Total	Urban	Rural	Nariño	Huila	Put.	Tolima
Capacity							
Tier 5	20.8%	29.1%	8.4%	16.7%	17.5%	37.9%	25.0%
Tier 4	53.9%	53.5%	54.6%	55.7%	57.9%	40.9%	58.3%
Tier 3	25.0%	17.4%	36.4%	27.1%	24.6%	21.2%	16.7%
Tier 2	–	–	–	–	–	–	–
Tier 1	0.3%	–	0.6%	–	–	–	–
Tier 0	–	–	–	–	–	–	–
Reliability *(short unpredictable interruptions)*							
Tier 5	65.6%	72.6%	55.2%	51.0%	81.6%	80.3%	66.7%
Tier 4	34.4%	27.4%	44.8%	49.0%	18.4%	19.7%	33.3%
Duration *(including day and night electricity supply duration)*							
Tier 5	68.0%	75.2%	57.1%	54.2%	84.2%	78.8%	75.0%
Tier 4	11.2%	7.8%	16.2%	14.6%	10.5%	–	25.0%
Tier 3	5.2%	4.3%	6.5%	7.3%	0.9	7.6%	–
Tier 2	5.5%	4.3%	7.1%	7.8%	1.8	6.1%	–
Tier 1	3.6%	4.3%	2.6%	4.7%	–	7.6%	–
Tier 0	6.5%	3.9%	10.4%	11.5%	2.6%		–
Quality *(appliances not damaged due to outages)*							
Tier 5	80.7%	86.1%	72.7%	69.8%	93.0%	87.9%	100%
Tier 0	19.3%	13.9%	27.3%	30.2%	7.0%	12.1%	–
Affordability *(electricity expenses below 5% of HH income)*							
Tier 5	93.6%	95.2%	91.3%	93.8%	90.6%	96.6%	100%
Tier 0	6.4%	4.8%	8.7%	6.2%	9.4%	3.4%	–
Legality *(legal connection)*							
Tier 5	99.2%	100%	98.1%	100%	97.4%	100%	100%
Tier 0	0.8%	–	1.9%	–	2.6%	–	–
Health and Safety *(absence of accidents or risks)*							
Tier 5	99.2%	100%	98.0%	100%	97.4%	100%	100%
Tier 0	0.8%	–	2.0%	–	2.6%	–	–

Table 5.8.: Results (in percetages) of the tier-ranking for electricity supply

		Area		Departments			
	Total	Urban	Rural	Nariño	Huila	Put.	Tolima
Capacity							
Tier 5	80	67	13	32	20	25	3
Tier 4	207	123	84	107	66	27	7
Tier 3	96	44	56	52	28	14	2
Tier 2	–	–	–	–	–	–	–
Tier 1	1	–	1	–	–	–	–
Tier 0	–	–	–	–	–	–	–
Reliability *(short unpredictable interruptions)*							
Tier 5	252	167	85	98	93	53	8
Tier 4	132	63	69	94	21	13	4
Duration *(including day and night electricity supply duration)*							
Tier 5	261	173	88	104	96	52	9
Tier 4	43	18	25	28	12	52	3
Tier 3	20	10	10	14	1	–	9
Tier 2	21	10	15	1	2	3	
Tier 1	14	10	4	9	–	4	–
Tier 0	25	19	16	22	3	–	–
Quality *(appliances not damaged due to outages)*							
Tier 5	310	198	112	134	106	58	12
Tier 0	74	32	42	58	8	8	–
Affordability *(electricity expenses below 5% of HH income)*							
Tier 5	323	197	126	180	77	56	10
Tier 0	22	10	12	8	2	–	
Legality *(legal connection)*							
Tier 5	381	230	151	192	111	66	12
Tier 0	3	–	3	–	3	–	–
Health and Safety *(absence of accidents or risks)*							
Tier 5	381	230	151	192	111	66	12
Tier 0	3	–	3	–	3	–	–

Table 5.9.: Results (number of households) of the tier-ranking for electricity supply

Electricity Consumption

In regards to the consumption of electricity supply, urban households have a similar average consumption patterns as rural houses, with, however, higher consumption peaks (Figure 5.8). Nevertheless, only few rural households (1.4%) achieved the highest tier (16.9% in the urban areas). In detail, monthly consumption estimation showed that an average yearly consumption of 1,500 kWh across the regions, with a clear difference between urban (1,860 kWh) and rural (1,070kWh) areas.

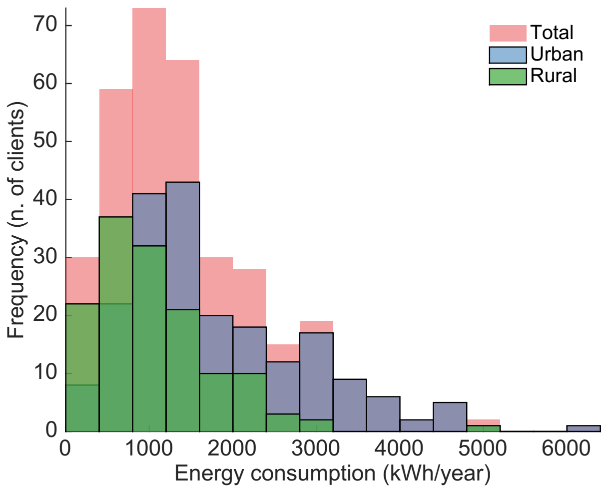


Figure 5.8.: Histogram of consumption data (considering total sample, urban and rural areas)

Energy Services

Consistently to what has been reflected in the capacity metrics, most of the clients are ranked in Tier 3 and Tier 4 according to the usage of medium and high-power appliances. More than half of rural households use low or medium power appliances (ranking in Tier 2 and Tier 3), and this situation resulted most frequent in Huila and Tolima.

Tier Rankings

The comparison of tier-rankings (see Table 5.10) drawn from electricity supply (composed of multiple attributes), electricity services and electricity consumption revealed a notable difference of characterization of the electricity access in urban and rural households (see subsections 5.2.2, 5.2.2 and 5.2.2. Using the lowest-tier assignment rule, according to the supply ranking, about 30% of households have been ranked in the lowest tier (Tier 0), and more than 35% of the households have been ranked in the lowest tiers (Tiers 0 to 2). Moreover, the analysis of electricity supply revealed differences between urban and rural areas. The access index, calculated using equation 2.1 (see also Section 2.6.3), was slightly above 50 (52.4) for the total sample. However, urban households achieved an index of 61.7, while rural households only of 38.7.

On the other hand, in the case of electricity consumption and electricity services, the vast majority of clients (more than 90%) achieved a better tier (3–5), yielding multi-tier indices above 70 in all cases, except for the case of electricity consumption in rural areas (index of 64.4).

	Total			Urban			Rural		
	Sup	Serv	Cons	Sup	Serv	Cons	Sup	Serv	Cons
Tier 5	12.5%	20.8%	10.5%	19.1%	23.9%	16.9%	2.6%	16.2%	1.4%
Tier 4	35.4%	47.1%	38.6%	40.9%	50.4%	44.9%	27.3%	42.2%	29.0%
Tier 3	15.6%	28.9%	44.9%	13.5%	23.9%	34.8%	18.8%	36.4%	60.1%
Tier 2	4.2%	2.1%	5.8%	3.0%	0.9%	3.4%	5.8%	3.9%	9.4%
Tier 1	2.6%	1.0%	–	2.6%	0.9%	–	2.6%	1.3%	–
Tier 0	29.7%	–	–	20.9%	–	–	42.9%	–	–
Index	52.4	76.8	70.6	61.7	79.2	75.0	38.5	73.6	64.4

Table 5.10.: Index and tier assignment according to Electricity Supply (Sup), Electricity Services (Serv) and Electricity Consumption (Cons) Frameworks

Sensitivity Analysis

In order to complete the results of the multi-tier approach, based on appling the lowest tier ranking among all attributes, this section is dedicated to a sensitivity study aiming to analyze the dependence of the final result from single attributes.

Table 5.11 shows the frequency of attributes ranked as the "lowest" within the sample. While *reliability*, *legality* and *health and safety* almost never determined the tier-ranking of the household energy access, *capacity* was in about half of the cases the lowest-ranked attribute among all. Furthermore, *quality* and *affordability* also appeared to be relevant, since these attributes are ranked lowest in about 20% of the cases.

Furthermore, Figures 5.9 and 5.10, together with Tables 5.12, 5.13 and 5.14, summarize the results obtained leaving out one attribute and recomputing the lowest-based tier ranking.

From these pictures, one can conclude that the framework is mainly sensitive to *capacity* (consistently with Table 5.11), and to *quality*. Specifically, removing the *capacity* yielded a shift in the highest tiers, moving households from Tiers 3 and 4 to Tier 5 (in both urban and rural areas). The *quality* affected in a greater extent the lowest tiers. Without this attribute, about 20% of the households in Tier 0 have been shifted to Tier 3 and Tier 4. Considering only the rural households, the framework resulted sensitive also to *duration* and *affordability*, as excluding one of these attributes leaded a shifts from Tier 0 to Tier 4.

These conclusions are also visible in Figure 5.11, which shows the sensitivity of

		Area	
	Total	Urban	Rural
Capacity	49.5%	51.3%	46.8%
Reliability	1.6%	2.6%	–
Duration	11.5%	9.6%	14.3%
Quality	19.0%	13.9%	26.6%
Affordability	17.4%	22.6%	9.7%
Legality	0.3	–	0.6
Health and Safety	0.8%	–	1.9%

Table 5.11.: Frequency of attributes ranked as the lowest tier for each household (energy supply)

		Without:						
	MTF	–Cap	–Rel	–Dur	–Qua	–Aff	–Leg	–HS
Tier 5	12.5%	50.7%	13.5%	12.8%	14.1%	12.8%	12.5%	12.5%
Tier 4	35.4%	9.9%	34.3%	43.5%	43.0%	39.1%	35.4%	35.4%
Tier 3	15.6%	3.1%	15.6%	17.7%	21.1%	16.4%	15.9%	15.9%
Tier 2	4.2%	4.2%	4.2%	–	5.5%	4.2%	4.2%	4.2%
Tier 1	2.6%	2.3%	2.6%	0.3%	3.6%	2.9%	2.6%	2.6%
Tier 0	29.7%	29.7%	29.7%	25.8%	12.8%	24.7%	29.4%	29.4%
Index	52.4	62.7	52.6	58.2	64.0	56.1	52.5	52.5

Table 5.12.: Results of sensitivity study of the tier ranking for electricity supply (total sample): lowest tier ranking leaving out single attributes, compared with the full MTF ranking

		Without:						
	MTF	–Cap	–Rel	–Dur	–Qua	–Aff	–Leg	–HS
Tier 5	19.1%	59.1%	20.9%	19.1%	21.7%	19.6%	19.1%	19.1%
Tier 4	40.9%	10.4%	39.1%	47.4%	47.4%	43.5%	40.9%	40.9%
Tier 3	13.5%	3.9%	13.5%	15.2%	14.8%	13.9%	13.5%	13.5%
Tier 2	3.0%	3.0%	3.0%	–	4.3%	3.0%	3.0%	3.0%
Tier 1	2.6%	2.6%	2.6%	–	3.9%	3.0%	2.6%	2.6%
Tier 0	20.9%	20.9%	20.9%	18.3%	7.8%	17.0%	20.9%	20.9%
Index	61.7	71.6	62.0	66.2	71.0	64.5	61.7	61.7

Table 5.13.: Results of sensitivity study of the tier ranking for electricity supply (urban area): lowest tier ranking leaving out single attributes, compared with the full MTF ranking

the index when leaving out a single attribute. Leaving out *capacity* and *quality* yielded an increase in the composite index of about 15 points, while leaving out *affordability* or *duration* increased the index mostly in the rural area (about 10 points).

		Without:						
	MTF	–Cap	–Rel	–Dur	–Qua	–Aff	–Leg	–HS
Tier 5	2.6%	38.3%	2.6%	3.2%	2.6%	2.6%	2.6%	2.6%
Tier 4	27.3%	9.1%	27.3%	37.7%	36.4%	32.4%	27.3%	27.3%
Tier 3	18.8%	1.9%	18.8%	12.5%	30.6%	20.1%	19.5%	19.5%
Tier 2	5.8%	5.8%	5.8%	–	7.1%	5.8%	5.8%	5.8%
Tier 1	2.6%	1.9%	2.6%	0.6%	3.2%	2.6%	2.6%	2.6%
Tier 0	42.9%	42.9%	42.9%	37.0%	20.1%	36.4%	42.2%	42.2%
Index	38.6	49.5	38.6	46.4	53.5	43.5	40.0	40.0

Table 5.14.: Results of sensitivity study of the tier ranking for electricity supply (rural area): lowest tier ranking leaving out single attributes, compared with the full MTF ranking

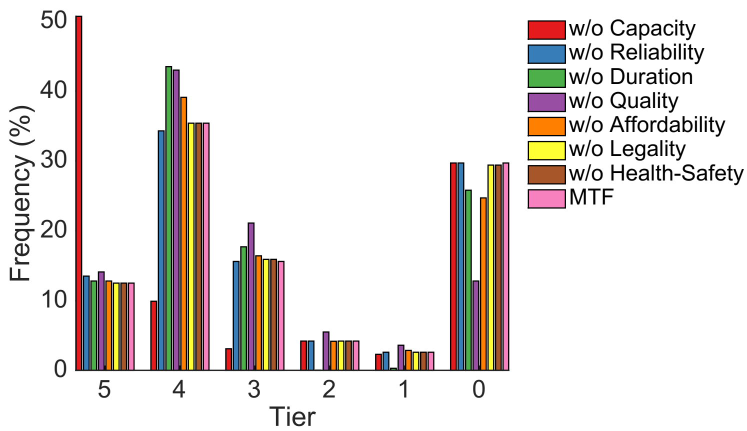


Figure 5.9.: Results of sensitivity study of the tier ranking for electricity supply: histogram of lowest tier ranking leaving out single attributes, compared with the full MTF ranking (in pink)

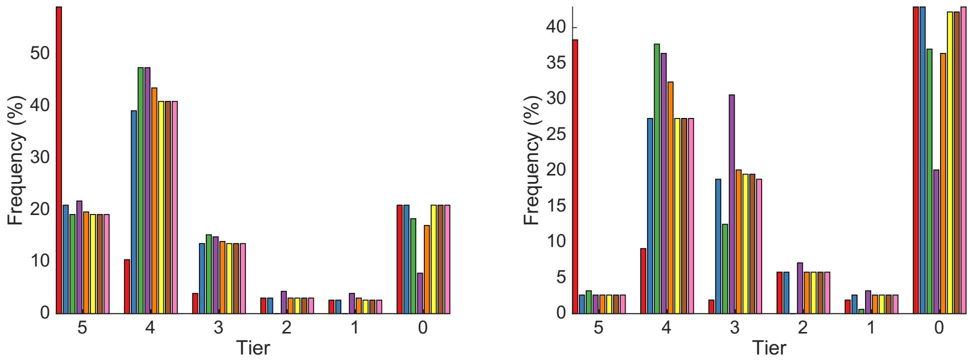


Figure 5.10.: Results of sensitivity study (in urban (left) and rural (right) areas) of the tier ranking for electricity supply: lowest tier ranking leaving out single attributes, compared with the full ESMAP MTF ranking (in pink). Legend as in Figure 5.9.

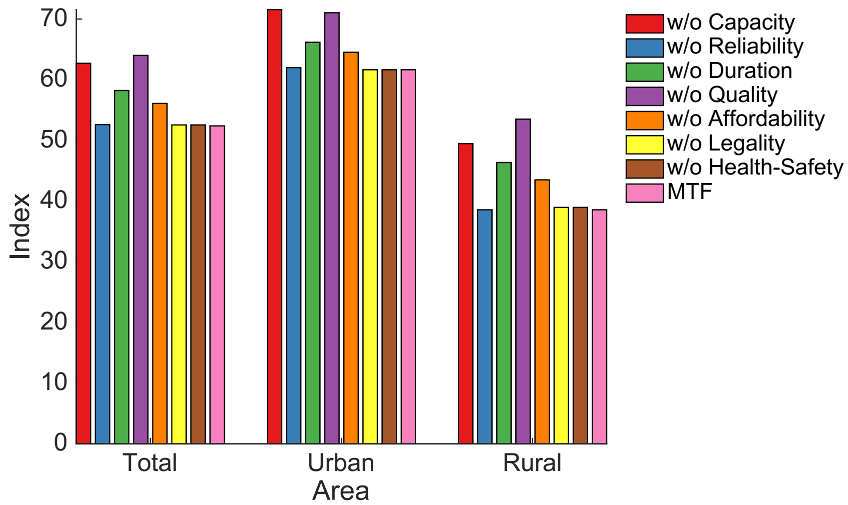


Figure 5.11.: Results of sensitivity study of the tier ranking for electricity supply: composite multi-tier index computed leaving out single attributes, compared with the full MTF index

5.3. Analysis of Access to Cooking Solutions

Regarding the access to cooking solutions, the considered regions are characterized by an ample availability of options (summarized in Table 5.15). Particularly, households are mainly provided by LPG (close to 70%, both in urban and rural areas), while access to natural gas is only found in urban areas, and mostly in Huila and Putumayo. Besides gas, the use of solid biomass cooking fuel for the primary stove (10% of the total sample) can be encountered in the rural areas of Nariño and Huila.

Furthermore, almost half of the rural households (48%) own a second stove. In these cases, the majority of secondary solutions (75%) consists of a hand-made stove, using firewood as cooking fuel.

		Area		Departments			
	Total	Urban	Rural	Nariño	Huila	Put.	Tolima
Primary Cooking Solution							
LPG	67.7%	66.5%	69.5%	91.1%	20.2%	90.9	16.7%
Natural gas	20.3%	31.7%	3.2%	–	54.4%	9.1	83.3%
Firewood	9.9%	0.4%	24.0%	4.7%	25.4%	–	–
Electrical	0.3%	–	0.6%	5.2%	–	–	–
Owns a 2nd stove	26.3%	11.7%	48.1%	43.2%	14.9%	1.5%	–
Type of secondary solution (if any)							
Firewood	75.2%	85.2%	71.6%	88.0%	17.6%	–	–
LPG	19.8%	3.7%	25.4%	7.2%	82.4%	–	–
Liquid	3.0%	7.4%	1.4%	3.6%	–	–	–
Electrical	2.0%	3.7%	1.4%	1.2%	–	100%	–

Table 5.15.: Summary of cooking solutions

The following part presents and discusses the tier ranking for each attribute characterizing access to cooking solutions, according to the MTF and following the thresholds established by [Bhatia and Angelou, 2015] (see Table 2.6). The results are also summarized in Table 5.16, Table 5.17 and Figure 5.14.

		Area		Departments			
	Total	Urban	Rural	Nariño	Huila	Put.	Tolima
Convenience *(time spent in stove and fuel acquisition and preparation)*							
Tier 5	57.2%	76.5%	27.7%	40%	70.3%	77.3%	91.7%
Tier 4	16.0%	15.0%	17.6%	21.6%	5.4%	21.2%	–
Tier 3	6.4%	5.8%	7.4%	12.4%	–	1.5%	–
Tier 2	2.7%	1.8%	4.1%	5.4%	–	–	–
Tier 0	17.6%	0.9%	43.2%	20.5%	24.3%	–	8.3%
Availability *(fuel availability throughout the year)*							
Tier 5	85.4%	82.2%	90.9%	94.8%	81.6%	63.6%	100%
Tier 4	9.4%	13.0%	3.9%	5.2%	3.5%	33.3%	–
Tier 0	4.9%	4.8%	5.2%	–	14.9%	3.1%	–
Affordability *(fuel and stove expenses below 5%)*							
Tier 5	70.2%	78.0%	58.2%	65.4%	70.0%	81.8%	83.3%
Tier 0	29.8%	22.0%	41.8%	34.6%	30.0%	18.2%	16.7%
Quality *(absence of heat variation of fuel)*							
Tier 5	96.8%	97.8%	95.3 %	93.5%	100%	100%	100%
Tier 0	3.2%	2.2%	4.7%	6.5%	–	–	–
Safety							
Tier 5	99.7%	99.6%	100 %	99.5%	100%	100%	100%
Tier 0	0.3%	0.4%	–%	0.5%	–	–	–

Table 5.16.: Results (in percentage) of the tier-ranking for cooking facilities for the different attributes

		Area		Departments			
	Total	Urban	Rural	Nariño	Huila	Put.	Tolima
Convenience *(time spent in stove and fuel acquisition and preparation)*							
Tier 5	214	173	41	74	78	51	11
Tier 4	60	34	26	40	78	14	–
Tier 3	24	13	11	23	6	1	–
Tier 2	10	4	6	10	–	–	–
Tier 0	66	2	64	38	27	–	1
Availability *(fuel availability throughout the year)*							
Tier 5	329	189	140	182	93	42	12
Tier 4	36	30	6	10	4	22	–
Tier 0	19	11	8	–	17	2	–
Affordability *(fuel and stove expenses below 5%)*							
Tier 5	262	177	85	121	77	54	10
Tier 0	111	50	61	64	33	12	2
Quality *(absence of heat variation of fuel)*							
Tier 5	365	222	143	173	114	66	12
Tier 0	12	5	7	12	–	–	–
Safety *(absence of past accidents)*							
Tier 5	374	225	149	182	114	66	12
Tier 0	1	1	–	1	–	–	–

Table 5.17.: Results (number of households) of the tier-ranking for cooking facilities

Convenience Concerning the convenience (an attribute based on the time required for preparing/collecting the fuel and the time needed for cooking), more than 75% of the urban households were assigned to the highest tier, and more than 90% achieved Tier 4 or Tier 5. This result is consistent with the fact that the majority of urban clients has access to gas (LPG or network) for cooking. On the contrary, only about one fourth (28%) of rural households achieved the highest tier ranking, although, as shown in Table 5.15, more than 70% use gas for cooking. The low assignment is due to the time spent in acquisition/collection of LPG in rural areas. Moreover, the majority of rural households (55%) is ranked in Tiers 1 to 3, further highlighting the difference between fuel access in urban and rural areas.

Figure 5.12 provides a more detailed picture of cooking time, fuel preparation time and collection time. It reveals that, while cooking time might be mainly associated with the usage of gas (implying very short time), both in urban and rural areas, the fuel preparation and collection times affects in a greater extent the rural households (whose times are roughly uniformly distributed between 1 and 8 hours per week) than the urban ones (as the majority needs less than 1h/week).

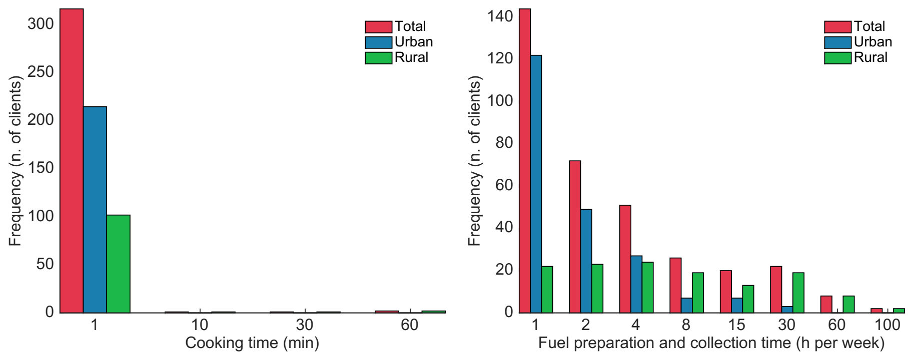


Figure 5.12.: Histogram of convenience data considering cooking time (left) and fuel preparation and collection time (right)

Availability On the one hand, most of the households declared to have fuel available for at least 10 months/year (except from the region of Putumayo with over 35% of affected households and almost 15% of households in Nariño). Rural households seem to be better placed in terms of availability rather than urban households. On the other hand, it is worth noticing that this might be due to the fact that households that are not able to use gas (i.e., not connected to a network), mostly in the rural area, need to adjust their cooking solution to the availability of fuel and of budget.

Affordability The affordability of cooking solutions (considering fuel costs per year, plus the price of the stove adjusted to the usage time) reveals that only 22% of urban households spent more than 5% of their income in cooking fuel, while almost the 42% of rural households exceeded this threshold of their expenses (with a peak of 35% in Nariño, where for the interviewed clients belong mainly to rural area). Compared with the expenses in electricity supply, households' expenses to satisfy their energy needs are dominated by their cooking needs.

Figure 5.13 shows the percentage of clients (on the y-axis) whose expenses for cooking fuel is below a given threshold (x-axis) between 0% and 50% of the monthly income. As for the fuel supply, the rural population seems to be more affected by affordability issues than the urban one (i.e., having, in average, higher expenses). However, unlike in the case of affordability of electricity supply, concerning cooking fuel setting the threshold between lowest and highest tier at 5% allows to differentiate between rural and urban population.

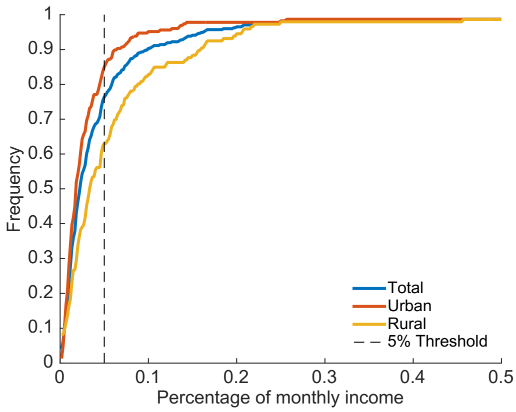


Figure 5.13.: Percentage of clients (y-axis) whose expenses for cooking fuel do not exceed a certain percentage of the monthly income (x-axis)

Quality Most of the households claimed not to be affected by the quality of the cooking fuel. Particularly, only the 3.12% that reported quality issues, and all these used LPG as cooking fuel.

Safety Only two cases of accidents have been reported in Nariño, and the remaining households did not consider that their health or security are at risk due to their cooking solution.

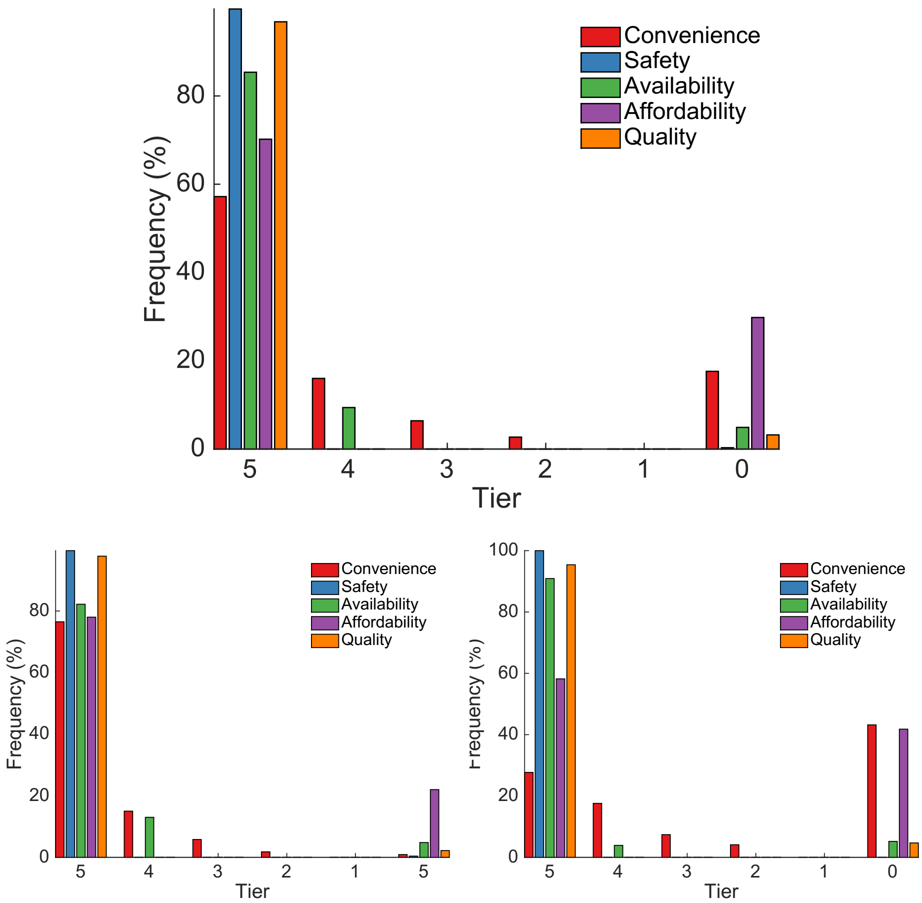


Figure 5.14.: Tier ranking for the different attributes (cooking solutions), considering the total sample (top), the urban area (bottom-left) and the rural area (bottom-right)

Tier Rankings

The tier ranking based on the lowest tier among all attributes is detailed in Table 5.18. Two main conclusions can be drawn from these results. Firstly, the majority of the population is ranked either in the highest or in the lowest tier (about 38% in tier 5 and about 44% in tier 0). This behavior depends on the level of threshold used for the attributes. Secondly, there are large differences between the urban and the rural areas. More than 50% of urban households are ranked in tier 5 and less than 30% in tier 0. On the contrary, less than 20% of rural households reach the highest tier, while about 68% of the households remain in tier 0.

Sensitivity Analysis

This section describes the result of a sensitivity study, in order to analyze the dependence of the final result from single attributes.

	Total	Urban	Rural
Tier 5	37.8%	50.4%	18.8%
Tier 4	13.3%	17.4%	7.1%
Tier 3	3.9%	3.5%	4.6%
Tier 2	1.3%	0.9%	1.9%
Tier 1	–	–	–
Tier 0	43.7%	27.8%	67.5%
Index	51.2	66.8	28.1

Table 5.18.: Results of the (lowest-based) tier-ranking and of the composite index for cooking facilities

Table 5.19 shows the frequency of attributes which were ranked as the "lowest" for each household. Unlike the case of electricity supply, the assessment of access to cooking facilities reveals a dominant role of *convenience* and *affordability*, while the remaining attributes rather determined in a lesser extent the tier assignment of the household. Specifically, since the *affordability* attribute is binary (in the sense that a household can be either in Tier 0 or in Tier 5), the threshold set for this attribute is responsible of placing more than 20% of households in the lowest tier.

		Area	
	Total	Urban	Rural
Convenience	67.4%	65.6%	70.1%
Safety	0.8%	0.4%	1.3%
Affordability	21.6%	21.3%	22.1%
Availabilty	8.3%	11.3%	3.9%
Quality	1.8%	1.3%	2.6%

Table 5.19.: Frequency of attributes ranked as the lowest tier for each household (cooking solutions)

Similar conclusion concerning the tier ranking sensitivity with respect to these two attributes can be drawn from Tables 5.20, 5.21 and 5.22, which show the lowest-based tier ranking obtained leaving out one attribute at a time. The outcome of this sensitivity study is also summarized in Figures 5.15 and 5.16.

Leaving out the *affordability* leaded to a shift of about 20% of households from Tier 0 to Tier 4 and Tier 5, with a greater effect in the urban area. Also the effect of removing the *convenience* attribute was different for urban and rural areas. In the former, it produced a slight shift of households from Tier 4 to Tier 5, while, in the latter, households moved mainly from Tier 0 to Tier 5.

The above conclusions are also reflected in the composite access index, shown in Figure 5.17 for the different cases.

	MTF	Without: –Conv	–Saf	–Ava	–Aff	–Qua
Tier 5	37.8%	57.8%	37.8%	41.7%	49.7%	38.3%
Tier 4	13.3%	7.0%	13.3%	10.4%	17.7%	14.6%
Tier 3	3.9%	–	3.9%	3.9%	6.0%	3.9%
Tier 2	1.3%	–	1.6%	1.3%	2.3%	1.3%
Tier 1	–%	–	–	–	–	–
Tier 0	43.7%	35.2%	27.4%	40.9%	24.2%	41.9%
Index	51.2	63.4	51.3	52.9	68.4	52.8

Table 5.20.: Results of sensitivity study of the tier ranking for cooking solutions (total sample): lowest tier ranking leaving out single attributes, compared with the full MTF ranking

	MTF	Without: –Conv	–Saf	–Ava	–Aff	–Qua
Tier 5	50.4%	61.7%	50.4%	58.7%	63.9%	50.9%
Tier 4	17.4%	10.9%	17.4%	11.7%	21.3%	18.3%
Tier 3	3.5%	–	3.5%	3.5%	5.2%	3.5%
Tier 2	0.9%	–	1.3%	0.9%	1.3%	0.9%
Tier 1	–	–	–	–	–	–
Tier 0	27.8%	27.4%	27.4%	23.9%	8.3%	26.5%
Index	66.8	70.4	67.0	70.5	84.6	69.0

Table 5.21.: Results of sensitivity study of the tier ranking for cooking solutions (urban area): lowest tier ranking leaving out single attributes, compared with the full MTF ranking

	MTF	Without: –Conv	–Saf	–Ava	–Aff	–Qua
Tier 5	18.8%	51.9%	18.8%	18.9%	28.6%	19.5%
Tier 4	7.1%	1.3%	7.1%	8.4%	12.3%	9.1%
Tier 3	4.6%	–	4.6%	4.6%	7.1%	4.6%
Tier 2	1.9%	–	1.9%	1.9%	3.9%	1.9%
Tier 1	–	–	–	–	–	–
Tier 0	67.5%	46.8%	67.5%	66.2%	48.1%	64.9%
Index	28.0	52.9	28.0	29.1	44.3	30.3

Table 5.22.: Results of sensitivity study of the tier ranking for cooking solutions (rural area): lowest tier ranking leaving out single attributes, compared with the full MTF ranking

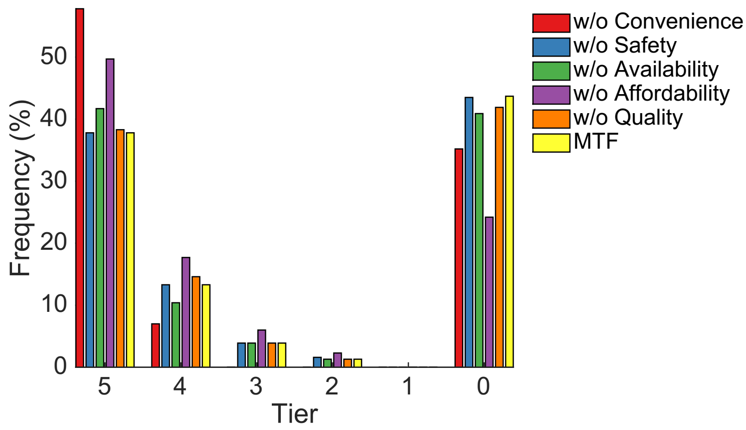


Figure 5.15.: Results of sensitivity study of the tier ranking for cooking solutions: lowest tier ranking leaving out single attributes, compared with the full MTF ranking

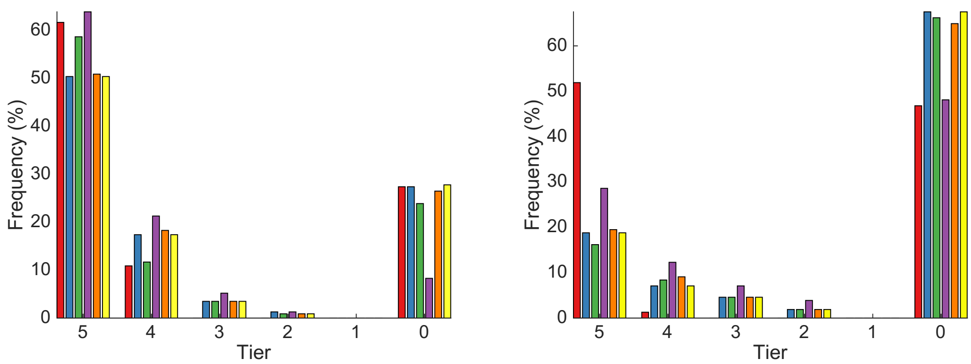


Figure 5.16.: Results of sensitivity study (in urban and rural areas) of the tier ranking for electricity supply: lowest tier ranking leaving out single attributes, compared with the full MTF ranking. Legend as in Figure 5.15.

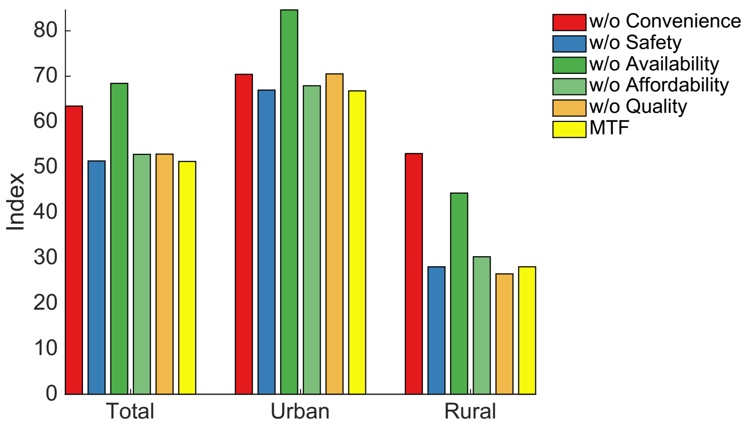


Figure 5.17.: Results of sensitivity study of the tier ranking for cooking solutions: composite multi-tier index computed leaving out single attributes, compared with the full MTF index

5.4. Multi-tier Ranking vs. PPI Data

As a following step, the performance for the different attributes and the tier ranking have been combined with the PPI data of the clients[9].

Electricity Supply The major differences across the sample have been observed for the attributes *capacity*, *reliability* and *duration*. The tier assignments associated to the attribute capacity are correlated to the PPI, as the average PPI scores increases per tier (e.g. 41.4 for Tier 3, 45.9 for Tier 4, 53.5 for Tier 5 (urban: 45.6, 49, 55, and rural: 38.6, 41.6, 46.2, respectively). As mentioned before, since one third of the PPI questionnaire depends on electricity services, the correlation is reflected in to the *capacity*, through the use of appliances. On the contrary, the *reliability* behaves differently; while an increase in the PPI scores also reflected an increase in reliability in urban households (46.7 average of PPI in Tier 4, 55.6 in Tier 5), in rural areas the PPI scores were more uniformly distributed across Tier 4 and Tier 5 (without any household in Tier 0). The correlation in urban area suggested that in households that are better off also have better electricity connection. Concerning the attribute *duration*, the average PPI did not correlate with the tier ranking, excluding the highest score for urban households in Tier 5. This suggests that a decrease in likelihood to fall under the poverty is related to the availability of longer electricity connection. For the remaining attributes, the household are mostly ranked in the highest tier, thus it was not possible to analyze their correlations with the PPI.

Considering the tier assignment according to the electricity supply framework, a relation between attributes and PPI could not be seen. In fact, average PPI scores per tier oscillated (between 41 and 55), as shown in Figure 5.18. However, households assigned in Tier 5 have by far the highest PPI scores. Similar PPI correlation behavior is also observed in urban and rural areas (not shown).

Electricity Consumption and Services The tier rankings of the electricity consumption and services frameworks appeared to be strongly related to the PPI score of the households. Specifically, in both cases a global increase of average PPI scores with the tier assignment was observed (see Figure 5.19–5.20). Moreover, a linear correlation analysis also revealed that the overall electricity expenses, not only consumption, increased with the PPI average scores.

Cooking Solutions Concerning the tier ranking for the cooking solutions, an increase in PPI was observed only between households in Tier 0 (average PPI

[9] Besides the PPI score, the monthly income (from the survey) and the loan of the clients (from the database of Contactar) were also available. However, these three variables result positively correlated, yielding also similar results with respect to the energy access attributed. Between the loan amount and the PPI score, the correlation resulted of 0.20, while between the loan amount and the monthly income of the household the correlation was of 0.15. Hence, in the following analysis, only the results using the latest PPI score (2014) to characterize the financial data will be reported.

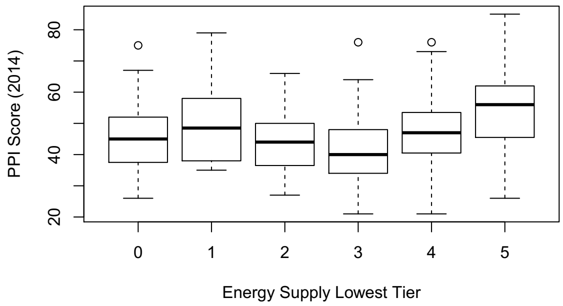


Figure 5.18.: Mean values and standard variations of PPI score *vs.* tier ranking for energy supply

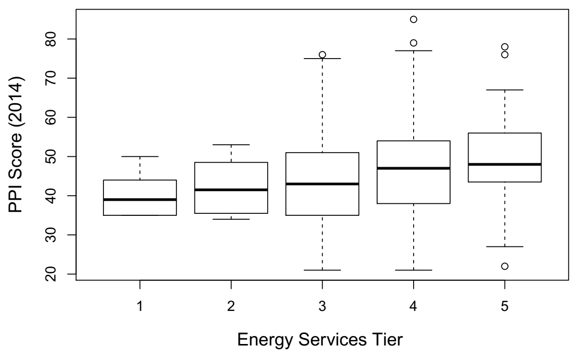


Figure 5.19.: Mean values and standard variations of PPI score *vs.* tier ranking for electricity consumption

slightly above 40) and the remaining tiers (average PPI score between 46.6 and 51), see Figure 5.21.

The detailed analysis of the correlation of PPI scores and tier rankings was limited to the attributes *affordability* and *convenience*, since, for the remaining attributes, the vast majority of households were assigned in Tier 5.

Namely, the average PPI scores increase with the tier assignment in affordability (e.g. Tier 3: 43.1, Tier 5: 47.8). This is valid both for urban and rural areas. However, in the case of *convenience* the average PPI resulted less related to the final tier ranking, suggesting that the fuel collection/preparation time might depend on other aspects (e.g., on the area), rather than on the poverty level (see also Figure 5.12).

Finally, Table 5.23 reports the Spearman correlation coefficients of the different attributes of electricity supply against the PPI score (2014). Results showed that only the *capacity* attribute is significantly correlated to the likelihood of falling below the poverty line. From an analogous analysis, in the case of cooking

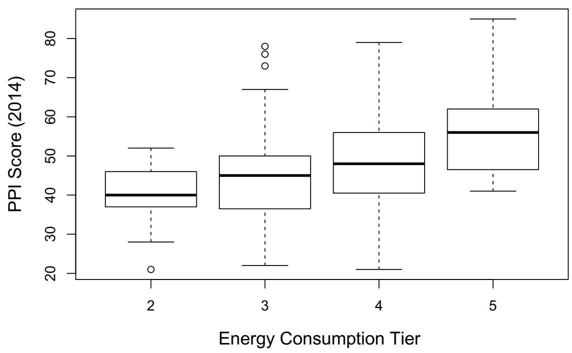


Figure 5.20.: Mean values and standard variations of PPI score *vs.* tier ranking for energy services

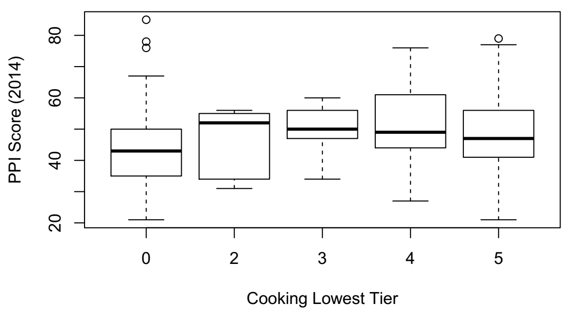


Figure 5.21.: Mean values and standard variations of PPI score *vs.* tier ranking for cooking solutions

Spearman correlation vs. PPI	
Energy Supply (lowest tier)	0.19
Capacity	0.34
Duration	0.15
Reliability	0.13
Quality	0.01
Affordability	0.02
Legality	0.11
Safety	0.04

Table 5.23.: Spearman correlation coefficients of tier ranking (energy supply) and PPI score

solutions (Table 5.24), it was observed that *affordability* and *convenience* are the only attributes correlated to the PPI score. This is in line with the graphs in Figure 5.14, which show that the results for these attributes were better in the urban area than in the rural one.

Spearman correlation vs. PPI

Cooking solutions (lowest tier)	0.20
Convenience	0.28
Safety	-0.08
Affordability	0.18
Quality	-0.12
Availability	0.02

Table 5.24.: Spearman correlation coefficients of tier ranking (cooking solutions) and PPI score

5.5. Summary of the Study

As a conclusion, Figure 5.22 provides the results of the application of the different multi-tier frameworks, comparing electricity supply, electricity services, electricity consumption and cooking solutions.

The outcome of the case study can be summarized as follows:

- The analysis of **electricity supply** showed that the majority of households lies in high tiers (4 or 5) for most of the attributes. However, the *capacity* attribute is dominant as in most cases it determines a lower tier ranking.
- Moreover, the *quality* of electricity supply in rural areas (with 20% of households reporting quality problems) requires intervention on the grid service in order to avoid voltage problems
- Concerning the access to **cooking solutions**, the analysis resulted in a higher number of households ranked in Tier 0, in comparison to the electricity supply assessment. In most cases, this low ranking was due to poor performance in *affordability* of the cooking solution.
- Moreover, rural households were also affected by *convenience* issues (time spent for cooking fuel acquisition and preparation), with more than 40% of the households in Tier 0 revealing a lack of suitable technologies according to fuel availability.
- The access indices showed large differences between urban and rural areas. Particularly, rural households achieved an access index of 38.5 concerning electricity supply (compared to 61.7 of the urban area) and of an index of 28.1 to cooking solutions (compared to 67.8 for the urban area).
- The rankings for electricity supply and cooking solutions showed only a low correlation with the PPI ranking (correlation coefficient of 0.20 in both cases).

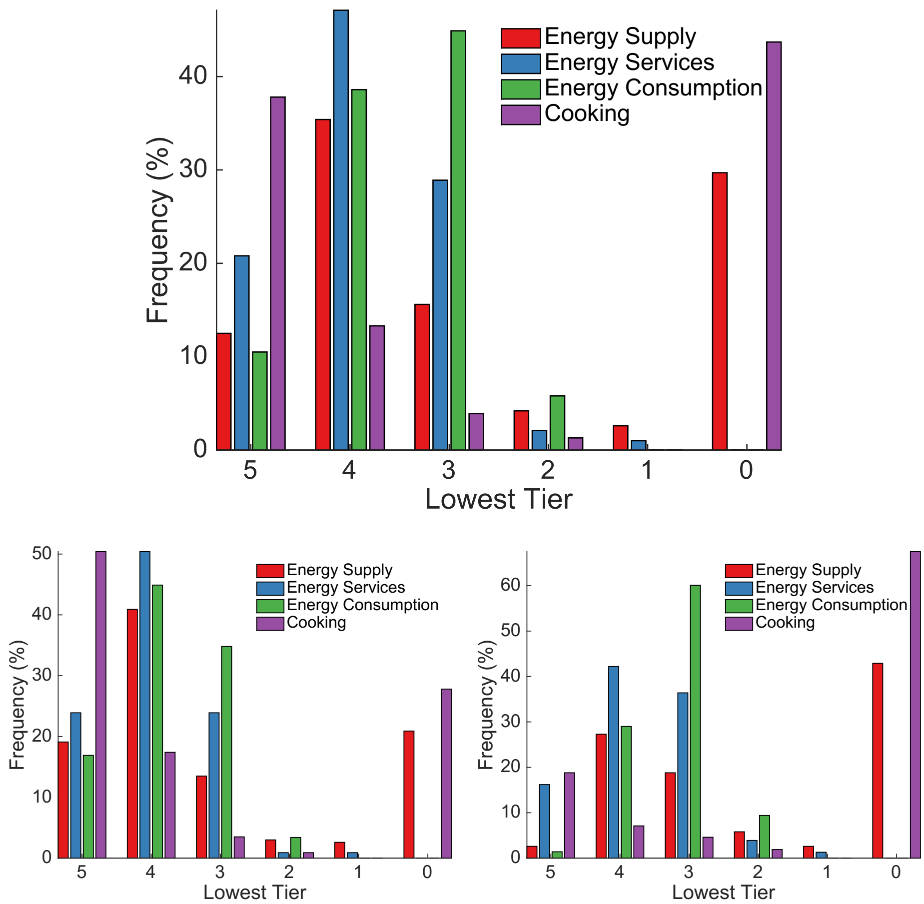


Figure 5.22.: Tier ranking (based on the lowest tier among all attributes) for the different frameworks, considering the total sample (top), the urban area (bottom-left) and the rural area (bottom-right)

6. Development of the PEPI Toolkit[1]

Microfinance institutions, whose primary social mission is the financial inclusion, are rarely aware of the energy needs of their customers. Moreover, since the core of their business lies in providing financial services, so far only a small number of institutions, although steadily increasing [Pierantozzi et al., 2015, Shuite and Forcella, 2015], have exploited their potential to also offer financing for modern energy services to foster energy inclusion [Realpe Carrillo et al., 2015]. These considerations suggest that MFIs, as well as other stakeholders, could benefit from better and more detailed information management tools towards efficiently addressing their triple bottom line (combined social, financial and environmental goals).

According to this view, the objectives of this research is to develop the Progress out of Energy Poverty Index (PEPI), a toolkit targeted to financial institutions and energy service suppliers, in order to support them in improving energy access of the base of the pyramid. Aimed at providing tools to be used initially by the microfinance industry, the presented toolkit seeks to enable MFIs to assess the energy access of their clients, and, at the same time, focuses on practicability for data collection and analysis.

Targeting the assessment of energy access, the PEPI is based on the methodology of the MTF (described in Section 2.6 and used for the case study discussed in Chapter 5), aligning the MTF attributes with the SDG targets. In particular, this is done by focusing on the energy services accessed by the population, considering a different set of attributes and tier thresholds, and, finally, defining specific metrics to measure progress on global attributes of energy access over time at the household level. From a practical point of view, the main qualities of the designed tool and progress metric are that it allows a comprehensive analysis of energy access at the household level, based on a simple and structured survey implementation tool, which supports flexible thresholds of energy attributes, in order to easily adapt the framework to different contexts and to efficiently evaluate the different attributes of energy access. Namely, in order to facilitate data collection within the financial institutions, the PEPI toolkit provides a set of surveys (based on precompiled Excel sheets), to be used by organizations together with their standard data collection processes.

The proposed tool is described in detail in this Chapter. Firstly, Section 6.1

[1] Part of this chapter was published as [Realpe Carrillo, Natalia, 'Development of the Progress out of Energy Poverty Index (PEPI) Toolkit', Technical Report of MicroEnergy International GmbH, 15.06.17].

discusses in detail the design of the PEPI building upon the experience of the MTF, addressing its limitations, proposing some modifications according to the Energy SDG, and introducing the progress measure related to the adapted framework. Next, the practical aspects of the tool are described in detail Section 6.3. Finally, in Section 6.2 the proposed frameworks are applied to the microfinance clients sample of Contactar, comparing the results with the outcome of the MTF (presented in Chapter 5).

6.1. Toolkit Design

6.1.1. Properties and Limitations of the Multi-tier Framework

As presented in Chapter 2, in recent years the discussion on the relevant attributes to describe and assess energy access has considered several overviews. In the search of energy access assessment tools, [Pachauri et al., 2012a] claimed that a fair metric of energy access should be able to capture more than the sole physical access to energy. In particular, they argued that, even among populations with physical access to electricity and modern fuels, the lack of affordability and reliable supplies would considerably limit the extent to which a transition to using these could occur. Similarly, [Nussbaumer et al., 2011] highlighted the relevance of these attributes, claiming the importance of measuring the extent of provision of energy services. However, the index developed in [Nussbaumer et al., 2011] (MEPI, see also Section 2.5) was defined based on the MPI and focused mainly on selected uses of energy. Therefore, limited attention was still devoted to other specific attributes of the provided energy.

The importance of quality, reliability and affordability of the delivered energy, besides monitoring the mere expansion of physical infrastructure or the fuel usage, has been also acknowledged by [Kittelson, 1998, Rehman et al., 2012, Groh et al., 2016], in order to effectively measure access to modern energy. Moreover, in regards to cooking facilities, [Modi et al., 2006] also claimed that one of the main objectives of better energy access is to improve the affordability, the availability and the safety of cooking fuels and practices.

Focusing on the role of clean energy technologies to address energy access, the developments of end user finance as well as the flexibility of payment should be considered when defining the affordability of electricity supply and cooking solutions. In fact, whether framed within green microfinance programs or as a consequence of mobile banking mechanisms, the flexibility of payment influences directly the affordability of end users for the acquisition and the usage of the technology.

The ESMAP MTF [Bhatia and Angelou, 2015] (described in more detail in Section 2.6) represents a first important step to improve traditional measurement approaches. By focusing on the different dimensions of energy, rather than only on the binary assessment of access, the main novelty of MTF lies in the assessment of energy access from the perspective of multiple attributes for all required energy applications across households, productive enterprises and community institutions.

However, in a preliminary step, its limitations should be cross-examined. As observed by [Groh et al., 2016], as there is no consensus on the amount of energy needed to meet human needs, the tiered-spectrum from the MTF highlights a preliminary point of debate. On the one hand, what is the optimal level of energy measured at the useful level from an end-user perspective that facilitates human development? On the other hand, how can these levels be translated into different tiers to be achieved on average? Given that needs vary significantly among countries and regions, social customs, weather and other specific region- and society-specific factors, a set of minimum basic energy needs is not yet accepted [Pachauri et al., 2004].

Upon the implementation of this methodology in Bangladesh (considering about 200 households), [Groh et al., 2016] critically assessed the MTF, stressing the relevance of using appropriate metrics to effectively track universal energy access objectives, and suggesting possible ways forward and improvements to the multi-tier approach. Their analysis reveals a clear trade-off between capturing the multidimensionality of energy access and defining an easy-to-use global framework. Despite the adoption of certain suggestions in the latest version (see [Bhatia and Angelou, 2015]), the assessment is still focused on the supply rather than addressing the "on-demand" side. Specifically, focusing on the meaningfulness of existing measurements to end users, [Groh et al., 2016] highlight the importance of "putting the services at the core of the metric" when defining an energy poverty measure. That aside, rather limited attention has been given to the quality, reliability and affordability of energy services. Furthermore, by defining the tiers based on specific combinations of attributes, [Groh et al., 2016] observed that the approach is prone to errors due to its complexity and the limitations of fixed thresholds and dichotomous attributes. In particular, as quality deficiencies might vary along a specific attribute, providing further scales of deprivation would increase the transparency of the energy access assessment. For instance, the goal of the tier ranking is to measure the ability of the energy supply to cater to specific energy applications. Notwithstanding, the tier ranking for electricity services and electricity consumption have separated frameworks of electricity supply [Bhatia and Angelou, 2015]. Therefore, their inter-relationship is not directly reflected, but the tiers are assigned independently of the performed quality of the electricity supply and the electricity services provided.

One of the outcomes of the MTF is the set of energy access indices (for the different frameworks), defined for a set of households (e.g., for a geographical area), which can be calculated as a weighted average of the tier ranking results in the different frameworks (e.g., households, productive uses and community facilities) [Bhatia and Angelou, 2015]. While these composite indices allow for the combination of multiple data in order to identify specific deficiencies of the energy supply, as also discussed by [Bhatia and Angelou, 2015], whether the proposed index provides an effective measure for assessing the impact of energy access programs is still an open question. Namely, as the weights are associated with the proportion of households ranked in the given tiers, the final indices might be biased by the concentration of the population in a specific (low) tier rather than providing a global picture of relevant attributes. Moreover, since the final tier-ranking, on which the indices are based on, depends only on the lowest tier from the assessed attributes, the performances might result to be very sensitive to a particular attribute while not tracking the improvements in the overall picture, thus yielding to an incorrect interpretation. A further limitation of the MTF access index consists in the fact that, by definition, it reflects the overall access of a whole population (the total sample considered for the survey implementation), and it does not allow to track changes at the household, micro-enterprise or installation level according to the tier-ranking of each attribute.

In conclusion, aiming at a multi-tier measurement of energy access able to support governments in setting and monitoring targets, both the condensed metric, obtained by applying the lowest tier among the attributes, and the composite index, depending on the average performance of the population, might not show where improvements have been achieved (e.g., in the case that the lowest tier remained constant, but some of the other attributes improved), possibly yielding biased conclusions and misleading decision-making processes.

6.1.2. The Development Agenda

The SDG 7, which dictates "ensure *affordable* and *reliable* energy access by 2030", recognizes not only the crucial role of energy access for development but also the importance of the quality of delivered energy. Specifically, this development goal is subdivided in three sub-targets:

- SDG 7.1: Ensure universal access to affordable, reliable and modern energy services
- SDG 7.2: Increase substantially the share of renewable energy in the global energy mix
- SDG 7.3: Double the global rate of improvement in energy efficiency

In order to achieve a significant change, it is important to be able to track the progresses towards the goal of this SDG, by setting clear milestones, defining specific indicators and aligning definitions and methodologies in the involved sectors.

However, several methods for measuring energy access significantly underestimate the scale of the challenge [Global Tracking Framework (GTF), 2015], and the need for a robust set of measurement tools to set common goals is claimed by different stakeholders, from academics to donors and practitioners.

A first effort to adopt the MTF to the SDG targets was conducted by [Stevens et al., 2015]. The authors adopted the original indicators and attributes defined by the MTF, proposing a methodology to assess progress towards the SDG 7 sub-targets:

- percentage of population with access to electricity of at least MTF Tier 3 (Target 7.1);

- percentage of population with access to clean and efficient cooking fuels and technology of at least MTF Tier 4 (Target 7.1);
- renewable energy share in the total energy final energy consumption (Target 7.2).

Furthermore, [Stevens et al., 2015] suggested that an indicator for the sub-target 7.1 should at least include a measure of the safety of energy access, in order to avoid potential conflicts with the overall Energy SDG or with other climate and health-related SDGs and targets. The importance of the attribute *safety*, especially when considering the assessment of energy access in rural areas through MES, was also acknowledged by [Groh et al., 2016], who, however, observed that the *safety* of energy access within the MTF is rather vaguely defined.

6.1.3. From the ESMAP to the PEPI Framework

Since its pioneer publication [Global Tracking Framework (GTF), 2013], the MTF has achieved a broad acknowledgement, yielding several improvements, which recognize energy access enhancing processes. As such, given the level of detail of the approach, future metrics aiming at tracking energy access should support its adoption and strive the harmonization of all decisions on the choices of sub-indicators and modifications [Bensch, 2014].

Considering the multidimensional nature of energy poverty, despite the trade-offs, implies that assessment tools must achieve a balance between methodological sophistication and theoretical accuracy, as well as between applicability and transparency [Bazilian et al., 2010]. Additionally, from an energy poverty metric, it is expected that the tools will combine political attractiveness and usefulness for policy design, as well as match practical data availability [Nussbaumer et al., 2011]. The scope of the PEPI is, therefore, to provide a framework for rating energy access quality against tiers of performance for the series of attributes, building upon the MTF and considering the indicators proposed from [Stevens et al., 2015] together with the observations and recommendations from [Groh et al., 2016].

To this end, the PEPI frameworks for electricity supply considers the following MTF attributes: capacity (based on power use), quality (based on efficiency of the supplied energy), duration, reliability, affordability, legality, health and safety. Besides which, seeking to enable stakeholders to assess the household's access to cooking facilities without the need of laboratory values (i.e., in the absence of the appropriate tools for smoke measurement), the PEPI framework for cooking solutions only takes into account the following previous attributes from the MTF: *convenience*, *availability*, *affordability* and *safety*, including a separate *health* attribute. However, in order to better align the metric to the Energy SDG target, the methodology groups these attributes in wider categories, that will be called *global attributes*: The framework is constructed measuring specifically the indicators assigned for each sub-target and global measurements of three groups of the MTF attributes.

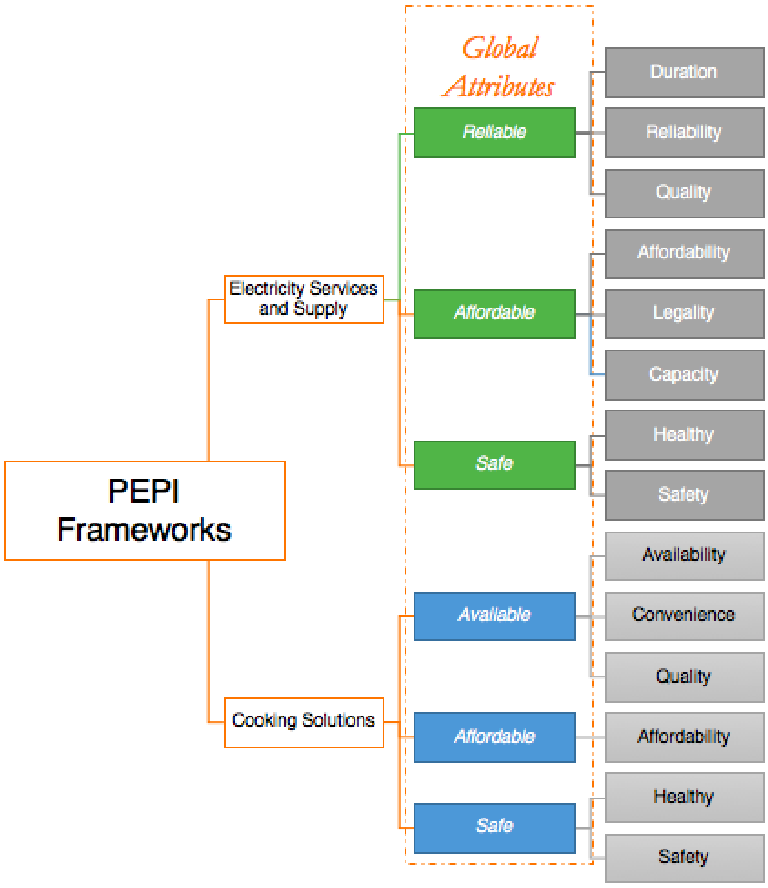


Figure 6.1.: Sketch of the PEPI Frameworks and Attributes

- **Reliability**, **Affordability,** and **Safety**, for electricity supply and services
- **Availability**, **Safety** and **Affordability**, for cooking facilities.

Figure 6.1 sketches the considered frameworks, while the subdivisions for energy supply and cooking are detailed in Tables 6.1 and 6.2, respectively, showing the selected attributes aggregated into the three main global attributes and indicating the corresponding information to be collected in each matrix.

	Electricity Services & Supply		
(Global) Attributes	Affordable	Reliable	Safe
	SDG explicit goal		*Suggestion* [Stevens et al., 2015]
MTF attributes [Bensch, 2014]	• Capacity • Affordability • Legality	• Duration • Reliability • Quality	• Health • Safety
Corresponding indicators	• Services • Electricity expenses • Payment, frequency and income	• Electricity hours • Unpredictable interruptions • Voltage fluctuations	• Electricity source • Accidents • Risks

Table 6.1.: PEPI Methodology: aggregation of the MTF attributes (electricity supply and electricity services) to adapt the framework to the Energy SDG

	Cooking facilities		
(Global) Attributes	Affordable	Available	Safe
	SDG explicit goal		*Suggestion* [Stevens et al., 2015]
Indicators	• Initial investment • Monthly fuel expenses • Maintenance costs	• Fuel Availability • Fuel quality • Fuel and stove convenience	• Health • Safety

Table 6.2.: PEPI Methodology: aggregation of the MTF attributes (cooking solutions) to adapt the framework to the Energy SDG

As envisioned, an unbiased picture of the state of play in regard to energy access for analysts and policy makers [Bensch, 2013], can be provided by a hybrid approach from the dashboard of the independent indicators integrated in the PEPI following the MTF. Hence, by defining the measured dimensions according to the SDG dictated goal, policy design can address targets in each axis and track actions and achievements.

Moreover, a series of modifications of the original frameworks (see Tables 2.4 and 2.6) have been added to the PEPI matrices in order to provide a deeper visualization of the quality of energy access, incorporating several suggestions from [Groh et al., 2016]. Electricity services have been kept in the same tier-ranking (based on the "usual" power demanded by the electrical appliance, see Table 6.3 and [Bhatia and Angelou, 2015]). However, the services are assessed within the same electricity supply framework, instead of defining a separate framework.

	Output services	**ESMAP Service classification**
Tier 5	Cooling/heating spaces; very high-power mechanical loads; electric cooking	Very high-power services
Tier 4	Heating; high-power mechanical loads;	High-power services (microwave, hair dryer, toaster, iron)
Tier 3	Refrigeration; Medium-power mechanical loads	Medium-power services (fridge, freezer, washing machine, mixer, rice cooker, water pump)
Tier 2	Entertainment; Information; Cooling	Low-power services (TV, PC, printer, ventilator)
Tier 1	Illumination; Communication	Very-low power services (light bulbs, phone charger, radio)
Tier 0	None	None of the above

Table 6.3.: Thresholds of tier-ranking standards for electricity services considered in the PEPI frameworks

Similarly, the PEPI does not contain a separate electricity consumption framework. The motivation behind this choice is to constrain the assessment of energy access within the quality of services that the household is able to use (and how the household makes use of them). In fact, according to [Groh et al., 2016], the inputs to measure the capacity attribute undermine efficiency goals, since the real service output is not measured. This is the case, for instance, in efficient lighting: while a higher consumption might lead the household to higher tiers, luminosity is rather lower than in traditional lighting.

At the level of single attributes, within the PEPI the *capacity* is measured as a function of the household usage of electricity services, while the *availability* of energy is no longer a dichotomy (either Tier 0 or Tier 5), but is described by multiple tiers, in order to provide a more accurate picture for the evaluation of off-grid solar applications, as suggested by [Groh et al., 2016]. A

Electricity Supply and Services

SDG Attributes	Associated Attributes			Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Reliable	Reliability	Outages	Max no. of outages per week			*28*	*21*	14	3
		Duration of outages	Max. duration of outages (min)			*299*	*239*	*179*	119
	Duration	Day	Min. duration of power supply (hours)		4	4	8	16	23
		Night	Min. duration of power supply (hours)		1	2	3	4	4
	Quality	*Damages*	*Damaged appliances or risk of damages*				*TRUE - risk*	FALSE	FALSE
Affordable	Affordability	%	Max. % of income for electricity consumption				*10%*	5%	*2%*
	Capacity	*Appliances*	Service output of categorised appliances		Task lighting, Phone charging	Lighting, TV, (Fan)	any medium-power app	any high-power app	any very high-power app
	Legality	Connection	Illegal connection				*TRUE - paying for services*	FALSE	FALSE
Safe	*Health*	*Affected health*	*Health hazards due to energy source*						*FALSE*
	Safety	Accidents or risks	Accidents or risks of injuries due to power supply		Accidents	High risk	Low risk	No accidents	No accidents

Table 6.4.: PEPI Multi-tier Matrix: Thresholds of attributes and tier-ranking standards for *Electricity Supply and Services* at household level

Cooking Facilities

SDG Attributes	**Associated Attributes**			**Tier 0**	**Tier 1**	**Tier 2**	**Tier 3**	**Tier 4**	**Tier 5**
Available	Convenience	Stove preparation time	Max. minutes to prepare stove for a meal			7	3	1,5	0,5
		Fuel acquisition and preparation time	Max. hours per week to acquire and prepare fuel			15	10	5	2
	Availability	Availability of primary fuel	% of fuel availability throughout the year				*50%*	80%	100%
	Quality	Quality of primary fuel	Variation of fuel quality for cooking					No	No
Affordable	Affordability	Fuel and stove costs	Max. % of income spent for stove and fuel				*20%*	5%	5%
Safe	*Health*	*Affected health*	*Health hazards due to fuel inhalation*					*FALSE*	*FALSE*
		Ventilation	*Absence of chimney - extraction of smoke*					*FALSE*	*FALSE*
	Safety	*Cooking area (for traditional fuels)*	*Cooking place same as of sleeping area*					*FALSE*	*FALSE*
		Accidents or risks	Accidents or risks of injuries due to cooking fuel or stove				FALSE	FALSE	FALSE

Table 6.5.: PEPI Multi-tier Matrix: Thresholds of attributes and tier-ranking standards for *Cooking Facilities* at household level

further modification, with respect to the MTF, is that the attributes *reliability* and *legality* have been expanded to include further indicators, in order to enable better tracking of the improvements of interventions. Furthermore, the attributes *health* and *safety* are evaluated using different indicators, although they are eventually kept under the same umbrella of the *safety* global attribute. In particular, the global attribute considers health hazards, pains and diseases that might be caused by the electricity power supply or fuel.

In the case of the attributes for describing access to cooking solutions, the indicators describing the *health* and *safety* attributes have been expanded to take into account the level of ventilation, the conditions of the cooking area and the level of hazards the household is exposed to due to the cooking fuel or to the stove.

6.1.4. Measuring the Progress

The tier rankings corresponding to the global attributes provide a first *one-shot* assessment of the energy access level. As a further step, the PEPI aims at becoming a methodology for long-term evaluation of energy access progresses at the household level. To this end, the goal of the PEPI is to be integrated within the standard survey tools of MFIs used to characterize their clients, thus allowing for multiple data-collections of the same households.

Namely, in order to quantify the (multidimensional) improvement of energy access at the household level, instead of calculating a composite index based on a one-shot evaluation (as is the case for the MFT access indices), we propose a methodology for defining the Progress out of Energy Poverty Index (PEPI), which consists in a composite metric for the variation of tier-ranking (positive or negative) over time.

Therefore, it is important to separately assess the attributes related to different SDG targets, in order to better track the improvements over time along the different dimensions. Specifically, a separate progress indicator is defined for the (SDG) global attributes in each framework (electricity supply and services, cooking solutions). The final hybrid index is then calculated as the arithmetic mean of the values of the indicators.

In order to formally introduce the Index, the three global attributes for electricity supply and services will be denoted with $\mathcal{S}_i,\ i = \mathrm{R}, \mathrm{A}, \mathrm{S}$ (reliability, affordability, safety, respectively) while $\mathcal{C}_i,\ i = \mathrm{Af}, \mathrm{Av}, \mathrm{S}$ stand for the three global attributes describing cooking solutions (affordability, availability, safety, respectively). Moreover, for each global attribute, let us denote with $\mathcal{S}_{i,j}$ or $\mathcal{C}_{i,j}$ the tiers of specific dimensions (with $j = 1, 2$ or $j = 1, 2, 3$ depending on the sub-attribute). For instance, $S_{\mathrm{A},3}$ will denote the tier of the legality of electricity supply (third dimension of the affordability global attribute).

Next, it is assumed to have available two different data collections at two different times, denoted by $\mathcal{S}^1_{i,j}, \mathcal{C}^1_{i,j}$ and $\mathcal{S}^2_{i,j}, \mathcal{C}^2_{i,j}$.

The progress is quantified assigning weights $\Delta(\mathcal{S}_{i,j})$ and $\Delta(\mathcal{C}_{i,j})$ depending on the (positive or negative) tier variation within each specific category of the three global attributes. These weights vary from -1 (the worst case, i.e., when a household moved back from Tier 4 or 5 to Tier 1 or 0) to 1 (best case, denoting a considerable improvement, e.g., from Tier 0 or 1 to 4 or 5). The values of the weights are detailed in Table 6.6 (see also Section 6.1.5 for more details), depending on the tier variation from the first to the second evaluation.

First evaluation	Second evaluation					
	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Tier 0	**0**	**0.2**	**0.6**	**0.8**	**1**	**1**
Tier 1	**0**	**0**	**0.3**	**0.8**	**1**	**1**
Tier 2	**-0.2**	**-0.2**	**0.2**	**0.6**	**1**	**1**
Tier 3	**-0.6**	**-0.6**	**-0.4**	**0.6**	**0.9**	**1**
Tier 4	**-1**	**-1**	**-0.6**	**-0.2**	**0.8**	**1**
Tier 5	**-1**	**-1**	**-0.8**	**-0.4**	**-0.2**	**1**

Table 6.6.: Matrix of values for measuring the progress in terms of tier variation

Finally, for each framework (electricity supply and services, cooking facilities) the two-dimensional PEPI is obtained by averaging, for each global attribute, the progresses of the different categories. Particularly,

$$\text{PEPI}_{\text{supply}} = \begin{pmatrix} \dfrac{\Delta(\mathcal{S}_{\text{R},1}) + \Delta(\mathcal{S}_{\text{R},2}) + \Delta(\mathcal{S}_{\text{R},3})}{3} \\ \dfrac{\Delta(\mathcal{S}_{\text{A},1}) + \Delta(\mathcal{S}_{\text{A},2}) + \Delta(\mathcal{S}_{\text{A},3})}{3} \\ \dfrac{\Delta(\mathcal{S}_{\text{S},1}) + \Delta(\mathcal{S}_{\text{S},2})}{2} \end{pmatrix} \tag{6.1}$$

and

$$\text{PEPI}_{\text{cooking}} = \begin{pmatrix} \dfrac{\Delta(\mathcal{C}_{\text{Av},1}) + \Delta(\mathcal{C}_{\text{Av},2}) + \Delta(\mathcal{C}_{\text{Av},3})}{3} \\ \dfrac{\Delta(\mathcal{C}_{\text{Af},1}) + \Delta(\mathcal{C}_{\text{Af},2}) + \Delta(\mathcal{C}_{\text{Af},3})}{3} \\ \dfrac{\Delta(\mathcal{C}_{\text{S},1}) + \Delta(\mathcal{C}_{\text{S},2})}{2} \end{pmatrix} . \tag{6.2}$$

6.1.5. Computation of the Progress Matrix

The coefficients displayed in Table 6.6, measuring the *progress* from t_1 to t_2, have been computed according to the following considerations.

As in the previous Section, let us denote with t_1 and t_2 the tier rankings obtained in two different evaluations for a particular attribute.

- If $t_1 < t_2$, it is assumed that the (positive) value of the coefficient depends on the difference $t_1 - t_2$, taking the value 0 if $t_1 = t_2$ and approaching 1 if $t_1 = 5$ (maximum tier). Moreover, increasing the value of t_1 (i.e., if the starting tier is higher), the function measuring progress must approach value 1 at a faster rate. In detail, the following function is considered (if

$t_2 > t_1$)

$$f_+(t_1,t_2) = 1 - \mathrm{e}^{-\left(\frac{1+t_1^2}{5}\right)(t_2-t_1)^2} . \quad (6.3)$$

The profiles of $f(t_1,t_2)$, for different t_1 are depicted in Figure 6.2.

- If $t_1 = t_2$ (no progress), the progress coefficient still takes a positive value if the initial tier is higher than 2. This is needed in order to avoid biasing the final results when households remain in high tiers (e.g., 3, 4 or 5) in both evaluations, thus giving a positive value based on the ability of a household to maintain its energy access conditions. Specifically, remaining in Tier 0 or in Tier 1 will be evaluated with zero, while, for $t_1 > 1$ the following function is used:

$$f_0(t_1) = 1 - \mathrm{e}^{-\frac{(t_1-1)^2}{5}} . \quad (6.4)$$

As observed above, (6.4) can be interpreted as the *value*, in terms of progress, of remaining in tier t_1.

- In the case of a negative variation ($t_1 > t_2$) the coefficient is computed as the difference between the values of $f_0(t_2)$ and $f_0(t_1)$.

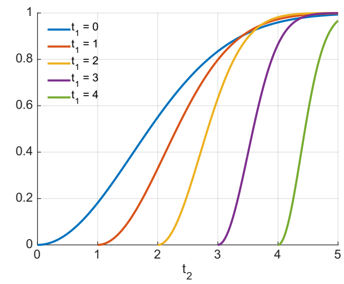


Figure 6.2.: Profile of the $f(t_1,t_2)$ (6.3) for different values of t_1 (initial tier), depending on t_2 (final tier)

In summary, Table 6.6 has been obtained via the following rules:

$$f(t_1,t_2) = \begin{cases} 1 - \mathrm{e}^{-\left(\frac{1+t_1^2}{5}\right)(t_2-t_1)^2} & t_1 < t_2 \\ 1 - \mathrm{e}^{-\frac{(t_1-1)^2}{5}} & t_1 = t_2,\ t_1 > 1 \\ 0 & t_1 = t_2 = 0,1 \\ \mathrm{e}^{-\frac{(t_1-1)^2}{5}} - \mathrm{e}^{-\frac{(t_2-1)^2}{5}} & t_1 > t_2, t_2 > 0 \\ \mathrm{e}^{-\frac{(t_1-1)^2}{5}} - 1 & t_1 > t_2, t_2 \leq 1 \end{cases} \quad (6.5)$$

rounding the outcome to the first decimal digit.

6.1.6. Summary: Properties of the PEPI framework

The main properties of the proposed framework and progress measure tool can be summarized as follows:

- The PEPI allows the improvements across different attributes to be followed and for the variations between the fulfilment of attributes to be better characterized. This is the result of considering the new classifications in two different frameworks and of monitoring the progress via the indices (6.1) and (6.2) at the household level (instead of considering only the lowest tier among all attributes).
- The measure of the improvement depends less on the particular definitions (thresholds) of the different tiers, than the *static* tier-ranking based on the lowest tier. The attribute variations are renormalized by the tier-ranking and by the progress matrix, making the PEPI less sensitive to modifications of the thresholds underlying the tier definitions.
- By considering different thresholds (e.g., varying thresholds at regional level, depending on climatic conditions or cultural traditions), the PEPI can be used to compare and monitor progress in different areas.
- Therefore, the dashboard of indicators provides analysts with critical perspectives on where improvements should be made, measuring whether policies and interventions have achieved their goals and recovered those pitfalls of quality access at household level.

6.2. PEPI Framework Assessments

The methodology of the PEPI described in Section 6.1 has been applied to the sample of microfinance clients considered in Chapter 5, evaluating the global attributes for electricity supply and services and cooking solutions. The calculation has also included the proposed modifications of the frameworks (reported in blue in Tables 6.4 and 6.5) and, for each global attribute, the lowest tier among the individual indicators entailing each group has been selected. The following sections are dedicated to the results for the individual attributes of the PEPI frameworks. In particular, Tables 6.7–6.9 and Figure 6.5 report the detailed tier ranking of the sample.

6.2.1. Electricity Access at the Household Level

The attribute *duration* is kept with its original thresholds providing the same results. By expanding the categories describing the remaining attributes, results demonstrate a broader allocation of tier assignment. This is the case of *reliability* and *quality*; in the former, by extending the range of number of outages per week and their duration, the sample was further classified in inferior tiers as tier 3. In the latter, households, whose electricity supply faced voltage fluctuations throughout the year were allocated to tier 3 and those with risk and damages to tier 2. Furthermore, according to the *affordability* of the electricity supply, while previously most of the population was found to be in tier 4 or 5, the graph 5.13, depicted in chapter 5, shows the distribution of the affordability, suggesting an increasing variability below and above the 5% threshold. The same can be seen in the assignments of the tier-ranking varying from tier 5 to tier 2. In regards to the *capacity* of the electricity supply it is estimated based on the electricity services the household makes use of, rather than on its consumption or daily capacity. The sample is more condensed in tiers 4 and 3. Considering that the whole population was connected to the grid, the energy source did not cause any health hazard and the *safety* attribute kept its values from the MTF [Bhatia and Angelou, 2015] tier ranking results.

The rankings for the single attributes are provided in Table 6.7, while Figure 6.3 shows the lowest-based ranking, comparing the results with the energy supply ranking of the MTF (see Chapter 5). The lowest results are obtained for the *affordability*, with the majority of households ranked in tiers 3 and 5. Comparing with Table 6.7, the low rankings is shown to depend mainly on capacity (lack of services). The *reliability* is mainly a concern for rural households (majority of households below tier 3), with 10% of households reporting a short duration of the supply and about 30% affected by unpredictable interruption and quality issues. Finally, almost all households achieved tier 5 in regards to the attribute *safety*.

Further conclusions can be drawn comparing the results with the ESMAP MTF ranking (see Figure 6.3). While the ESMAP MTF lowest-based ranking identified about 30% of households lacking sufficient energy supply (40% in the rural area), it is worth noticing that considering the attributes separately yields a clearer picture of the missing services, in particular, in terms of low reliability in the rural areas.

Sensitivity Study and Relation with PPI

As in the previous chapter, the last part of the framework assessment focuses on a sensitivity study, computing the tier ranking and leaving out single attributes. Notice that *safety* has not been considered as almost all households achieved the highest ranking in both sub-attributes (see Table 6.7). The results, shown in Figure 6.4, confirm that the ranking is most sensitive to *capacity*. Namely, leaving out this attribute yields a shift of households from tiers 3 and 4 to 5, in both urban and rural areas. With respect to the global attribute of Reliability, the sub-attributes *reliability* and *quality* appear to be the most important. Particularly, leaving out *quality* increases of about 10% the households in tier 5.

Finally, Table 6.8 provides the Spearman correlation coefficients for the three tier rankings (Affordability, Reliability, Safety) with respect to the PPI data, showing that the PEPI attributes are not strongly correlated with the PPI score. Specifically, while *capacity* shows the highest correlation (0.2, in line with the results obtained for the ESMAP MTF), the attribute *quality*, which resulted to be very important in the reliability ranking, seems to be uncorrelated with the poverty index.

		Area		Departments			
	Total	Urban	Rural	Nariño	Huila	Putumayo	Tolima
Reliable							
Reliability *(short unpredictable interruptions)*							
Tier 5	65.6%	72.6%	55.2%	51.0%	81.6%	80.3%	66.7%
Tier 4	6.5%	7.3%	5.2%	6.3%	2.6%	15.2%	–
Tier 3	5.7%	5.7%	5.8%	7.8%	2.6%	4.6%	8.3%
Tier 1	22.1%	14.3%	33.8%	34.9%	13.2%	–	25%
Duration *(including day and night electricity supply duration)*							
Tier 5	68.0%	75.2%	57.1%	54.2%	84.2%	78.8%	75.0%
Tier 4	11.2%	7.8%	16.2%	14.6%	10.5%	–	25.0%
Tier 3	5.2%	4.3%	6.5%	7.3%	0.9	7.6%	–
Tier 2	5.5%	4.3%	7.1%	7.8%	1.8	6.1%	–
Tier 1	3.6%	4.3%	2.6%	4.7%	–	7.6%	–
Tier 0	6.5%	3.9%	10.4%	11.5%	2.6%		–
Quality *(damages or risks due to voltage fluctuations)*							
Tier 5	70.3%	76.5%	61.0%	59.4%	83.3%	81.8%	58.3%
Tier 3	10.4%	9.6%	11.7%	10.4%	9.6%	6.1%	–
Tier 2	19.3%	13.9%	27.3%	30.2%	7.0%	12.1%	41.7%
Affordable							
Affordability *(electricity expenses below defined thresholds of HH income)*							
Tier 5	82.0%	86.9%	74.6%	78.1%	81.2%	93.1%	100%
Tier 4	11.6%	8.2%	16.7%	15.6%	9.4%	3.5%	–
Tier 3	4.6%	2.9%	7.2%	4.7%	8.2%	–	–
Tier 2	1.7%	1.9 %	1.5%	1.6%	1.2%	3.5%	–
Capacity *(enabled services)*							
Tier 5	19.8%	23.9%	13.6%	28.1%	1.7%	30.3%	–
Tier 4	42.7%	46.5%	37.0%	30.7%	64.9%	36.4%	58.3%
Tier 3	33.6%	27.4%	42.8%	36.5%	28.9%	33.3%	33.3%
Tier 2	2.1%	1.3%	3.2%	2.1%	2.6%	–	8.3%
Tier 1	1.3%	0.8%	1.9%	2.6%	–	–	–
Tier 0	0.5%	–	1.2%	–	1.7%	–	–
Legality *(legal connection and costs)*							
Tier 5	99.2 %	100 %	98.1 %	100%	97.4%	100%	100%
Tier 3	0.8%	–	1.9%	–	2.6%	–	–
Safe							
Health *(absence of diseases or health hazards)*							
Tier 5	100%	100%	100%	100%	100%	100%	100%
Safety *(absence of accidents or risks)*							
Tier 5	99.2%	100%	98.0%	100%	97.4%	100%	100%
Tier 3	0.8%	–	2.0%	–	2.6%	–	–

Table 6.7.: PEPI Framework: Results of the tier ranking for electricity supply

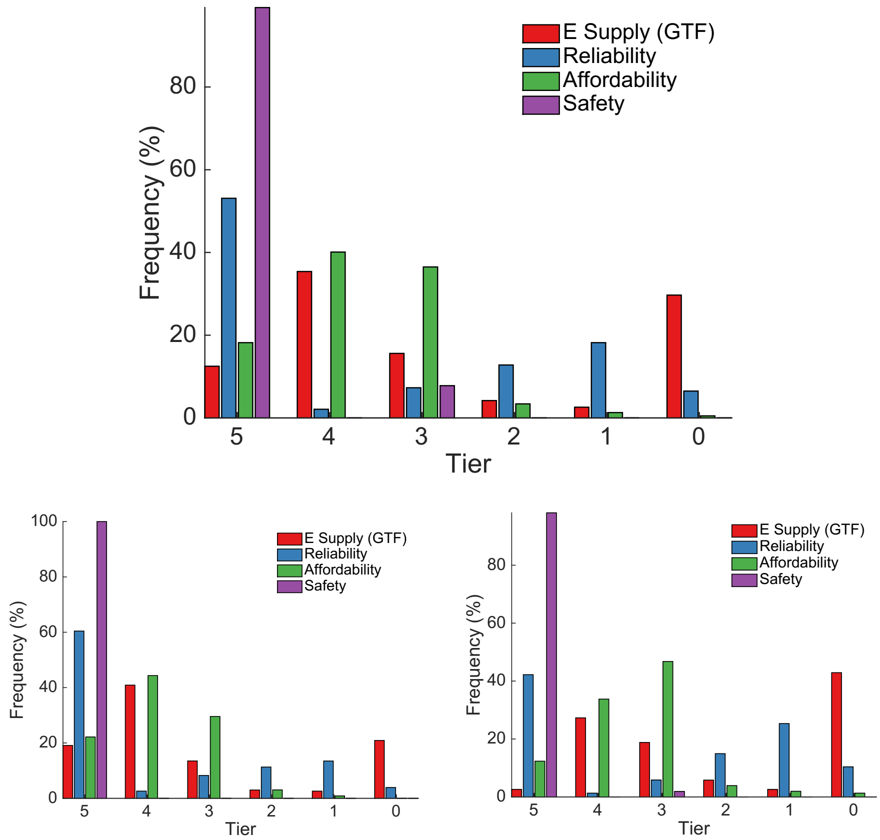


Figure 6.3.: Comparison of the results of the ESMAP MTF tier ranking and of the PEPI Frameworks tier ranking for the total sample (top) and for urban (bottom left) and rural (bottom right) areas

6.2.2. Access to Cooking Facilities

Through the PEPI frameworks, the original attributes *convenience* and *quality* were kept with the original thresholds provided by the ESMAP MTF. The attributes *availability* and *affordability* were expanded in further thresholds for tier 3. The results displayed in Table 6.9 show minimal portions of the sample assigned in the lowest tiers, though still providing a clearer view of the conditions of fuel access and affordability of the households. Considering that the framework has excluded those attributes to be assessed by a third party (laboratory), the attribute *safety* has been modified including an indicator of the cooking place and its ventilation. Both of these can provide a picture of the health hazards that might attempt to affect the household when using traditional stoves, in addition to the risks or accidents the household has had related to the cooking fuel or stove. As observed in 6.9, around 20% of the households have poor ventilation, though are better off in terms of safety; marginal portions cook inside the sleeping area and almost none have had any accident.

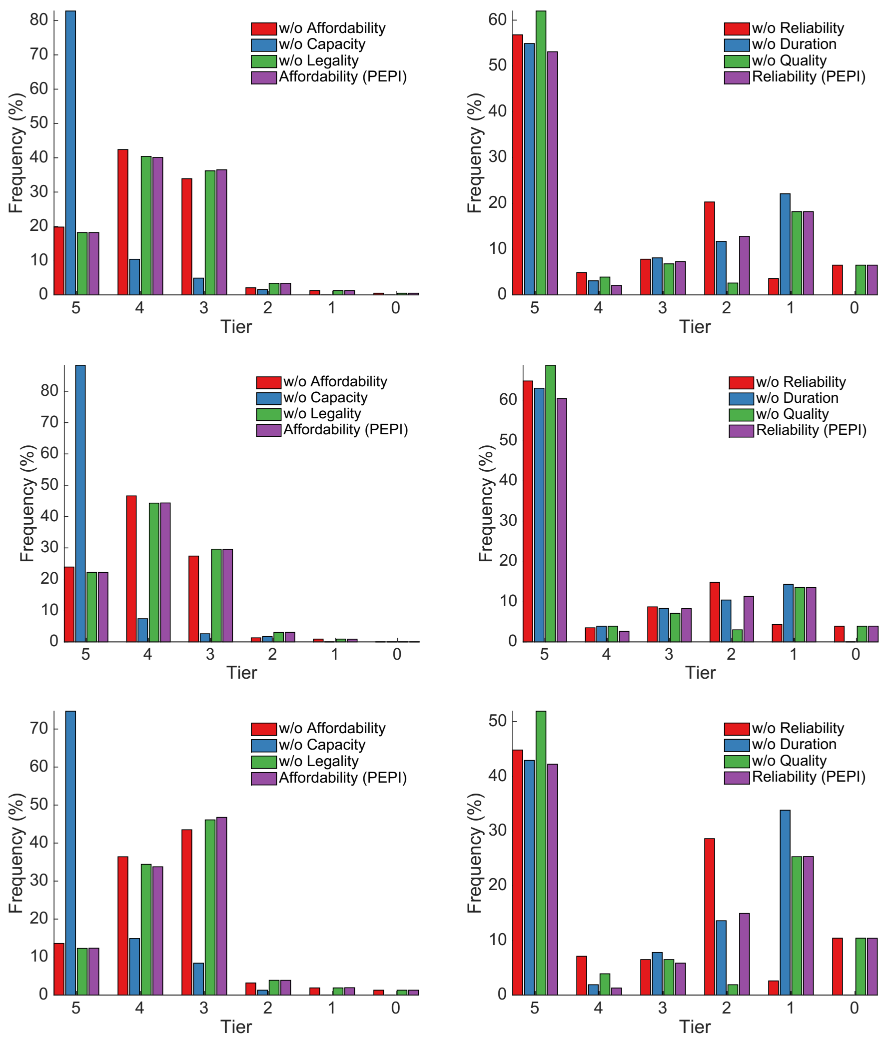


Figure 6.4.: Sensivity study for the PEPI energy supply framework: tier ranking for *affordability* (left) and *reliability* (right), leaving out single attributes. Top row: total sample; middle row: urban area; bottom row: rural area.

The rankings for the single attributes are provided in Table 6.9, while Figure 6.5 shows the lowest-based ranking, comparing the results with the energy supply ranking of the ESMAP MTF (see Chapter 5). The main issues are related to the availability of fuel, affecting 50% of rural households. A further notable aspect is that about 20% of urban households appears to be affected by safety issues (lack of ventilation, see Table 6.9).

Comparing the results of both household's energy access assessments, the ESMAP MTF lowest-based ranking divided mainly the households in two categories (80% of households are split between tier 0 and 5), while the PEPI framework is more able to identify the different issues, also considering the differences be-

Spearman correlation vs. PPI	
Affordability (lowest tier)	0.18
Affordability	0.07
Capacity	0.21
Legality	0.11
Reliability (lowest tier)	0.14
Reliability	0.18
Duration	0.15
Quality	0.01
Safety (lowest tier)	0.04
Safety	0.04
Health	0.04

Table 6.8.: Spearman correlation coefficients of energy supply tier ranking (for the three main attributes and the corresponding sub-attributes) and PPI score

tween rural and urban areas. Figure 6.5 compares the results with the ranking obtained using the ESMAP MTF, the depiction of the attributes assessment of the total sample, and in urban and rural areas it shows the range and diversity of information unobserved under a single metric.

Sensitivity Study and Relation with PPI

As a further step a sensitivity study is performed, computing the tier ranking leaving out single attributes in the category *availability.* The global attribute *safety* has not been considered as almost all households achieved the highest ranking in the sub-attribute *safety* and the ranking mainly depends on the *health* attribute (see Table 6.9). while the attribute *affordability* has not been considered as it does not have sub-attributes. The results show that the *convenience* is the attribute which determines at most the lowest tier. When the attribute is not considered, about 25% of households in the total sample (and about 50% of rural households) are shifted to the highest tier.

Finally, Table 6.10 provides the Spearman correlation coefficients for the three tier ranking (availability, affordability, safety) with respect to the PPI data, showing that the PEPI global attributes are not strongly correlated with the PPI score. Particularly, only *convenience* shows a large correlation with PPI (0.28, in line with the results obtained for the ESMAP MTF).

	Total	Area		Departments			
		Urban	Rural	Nariño	Huila	Putumayo	Tolima
Available							
Convenience *(time spent in stove and fuel acquisition and preparation)*							
Tier 5	57.2%	76.5%	27.7%	40.0%	70.3%	77.3%	91.7%
Tier 4	16.0%	15.0%	17.6%	21.6%	5.4%	21.2%	–
Tier 3	6.4%	5.8%	7.4%	12.4%	–	1.5%	–
Tier 2	2.7%	1.8%	4.1%	5.4%	24.3%	–	8.3%
Tier 1	17.6%	0.9%	43.2%	20.5%	–	–	–
Availability *(fuel availability throughout the year)*							
Tier 5	85.7%	82.2%	90.9%	94.8%	81.6%	63.6%	100%
Tier 4	9.4%	13.0%	3.9%	5.2%	3.5%	33.3%	–
Tier 3	3.6%	3.5%	3.9%	–	10.5%	3.0%	–
Tier 2	1.3%	1.3%	1.3%	–	4.4%	–	–
Quality *(absence of heat variation of fuel)*							
Tier 5	96.8%	97.8%	95.3%	93.5%	100%	100%	100%
Tier 3	3.2%	2.2%	4.7%	6.5%	–	–	–
Affordable							
Affordability *(fuel and stove expenses below defined thresholds of HH income)*							
Tier 5	70.2%	78.0%	58.2%	65.4%	70.0%	81.8%	83.3%
Tier 3	24.7%	18.9%	33.6%	28.67%	25.4%	13.6%	16.7%
Tier 2	5.1%	3.1%	8.2%	5.9%	4.6	4.6%	–
Safe							
Safety *(cooking place outside of sleeping area and no accidents)*							
Tier 5	97.3%	96.0%	99.3%	99.0%	97.4%	93.9%	91.7%
Tier 3	0.3%	0.4%	–	0.5%	–	–	–
Tier 2	2.4%	3.6%	0.7%	0.5%	2.6%	6.1%	8.3%
Health *(sufficient ventilation)*							
Tier 5	58.0%	48.5%	72.5%	83.2%	28.3%	43.9%	25.0%
Tier 4	23.9%	29.5%	15.4%	16.8%	31.9%	27.3%	41.7%
Tier 3	18.1%	22.0%	12.1%	–	39.8%	28.8%	33.3%

Table 6.9.: PEPI Framework: Results of the tier ranking for cooking facilities

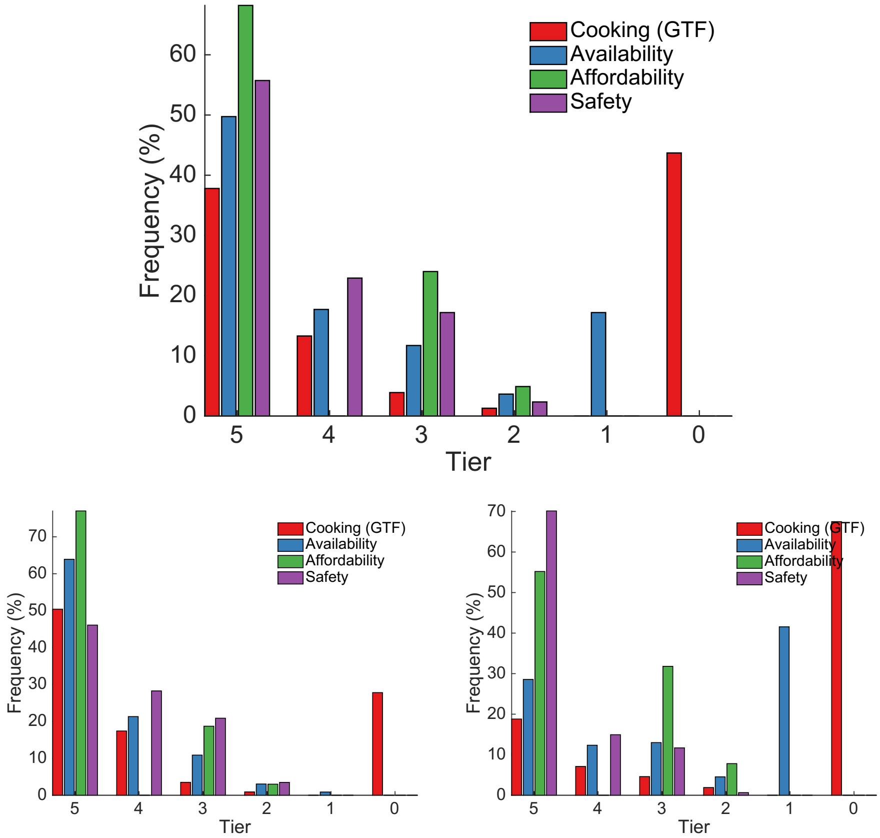


Figure 6.5.: Comparison of the results of the ESMAP MTF tier ranking (cooking solutions) and of the PEPI Frameworks tier ranking for the total sample (top), the urban area (bottom left) and the rural area (bottom right)

Spearman correlation vs. PPI	
Availability (lowest tier)	0.18
Convenience	0.28
Availability	-0.12
Quality	0.02
Affordability (lowest tier)	0.14
Safety (lowest tier)	-0.1
Safety	-0.04
Health	-0.08

Table 6.10.: Spearman correlation coefficients of cooking solution tier ranking (for the three main global attributes and the corresponding sub-attributes) and PPI score

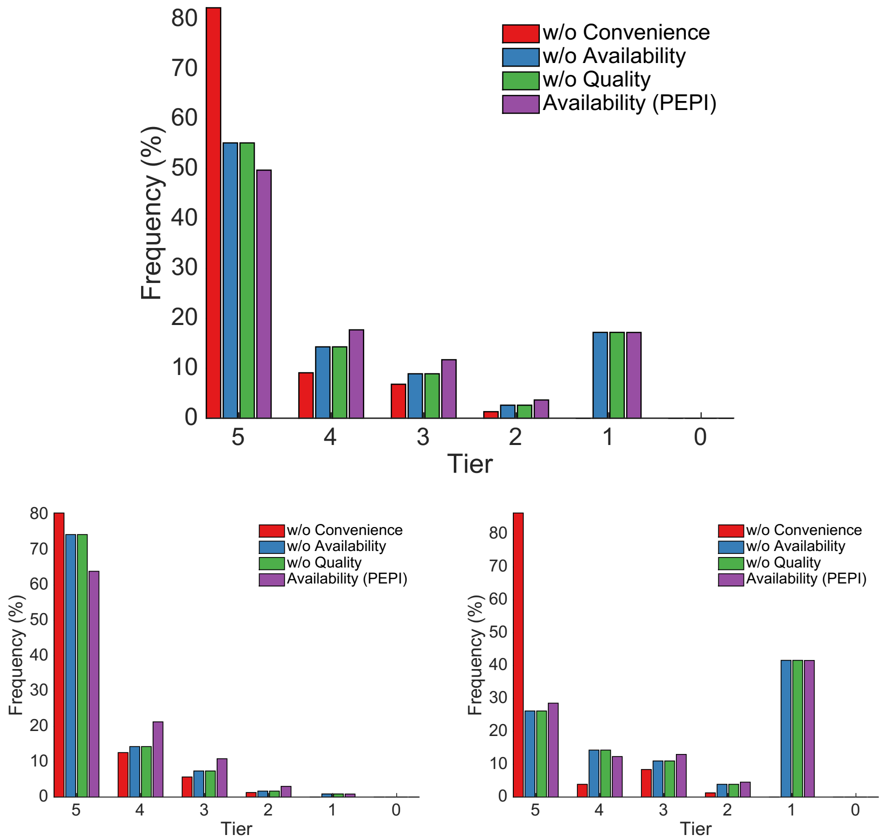


Figure 6.6.: Sensivity study for the *availability* leaving out single sub-attributes. Top: total sample; Bottom-left: urban area; Bottom-right: rural area

6.3. A Toolkit for Assessment of Energy Services

Within the goals of the PEPI, the provision of practical tools to the microfinance industry aims at enabling MFIs to identify the electricity and cooking needs of their clients and at allowing them tracking the effects of their green lending programs by measuring the progress out of energy poverty.

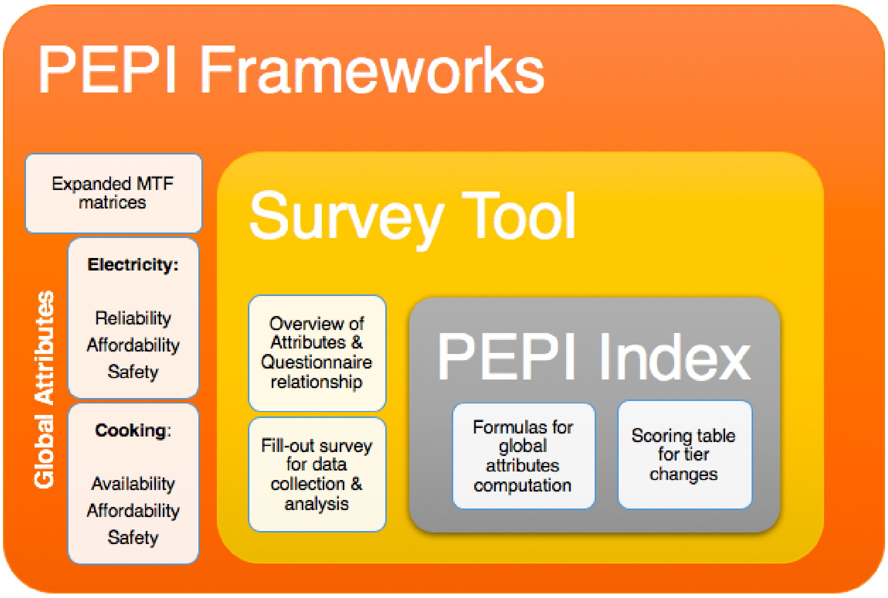


Figure 6.7.: Components of the PEPI Toolkit

To this purpose, the PEPI frameworks and the progress measure described in Sections 6.1.3 and 6.1.4, respectively, are embedded in a *PEPI toolkit*, containing a precompiled survey, designed to facilitate the field data collection over time, as well as data management and analysis.

Specifically, by avoiding text documents with narrative surveys and the use of multiple, separate files and tools for data collection, data cleaning and analysis, the toolkit enables the user (i.e., the surveyor) to apply the tool directly on the field. Moreover, the gathered data is automatically organized in a single database, in order to simplify the final format and to unify the data analysis and the interpretation of the results. Algorithms for tier ranking calculation are integrated in the data analysis R file, fed by the database collected in the field.

As ultimate goals, this toolkit aims at contributing to the MFIs effort in innovating in products and services and striving the access to clean energy technologies through microfinance services by providing a measure of microfinance performance in contributing to the SDGs. Furthermore, the toolkit can serve as a model for develop further extension to identify, measure and monitor the progress and performance of other basic-needs related microloans, such as for loans sustainable housing, education, health, water, and transportation.

The PEPI Toolkit developed in the framework of this research can be downloaded upon request from nataliarealpecarrillo.weebly.com.

6.3.1. The PEPI Survey

Keeping energy applications at the core of the approach in order to ensure its relevance to users [Nussbaumer et al., 2011, Bhatia and Angelou, 2014, Groh et al., 2016], the PEPI toolkit entails a comprehensive survey, contained in multiple Microsoft Excel® sheets, for electricity and cooking facilities access assessment. The focus of the electricity supply is based on the enabled services the electricity supply for the household and its quality. Meanwhile, the access to cooking facilities builds on the types of cookstoves the household uses.

The survey is based on the ESMAP MTF [Bhatia and Angelou, 2015] modified as described in Section 6.1 and on the corresponding tier-ranking, as previously described in Tables 6.4 and 6.5. Moreover, the tool enables the modification of the thresholds defining the tier-ranking. and the comparison of the results with the ones obtained using the original ESMAP MTF thresholds. The survey tools allow to store data in a fill-in table, which, combined with a periodical use of the tool, allows to easily compute the evolution of energy access based on the designed PEPI (see also Table 6.6).

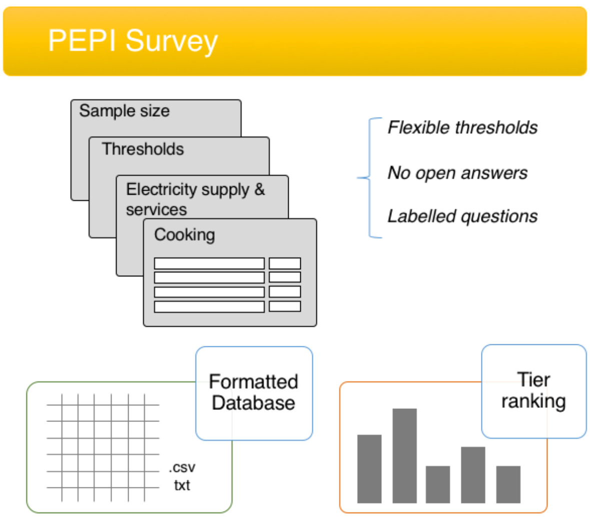


Figure 6.8.: PEPI Survey Sketch and Components

The toolkit builds on MFIs ability to periodically collect large amount of social, financial and demographical data for assessment and monitoring of their client. Hence, the toolkit survey focuses exclusively on capturing information related to electricity and cooking solutions at household level, excluding data which can be extracted from the database of the institution (social and financial data). Whether institutions decide for implementing the tool with its complete clientele or a selected sample will depend on their capacities and resources. In either cases, the toolkit can be viewed as a marginal extension in the amount of data to be collected, which, however, will allow MFIs to have a broader overview of the scale of energy access of the target population and make data available for policy design and internal strategic objectives. On the other hand, correlations and data analysis combining both socio-economical and electricity and/or cooking data cannot be integrated in the toolkit as they require the institutional databases. However, organizations interested in such analysis can extract the PEPI database and combine it with their own database for these purposes.

Improved Data Collection and Management

The PEPI survey simplifies data collection, management and analysis under different aspects. The properties of the toolkit can be summarized as follows.

- **Labelled questions:** Each question of the survey is associated to an attribute and a global attribute. This ensures that all the questions of the survey are relevant for the final assessment and enhances transparency on the attributes assessed per question.
- **Questions and associated variables:** The variables derived from each question are already defined and labelled. Hence, the surveyor/organization does not need to create an additional file or sheet for data collection nor label the specific variables. The fill-in tables have hidden the variables column between the questions and the fill-in spaces for the answers. The column displaying the variables is only used for the subsequent statistical and econometrical analysis.
- **Multiple choice answers:** Each question has a predefined list of possible answers, i.e., there are no open questions. All the answers are given in numbers or a numerical value; whether categories are titled with numbers or the variable is integer with a specific range.
- **Flexible thresholds:** One of the main differences with the ESMAP MTF methodology [Bhatia and Angelou, 2015]) consists in the possibility of modifying the tier thresholds. Specifically, taking into account the on-going debate on attributes [Groh et al., 2016], their cut-offs and their relevance [Stevens et al., 2015], the PEPI toolkit integrates a dashboard enabling modifications according to the established limits for each tier assignment. These frameworks can be updated according to the developments of the sector and to the geographical region of interest.
- **Association of answers with tier ranking:** Following the thresholds, depicted in the corresponding PEPI framework matrices, the tier assignment can be automatically estimated.
- **Fill-in table design:** The toolkit survey provides the questions in rows, while subjects data is collected in columns. Thus, the fill-in table validates answers according the established ranges of each questions as quality control. Moreover, observing the individual answers in different columns facilitates the comparison between subjects, as well as helps to continu-

ously validate the data collection.

- **Efficient survey implementation:** Thanks to the filtering of questions related to the power sources and the cooking devices used by the household, the questionnaire avoids skipping patterns, thus the survey can be efficiently implemented in 5 to 20 minutes. Moreover, the absence of skipping patterns reduces errors due to misunderstanding of the questionnaire by the implementer. As an example, households without electricity (using kerosene, candles, or similar light sources) only answer a maximum of 13 questions, while grid-connected households answer up to 40 questions.
- **Formatted database** At last, the fill-in table can be easily transposed (unhiding the column with the variables) and exported (e.g., as CVS or text file), in order to be read into an external program for data analysis (e.g., R, Stata, SPSS). Hence, the toolkit can be used within an automatic workflow to deliver the final results.

6.3.2. How to

The following part describes in detail the steps for the implementor to take in regards to the contents and objectives of the different components of the Excel-based toolkit.

I. Required Sample Size

As a preliminary step, the toolkit contains a precompiled sheet for determining the most convenient sample size for the data collection. Particularly, the user has to provide the desired margin of error and the confidence level, and the tool computes the sample size based on the selected statistical significance and on the size of the total population (see also Section 5.1 for more details).

II. Tiers Thresholds Matrices

The tier ranking depends on several thresholds, which must be set for each attribute. The established thresholds incorporate characteristics of MES performances in order to better assign them. Frameworks from ESMAP MTF [Bhatia and Angelou, 2015] for electricity supply, electricity services, electricity consumption and cooking facilities are also described indicating the thresholds within each attribute. The integration of these frameworks aim at showing the user the differences between the ESMAP MTF and the PEPI framework matrices displayed in the next sheet. In the PEPI toolkit, the ESMAP MTF thresholds are used as default values, with slight modification motivated by the recommendations of [Groh et al., 2016] previously described (see Section 6.1). However, in the dedicated sheet, the threshold for each attribute can be set independently and adjusted to the local conditions.

III. PEPI Matrices

Within the toolkit provided in the Excel file, the PEPI framework matrices for the assessment of access to electricity and to cooking facilities access are depicted. As the user can observe, the PEPI is based on the attributes of the ESMAP MTF frameworks, with the above mentioned modifications of the thresholds and considering only a single framework for measuring electricity access. All modifications of the thresholds with respect to the ESMAP MTF published in [Bhatia and Angelou, 2015] are marked in blue (see Tables 6.4 and 6.5).

IV. Questionnaire Electricity Services and Supply

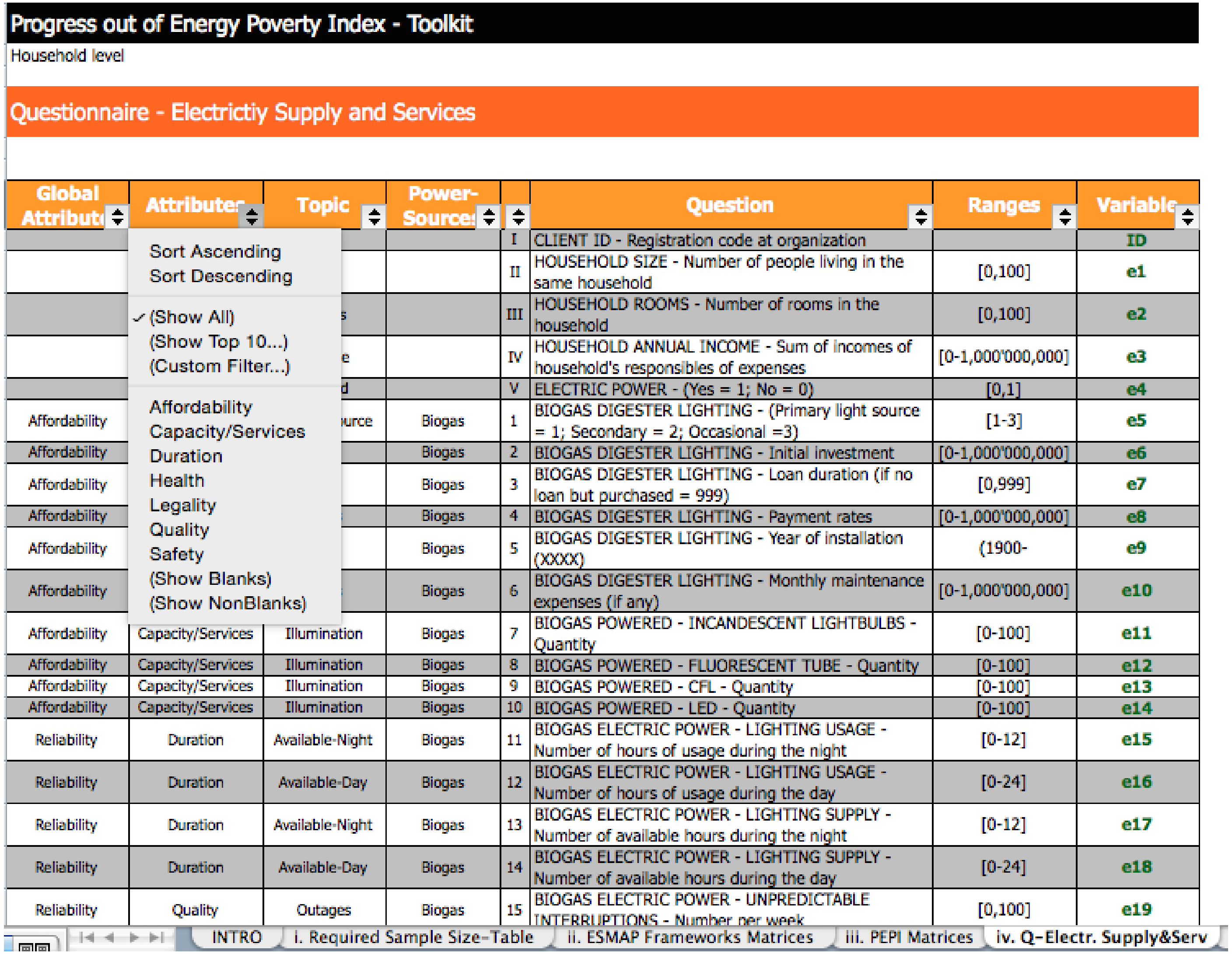
In order to assess the quality of access to electricity, the designed questionnaire filters at first place the source of power at the household, for which the enabled services and the quality of performance of energy supply are assessed. All questions are related to specific attributes measuring the quality of energy access, associated also with the described global attributes (see excerpt in Figure 6.9). Thus, the methodology allows the analysis of energy services costs depending on the energy supply source and the related costs of the (multiple) power source(s) of the household.

V. Questionnaire Cooking Facilities

Mirroring the assessment of electricity supply and services, access to cooking facilities is assessed through the lens of the cooking stoves the household use for the preparation of its meals. Excluding the attributes to be measured at laboratory and considering only the proposed in the PEPI frameworks, all questions are as well related to the corresponding attributes and global attributes (see excerpt in Figure 6.10).Through this methodology, multiple usage of cooking stoves and their corresponding fuels can be easily analyzed as well as their respective quality of performance.

VI. – VII. Fill-in Surveys (Electricity Supply and Services and Cooking Facilities)

The fill-in sheets are aimed for the ease of data collection in the field. By choosing first the *power supply* or *cooking stove* used at the household, respectively, the interviewer only captures the relevant information for the household assessment avoiding instructions for skipping patterns. All variables are numeric, whether categorical or continuous. Excerpts of the surveys are displayed in Figures 6.11 and 6.12, for electricity access and cooking solutions assessment, respectively. While the questionnaire shows the relationship between each question, attributes and global attributes, the fill-in sheets serve the purpose to directly respond to the specific survey.



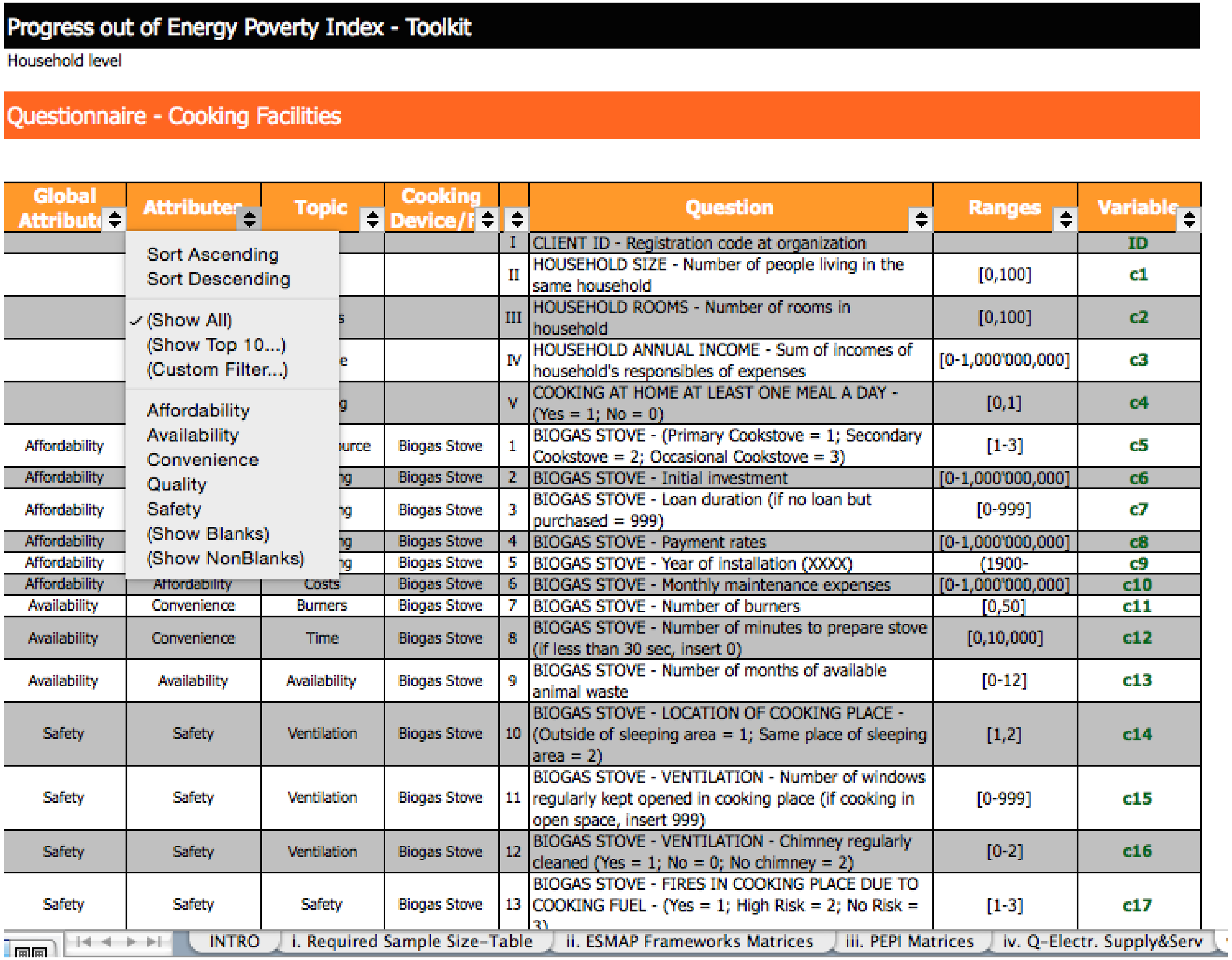
Progress out of Energy Poverty Index - Toolkit

Household level

Questionnaire - Electrictiy Supply and Services

Global Attribute	Attributes	Topic	Power-Sources		Question	Ranges	Variable
				I	CLIENT ID - Registration code at organization		ID
				II	HOUSEHOLD SIZE - Number of people living in the same household	[0,100]	e1
		s		III	HOUSEHOLD ROOMS - Number of rooms in the household	[0,100]	e2
		e		IV	HOUSEHOLD ANNUAL INCOME - Sum of incomes of household's responsibles of expenses	[0-1,000'000,000]	e3
		d		V	ELECTRIC POWER - (Yes = 1; No = 0)	[0,1]	e4
Affordability		urce	Biogas	1	BIOGAS DIGESTER LIGHTING - (Primary light source = 1; Secondary = 2; Occasional =3)	[1-3]	e5
Affordability			Biogas	2	BIOGAS DIGESTER LIGHTING - Initial investment	[0-1,000'000,000]	e6
Affordability			Biogas	3	BIOGAS DIGESTER LIGHTING - Loan duration (if no loan but purchased = 999)	[0,999]	e7
Affordability			Biogas	4	BIOGAS DIGESTER LIGHTING - Payment rates	[0-1,000'000,000]	e8
Affordability			Biogas	5	BIOGAS DIGESTER LIGHTING - Year of installation (XXXX)	(1900-	e9
Affordability			Biogas	6	BIOGAS DIGESTER LIGHTING - Monthly maintenance expenses (if any)	[0-1,000'000,000]	e10
Affordability	Capacity/Services	Illumination	Biogas	7	BIOGAS POWERED - INCANDESCENT LIGHTBULBS - Quantity	[0-100]	e11
Affordability	Capacity/Services	Illumination	Biogas	8	BIOGAS POWERED - FLUORESCENT TUBE - Quantity	[0-100]	e12
Affordability	Capacity/Services	Illumination	Biogas	9	BIOGAS POWERED - CFL - Quantity	[0-100]	e13
Affordability	Capacity/Services	Illumination	Biogas	10	BIOGAS POWERED - LED - Quantity	[0-100]	e14
Reliability	Duration	Available-Night	Biogas	11	BIOGAS ELECTRIC POWER - LIGHTING USAGE - Number of hours of usage during the night	[0-12]	e15
Reliability	Duration	Available-Day	Biogas	12	BIOGAS ELECTRIC POWER - LIGHTING USAGE - Number of hours of usage during the day	[0-24]	e16
Reliability	Duration	Available-Night	Biogas	13	BIOGAS ELECTRIC POWER - LIGHTING SUPPLY - Number of available hours during the night	[0-12]	e17
Reliability	Duration	Available-Day	Biogas	14	BIOGAS ELECTRIC POWER - LIGHTING SUPPLY - Number of available hours during the day	[0-24]	e18
Reliability	Quality	Outages	Biogas	15	BIOGAS ELECTRIC POWER - UNPREDICTABLE INTERRUPTIONS - Number per week	[0,100]	e19

Figure 6.9.: Excerpt of PEPI Questionnaire indicating the respective attributes to be assessed - Access to Electricity Supply and Electricity Services



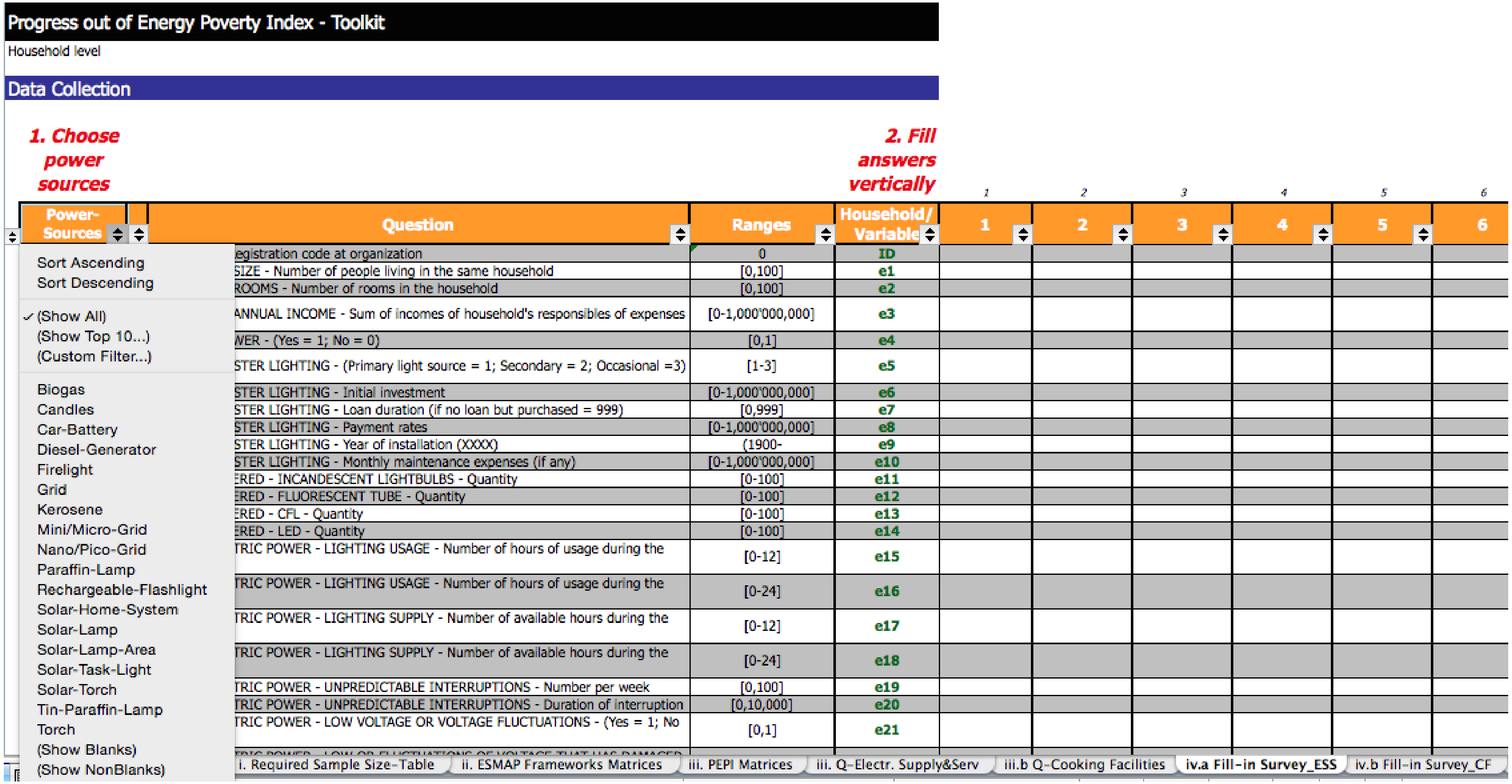
Progress out of Energy Poverty Index - Toolkit

Household level

Questionnaire - Cooking Facilities

Global Attribut	Attributes	Topic	Cooking Device/F		Question	Ranges	Variable
				I	CLIENT ID - Registration code at organization		ID
				II	HOUSEHOLD SIZE - Number of people living in the same household	[0,100]	c1
		s		III	HOUSEHOLD ROOMS - Number of rooms in household	[0,100]	c2
		e		IV	HOUSEHOLD ANNUAL INCOME - Sum of incomes of household's responsibles of expenses	[0-1,000'000,000]	c3
		g		V	COOKING AT HOME AT LEAST ONE MEAL A DAY - (Yes = 1; No = 0)	[0,1]	c4
Affordability		urce	Biogas Stove	1	BIOGAS STOVE - (Primary Cookstove = 1; Secondary Cookstove = 2; Occasional Cookstove = 3)	[1-3]	c5
Affordability		ng	Biogas Stove	2	BIOGAS STOVE - Initial investment	[0-1,000'000,000]	c6
Affordability		ng	Biogas Stove	3	BIOGAS STOVE - Loan duration (if no loan but purchased = 999)	[0-999]	c7
Affordability		ng	Biogas Stove	4	BIOGAS STOVE - Payment rates	[0-1,000'000,000]	c8
Affordability		ng	Biogas Stove	5	BIOGAS STOVE - Year of installation (XXXX)	(1900-	c9
Affordability	Affordability	Costs	Biogas Stove	6	BIOGAS STOVE - Monthly maintenance expenses	[0-1,000'000,000]	c10
Availability	Convenience	Burners	Biogas Stove	7	BIOGAS STOVE - Number of burners	[0,50]	c11
Availability	Convenience	Time	Biogas Stove	8	BIOGAS STOVE - Number of minutes to prepare stove (if less than 30 sec, insert 0)	[0,10,000]	c12
Availability	Availability	Availability	Biogas Stove	9	BIOGAS STOVE - Number of months of available animal waste	[0-12]	c13
Safety	Safety	Ventilation	Biogas Stove	10	BIOGAS STOVE - LOCATION OF COOKING PLACE - (Outside of sleeping area = 1; Same place of sleeping area = 2)	[1,2]	c14
Safety	Safety	Ventilation	Biogas Stove	11	BIOGAS STOVE - VENTILATION - Number of windows regularly kept opened in cooking place (if cooking in open space, insert 999)	[0-999]	c15
Safety	Safety	Ventilation	Biogas Stove	12	BIOGAS STOVE - VENTILATION - Chimney regularly cleaned (Yes = 1; No = 0; No chimney = 2)	[0-2]	c16
Safety	Safety	Safety	Biogas Stove	13	BIOGAS STOVE - FIRES IN COOKING PLACE DUE TO COOKING FUEL - (Yes = 1; High Risk = 2; No Risk = 3)	[1-3]	c17

Figure 6.10.: Excerpt of PEPI Questionnaire indicating the respective attributes to be assessed - Access to Cooking Facilities



Progress out of Energy Poverty Index - Toolkit

Household level

Data Collection

1. Choose power sources

2. Fill answers vertically

Power-Sources	Question	Ranges	Household/ Variable	1	2	3	4	5	6
Sort Ascending	egistration code at organization	0	ID						
Sort Descending	SIZE - Number of people living in the same household	[0,100]	e1						
	ROOMS - Number of rooms in the household	[0,100]	e2						
✓ (Show All)	ANNUAL INCOME - Sum of incomes of household's responsibles of expenses	[0-1,000'000,000]	e3						
(Show Top 10...)	WER - (Yes = 1; No = 0)	[0,1]	e4						
(Custom Filter...)	STER LIGHTING - (Primary light source = 1; Secondary = 2; Occasional =3)	[1-3]	e5						
Biogas	STER LIGHTING - Initial investment	[0-1,000'000,000]	e6						
Candles	STER LIGHTING - Loan duration (if no loan but purchased = 999)	[0,999]	e7						
Car-Battery	STER LIGHTING - Payment rates	[0-1,000'000,000]	e8						
Diesel-Generator	STER LIGHTING - Year of installation (XXXX)	(1900-	e9						
Firelight	STER LIGHTING - Monthly maintenance expenses (if any)	[0-1,000'000,000]	e10						
Grid	ERED - INCANDESCENT LIGHTBULBS - Quantity	[0-100]	e11						
Kerosene	ERED - FLUORESCENT TUBE - Quantity	[0-100]	e12						
Mini/Micro-Grid	ERED - CFL - Quantity	[0-100]	e13						
Nano/Pico-Grid	ERED - LED - Quantity	[0-100]	e14						
Paraffin-Lamp	TRIC POWER - LIGHTING USAGE - Number of hours of usage during the	[0-12]	e15						
Rechargeable-Flashlight	TRIC POWER - LIGHTING USAGE - Number of hours of usage during the	[0-24]	e16						
Solar-Home-System	TRIC POWER - LIGHTING SUPPLY - Number of available hours during the	[0-12]	e17						
Solar-Lamp	TRIC POWER - LIGHTING SUPPLY - Number of available hours during the	[0-24]	e18						
Solar-Lamp-Area	TRIC POWER - UNPREDICTABLE INTERRUPTIONS - Number per week	[0,100]	e19						
Solar-Task-Light	TRIC POWER - UNPREDICTABLE INTERRUPTIONS - Duration of interruption	[0,10,000]	e20						
Solar-Torch	TRIC POWER - LOW VOLTAGE OR VOLTAGE FLUCTUATIONS - (Yes = 1; No	[0,1]	e21						
Tin-Paraffin-Lamp									
Torch									
(Show Blanks)									
(Show NonBlanks)									

i. Required Sample Size-Table | ii. ESMAP Frameworks Matrices | iii. PEPI Matrices | iii. Q-Electr. Supply&Serv | iii.b Q-Cooking Facilities | iv.a Fill-in Survey_ESS | iv.b Fill-in Survey_CF

Figure 6.11.: Excerpt of PEPI Survey tool to assess access to electricity supply and electricity services

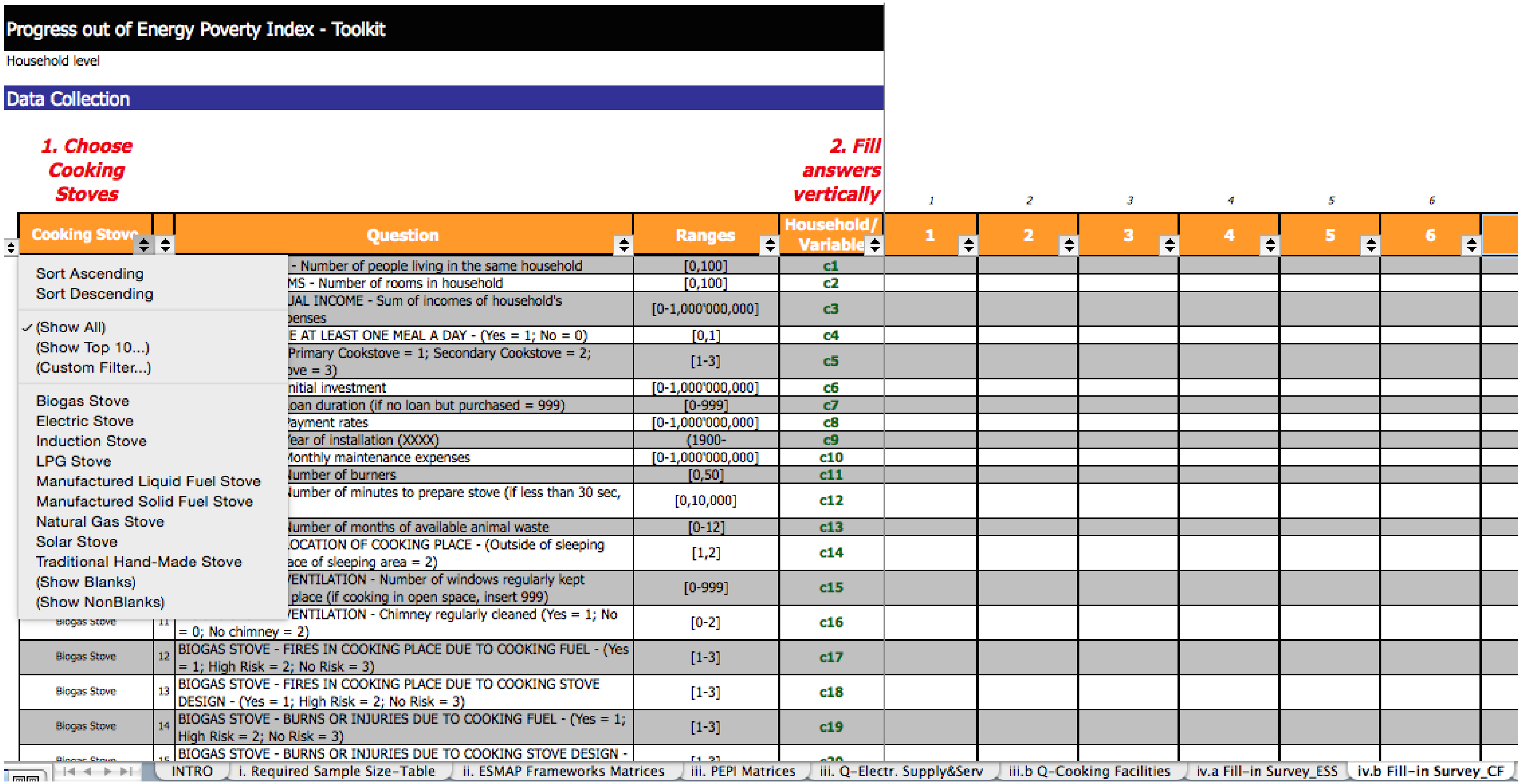


Figure 6.12.: Excerpt of PEPI Survey tool to assess access to cooking facilities

7. Conclusions

The SDGs incorporated in 2015 identify "energy access for all" as part of the global goals to be adopted by all nations, recognizing that universal energy access is an imperative goal to enable global development.

Besides developing technical and financial solutions aimed at improving the access to energy, the ability to measure energy poverty rates and to determine the quantity and quality of energy access of the population with insufficient and unsatisfactory access is necessary . Governments, development communities, NGOs, private companies and financial institutions require this information in order to identify policies and potential projects tailored to the energy needs of populations, to track the progress and evolution of energy access over time and along programs implementation, and to identify the effects of interventions and other initiatives that are intended to alleviate energy deprivation.

Traditional energy access assessments, specifically for electricity and cooking facilities, are often reduced to the availability of a physical grid connection, or on the dependence of biomass for cooking. Thus, the true value of energy of energy access and variations across its many attributes are not discussed. By assessing the quality of the connection, the role of decentralized electricity access approaches and the efficient use of fuels for cooking, among other factors, innovative metric systems research has led to more detailed definitions, acknowledging the multidimensional nature of energy access and the need of multiple frameworks to capture the various attributes thereof.

The growing consensus on the definition of energy poverty and the demand for practical but comprehensive measurement tools across the diverse attributes of energy access reveals the potential of decentralized MES for fulfilling energy needs, transforming global energy discourse. Nevertheless, the potential for the dissemination of MES has to date strongly depended on the potential for providing customized financial approaches to tackle affordability challenges. Among a range of possibilities, green microfinance strategies enable MFIs to distribute MES by tackling affordability and sustainability challenges through so called green lending programs. Through these programs, following a two-hand model approach, financial institutions and energy service suppliers establish partnerships in order to develop financial products to enhance access to specific technologies and meet latent energy needs.

The benefit of these intersectorial partnerships, between the financial and the energy sectors, is twofold. If, on the one hand, MFIs can play a relevant role in the achievements of the SDG 7 by improving access to renewable and efficient energy technologies. Furthermore, noting that MFIs are condemned to constantly innovate in order to remain attractive to clients, green loans are a promising avenue to consolidate or expand market share. Green lending can be also seen as a model for other “directed” microloans, whether targeted to housing, education, health, transport or water (as in the case of the partner MFI Contactar) among other basic needs.

In accordance with these considerations, the focus of this dissertation is the assessment of household energy access and needs in the context of green microfinance, with the ultimate goal of supporting MFIs with dedicated decision-making tools. To this end, the first part of the thesis consisted of an introduction concerning energy poverty, discussing its definition and relevant metrics, and concerning the role of microfinance in tackling energy access (via MES dissemination through green lending programs). The outcomes of a case study in Southern Colombia where then presented, introducing the profile of the Colombian MFI Contactar and the integration of its green lending program; describing the detailed results of this program through application of the ESMAP multi-tier frameworks for electricity and cooking on a sample of microfinance clients (households). Besides the analysis of energy access in this particular context, the case study aimed at testing the potential and limitations of the ESMAP MTF approach, and at assessing the ability of poverty metrics to describe electricity supply and cooking fuels of the organization’s clients. Furthermore, it provided the basis for a novel tool for measuring the provision and quality of electricity supply and services and cooking facilities among microfinance clients. Finally, this research aimed at introducing the Progress out of Energy Poverty Index (PEPI) toolkit, initially targeted to the green microfinance industry. This toolkit is designed to be used for measuring the energy access at household level in regards to electricity supply and services as well as cooking solutions, in order to facilitate green lending programs design, implementation and tracking.

7.1. Results and Main Contributions

7.1.1. Assessment of Energy Access of Microfinance Clients

The field research performed in collaboration with Contactar provided a detailed picture of electricity and improved cooking facility access of the clients, portrayed by the ESMAP MTF frameworks [Bhatia and Angelou, 2015]. At the same time, the implementation of the case study provided relevant experience concerning the requirements of an assessment tool in order to be successfully used by the microfinance industry, in terms of practical usage and in terms of the relevance of the different attributes to assess.

From the point of view of the electricity supply, services and consumption, the case study revealed that the majority of households are in high tiers (i.e., well performing) for most of the attributes. However, among all attributes, the capacity of electricity services appeared to be the one that in most cases determined a lower overall tier ranking. Moreover, although the physical access to electricity was almost completely legal, several rural households reported quality problems (related to voltage problems and/or to unexpected service interruptions), hence demonstrating that electricity access assessment should consider multiple dimensions, rather than the mere existence of a grid connection.

Concerning the access to cooking solutions, the analysis based on the ESMAP MTF resulted in a higher number of households ranked in Tier 0 due to the limited affordability of the cooking solution. In this case, this is strongly determined by the thresholds set in the ESMAP MTF, for which a household is ranked in Tier 0 whenever the fuel costs overshoot 5% of the monthly income, hence not taking into account the possibility of financing via, for example, microcredits or mobile banking. Moreover, rural households are also affected by issues related to the convenience of the cooking solution (time spent for cooking fuel acquisition and preparation), revealing the lack of suitable technologies according to fuel availability.

Overall, the obtained access indices showed large differences between the urban and the rural areas, quantifying to which extent the lack of infrastructure might affect the access to energy (especially in the case of cooking solutions).

The study cross-analyzed the energy access assessment and the poverty metric PPI panel data available for each client from the database of the MFI. The results revealed only a relatively low correlation between the tier-ranking of a household in terms of energy access and the probability that it lies below the poverty line. Specifically, the electricity consumption, the capacity of services and the convenience of cooking solution resulted to be the variables with the most correlation with PPI data.

Beyond the detailed analysis of energy access of the microfinance clients, the successful collaboration with an MFI has to be considered one of the major outcomes of the case study. Particularly, the preparation of the case study required a close collaboration with the Social and Environmental Performance Management Department of Contactar, which benefitted the quality of this research. Thanks to the deep level of knowledge, commitment and to the valuable practical experience of Contactar employees, the field research methodology, time plan and logistics were smoothly and efficiently organized. At the same time, Contactar considered the study as an important opportunity to innovate and to stand ahead in their green initiative. These aspects further motivated the institution in developing tools to monitor its achievements.

Moreover, since the data collection was planned and carried out in collaboration with recent economics graduates of the local university (*Universidad de Nariño*), the case study also represented an important opportunity to strengthen the link between practitioners and academia. Contactar has been invited by the PIFIL[1] group of the *Universidad de Nariño* and by the *Universidad Pontificia Bolivariana* from Medellín to present the results of the PEPI assessment, and has applied to the Citi Award for Microentrepreneurs and to the Master-Card

[1] *Plan de Investigación para el Fortalecimiento Integral de las Comunidades* (Research Plan for the Strengthening of Communities)

Client Centric Awards with its green initiative and tools development.

7.1.2. Development of the PEPI Toolkit

The main motivation for the development of the PEPI toolkit lies in the potential of green microfinance to improve electricity and cooking solutions access and in the fact that, despite the existing debate concerning the long-term sustainability and successful upscaling of projects combining energy access and microfinance schemes, there is an increasing number of MFIs disbursing green loans. As the concept of green inclusive microfinance gains increasing attention, two clear needs arise, including; the development of different metrics to track performance of MFIs in the broad spectrum of environmental management and a clear methodology to assess the performance of green loans in enhancing energy access. Henceforth, the PEPI toolkit was conceived and designed to fill this methodological gap.

Within this research, the development of the toolkit consisted of two main steps. On the one hand, the existing energy poverty metrics and green microfinance indicators have been reviewed, highlighting their main properties. On the other hand, the relevant practical aspects of the field study in collaboration with Contactar have been taken into account, aiming at developing an efficient toolkit to be used by MFIs to collect client data.

Among the available methodologies for the assessment of energy access, the ESMAP MTF provides by far the most complete set of attributes to characterize the different dimensions of energy. Acknowledging the qualities of the MTF, the PEPI has been built from this multi-tier approach, taking into account a set of modifications motivated by recent applications of the MTF in different contexts (see, e.g., [Groh et al., 2016]) and aligning the considered attributes with the Energy SDG targets. Specifically, the PEPI framework retains the attributes of the original ESMAP MTF, grouping them in global attributes (reliability, affordability and safety for assessing electricity supply and services; availability, as well as safety and affordability for assessing cooking facilities) reflecting the sub-targets of the SDG 7.

An important aspect of the PEPI is that the toolkit builds on the ability of MFIs to periodically collect large amount of detaileddata at the household level for monitoring their client. Particularly, aiming at being integrated as a toolkit within the standard data collection of MFIs, the PEPI toolkit proposes a methodology to quantify the progress out of energy poverty taking into account the value of quantity and quality assessments (tier-ranking) of electricity and cooking access.

From a practical point of view, the design of the PEPI toolkit is based on a cost-effective approach in regards to its methodology: the ready to fill-out surveys are contained in Microsoft Excel® sheets, for electricity supply and services (condensed) and cooking facilities access assessment, and the questions can be easily filtered in order to focus on relevant aspects. Moreover, the outcomes can be easily exported in different formats to be directly analyzed using professional statistical programs.

The surveys take into account the attributes of the ESMAP MTF [Bhatia and Angelou, 2015], whose thresholds have been modified taking into account the aforementioned considerations on the frameworks including several features to increase its flexibility, its interpretation and to favor its dissemination. Firstly, each question is clearly associated to an attribute, ensuring that all the questions of the survey are relevant for the final assessment; enhancing transparency on the attributes assessed per question and without skipping patterns. At the same time, for each question the relevant variables for data analysis are labeled. Additionally, the user has the possibility to hide the variables column in the fill-in tables between the questions, hence using the variables only for the subsequent statistical and econometrical analysis. Secondly, taking into account the on-going debate on the role of attribute cut-offs and nature (binary or graded) [Groh et al., 2016, Stevens et al., 2015], the PEPI survey toolkit integrates a dashboard enabling modifications according to the established limits for each tier assignment, computing the resulting ranking accordingly. This feature allows the user to update the frameworks according, for instance, to the developments of a particular sector and/or to the geographical region of interest. Finally, the fill-in table of the PEPI survey can be easily transposed (unhiding the column with the variables) and exported (e.g., as CVS or text file), in order to be imported into an external program for data analysis (e.g., R, Stata, SPSS), allowing to use the PEPI toolkit within an automatic workflow to deliver the final results.

7.2. Outlook: a Tool for the Microfinance Industry

The SDG 7 targets must be linked with robust and well chosen indicators. The adoption of multi-tier approaches makes it possible to reveal the realities behind the traditional binary measures, i.e. the on-grid and off-grid population and of those cooking with solid and non-solid fuels. To date, unfortunately, national indicators and available statistics to measure and monitor the different dimensions of energy access are extremely scarce, particularly for the least developed countries and regions where the issue is the most pressing [Pachauri et al., 2012a]. However, empirical evidence calls for further research on the role of microfinance on improving energy access at household and MSMEs level in order to; estimate its potential, to assess its impact, and to fulfil the data needs of microfinance stakeholders. Thus it also assists global programs on green lending.

The long-term goal of the PEPI toolkit is to support the microfinance industry in the standardised self-monitoring and self-assessment of its achievements, by providing a tailored easy to use toolkit and to integrate within existing clients' surveys. Moreover, it supports the management and the automatic post-processing of the results. The latter can be both integrated within the processes of the organization or outsourced to deliver a report of results. Through the implementation of the PEPI in the microfinance sector, an industry specialized in serving remote populations, the collected data will help to understand power source and fuels usage and needs, and provide an extremely valuable picture of the actions to be undertaken. This overview serves to develop a framework for sectoral interventions and policy design towards realistic environmental goals.

Based on the proposal and on the results of this research, further steps towards these goals can be listed as:

- **Implementation of PEPI in the microfinance industry**
  Through the publication of the results of the case study and of the PEPI toolkit, interested MFIs are invited to track the impact of their green lending programs within their institutions. The toolkit provides MFIs with a comprehensive approach to detail the electricity supply and services and cooking facilities of the clientele at any stage of experience in green lending, identifying, among others, further needs, uses and costs of their clients, as well as payment capabilities.
- **Assessment of energy needs for productive activities**
  Energy access, by improving living standards, has an effective and long-lasting impact on livelihood and income generation. However, besides the provision of energy services at the household level, productive activities that yield improved income generation should also be assessed. In fact, productive activities can have a positive impact on the economic and social benefits of energy access, while increasing the economic sustainability of energy access projects as the ability to pay of end-users increases with their newly generated profits [Etcheverry, 2003, Kapadia, 2004]. As described in Chapter 4 such assessment is of utmost importance from the point of view of MFIs when developing strategic plans for green microfinance programs. Moreover, while, most of the research has been focused on rural electrification, the role of thermal or mechanical energy has been explored in a lesser extent. A further development of the PEPI toolkit will be aimed at including an additional framework with a focus on productive uses of energy, taking into account different sources and different uses of energy.
- **Support the testing of the PEPI toolkit**
  Future research will be dedicated to developing a set of automatic analysis and reporting templates, in order to process more efficiently the collected data and support the continuous implementation of the survey among existing and new microfinance clients. Firstly, these tools will be important to test the potential and the limitations of the proposed metric and framework, both in terms of their capability of assessing energy needs and in terms of practical implementation. At the same time, MFIs willing to share information and learned lessons will be encouraged to publish their results and comments, making them available for academia and interested stakeholders.
- **Capacity building and empowerment process for MFIs**
  Given the complexity of such initiatives, typically, intensive technical assistance is required from development institutions to assist MFIs in their approach to the topic of energy [von Wolff and Phalpher, 2014]. For implementation and results monitoring, technical and financial assistance

should be provided to help guide MFIs in implementation (e.g. standard sample-sizes/regions/clusters) and support the planning of multi-stakeholder interventions aiming at improving specific attributes for energy access and track its success. Moreover, long-term testing and pilot cases will reveal additional challenges and add-ons to integrate in the toolkit. Once the institution estimates the effort, time constraints and data uploading capabilities, a systematization of the tool within their management information system should follow.

Appendices

A. Contactar Exclusion List

According to the policy of Contactar, the following activities are banned to receive any kind of financing:

- Illegal, sale and trafficking of narcotics, trafficking crops
- Production or activities involving forced or child labor
- Trade of wildlife
- Fishing on the marine environment with nets larger than 2.5 km long
- The destruction of critical habitat or any forestry project which is not carried out a plan for sustainable development
- Illegal logging, for manufacture and sale of charcoal
- Production, use or trade of hazardous materials such as fibers, asbestos and products containing PCBs
- Production, use or trade of pharmaceuticals, pesticides, herbicides, chemicals, substances that deplete the ozone layer and other hazardous substances that affect the atmosphere and others
- Cross-border trade of wastes and residues
- Production or trade in arms and ammunition
- Brick manufacturing
- No legalized gambling
- Raffles, sales and purchases, lenders
- Illegal activities, brothels and / or disreputable establishments

B. PPI Tool - Colombia

Colombia PPI®: Lookup Tables

The following lookup tables convert PPI scores to the poverty likelihoods below each of the poverty lines.

PPI Score	National Food (%)	100% National (%)	150% National (%)	200% National (%)
0-4	88.7	96.2	96.2	96.2
5-9	79.7	98.2	100.0	100.0
10-14	74.9	96.5	98.3	99.3
15-19	57.2	92.9	98.7	99.7
20-24	42.2	85.2	95.1	98.4
25-29	28.8	72.9	90.4	95.7
30-34	17.5	60.9	81.9	91.4
35-39	9.2	45.0	70.8	83.2
40-44	5.6	29.6	54.3	70.7
45-49	2.6	18.2	41.7	60.7
50-54	1.0	8.6	26.1	43.9
55-59	0.6	4.3	14.5	31.4
60-64	0.4	1.9	7.7	19.8
65-69	0.1	1.1	3.8	11.5
70-74	0.0	0.2	1.5	4.2
75-79	0.0	0.2	0.4	2.6
80-84	0.1	0.1	0.2	1.3
85-89	0.0	0.0	0.0	0.3
90-94	0.0	0.0	0.0	0.0
95-100	0.0	0.0	0.0	0.0

Figure B.1.: Colombia- PPI Scorecard Tool Lookup Table (Part 1). Source: http://www.progressoutofpoverty.org/country/colombia from Microfinance Risk Management, L.L.C, based on Colombia's 2009 *Encuesta Integrada de Hogares*

Colombia PPI®: Lookup Tables

The following lookup tables convert PPI scores to the poverty likelihoods below each of the poverty lines.

PPI Score	USAID Extreme (%)	$1.25 2005 PPP (%)	$2.50 2005 PPP (%)	$3.75 2005 PPP (%)	$5.00 2005 PPP (%)
0-4	88.8	62.8	90.7	96.2	96.2
5-9	83.0	49.8	84.7	97.6	99.9
10-14	78.8	46.1	84.5	94.8	97.3
15-19	63.9	28.4	67.8	90.5	97.3
20-24	51.8	19.6	56.5	81.6	91.7
25-29	40.2	12.8	43.2	68.4	83.6
30-34	27.6	7.4	29.3	56.3	73.7
35-39	16.3	3.8	17.9	39.8	59.2
40-44	9.9	2.3	10.4	25.3	42.3
45-49	4.9	1.3	5.1	14.4	28.6
50-54	2.2	0.6	2.5	6.7	16.0
55-59	1.2	0.4	1.1	3.3	8.2
60-64	0.7	0.3	0.6	1.3	3.9
65-69	0.2	0.0	0.2	0.8	1.8
70-74	0.0	0.0	0.3	0.2	0.6
75-79	0.0	0.0	0.1	0.2	0.3
80-84	0.1	0.1	0.1	0.1	0.1
85-89	0.0	0.0	0.0	0.0	0.0
90-94	0.0	0.0	0.0	0.0	0.0
95-100	0.0	0.0	0.0	0.0	0.0

Figure B.2.: Colombia- PPI Scorecard Tool Lookup Table (Part 2). Source: http://www.progressoutofpoverty.org/country/colombia from Microfinance Risk Management, L.L.C, based on Colombia's 2009 *Encuesta Integrada de Hogares*

Colombia PPI®: Legacy Lookup Tables

The following lookup tables convert PPI scores to the poverty likelihoods below each of the poverty lines. These lines are the 'legacy' lines and should be used by those wishing to measure changes in poverty likelihoods from the original Colombia PPI scorecard.

PPI Score	National Food (%)	100% National (%)	150% National (%)	200% National (%)
0-4	98.1	100.0	100.0	100.0
5-9	87.3	99.7	100.0	100.0
10-14	77.8	97.1	98.7	99.3
15-19	60.7	95.5	99.3	99.8
20-24	46.1	89.6	97.2	99.2
25-29	36.3	82.6	93.9	97.3
30-34	23.4	69.4	87.6	94.1
35-39	13.9	53.4	77.4	87.9
40-44	8.6	37.3	61.9	76.8
45-49	4.7	24.9	49.7	66.6
50-54	2.4	14.0	33.0	52.0
55-59	1.2	7.6	22.9	40.6
60-64	0.9	4.1	14.9	29.9
65-69	0.4	1.7	7.7	18.5
70-74	0.2	0.9	4.1	9.2
75-79	0.1	0.6	1.7	5.5
80-84	0.3	0.4	0.7	1.9
85-89	0.0	0.1	0.1	1.9
90-94	0.0	0.0	0.0	0.0
95-100	0.0	0.0	0.0	0.0

Figure B.3.: Colombia- PPI Scorecard Tool Lookup Table (Part 3). Source: http://www.progressoutofpoverty.org/country/colombia from Microfinance Risk Management, L.L.C, based on Colombia's 2009 *Encuesta Integrada de Hogares*

Colombia PPI®: Legacy Lookup Tables

The following lookup tables convert PPI scores to the poverty likelihoods below each of the poverty lines. These lines are the 'legacy' lines and should be used by those wishing to measure changes in poverty likelihoods from the original Colombia PPI scorecard.

PPI Score	USAID Extreme (%)	$1.25 2005 PPP (%)	$2.50 2005 PPP (%)	$3.75 2005 PPP (%)	$5.00 2005 PPP (%)
0-4	100.0	81.1	100.0	100.0	100.0
5-9	89.8	71.6	97.7	99.1	99.9
10-14	84.0	64.4	93.8	97.6	98.7
15-19	68.9	45.7	87.9	97.1	99.2
20-24	58.0	33.7	74.0	91.5	97.2
25-29	47.1	24.7	60.7	83.1	92.4
30-34	34.2	15.9	42.6	69.6	82.9
35-39	21.9	8.9	26.7	51.2	69.0
40-44	13.6	6.1	16.8	35.0	52.2
45-49	7.5	3.2	9.1	20.0	35.2
50-54	3.9	1.3	3.6	8.8	18.7
55-59	2.5	0.8	2.1	4.4	10.2
60-64	1.4	0.5	1.1	2.5	5.3
65-69	0.6	0.1	0.4	0.9	2.3
70-74	0.3	0.1	0.3	0.6	1.1
75-79	0.1	0.0	0.1	0.2	0.7
80-84	0.3	0.1	0.3	0.4	0.5
85-89	0.0	0.0	0.0	0.0	0.1
90-94	0.0	0.0	0.0	0.0	0.0
95-100	0.0	0.0	0.0	0.0	0.0

Figure B.4.: Colombia- PPI Scorecard Tool Lookup Table (part 4) Source: http://www.progressoutofpoverty.org/country/colombia from Microfinance Risk Management, L.L.C, based on Colombia's 2009 *Encuesta Integrada de Hogares*

C. Maps and Description of Selected Regions

Tolima

The department of Tolima is the most northern among the four departments considered in this study. It is located in the Andean regions (mid-west Colombia). It has a total surface of 23,562 km^2 (1.74% of the total surface of Colombia) and a total of 1'410,000 inhabitants, divided in 47 municipalities.

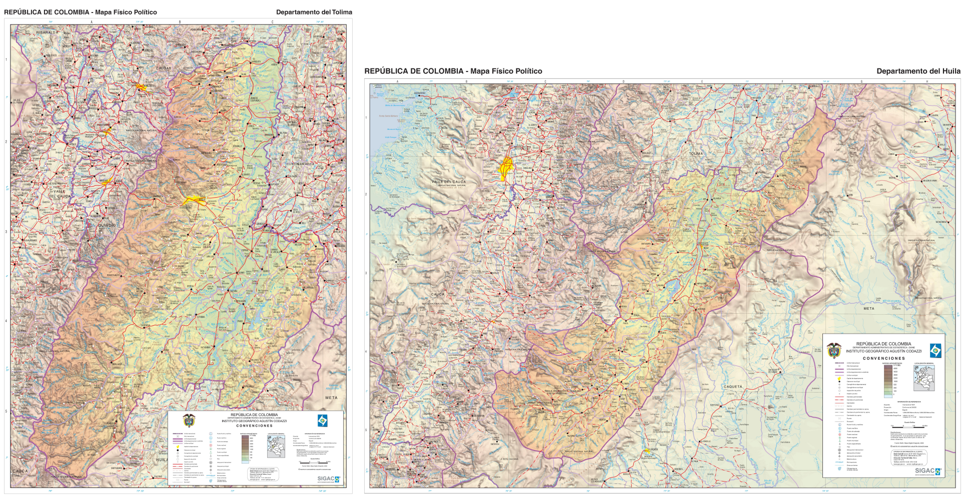


Figure C.1.: Maps of the departments of Tolima (left) and Huila (right). Source: www.vmapas.com

Huila

The department of Huila is locate in south-west of Colombia, within the Andean region. It has a surface of 19,890 km^2, with a population of about 1'174,000 inhabitants divided in 37 municipalities.

Nariño

The department of Nariño (where the head office of Contactar is located) defines the south-east border between Colombia and Ecuador, and its geography is divided in the plain Pacific region, characterized by elevate temperature and abundant rains, in the Andean region, with high mountains (up to 4.700m) and low temperatures and in the Amazonas region, mainly covered by forests. The total surface of the department of Nariño is of 33,268 km^2, with about 1'744,000 inhabitants, divided in 64 municipalities.

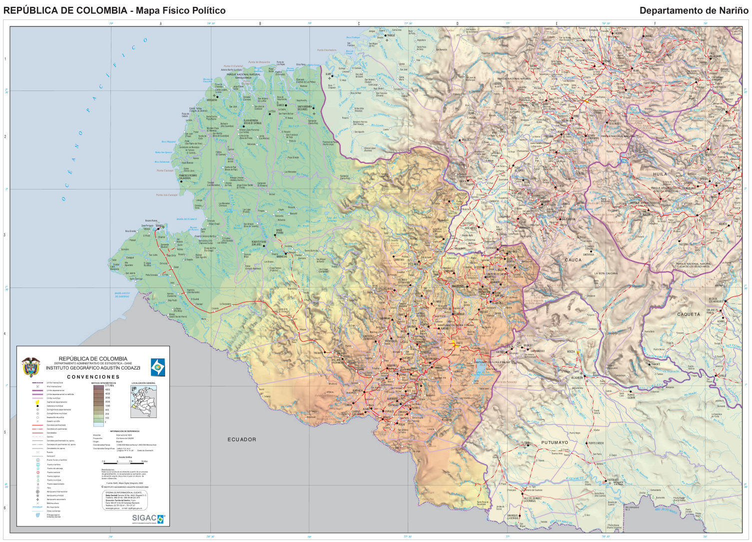


Figure C.2.: Map of the department of Nariño. Source: www.vmapas.com

Putumayo

The department of Putumayo, located in the south-eastern part of Colombia, defines the border between Colombia, Ecuador and Peru. With a surface of 24,885 km^2, Putumayo has a population of 345,000 inhabitants, divided in 13 municipalities.

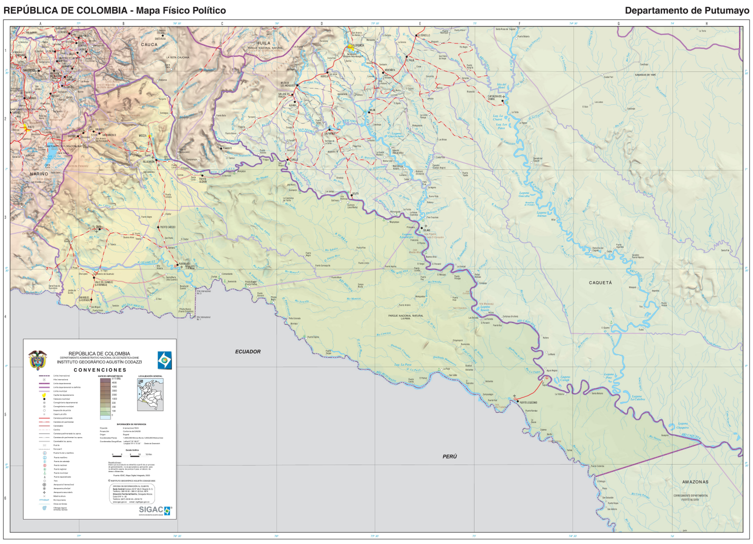


Figure C.3.: Map of the department of Putumayo. Source: www.vmapas.com

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[Agbemabiese, 2009] Agbemabiese, L. (2009). A Framework for Sustainable Energy Development Beyond the Grid: Meeting the Needs of Rural and Remote Populations. *Bulleting of Science, Technology and Society*.

[AGECC, 2010] AGECC (2010). *Energy for a Sustainable Future: Report and Recommendations.* The Secretary Generals Advisory Group on Energy and Climate Change (AGECC).

[Ahlin and Neville, 2008] Ahlin, C. and Neville, J. (2008). Can Micro-Credit Bring Development? *Journal of Development Economics*, 86.

[Allderdice et al., 2007] Allderdice, A., Wienicki, J., and Morris, E. (2007). Using Microfinance to Expand Access to Energy Services. Summary of Findings. Technical report, The SEEP Network, Washington DC.

[Allet, 2011] Allet, M. (2011). Measuring the Environmental Performance of Microfinance. *CEB Working paper*, 11/045.

[Allet, 2012] Allet, M. (2012). Microfinance and Environment: Why Do Microfinance Institutions Go Green? *CEB Working paper*, 12/015.

[Allet, 2014] Allet, M. (2014). The Green Index, an Innovative Tool to Assess the Environmental Performance of MFIs. Technical report, European Microfinance Platform. Prepared in collaboration with the e-MFP Microfinance and Environment Action Group.

[Allet and Hudon, 2013] Allet, M. and Hudon, M. (2013). Green Microfinance. Characteristics of Microfinance Institutions Involved in Environmental Management. *Journal of Business Ethics*, 126(3):395–414.

[Armendáriz de Aghion and Morduch, 2005] Armendáriz de Aghion, B. and Morduch, J. (2005). *The Economics of Microfinance*. The MIT Press, Cambridge, London.

[Banerjee et al., 2010] Banerjee, A., Duflo, E., Glennester, R., and Kinnon, C. (2010). The Miracle of Microfinance? Evidence from a Randomised Evaluation. Technical report, BREAD Working Paper no.278.

[Barnes, 2007] Barnes, D. (2007). *The Challenge of Rural Electrification: Strategies for Developing Countries*. Resources for the Future (Rff) Press.

[Barnes et al., 2011] Barnes, D., Khandker, S. R., and Samad, H. A. (2011). Energy Poverty in Rural Bangladesh. *Energy Policy*, 39:894–904.

[Barnes and Toman, 2006] Barnes, D. and Toman, M. (2006). *Energy, Equity, and Economical Development*, chapter Economic Development and Environmental Sustainability. Oxford University Press. Lopez. R. and Toman, M.

[Barnes and Floor, 1996] Barnes, D. F. and Floor, W. (1996). Rural Energy in Developing Countries: A Challenge for Economic Development. *Annual Review of Energy*, 21(1):497530.

[Barnett, 1990] Barnett, A. (1990). The Diffusion of Energy Technology in The Rural

Areas of Developing Countries: A Synthesis of Recent Experience. *World Development*, 18:539–553.

[Bazilian et al., 2010] Bazilian, M., Nussbaumer, P., Cabraal, A., Centurelli, R., Detchon, R., Gielen, D., Rogner, H.-H., Howells, M., McMahon, H., V., M., and Nakicenovic, N. (2010). Measuring Energy Access: Supporting a Global Target. Technical report, The Earth Institute, Columbia University.

[Beck and Martinot, 2004] Beck, F. and Martinot, E. (2004). Renewable Energy Policies and Barriers. In Cleveland, C. J., editor, *Encyclopedia of Energy*, pages 365–383. New York: Elsevier.

[Bensch, 2013] Bensch, G. (2013). Inside the Metrics: An Empirical Comparison of Energy Poverty Indices for Sub-Saharan Countries. Technical report, Ruhr Economic Papers, No. 464.

[Bensch, 2014] Bensch, G. (2014). Tracking the Energy Poor – Empirical Insights on Energy Poverty Measurement Approaches. Technical report, International Association for Energy Economics. First Quarter 2014.

[Bhatia and Angelou, 2014] Bhatia, M. and Angelou, N. (2014). Capturing the Multi-Dimensionality of Energy Access. World Bank. Energy Sector Management Assistance Program (ESMAP).

[Bhatia and Angelou, 2015] Bhatia, M. and Angelou, N. (2015). Beyond Connections: Energy Access Redefined. Technical report, Energy Sector Management Assistance Program (ESMAP) Technical Report 008/15, Washington. USA: The World Bank Group.

[Brew-Hammond, 2010] Brew-Hammond, A. (2010). Energy Access in Africa: Challenges Ahead. *Energy Policy*, 38(5):2291–2301.

[Cabraal et al., 2005] Cabraal, A., Barnes, D., and Agarwal, S. . (2005). Productive Uses of Energy for Rural Development. *Annual Review of Environment and Resources*, 30(1):117–144.

[Castán Broto et al., 2015] Castán Broto, V., Stevens, L., and Salazar, D. (2015). Energy Access and Urban Poverty. *Poor People's Energy Briefing*, 4.

[Cisco Foundation, 2014] Cisco Foundation (2014). Mejora en la toma de decisiones en Instituciones que sirven a los pobres a través de un mejor uso del PPI. Technical report, Cisco Foundation and Grameen Foundation.

[CNG and Asobancaria, 2012] CNG and Asobancaria (2012). Green Protocol. Technical report, Colombian National Government (CNG) & Asobancaria.

[Coleman, 2006] Coleman, B. E. (2006). Microfinance in northeast Thailand: who benefits and how much? *World Development*, 34(9):1612–38.

[COSA, 2015] COSA (2015). Testing the Progress out of Poverty Index. Technical report, Committee on Sustainable Assessment (COSA) for Ford Foundation.

[d'Almeida and Roberts, 2014] d'Almeida, S. and Roberts, M. (2014). Power to the People: What's Driving the Supply of Green Microfinance? Technical report, DPIBE.

[De Gouvello and Durix, 2008] De Gouvello, C. and Durix, L. (2008). Maximizing the Productive Uses of Electricity to Increase the Impact of Rural Electrification Programs. Technical report, Energy Sector Management Assistance Program (ESMAP), The World Bank, Washington DC.

[Devine et al., 2010] Devine, G., Sheldon, T., and Smith, S. (2010). Making the Connection: Partnerships in Sustainable Energy and Development Finance. Technical report, Yale School of Management.

[DFID, 2002] DFID (2002). Energy for the Poor – Underpinning the Millennium Development Goals. UK Department for International Development (DFID).

[e-MFP, 2015] e-MFP (2015). Green Training - Environmental Management and MFIs. e-MFP Action Group Microfinance and Environment.

[Elias and Victor, 2005] Elias, R. and Victor, D. (2005). Energy Transitions in Developing Countries: A Review of Concepts and Literature. Working Paper 40, Stanford University, Program on Energy and Sustainable Development.

[Etcheverry, 2003] Etcheverry, J. (2003). Renewable Energy for Productive Uses: Strategy to Enhance Environmental Protection and the Quality of Rural Life. Technical report, Department of Geography and Institute for Environmental Studies.

[Foster et al., 2000] Foster, V., Tre, J.-P., and Wodon, Q. (2000). Energy Prices, Energy Efficiency, and Fuel Poverty.

[Ghosh, 2013] Ghosh, J. (2013). Microfinance and the Challenge of Financial Inclusion for Development. *Cambridge Journal of Economics*.

[Global Tracking Framework (GTF), 2013] Global Tracking Framework (GTF) (2013). Progress Toward Sustainable Energy. Technical report, International Bank for Reconstruction and Development/The World Bank & the International Energy Agency.

[Global Tracking Framework (GTF), 2015] Global Tracking Framework (GTF) (2015). Progress Toward Sustainable Energy. Technical report, International Bank for Reconstruction and Development/The World Bank & the International Energy Agency.

[Goldemberg, 2004] Goldemberg, J. (2004). The Case for Renewable Energies. In *Renewables 2004*.

[GpsPrune, 2015] GpsPrune (2015). Computer software (Version 18.2) available at http://activityworkshop.net/software/gpsprune.

[Gradl and Knobloch, 2011] Gradl, C. and Knobloch, C. (2011). Energize the BoP! Energy Business Model for Low Income Markets. Technical report, Endeva.

[Grameen-Foundation, 2012] Grameen-Foundation (2012). *PPI Glance - Colombia*. Grameen Foundation.

[GreenMicrofinance, 2007] GreenMicrofinance (2007). Microfinance and the Environment: Setting the Research and Policy Agenda. Roundtable, May 5–6, 2006. Philadelphia: GreenMicrofinance–LLC.

[Groh, 2014] Groh, S. (2014). The Role of Energy in Development Processes – The Energy Poverty Penalty: Case Study of Arequipa (Peru). *Energy for Sustainable Development*, 18:83–99.

[Groh, 2015] Groh, S. (2015). *The Role of Access to Electricity in Development Processes*. PhD thesis, Aalborg University.

[Groh et al., 2016] Groh, S., Pachauri, S., and Narasimha, R. (2016). What are We Measuring? An Empirical Analysis of Household Electricity Access Metrics in Rural Bangladesh. *Energy for Sustainable Development*, 30:21–31.

[Groh and Taylor, 2015] Groh, S. and Taylor, H. (2015). The Role of Microfinance in Energy Access: Changing Roles, Changing Paradigms, and Future Potential. *Enterprise Development and Microfinance*.

[Gutiérrez and Reddy, 2015] Gutiérrez, E. and Reddy, R. (2015). Expanding Opportunities for Rural Finance in Colombia. Report. Finance and Markets Practice, Latin America and the Caribbean Region. AUS10747, World Bank.

[Hall et al., 2008] Hall, J., Collins, L., Israel, E., and Wenner, M. (2008). The Missing Bottom Line: Microfinance and the Environment. In *Philadelphia: GreenMicrofinance-LLC*.

[Hosier, 2004] Hosier, R. (2004). Energy Ladder in Developing Nations. *Enciclopedia* *of Energy*, 2.

[Hulme, 2000] Hulme, D. (2000). Is Microdebt Good for Poor People? A Note on the Dark Side of Microfinance. *Small Enterprise Development*, 11(1):26–29.

[IEA, 2004] IEA (2004). World Energy Outlook 2004. Technical report, International Energy Agency (IEA).

[IEA, 2011] IEA (2011). World Energy Outlook 2011 - Special Report - Energy for All Financing Access for the Poor. Technical report, International Energy Agency (IEA).

[IEA, 2013] IEA (2013). World Energy Outlook 2013. Technical report, International Energy Agency (IEA).

[IEA, 2015] IEA (2015). World Energy Outlook 2015. Technical report, International Energy Agency (IEA).

[IEA and WB, 2014] IEA and WB (2014). Sustainable Energy for All 2013-2014: Global Tracking Framework Report. Technical report, International Energy Agency (IEA) and The World Bank (WB).

[IEA and WB, 2015] IEA and WB (2015). Sustainable Energy for All 2015 – Progress Toward Sustainable Energy. Technical report, International Energy Agency (IEA) and The World Bank (WB).

[IEA and Photovoltaic Power Systems Program, 2002] IEA and Photovoltaic Power Systems Program (2002). Implementing Agreement on Photovoltaic Power Systems. Technical report, International Energy Agency (IEA) and Photovoltaic Power Systems Program.

[IFC, 2013] IFC (2013). Mobilising Public and Private Funds for Inclusive Green Growth Investment in Developing Countries. Technical report, International Finance Corporation (IFC).

[IFC and WRI, 2007] IFC and WRI (2007). The Next 4 Billion. Market Size and Business Strategy at the Base of the Pyramid. Technical report, International Financial Corporation (IFC) and World Resource Institute (WRI).

[Ilskog, 2008] Ilskog, E. (2008). Indicators for Assessment of Rural Electrification An Approach for the Comparison of Apples and Pears. *Energy Policy*, 36(7):2665–2673.

[Kapadia, 2004] Kapadia, K. (2004). Productive Uses of Renewable Energy. A Review of Four Bank-GEF Projects. DRAFT Productive Use of Renewables.

[Kaygusuz, 2011] Kaygusuz, K. (2011). Energy Services and Energy Poverty for Sustainable Rural Development. *Renewable and Sustainable Energy Reviews*, 15:936–947.

[Kebir, 2009] Kebir, N. (2009). Development of a Certification Process for Microenergy Systems. In *International Conference on Engineering Design*.

[Kebir and Heipertz, 2010] Kebir, N. and Heipertz, J. (2010). Financing Energy. The Role of Microfinance Institutions. Technical report, UMM Workshop Report E-MFP Action Group. Bergamo: PlaNet Finance.

[Kebir et al., 2013] Kebir, N., Spiegel, N., Schrecker, T., Groh, S., Scott, C., and Aliaga Ferrufino, G. (2013). Exploring Energy SME Financing in Emerging and Developing Countries. Technical report, California: Sustainable Business Institute.

[Khandker et al., 2012] Khandker, S. R., Barnes, D. F., and Samad, H. A. (2012). Are the Energy Poor also Income Poor? Evidence from India. *Energy Policy*, 47:1–12.

[Kittelson, 1998] Kittelson, D. (1998). Productive Uses of Electricity: Country Experiences. In *Village Power' 98*. (Conference Paper).

[Kowsari and Zerriffi, 2011] Kowsari, R. and Zerriffi, H. (2011). Three Dimensional

Energy Profile. *Energy Po*, 39(12):7505–7517.

[Legros et al., 2009] Legros, G., Havet, I., Bruce, N., and Bonjour, S. (2009). The Energy Access Situation in Developing Countries: A Review Focusing on the Least Developed Countries and Sub-Saharan Africa. Technical report, United Nations Development Programme (UNDP) and World Health Organization.

[Levaï et al., 2011] Levaï, D., Rippey, P., Rhyne, E., and Allderdice, A. (2011). Microfinance and Energy Poverty: Findings from the Energy Links Project. Technical report, Final Report to AFD (now FHI 360) and USAID under the FIELD Project. Center for Financial Inclusion. Publication No. 13.

[Lucas et al., 2003] Lucas, H., Barnett, A., Standing, H., Yuelai, L., and Jolly, S. (2003). Energy, Poverty and Gender: A Review of the Evidence and Case Studies in Rural China. Technical report, Report for the World Bank by The Institute of Development Studies at the University of Sussex, UK.

[MacLean and Siegel, 2007] MacLean, J. and Siegel, J. M. (2007). Financing Mechanisms and Public/Private Risk Sharing Instruments for Financing Small Scale Renewable Energy Equipment and Projects. (Research Paper). Technical report, United Nations Environment Programme (UNEP), Global Environment Facility (GEF).

[Maren et al., 2011] Maren, D., Palmer-Jones, R., Copestake, J. G., Hooper, L., Loke, Y., and N., R. (2011). What is the Evidence of the Impact of Microfinance on the Well-being of Poor People? Technical report, EPPI-Centre, Social Science Research Unit, Institute of Education, University of London.

[Martinot et al., 2001] Martinot, E., Cabraal, A., and Marthu, S. (2001). World Bank/GEF Solar Home System Projects: Experiences and Lessons Learned 1993-2000. *Renewable and Sustainable Energy Reviews*, 5(1):39–57.

[Martinot et al., 2002] Martinot, E., Chaurey, A., Lew, D., Moreira, J., and Wamukonya, N. (2002). Renewable Energy Markets in Developing Countries. *Annual Review of Energy*, 27(1):309–348.

[Masera et al., 2000] Masera, O., Saatkamp, B., and Kammen, D. (2000). From Linear Fuel Switching to Multiple Cooking Strategies: A Critique and Alternative to the Energy Ladder Model. *World Development*, 28(12):2083–2103.

[Matas et al., 2015] Matas, B., Ramirez, J., and Kahlen, L. (2015). Green Microfinance in Contactar. Market Study: Pre-selection of Green Technologies of Relevance. Technical report, MicroEnergy International.

[Meadows et al., 2003] Meadows, K., Riley, C., Rao, G., and Harris, P. (2003). Modern Energy: IImpact on Micro-enterprises. A Literature Review into the Linkages between Modern Energy and Micro-Enterprise. Technical report, UK Department for International Development, London.

[MEI and PF, 2010] MEI and PF (2010). Fact Sheet: The Potential of Linking Microfinance and Energy Supply. Technical report, MicroEnergy International (MEI) and PlaNet Finance (PF).

[MicroEnergy International, 2014] MicroEnergy International (2014). Green Profile - Contactar. Internal Report.

[MIF and Bloomberg, 2012] MIF and Bloomberg (2012). Climatescope 2012. Technical report, Multilateral Investment Fund (MIF) and Bloomberg New Energy Finance.

[Mirza and Szirmai, 2010] Mirza, B. and Szirmai, A. (2010). Towards a New Measurement of Energy Poverty: A Cross-Community Analysis of Rural Pakistan. Technical report, Maastricht Economic and Social Research and Training Centre on Innovation and Technology.

[Modi, 2004] Modi, V. (2004). Energy Services for the Poor (Commissioned paper for the Millennium Project Task Force 1). Technical report, Earth Institute and Department of Mechanical Engineering, Columbia University.

[Modi et al., 2006] Modi, V., McDade, S., Lallement, D., and Saghir, J. (2006). Energy Services for the Millennium Development Goals. Technical report, New York: Energy Sector Management Assistance Programme (ESMAP), United Nations Development Programme, UN Millennium Project, and World Bank.

[Mohiuddin, 2006] Mohiuddin, S. (2006). Expanding the Role of Microfinance in Promoting Renewable Energy Access in Developing Countries. *The Georgetown Public Policy Review*, 11(1).

[Morris and Kirubi, 2009] Morris, E. and Kirubi, G. (2009). Bringing Small Scale Finance to the Poor for Modern Energy Services: What is The Role Of Government? Experiences from Burkina Faso, Kenya, Nepal and Tanzania. Technical report, United Nations Development Programme.

[Morris et al., 2007] Morris, E., Winiecki, J., Chowdhard, S., and Cortiglia, D. (2007). Using Microfinance to Expand Access to Energy Services: Summary of Findings. Small Enterprise Education and Promotion Network (SEEP) Network.

[Nussbaumer et al., 2011] Nussbaumer, P., Bazilian, M., Modi, V., and Yumkella, K. (2011). Measuring Energy Poverty: Focusing on What Matters. Oxford Poverty & Human Development Initiative (OPHI) Oxford. Technical report, Department of International Development Queen Elizabeth House (QEH), University of Oxford, OPHI Working Paper Nr. 42.

[OECD, 2007] OECD (2007). Energy for Sustainable Development. Technical report, The Organisation for Economic Cooperation and Development (OECD). Contribution to the United Nations Commission on Sustainable Development 15. Paris: OECD.

[OECD and IEA, 2010] OECD and IEA (2010). Energy Poverty: How to make Modern Energy Access Universal? Energy Poverty: Special early excerpt of the World Energy Outlook for the UN General Assembly on the Millennium Development Goals? Technical report, The Organisation for Economic Cooperation and Development (OECD) and International Energy Agency (IEA).

[Pachauri, 2011] Pachauri, S. (2011). Reaching an International Consensus on Defining Modern Energy Access. *Current Opinion in Environmental Sustainability*, 3(4):235–240.

[Pachauri et al., 2012a] Pachauri, S., Brew-Hammond, A., Barnes, D. F., Bouille, D. H., Gitonga, S., Modi, V., Prasad, G., Rath, A., and Zerriffi, H. (2012a). *Global Energy Assessment – Toward a Sustainable Future*, chapter Energy Access for Development (Chapter 19), pages 1401–1458. Cambridge University Press, Cambridge, UK and New York, NY, USA and the International Institute for Applied Systems Analysis, Laxenburg, Austria.

[Pachauri et al., 2004] Pachauri, S., Mueller, A., Kemmler, A., and Spreng, D. (2004). On Measuring Energy Poverty in IIndia Households. *World Development*, 32(12):2083–2104.

[Pachauri et al., 2012b] Pachauri, S., Rao, D., Nagai, Y., and Riahi, K. (2012b). Access to Modern Energy Assesment and Outlook for Developing and Emerging Regions. Technical report, International Institute for Applied Systems Analysis (IIASA), United Nations Industrial Development Organization (UNIDO), Global Environment Facility (GEF).

[Pachauri and Spreng, 2004] Pachauri, S. and Spreng, D. (2004). Energy Use and Energy Access in Relation to Poverty. *Economic and Political Weekly*, 39(3):271–278.

[Pachauri et al., 2013] Pachauri, S., van Ruijven, B., Nagai, Y., Riahi, K., Van Vuuren, D., Brew-Hammond, A., and Nakicenovic, N. (2013). Pathways to achieve universal household access to modern energy by 2030. *Environment Research Letters*, 8:024015 (7pp).

[Parkerson, 2005] Parkerson, D. (2005). Assessing the Potential for Microfinance Institutions to Finance Solar Photovoltaic Systems in the Dominican Republic. Technical report, SEEP Network. Working Paper.

[Peters et al., 2009] Peters, J., Harsdorff, M., and Ziegler, F. (2009). Rural Electrification: Accelerating Impact with Complementary Services. *Energy for Sustainable Development*, 13(1):38–42.

[Philipp and Schäfer, 2009] Philipp, D. and Schäfer, M. (2009). Interdisziplinärer Forschungsansatz zur Analyse von Mikroenergie-Systeme. Discussion Paper. Graduiertenkolleg Mikroenergie-Systeme.

[Pierantozzi et al., 2015] Pierantozzi, A., Allet, M., Forcella, D., Huybrechts, F., Mauro, A., Realpe Carrillo, N., Spiaggari, L., and Shuite, G. (2015). Assessing Green Microfinance Qualitative and Quantitative Indicators for Measuring Environmental Performance. Technical report, Mix Market.

[Practical Action, 2012] Practical Action (2012). Poor People's Energy Outlook 2012: Energy for Earning a Living. Practical Action Publishing, Rugby, UK.

[Practical Action, 2013] Practical Action (2013). Poor Peoples Energy Outlook 2013: Energy for community services. Practical Action Publishing, Rugby, UK.

[Rao and Rao, 2010] Rao, D. and Rao, K. (2010). *Micro Credit and Economic Development*, chapter The Role of Micro Credit in Poverty Alleviation, pages 193–207. New Delhi: Regal Publications.

[Rao et al., 2009] Rao, P., Miller, J., Wang, Y., and Byrne, J. (2009). Energy-Microfinance Intervention for Below Poverty Line Households in India. *Energy Policy*, 37(5):1694–1712.

[Realpe Carrillo, 2014] Realpe Carrillo, N. (2014). A Practitioner's Outlook on the Debate Why Green Microfinance, and if so, How? In *10th University Meets Microfinance Workshop. Frankfurt School of Finance & Management. July, 2013*, pages 43–38. UMM Thematic Paper. Understanding the Challenges: New Insights from Practice & Research on Mobile Banking, Remittances and Green Microfinance.

[Realpe Carrillo et al., 2015] Realpe Carrillo, N., Kahlen, L., and Dumitrescu, R. (2015). Implementing a Green Microfinance – The Case of Contactar. In *International Conference Micro Perspectives for Decentralized Energy Supply. Bangalore, India.*

[Rehman et al., 2012] Rehman, I. H., Kar, A., Banerjee, M., Kumar, P., Shardul, M., Mohanty, J., and Hossain, I. (2012). Understanding the Political Economy and Key Drivers of Energy Access in Addressing National Energy Access Priorities and Policies. *Energy Policy*, 47:27–37.

[Rippey, 2009] Rippey, P. (2009). Microfinance and Climate Change: Threats and Opportunities. Technical report, CGAP Focus Note, No. 53.

[Rippin, 2011] Rippin, N. (2011). A Response to the Weaknesses of the Multidimensional Poverty Index (MPI): The Correlation Sensitive Poverty Index (CSPI). Technical report, Deutsches Institut für Entwicklungspolitik, Briefing Paper 19/2011.

[Rogerson, 1997] Rogerson, C. (1997). Rural Electrification and the SMME Economy in South Africa. Technical report, University of Cape Town.

[Saari, 2006] Saari, S. (2006). Productivity Theory and Measurement in Business. In *European Productiviy Conference*, Finland.

[Saghir, 2005] Saghir (2005). Energy and Poverty: Myths, Links, and Policy Issues. Energy Working Notes 4, The World Bank, Energy and Mining Sector Board, Washington D.C.

[SantaMaría, 2011] SantaMaría, H. S. (2011). Sistema Técnico Mejorado de Secado de Café a Nivel Familiar. Secador Solar vs. Sistema Tradicional. Technical report, Instituto Nacional de Innovación Agraria (INIA) - Fondo Nacional de Capacitación Laboral y Promoción del Empleo (FONDOEMPLEO).

[Schäfer et al., 2011] Schäfer, M., Kebir, N., and Neumann, K. (2011). Research Needs for Meeting the Challenge of Decentralized Energy Supply in Developing Countries. *Energy for Sustainable Development*, 15(3):24–32.

[Schreiner, 2004] Schreiner, M. (2004). A Simple Scorecard for Nepal. Microfinance Risk Management. L.L.C., microfinance.com.

[SE4ALL and WB, 2014] SE4ALL and WB (2014). Energy Survey. Household Questionnaire.

[Serrano, 2009] Serrano, J. (2009). Microfinanzas e Instituciones Microfinancieras en Colombia. Technical report, Comisión Económica para América Latina y el Caribe (CEPAL).

[Shuite and Forcella, 2015] Shuite, G. and Forcella, D. (2015). Green Inclusive Finance. Status, Trends and Opportunities! Technical report, NpM, Enclude, Hivos.

[Smith, 2000] Smith, J. (2000). Solar-Based Rural Electrification and Microenterprise Development in Latin America: A Gender Analysis. Technical report, National Renewable Energy Laboratory (NREL), Golden, Colorado.

[Srinivasan, 2007] Srinivasan, S. (2007). Microfinance for Renewable Energy: Financing the Former Poor. *World Review of Entrepreneurship, Management and Sustainable Development*, 3(1):79–89.

[Stern and Cleveland, 2004] Stern, D. and Cleveland, C. (2004). Energy and Economic Growth. Renlasser working papers on economics, Rensselaer Polytechnic Institute.

[Stevens et al., 2015] Stevens, L., Wykes, S., and Singer, S. (2015). Measuring what matters in the Energy SDG. infoHub (Practical Action).

[The World Bank, 2008a] The World Bank (2008a). Designing Sustainable Off-Grid Rural Electrification Projects: Principles and Practices. Technical report, Energy and Mining Sector Board, The World Bank Group (Washington DC).

[The World Bank, 2008b] The World Bank (2008b). REToolkit: A Resource for Renewable Energy Development. Technical report, The World Bank, Washington D.C.

[The World Bank, 2016] The World Bank (2016). World Development Indicators. Statistical Report.

[UNCDF, 2012] UNCDF (2012). Clean Start Detailed Business Plan. Technical report, United Nations Capital Development Fund (UNCDF).

[UNDP, 2000] UNDP (2000). World Energy Assessment: Energy and the Challenge of Sustainability. Technical report, United Nations Development Programme (UNDP).

[UNDP, 2016] UNDP (2016). UNDP Support to the Implementation of the 2030 Agenda for Sustainable Development. United Nations Development Programme (UNDP) Policy and Programme Brief.

[UNDP and WHO, 2009] UNDP and WHO (2009). The Energy Access Situation in Developing Countries: A Review Focusing on the Least Developed Countries and Sub-Saharan Africa. Technical report, United Nations Development Programme (UNDP) and World Health Organization (WHO), New York.

[Urbaniak and Plous, 2013] Urbaniak, G. C. and Plous, S. (2013). Research Randomizer

[Computer software] – URL: http://www.randomizer.org/. (Version 4.0).

[van der Kroon et al., 2013] van der Kroon, B., Brouwer, R., and van Beukering, P. (2013). The Energy Ladder: Theoretical Myth or Empirical Truth? Results from a Meta-Analysis. *Renewable and Sustainable Energy Reviews*, 20:504–513.

[van der Straeten et al., 2014] van der Straeten, J., Friederici, K., and Groh, S. (2014). Taking a Micro-Perspective on the Global Challenge of Climate Change: The Microenergy Systems Research Focus at the Technische Universität Berlin. In Leal Filho, W., editor, *International Perspectives on Climate Change, Climate Change Management*, pages 135–149. Springer International Publishing.

[Van Elteren, 2007] Van Elteren, A. (2007). Environmental and Social Risk Management and Added Value at MFIs and MFI funds the FMO Approach. Technical report, The Hague: Netherlands Development Finance Company (FMO).

[Viscidi, 2010] Viscidi, L. (2010). Colombia's Energy Renaissance. Technical report, Americas Society and Council of the Americas Energy Action Group.

[von Wolff and Phalpher, 2014] von Wolff, S. and Phalpher, K. (2014). Green Finance. Successes and Challenges - A Landscape Overview. Technical report, Finance in Motion.

[Waterfield, 2001] Waterfield, C. (2001). Designing Microfinance Loan Products. Institutional paper, MFI Solutions, LLC, Lancaster, PA USA.

[Wenner, 2002] Wenner, M. (2002). Microenterprise Growth and Environmental Protection. *Microenterprise Development Review*, 4(2):1–8.

[Winkler et al., 2011] Winkler, H., Simões, A. F., Lébre La Rovere, E., Alam, M., Rhaman, A., and Mwakasonda, S. (2011). Access and Affordability of Electricity in Developing Countries. *World Development*, 39(6):1037–1050.

[Zerriffi, 2007] Zerriffi, H. (2007). Making Small Work: Business Model for Electrifying the World. Technical report, Stanford University.